DO NOT REMOVE

FLOOD PLAIN INFORMATION

REPORT ON

RANCOCAS CREEK

BURLINGTON COUNTY, NEW JERSEY

REVISED

Prepared for BURLINGTON COUNTY PLANNING BOARD

by

S. ARMY ENGINEER DISTRICT, PHILADELPHIA

ORPS OF ENGINEERS . . . . APRIL, 1967

ESSAYONS

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INTRODUCTION

1. GENERAL. In 1960, Congress authorized the Secretary of the Army to conduct detailed investigations, upon the request of State or responsible local governmental agencies, on floods and potential flood hazards resulting from indiscriminate use of and encroachment upon flood plains. At the request of the Burlington County Planning Board, a flood plain information study was undertaken for that portion of Rancocas Creek and its North, South and Southwest Branches illustrated on plate 1. The results of that study, as reported here, are for the use of State and local officials as guidance in future development and regulation of the flood plains. In addition, a summary report was prepared from the information contained herein, and is presented in a manner suitable for widespread distribution to the general public.

2. AUTHORIZATION. The authority for the Corps of Engineers to compile and disseminate the desired information on floods and potential flood hazards is derived from Section 206 of the Flood Control Act of 1960, Public Law 86-645, as amended. The law is quoted verbatim in the General Appendix to this report. The request for the flood plain information study was submitted by the Burlington County Planning Board, through the New Jersey Department of Conservation and Economic Development, in an application dated 25 May 1962. In the accompanying resolution, the local agency gave satisfactory assurances to publicize and use the information in the report for the guidance of townships and boroughs in Burlington County on the use of and the hazard of using the flood plains.

3. Initiation of this study was approved by the Chief of Engineers on 27 June 1963 with approval for release of the report granted by the Division Engineer, North Atlantic Division, on 25 October 1966. Approval for release of the report was granted on 17 October 1966 by the Commissioner, Department of Conservation and Economic Development, State of New Jersey, the agency designated by the Governor to coordinate the flood plains information study program in the State. A copy of the application is included in the General Appendix.

4. PURPOSE OF STUDY. The general purpose of this study is to provide engineering advice and information on flood hazards to serve as a guide for planning and developing the flood plains of the Rancocas Creek watershed within the study area, and serve as a basis for reducing future flood damages and hazards.

5. The specific purposes of this study are:

a. To compile and disseminate to State and local governments pertinent data on floods and flood hazards in the study area.

b. To encourage the optimum and prudent use of the flood plains in the study area by providing the State and local governmental agencies a factual basis for: reducing future flood damages and hazards through State and local regulation of the use of the flood plains; developing land use plans; and establishing adequate flood plain and floodway limits.

c. To publicize available information for the guidance of private citizens and interests on use of and hazards of using the flood plains.

d. To reduce future expenditures for Federal projects to protect developments which, in the absence of the information program, would have taken place, or for the alleviation of flood problems arising from improper flood plain development.

6. SCOPE OF STUDY.

a. Geographic area. The geographic scope of the study includes the following lengths of streams: (1) The main stem of Rancocas Creek from the bridge at Centerton, which is 7.8 miles upstream of the mouth of the Creek, to the junction of the North and South Branches, a distance of approximately 0.7 mile; (2) the North Branch from its confluence with the South Branch, to Pemberton-Browns Mills Road (Rt. 530) at Browns Mills, a distance of approximately 22 miles; (3) the South Branch from its confluence with the North Branch to Millpond Dam at Vincentown, a distance of approximately 12 miles; and (4) the Southwest Branch from its confluence with the South Branch to State Highway 70 upstream of Medford, a distance of approximately 11 miles. The limits of study are indicated on plate 1.

b. Historic flood period. Periodic flooding has been witnessed along Rancocas Creek since the time of the watershed's earliest settlement, more than 250 years ago. However, flooding did not become a problem until development of the flood plain took place. Recorded flood data are available only from 1921. Since that time the three greatest flood, as recorded by a U. S. Geological Survey stream gage at Pemberton, occurred on 21 August 1939, 22 September 1938, and 1 September 1940 (listed in order of decreasing magnitude).

c. Characteristics of the flood of record. Although the 1940 flood was the third greatest flood recorded at Pemberton on the North Branch, it is considered the largest flood of record for the overall watershed, because it produced record high discharges and high-water elevations over most of the drainage basin due to the rainfall timing and distribution. The storm period was from about midnight 31 August to about noon 1 September. A total rainfall of 24 inches was unofficially reported at Ewan, New Jersey (32 miles southwest of Pemberton), the storm center. More details on the magnitude and extent of that flood are contained in paragraph 19.

d. Data and analyses. The hydraulic and hydrologic information on floods and flood hazards in the study area was developed through analyses assuming certain flow conditions and probabilities. It is based on both available data and that obtained by a cross-section survey performed specifically for the study. This information is supplemented graphically by plates 2 through 6, which are a series of flood-plain maps on which flood limit lines for the 20-year, 100-year and standard project floods are delineated for these portions of Rancocas Creek and its branches included in the study area. The limits of inundation for the selected flood frequencies were determined by hydrologic and hydraulic analyses based on flood plain conditions in 1964. The maps are presented only as pictorial references which illustrate the flood hazard showing the approximate width of the flood plains for the selected flood frequencies, and at the same time permit the non-technical reader to readily identify the inundated areas. The limits of inundation were plotted from available topographic information on uncontrolled aerial mosaics of a relatively small scale (one inch equals 1,250 feet) possessing an inherent degree of distortion. It is therefore emphasized that actual elevations on the ground may vary considerable from those indicated by the flood lines shown on the aerial mosaics. A more exact determination of the limits of flooding can be made in the field by referring to elevations indicated by the profiles which are shown on plates 7, 8, 9 and 10. Consequently, plates 2 through 6 are not intended to be construed as showing rigid limits on which flood plain regulations or zoning ordinances should be based. Additional data and information pertaining to this study

9. The data presented here have certain limitations. It must be clearly understood that the lines delineating flood boundaries, as shown on plates 2 through 6, should not be assumed to be rigid limits that preclude any possibility of damaging floods reaching areas beyond these lines. Data from available records indicate that the designated floods will cover the flood plain approximately to the lines shown on plates 2 through 6. It should also be noted that the limits of flooding as determined in this study reflect the 1964 level of development in the study area and that additional urban development beyond that time will affect the computed and illustrated flood limits.

10. ACKNOWLEDGMENTS. The cooperation and assistance of the following Federal and non-Federal agencies and interests in observing, collecting, and compiling the information for this report are hereby acknowledged:

a. <u>Federal</u>

Coast and Geodetic Survey, U. S. Department of Commerce
Weather Bureau, U. S. Department of Commerce
Fish and Wildlife Service, U. S. Department of the Interior
Geological Survey, U. S. Department of the Interior
Housing and Home Finance Agency, Urban Renewal Administration

b. <u>Non-Federal</u>

New Jersey Department of Conservation and Economic Development
New Jersey Division of Fish and Game
Burlington County Civil Defense
Burlington County Planning Board

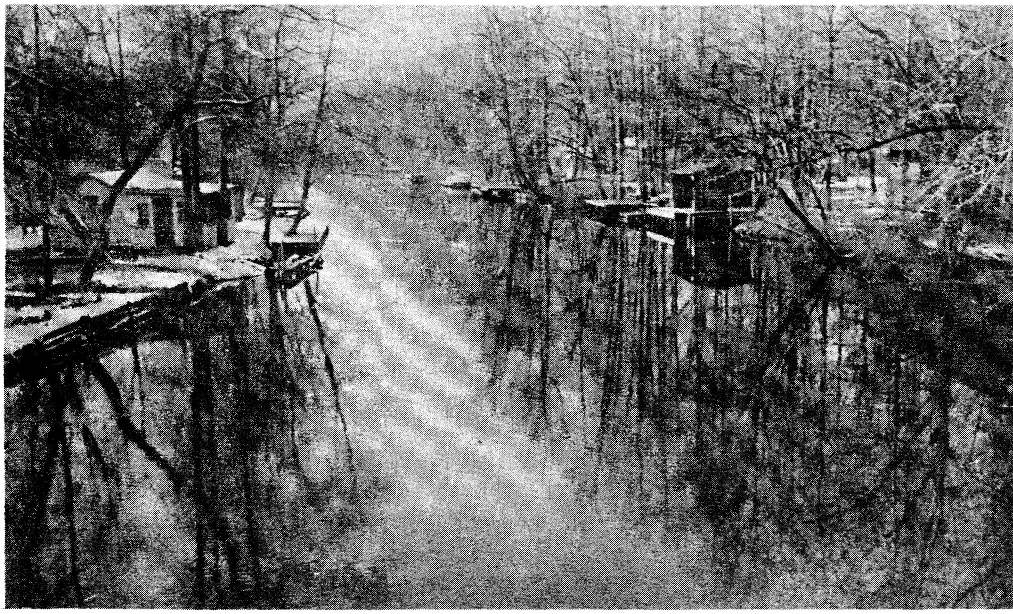
11. CONTINUING ASSISTANCE OF CORPS OF ENGINEERS. The technical assistance of the Corps of Engineers will be available upon request of the State and local governmental agencies concerned to interpret and explain the information in the report and to provide other available flood data for State and local planning and regulation of use of the flood plains in the area studied.

DESCRIPTION OF PROBLEM

12. GENERAL DESCRIPTION OF THE STUDY AREA. The area covered by this report includes that portion of Rancocas Creek and North, South and Southwest branches located in Burlington County, New Jersey, as previously identified in paragraph 6a and shown on plate 1. Rancocas Creek, a small tributary of Delaware River, has its headwaters in the swamplands and cranberry bogs of central Burlington County and flows northward and westward to its confluence with Delaware River opposite Torresdale, Philadelphia County, Pennsylvania. The creek is tidal from its mouth for 14.3 miles upstream to Mount Holly on the North Branch, and 13.8 miles upstream to Lumberton on the South Branch. Basically rectangular in shape, the Rancocas watershed is approximately 28 miles in length, 12 miles in width and contains 329 square miles of drainage area at the Centerton bridge. About 92 square miles of the total area drain to the South Branch, about 142 square miles drain to the North Branch and about 95 square miles drain to the Southwest Branch. The watershed is relatively flat, varying in elevation from about 200 feet above mean sea level in the headwaters to mean sea level at the mouth, and is characterized by porous and sandy soil.

13. The tidal portions within the study area are, for the most part, bordered by low, flat marshlands with two residential developments located at Rancocas Heights and Hainesport. On a small tributary, Mason Creek, there is another small development at Rancocas Woods. Above Lumberton and Mount Holly, the branches of Rancocas Creek are largely bordered by woodland. On the South and Southwest Branches of Rancocas Creek, development is sparse, consisting generally of summer cottages, but the area is growing rapidly. In the last 15 years the townships bordering these two branches and their tributaries, have more than doubled in population.

14. The area along the North Branch of Rancocas Creek is the most extensively developed portion of the study area, the heaviest development being at Mount Holly. Between Mount Holly and Pemberton, particularly in Eastampton Township, the Creek is bordered by sparse summer cottages, built just a few feet above the normal stream surface. Photographs 1 and 2 show the susceptibility of these cottages to frequent flooding. Concentrations of developments of this type are found in Smithville, Ewansville and Birmingham. Upstream of Pemberton, the stream banks are heavily wooded and the channel choked with vegetation, but here too the area is being developed rapidly. Along the banks,



PHOTOGRAPH 1. LOOKING DOWNSTREAM NORTH BRANCH RANCOCAS CREEK FROM ROUTE 206 BRIDGE IN EWANSVILLE AT SUMMER COTTAGES TYPICAL OF THAT AREA. NORMAL FLOW CONDITIONS PREVAIL. DECEMBER 1964.

PHOTOGRAPH 2. A FREQUENT OCCURRENCE - RANCOCAS CREEK USING ITS FLOOD PLAIN AT EWANSVILLE. FEBRUARY 1958.

summer cottages are scattered with a small concentration at New Lisbon and a major development at Browns Mills. This area has tripled in population since 1950. The North Branch, to a certain degree, is controlled by a series of dams, reservoirs and artificial lakes. Photographs 3 and 4 show two examples of structures along that branch. These lakes and reservoirs are designed for water supply and recreation, and, consequently, have very little flood control capacity. Their capability to reduce flood stages is therefore very limited. The principal dams are at Mount Holly, Smithville, New Lisbon and Browns Mills.

15. PROSPECTIVE DEVELOPMENTS AFFECTING THE FLOOD PLAIN. The greatest development in the Rancocas Creek watershed is the expanding population with its consequential increased need for residential and recreational home sites, which are often desired near water for its aesthetic value. The population of Burlington County increased from 135,910 in 1950 to 224,499 in 1960, an increase of approximately 65 percent. It is estimated that in 1980 the population in the county will total 441,000. Table 1 illustrates growth rates which have already occurred and those which are anticipated for Burlington County over the three decades following 1960.

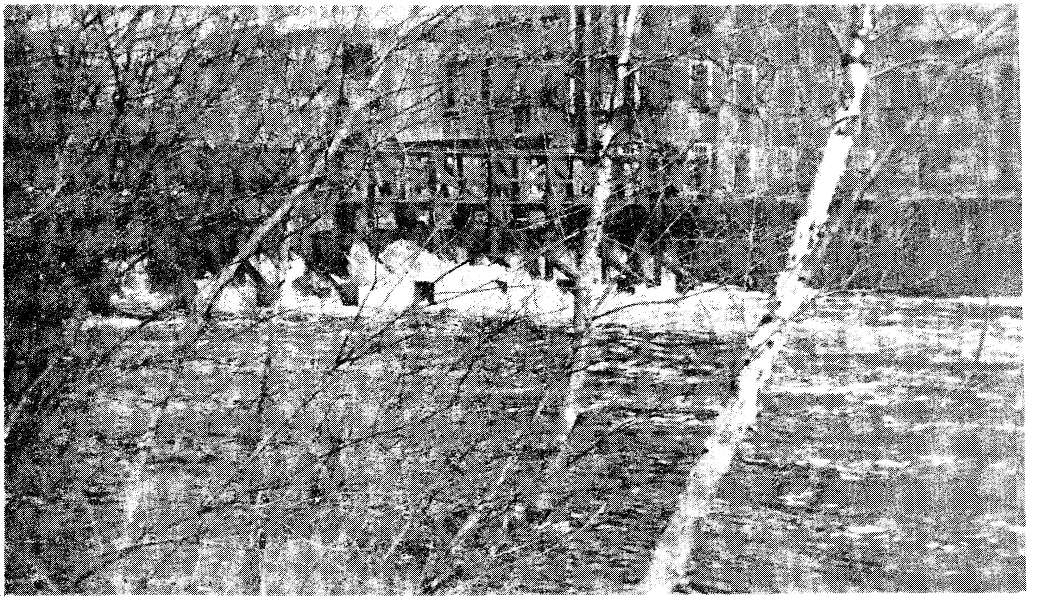
TABLE 1

POPULATION ESTIMATES FOR BURLINGTON COUNTY, NEW JERSEY

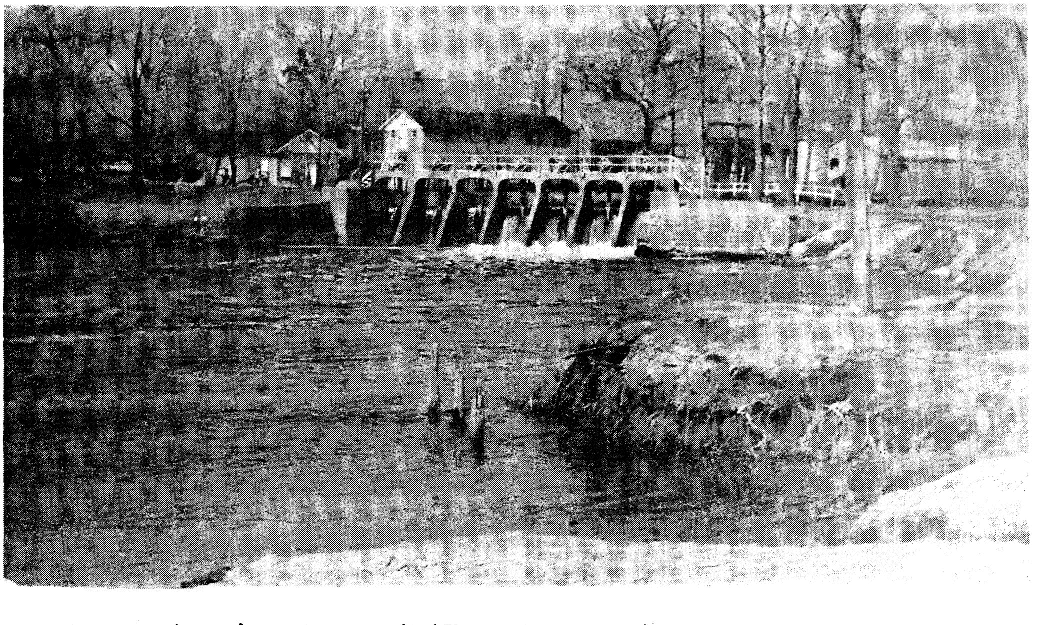
Year	Population	Net Increase Each 10 Years	Percent Increase Each 10 Years
1940	97,013 1/	-	-
1950	135,910 1/	38,897	40
1960	224,499 1/	88,589	65
1970	358,000 2/	133,501	60
1980	441,000 2/	83,000	23
1990	484,000 2/	43,000	10

1/ Reported by U. S. Bureau of Census.

2/ Estimated by New Jersey Department of Conservation and Economic Development.



PHOTOGRAPH 3. LOOKING UPSTREAM AT SMITHVILLE DAM ON THE NORTH BRANCH. THE DAM IS NO LONGER ADJUSTABLE FOR HEIGHT. MARCH 1964.



PHOTOGRAPH 4. A COMPARATIVELY NEW DAM AT IRON WORKS PARK ON NORTH BRANCH RANCOCAS CREEK. MARCH 1964.

Based on the past rate of growth and the estimated future growth, it is expected that many of the large tracts of undeveloped land and farmland will be developed in the near future. Although there is no present indication that these large open-space areas will undergo immediate intense development, it is certain that the pressures of subdivision will increase with time. If and when such development becomes imminent, intelligent planning using the data presented in this report will be possible. The increased use of the land for buildings, roadways, parking areas, lawns and other urban uses will decrease the watershed's moisture absorption capability and thereby increase flood peaks. Considering all other factors constant, an increase in the flood peak will cause an increase in the flood damage. Future flood losses will therefore depend greatly on the extent of development of the flood plains.

16. FLOOD WARNING AND FORECASTING SERVICES. Formal flood warning or forecasting services are effective in reducing flood damage and hazard to human life. For that portion of Rancocas Creek from Pemberton to Mt. Holly such a service is provided by the U. S. Weather Bureau at Trenton, New Jersey. The Burlington County Civil Defense Organization, with the cooperation of the Trenton Forecasting Center, has been receiving advanced warnings of heavy rainfall together with the calculated six-hour amount of rainfall necessary to cause overflow of the natural banks of the stream at the Pemberton gage. Then, if the situation warrants, based on this information an attempt is made to regulate the stream flow and prevent downstream flooding by manipulation of the outlet gates for the series of dams located on the North Branch. Further information on the techniques of flood forecasting and warning are provided later in this report in the section on "Guidelines for Use of Flood Plain and for Reducing Future Flood Damages".

17. FLOOD FIGHTING AND EMERGENCY EVACUATION PLANS. No formal flood fighting or emergency evacuation plans have been adopted for the Rancocas Creek Watershed. However, attempts have been made in the past to control excessive runoff with the small independently-operated reservoirs along the North Branch of Rancocas Creek. However, these attempts have been ineffectual in many instances partially due to the lack of coordination and a definite plan for emergency operation. It is suggested that such plans be considered by the Burlington County Planning Board for inclusion in its program of activities.

18. NATURE AND EXTENT OF FLOOD PROBLEMS. Large floods usually occur along Rancocas Creek as a result of torrential rains during the summer and fall of the year. For example, the three greatest floods experienced in the watershed occurred during that time of

the year. However, floods of lesser magnitude have occurred at various times of the year, thereby indicating that the watershed is vulnerable to the threat of flood at all times of the year, and to the most severe floods during the summer and autumn. Storm water which cannot be absorbed by the soil runs off into Rancocas Creek, and flood stages develop when the capacity of the channel is exceeded. The resultant overbank flood flow is carried downstream by the flood plain. This problem becomes compounded in the lower reaches of Rancocas Creek when abnormally high tides in Delaware River occur simultaneously with runoff produced from intensive rainfall. Flooding becomes extensive in areas where stream obstructions, such as bridges with inadequate channel openings or other encroachments, restrict the passage of flood flows. The problem in those areas is further aggravated when debris is trapped at the obstruction. In addition, summer and fall flood stages may be increased by the heavy vegetative cover that exists in the floodway during those times of the year.

19. The storm of 1 September 1940 was one of the most damaging storms experienced in southern New Jersey. It was characterized by extremely intense rainfall over a relatively narrow area and produced what is considered to be the greatest flood of record in the Rancocas Creek watershed. Ten inches of precipitation fell at Medford on the Southwest Branch, 8.2 inches fell at Vincentown on the South Branch, and 6.7 inches fell at Pemberton on the North Branch. Although this intense rainfall fell at those locations on the North and South Branches, the upper portions of both the North and South Branches experienced rainfall of significantly lower intensity. The intense rainfall on the Southwest Branch caused the dams at Taunton and Medford Lakes to fail, resulting in flooding downstream. Approximately 150 persons were left homeless at Lumberton and Mount Holly as a result of this devastating flood. The magnitude of the flood hazard in the study area can be expressed by the amount of damage caused by that flood. Property damage in Mount Holly alone amounted to $128,900 as estimated by the Corps of Engineers in 1941.[1/]

20. It is a natural condition for a portion of the flood plain to contribute to the transport of the flood flows. However, when this segment of the flood plain along with the stream channel are modified by the construction of highway bridges that restrict flood flow, or are encroached upon and constricted by dumping and filling operations, a backwater effect is produced and ponding or storage

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1/ Delaware River Basin Report, House Document 522, 87th Congress, 2d Session areas usually result on the upstream side of these obstructions. This problem of restrictive bridges and encroachments is not a serious one on Rancocas Creek since channel restrictions appear to be adequately controlled under the New Jersey Encroachment Law (see paragraph 23.). However, care should be exercized in the future, as development of the watershed takes place, to insure that compliance with the Encroachment Law continues. A sharp, winding channel alignment, dense vegetation, debris and other obstructions also hamper the passage of flood waters, and tend to increase flood stages. Turbulence at constrictions can often be damaging and may result in erosion and washouts. It is suggested that an investigation of such instances be made and care be taken to provide waterway areas adequate to allow for the passage of flood flows.

21. The damaging effects of flood waters on open space, park lands, parking areas and agricultural land are generally of minor consequence. However, damage to other more highly developed types of uses such as residential, commercial, or industrial buildings with their inventories, can be very costly. It is suggested that every effort be made to prevent the intense development of existing open-space areas in the flood plain, and that careful consideration be given to use of the flood plain for purposes to which only minor damage can be expected.

22. EXISTING AND AUTHORIZED FLOOD CONTROL AND RELATED PROJECTS. Public Law 228-77, adopted 18 August 1941, authorized the U. S. Army Corps of Engineers to construct a flood control project at Mount Holly. Construction was started on 20 April 1942 and completed on 8 March 1944. The location of the project is shown on plate 11. Elements of the project consist of the enlargement and relocation of sections of Rancocas Creek through the eastern and western sections of Mount Holly; a controlled by-pass channel to divert flood waters from the loop in the center of town; a new cut-off channel extending upstream from the by-pass channel, rejoining the original alignment in the eastern section of the town, and construction of one highway bridge and one railroad bridge. The total length of the entire project is 7,134 feet, and the cost was $283,655. In addition, as an integral part of the project, a highway bridge was constructed over the upper section of the improved channel by the County of Burlington. The project was designed to provide a channel capacity of 2,300 cubic feet per second (cfs) including 1,600 cfs through the by-pass channel and 700 cfs through the loop. There are no other Federal or non-Federal flood control or major drainage projects in the study area.

23. EXISTING REGULATIONS. The municipalities concerned along the Rancocas Creek do not at present have any local ordinances which regulate encroachment on or construction in the flood plain. However, the State of New Jersey enacted an encroachment law in 1929 which is essentially a preventative flood loss measure. The law is known as the "1929 Encroachment Law (R.S. 58:1-26)" and is administered by the Division of Water Policy and Supply of the Department of Conservation and Economic Development. The law reads in part as follows:

> "No structure within the natural and ordinary high water mark of any stream shall be made by any public authority or private person or corporation without notice to the [Division] and in no case without complying with such conditions as the [Division] may prescribe for preserving the channel and providing for the flow of water therein to safeguard the public against danger from the waters impounded or affected by such a structure and this prohibition shall apply to any renewal of existing structures."2/

Under provision of this law, the Division issues permits for the construction of bridges, culverts, fills, walls, channel improvements, pipe crossings and other encroachments located within the natural and ordinary high water mark of the streams. Another New Jersey encroachment law (Chapter 229, Laws of 1938, amending a previous law known as R.S. 40:46-1) permits municipalities of the State to construct improvements, remove obstructions, define the location, establish widths, grades, and elevations of any stream and to prevent encroachments thereon--subject to approval by the State of the flood carrying capacity to be provided. Under this law counties in New Jersey are permitted to assist municipalities in local flood damage alleviation programs. The New Jersey flood plain designation and marking law, enacted in 1962 [R. S. 58:16A (50-54)], empowers the Division of Water Policy and Supply to delineate and mark flood hazard areas, and coordinate effectively the development, dissemination, and use of information on floods and flood damages that may be available.

24. It is understood that the Burlington County Planning Board intends to evaluate the flood problem in the study area with the use of the data included in this report and make available to the

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2/ Flood Damage Alleviation in New Jersey - Water Resources Circular 3-1961 by State of New Jersey - Department of Conservation and Economic Development.

municipalities concerned all available information that could be used as a basis for the development of flood plain regulations. It is suggested that any proposed laws and regulations include a provision to the effect that in the event a new highway or railway traverses the flood plain, the hydrologic and hydraulic data contained in this report be furnished the agency responsible for the facility for use in its design so as to prevent future obstructions to flood flow.

RAINFALL AND FLOODS

25. GENERAL TREATMENT. To arrive at a solution of the problem of flooding, it is of first importance to evaluate the cause and define the effect. The following paragraphs show the evaluation, beginning with observed rainfall and runoff data, and the effects by means of the flood plain maps, showing the extent of flooding from floods of various magnitudes, based on the law of probability.

26. BASIC DATA. The basic data used in the hydrologic and hydraulic analyses were obtained from the records of two streamflow recording gages, one recording precipitation station, and one non-recording precipitation station, all located within the watershed; from the records of recording and non-recording precipitation stations located within close proximity to the watershed; and by field surveys performed specifically for the study. The two stream gages are operated by the U. S. Geological Survey (USGS). One gage, located at the highway bridge in Pemberton approximately 23.5 stream miles upstream from the mouth of Rancocas Creek, records runoff from 111.0 square miles of drainage area. Published records are available for that gage for a continuous 43-year period beginning in 1921. The second gage, which records runoff from 53.3 square miles of drainage area, is located on the South Branch just downstream from the Mount Holly-Eayrestown-Vincentown Road highway bridge. The latter gage is approximately 20.0 stream miles from the mouth of Rancocas Creek, and has been recording since 1961. There are no first order Weather Bureau stations located in the watershed, where complete meteorological data are recorded. There are, however, two precipitation stations, one at Pemberton and the other at Lumberton. The Lumberton station is an hourly-recording station having 20 years of record. The Pemberton station, having 35 years of record, provides only daily measurements. An additional rainfall recording station at Freehold, and four non-recording stations at Moorestown, Marlton, Indian Mills, and Chatsworth, in close proximity to the watershed, provide additional precipitation data.

27. A survey was made specifically for this study to determine flood plain and stream cross section geometry at 29 locations along Rancocas Creek and its South and Southwest Branches.[3/] The locations of these cross sections are shown on the stream profiles presented on plates 7 through 10. In addition, detailed data on all bridge crossings and other structures, such as dams and sluices, affecting stream flow were obtained during that survey.

28. RAINFALL. U. S. Weather Bureau Bulletin No. 40, "Rainfall Frequency Atlas of the United States", dated May 1961, was used to determine the rainfall depth - duration - frequency relationships for the watershed. The resulting values are shown in table 2 and depicted in graphical form on figure A-1.

3/ Survey by John G. Reutter Associates, Civil Engineers, 1964.

TABLE 2

RAINFALL DEPTH-DURATION-FREQUENCY RELATIONSHIPS
RANCOCAS CREEK WATERSHED

Duration In Hours	RAINFALL FREQUENCY (recurrent interval) 2 Yr.	5 Yr.	10 Yr.	25 Yr.	50 Yr.	100 Yr.
			Rainfall in Inches			
1	0.99	1.27	1.48	1.72	1.91	2.15
2	1.24	1.75	2.06	2.36	2.59	3.01
3	1.52	2.07	2.42	2.84	3.20	3.60
6	1.89	2.70	3.14	3.69	4.17	4.71
12	2.49	3.19	3.79	4.48	5.20	5.72
24	3.08	3.98	4.56	5.35	6.07	6.76

The mean monthly precipitation, including the moisture equivalent of snowfall, for several of the New Jersey precipitation stations is given in table 3 and is assumed to be indicative of the average expected rainfall over the area of interest. Of the average annual precipitation of 45.38 inches, it is estimated that approximately 20 inches show up as stream runoff.

TABLE 3

PRECIPITATION RECORDINGS AT NEW JERSEY STATIONS - IN INCHES

MONTHLY MEANS

Month	Stations: Freehold	Pemberton	Moorestown	Chatsworth	Indian Mills	Avg.
Jan	3.58	3.30	3.12	2.95	3.62	3.31
Feb	3.14	2.88	2.73	4.58	3.11	3.29
Mar	4.24	3.85	3.81	3.60	4.28	3.96
Apr	3.58	3.45	3.44	3.37	3.42	3.45
May	4.03	3.76	4.07	1.60	3.88	3.47
Jun	3.68	3.70	3.56	5.23	3.90	4.01
Jul	4.24	4.65	4.17	5.01	4.27	4.47
Aug	4.76	5.05	4.75	9.20	5.46	5.84
Sep	3.78	3.77	3.75	3.42	3.60	3.66
Oct	3.59	3.27	3.06	1.88	3.41	3.04
Nov	3.96	3.51	3.61	4.26	3.71	3.81
Dec	3.45	3.08	2.91	2.68	3.23	3.07
Totals	46.03	44.27	42.98	47.78	45.89	45.38

29. FLOODS.

a. Major Floods of Record. The three major floods at the Pemberton USGS gage during the 43 years of record, and their corresponding peak stages and discharges, are listed in table 4.

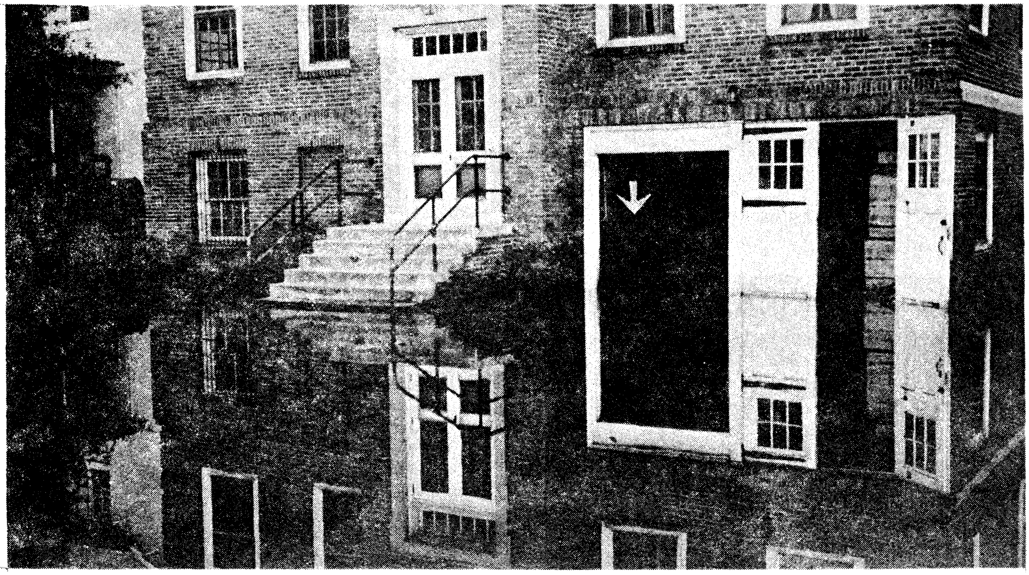
TABLE 4

STAGE-DISCHARGE VALUES FOR THE THREE MAJOR FLOODS AT THE PEMBERTON GAGE

Flood Date	Stage (Ft/SLD)	Peak Discharge
21 August 1939	41.96	1,730
22 September 1938	41.75	1,680
1 September 1940	40.84	1,480

(1) The flood of 1 September 1940, as stated previously, ranks third in magnitude of discharge at the Pemberton gage, although record flood stages occurred on the South Branch, Southwest Branch, and on the North Branch downstream of Pemberton, due to the rainfall timing and distribution. Photographs 5, 6, and 7 show flooding conditions during that event at various locations in the study area. That storm was an isolated, local, non-hurricane, 12-hour event, centralized over Ewan, New Jersey, and covered an area approximately 9 miles wide and 37 miles long. Table 5 presents a list of USGS high-water mark elevations for the flood of 1 September 1940 with estimated flood levels for the 20-year, 100-year and standard project floods at the locations indicated.

(2) The flood of 21 August 1939. It has been determined from a study of great storms that have occurred over northeastern United States, that the worst probable flood on the Rancocas Watershed above Mount Holly would have occurred, had the storm of August 1939 been centered over this portion of the watershed. That storm was of tropical origin and after coming into this latitude remained comparatively stationary at a point about 200 miles off the New Jersey Coast from 17 to 19 August 1939. Generally heavy rainfall was centered near Tuckerton, New Jersey, and had a duration of about 15 hours. Since the center of this storm was separated from Mount Holly by only 35 miles of flat terrain, there is reason to believe that the center might easily have occurred over the Rancocas watershed with an estimated average rainfall of 15.8 inches falling on the drainage area above Mount Holly. Photograph 8 shows the stream under normal conditions at Mount Holly, and photographs 9 and 10 show conditions in the town during the August 1939 flood.



PHOTOGRAPH 5. REAR OF CITY HALL BUILDING IN MOUNT HOLLY SHOWING HIGH WATER MARK ON GARAGE WALLS LEFT BY RECEDING WATERS. 2 SEPTEMBER 1940.

PHOTOGRAPH 6. EXTENSIVE FLOODING ON SOUTH BRANCH OF RANCOCAS CREEK IMMEDIATELY DOWNSTREAM OF ROUTE 38 HIGHWAY BRIDGE. 2 SEPTEMBER 1940.

PHOTOGRAPH 7. FLOODING CAUSED BY SOUTH BRANCH RANCOCAS CREEK AT LUMBERTON DURING FLOOD OF 1 SEPTEMBER 1940. ARROW INDICATES HEIGHT OF FLOODING. 2 SEPTEMBER 1940.

TABLE 5

COMPARISON OF ACTUAL AND ESTIMATED FLOOD ELEVATIONS
FOR RANCOCAS CREEK

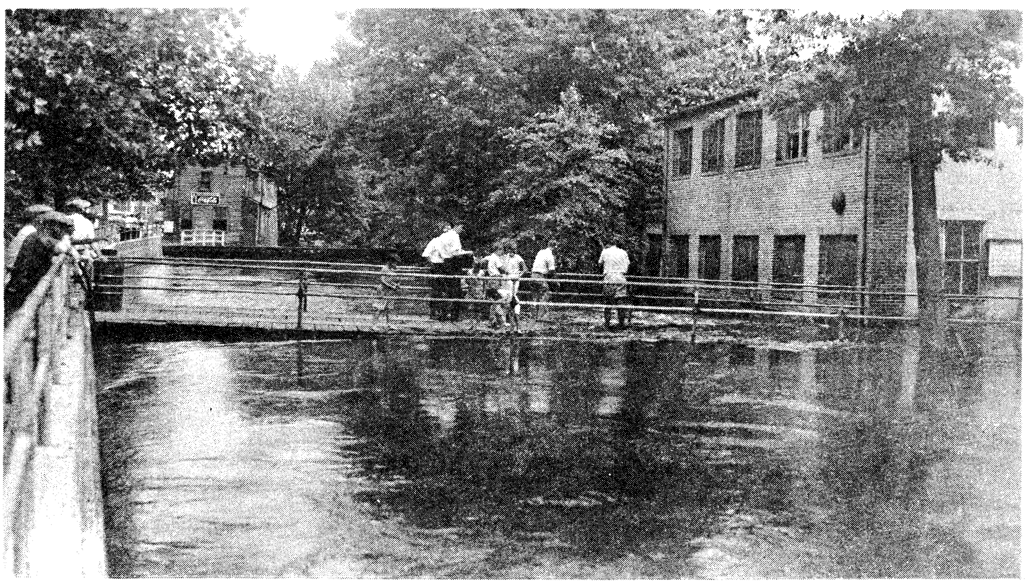
	Elevations in Feet Above Sea Level Datum			
Location	1 Sept 1940	20-Year	100-Year	Standard Project Flood
NORTH BRANCH				
Mt. Holly @ Wash. St. Br.	14.77 1/	10.2	10.9	16.7
Mr. Holly @ Pine St. Br.	16.23 1/	11.2	12.0	19.3
Ewansville @ U.S. Route 206	26.82 2/	24.6	25.5	30.8
SOUTH BRANCH				
Hainesport @ Marne Hwy	12.76 3/	09.0	10.1	12.5
Lumberton @ Mr. Holly-Medford Rd.	17.43 3/	09.4	10.4	14.3
SOUTHWEST BRANCH				
Church Rd. @ Bridge	32.37 3/	24.5	26.0	28.1

1/ These values cannot be correlated with the 20-year, 100-year or standard project flood elevations because the Mount Holly flood control project completed in 1944 has reduced the estimated stages for those events.

2/ This value is approximately 2.2 feet higher than the 20-year flood at the same location, although the exceedence frequency of 1 Sept. 1940 flood was approximately 20 years. This difference in elevations is probably attributable to partial obstruction of the bridge during the 1940 event.

3/ Affected by Taunton and Medford Lakes dam failures combined with intense rainfall pattern over the Southwest Branch drainage area.

PHOTOGRAPH 8. NORMAL FLOW CONDITIONS PREVAILING ALONG NORTH BRANCH RANCOCAS CREEK IN MOUNT HOLLY IN MAY 1939. LOOKING DOWNSTREAM ALONG WASHINGTON STREET. 18 MAY 1939.



PHOTOGRAPH 9. SAME AREA AS ABOVE DURING THE AUGUST 1939 FLOOD. 21 AUGUST 1939.

(3) The flood of 22 September 1938 resulted from the "Long Island Hurricane" that originated about 15 September 1938, in the eastern part of the subtropical Atlantic. The center of the storm traveled northward along the Atlantic Coast, passing to the eastward of the Rancocas watershed over Long Island and into Canada. Winds of gale force and the torrential rains accompanying and preceding the storm caused considerable damage in the watershed. It was estimated that about 10 inches of rain fell in five days, of which approximately 5 inches fell on 21 September 1938, inundating over one-third of the total area of Mount Holly.

b. Standard Project Flood. The standard project flood for the Rancocas Creek watershed, as commonly derived by the Corps of Engineers in planning flood protection works, is estimated to have a peak discharge of 7,680 cfs at the Pemberton gage and bridge. The standard project flood is an extremely rare occurrence and, if used as a basis for planning flood plain use, would reduce flood risks to negligible proportions. The extent of inundation along the creek due to a flood of that magnitude is shown on plates 2 through 6.

c. Intermediate Flood Risks. Floods of lesser magnitude than that of the standard project flood have also been estimated to illustrate the hazards or possibilities of flood plain use under various degrees of risk. These events with 100-year and 20-year recurrence intervals are estimated to have peak discharges of 2,020 cfs and 1,510 cfs, respectively, at the Pemberton gage. Computed discharges at other locations for these floods are given later in the report in table 6. As explained in more detail in paragraph 31, "Flood Frequencies", these flood events should be considered as occurring at average intervals over long periods of time with no assurance of regularity in the time interval. The extent of inundation along the streams due to floods with the above frequencies is shown on plates 2 through 6. This study has also indicated that along most of the reaches of stream considered, floods that are smaller and more frequent than the 20-year flood would not cause extensive overbank flow that would result in appreciable damage.

d. Unit Hydrograph. The purpose of the unit hydrograph study is to develop peak instantaneous discharges for selected flooding events. Ordinarily a synthetic unit hydrograph is developed for a gage site and compared to an actual unit hydrograph for the same location. A ratio for adjustment is then developed between the two hydrographs and applied to synthetic hydrographs constructed for other selected points along the stream to estimate the peak discharges at such points for particular events. A unit hydrograph derivation for the Rancocas Creek gage at Pemberton from actual discharge records was compared to a synthetic hydrograph at the same location, developed by using Snyder's coefficients. 4/ Peak discharges were developed for the following locations:

On the Main Stem
At Centerton Bridge

On the North Branch
a) Upstream of confluence with main stem.
b) Pemberton gage

On the South Branch
a) Upstream of confluence with main stem.
b) Vincentown gage

On the Southwest Branch
Upstream of confluence with South Branch.

30. SPECIAL FACTORS AFFECTING FLOODS. Flood flows on Rancocas Creek vary not only with meteorological conditions such as amount and intensity of rainfall but are also affected by physical factors such as ice and debris jams, stream encroachment, heavy vegetation in the floodway, restrictive bridge openings, and topographic conditions which contribute to the rapid rise of flood waters. In the lower reaches of the stream, however, tidal action plays a major role in affecting the flood hazard. For example, Rancocas Heights along the South Branch is susceptible not only to flooding by flows from upstream but also to tidal flooding, and usually a combination of both. More information as to assumptions made in calculating discharges for these various situations, is found in the portion of this report on "Flood Profiles".

31. FLOOD FREQUENCIES. Frequency estimates were determined for creek discharges and for tidal stages near the mouth of the creek. A discharge-frequency curve was developed for Rancocas Creek at the Pemberton gage by applying Beard's statistical frequency analysis to the annual peak discharges which occurred during the period of record. 5/ In addition, a set of frequency curves, including a curve at the Pemberton gage, was determined by means of the

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4/ Developed from empirical relations by Franklin F. Snyder. They are useful in the study of runoff characteristics of drainage areas where stream-flow records are not adequate.

5/ A method of frequency analysis described in the paper "Statistical Methods in Hydrology", dated January 1962, by Leo R. Beard of the Corps of Engineers.

regionalized method developed in the Delaware River Basin Report. Then the regionalized curve developed at the gage was adjusted to agree with the curve obtained by Beard's analysis. Frequency-discharge relationships were determined at each of the locations at which a unit hydrograph was established by making a similar adjustment to each regionalized curve. Figure A-2 in the General Appendix and table 6 are the resulting frequency curve relationships.

TABLE 6

FREQUENCY-DISCHARGE RELATIONSHIPS
FOR RANCOCAS CREEK

Location	20-Year Flood	100-Year Flood	Standard Project Flood
MAIN STEM			
Centerton Bridge	2,470 cfs	3,170 cfs	19,400 cfs
NORTH BRANCH			
Above Mouth of North Branch	1,630	2,150	10,120
Pemberton Gage	1,510	2,020	7,680
SOUTH BRANCH			
Above Mouth of South Branch	2,040	2,690	10,830
Southwest Branch Confluence	1,900	2,480	10,040
Vincentown Gage	920	1,280	4,080

It is emphasized that the probability of any of these discharges being equalled or exceeded in any one year is based on the average chance of occurrence over a long period of time, and it is not to be construed that the events will occur with any regularity over a short interval of time. For example, the assignment of a 20-year frequency to a specific discharge does not mean that this discharge will be equalled or exceeded every 20 years or twice every 40 years, but rather that over a long period of time, say 100 years, it can be expected to be equalled or exceeded about five times.

32. The frequency analysis for the tidal stages near the mouth of Rancocas Creek was based on actual stage records of the Delaware

River at Philadelphia, Pa. and Burlington, N. J. Through interpolation of these records, heights of tidal stages were estimated for given frequencies at the Rancocas Creek-Delaware River confluence. The resultant frequency-elevation relationships are presented in table 7.

TABLE 7

TIDAL FREQUENCY VS. ELEVATION AT
RANCOCAS CREEK-DELAWARE RIVER CONFLUENCE

Number of Occurrences Per 100 Years	Elevation Ft. (SLD)
1	10.5
5	8.7
100	6.4

Once again the values in the above table are not meant to imply that an elevation of 10.5 feet will occur once in every 100-year period, but rather that over an extended period of record, such a stage has the probability of being equalled or exceeded on the average of once in 100 years.

33. FLOOD PROFILES. Flood profiles were determined for the 20-year, 100-year and standard project floods and are shown on plates 7 through 10. In developing these profiles, stage-discharge relationships were determined by analyzing the hydraulic properties of each of the 29 cross-sections obtained by the field surveys conducted for this study. Assumptions for the Manning's roughness coefficient, n, were made initially, and were adjusted after comparing the derived stages with the actual stage-discharge or rating curve for the gage. The stream was then divided into 11 reaches, where the hydraulic properties in each reach were considered generally similar. Rating curves were computed for each reach by averaging the normal flow conveyance curve values of each cross-section within the reach and applying Manning's equation

$$Q = \frac{1.486}{n} AR^{2/3} S^{1/2}$$

or $Q = KS^{1/2}$

Where Q = discharge in cfs

A = cross-sectional area in sq. ft.

R = hydraulic radius in ft. (Area divided by wetted perimeter)

S = slope of hydraulic gradient in feet of head loss per foot of stream length

$$K = \frac{1.486}{n} AR^{2/3} \quad \text{conveyance}$$

Having available the discharge for a particular flood frequency at any given location, this value was translated into a corresponding water surface elevation by means of the rating curves.

34. These profiles were constructed assuming that normal depth would prevail where no restrictions were present. The profiles were then adjusted to show the backwater effects of 14 bridge crossings and 6 low dams on the North Branch; 9 bridge crossings and 1 low dam on the South Branch; and 11 bridge crossings and 1 low dam on the Southwest Branch. Further adjustments were made to the profiles for the tidal reaches of Rancocas Creek by beginning with a specific tide condition in Delaware River. Then a profile was developed by computing friction losses from the mouth of the creek upstream to the point where the surface runoff flood profile is no longer affected by the tide. This was then modified by computing the losses through 12 bridges and combining them with the backwater, providing continuous water surface profiles throughout those reaches. The standard project flood profile was developed in the tidal reaches considering an annual peak tide elevation at the mouth of Rancocas Creek, and the standard project flood discharge upstream. The 20-year and 100-year flood profiles in the tide-affected reaches were determined for two coincident combinations of tide and runoff for each flood event. In the first condition of analysis, an annual peak tide elevation at the mouth was combined with a 20-year discharge and a 100-year discharge in the channel. In the second condition of analysis, a 5-year discharge in the channel was combined with 20-year and 100-year high tide elevations at the mouth, respectively. This second condition of analysis resulted in higher water surface profiles in the tidal portions of the creek. The first condition of analysis resulted in a higher flood profile in the upper portion of the tide-affected reach. In each case, the combination that resulted in the higher flood profile was accepted as representative for the given upstream flow frequency.

35. The descriptions of the bridges and low dams are included in tables 8 and 9, respectively. Additional flow restrictions of the water openings due to debris accumulations were not considered because of the unpredictability of their occurrence and magnitude. Rating curves were developed at the upstream side of the low dams using the equation

$$Q = CLH^{3/2}$$

Where Q = discharge in cfs
C = coefficient of discharge 3.2
L = length of weir in feet
H = head on the crest of the weir

TABLE 8

DESCRIPTION OF BRIDGES OVER RANCOCAS CREEK

Name	Distance in 100 ft. from Centerton Br.	Description	No. of Spans	Total Width of Opening (feet)	Clearance Above Low Point In Stream Bed (feet)
MAIN BRANCH					
Centerton Br.	0	(4) (6) (9)	5	270	12.8
N.J. Turnpike	20	(2) (6) (9)	11	660	34.0
NORTH BRANCH					
King St., Mt. Holly	283	(2) (6) (9)	2	63	11.0
Ft. Bridge at Mt. Holly	285	(4) (6)	1	58	14.5
Marne Highway (Washington St., Mt. Holly)	288	(1)	1	43	13.7
Penna. R.R. Bridge #1	294	(5) (7) (8)	9	118	12.8
Pine St., Mt. Holly	314	(2) (6) (9)	2	76	17.5
Ft. Bridge at Iron Works Park	329	(5) (6) (8)	5	63	14.6
Bridge by Smithville Post Office	524	(5) (6) (8)	3	50	12.4
Mt. Holly - Smithville Rd.	530	(2) (6) (9)	7	112	11.5
U.S. Route 206	568	(2) (6)	1	66	10.5
Birmingham Inn Rd.	698	(5) (6) (8)	3	30	10.2
Penna. R.R. Bridge #2	781	(5) (6) (9)	3	78	7.8
Route 530, Pemberton	838	(4) (6)	1	96	10.4
Farm Rd. (between Route 530 and New Lisbon - Magnolia Rd.)	947	(5) (7) (8)	5	54	10.3
Four Mile Colony Rd.	1,034	(2) (6)	1	48	13.0
Pemberton - Browns Mills Rd.	1,187	(2) (6)	1	15	13.8
SOUTH BRANCH					
Marne Highway	170	(4) (6) (9)	3	157	19.8
R.R. Bridge #3	192	(3) (6) (9)	3	179	40.0
N.J. Route 38	211	(2) (6) (9)	4	160	27.2

Name	Distance in 100 ft. from Centerton Br.	Description	No. of Spans	Total Width of Opening (feet)	Clearance Above Low Point In Stream Bed (feet)
SOUTH BRANCH (Cont'd)					
Mt. Holly - Medford Rd.	301	(4) (6) (8) (9)	8	101	13.0
R.R. Bridge #4	310	(3) (6) (9)	3	87	18.5
Fostertown - Eayrestown Rd.	440	(4) (6)	1	49	11.8
Mt. Holly - Eayrestown - Vincentown Rd.	583	(5) (7) (8)	4	68	10.3
Church Rd.	650	(2) (6)	1	34	6.8
Light Duty Rd. at Millpond Dam	656	(2) (6)	1	32	8.5
SOUTHWEST BRANCH					
Fostertown - Eayrestown Rd.	433	(4) (6)	1	62	11.9
Church Rd.	628	(4) (6)	1	63	14.7
Unnamed Rd.	645	(5) (7) (8)	5	75	11.2
N.J. Route 70	687	(2) (6)	1	58	12.5
Branch St., Medford	705	(2) (6) (8)	3	51	13.5
Route 541, Medford	743	(1)	1	67	13.1
Hartford Rd.	792	(5) (7) (8)	3	48	10.7
Sorino's Farm Rd.	885	(5) (6) (9)	2	20	3.6
Medford-Marlton Rd.	936	(5) (7)	1	21	6.5
Elmwood Rd.	959	(5) (6)	1	19	5.2
N.J. Route 70	1,000	(2) (6)	1	12	9.0

(1) Concrete Arch
(2) Structural Concrete
(3) Steel Girder
(4) Steel Truss
(5) Structural Timber
(6) Concrete or Masonry Abutments
(7) Timber Abutments
(8) Piles
(9) Concrete Pier

TABLE 9

DAMS ON RANCOCAS CREEK

Distance in 100 ft. from Centerton Br.	Stream	Crest El. (Ft/SLD)	Approx Ht. above Stream Bed (feet)
327	North Branch	10.0	10.0
521	North Branch	18.5	8.5
836	North Branch	32.6	10.3
836.5	North Branch	32.5	10.5
1,033.5	North Branch	44.3	14.3
1,187.5	North Branch	58.4	13.5
656	South Branch	23.2	10.0
628	Southwest Branch	22.4	10.9

Losses through or over a bridge were computed utilizing the equations

$$Q_t = Q_c + Q_o$$
$$Q_c = K_cA \quad 2gZ + V^2$$
$$Q_o = CLH^{3/2}$$

Where Q_t = total discharge in cfs
Q_c = channel discharge in cfs
Q_o = overbank discharge in cfs
K_c = coefficient of contraction
A = flow area in square feet
g = acceleration of gravity 32.2 ft/sec^2
Z = head loss in feet
V = average velocity of approach

36. It must be recognized that the accuracy of the flood profiles shown on plates 7 through 10 is dependent upon the accuracy or validity of each of the hydraulic or hydrologic factors used in the basic analysis. Since hydrologic conditions do not remain constant, a slight variance in any of those factors could result in varying degrees of inaccuracies in the determination of water surface elevations. Combining the possible additive errors of all those factors, it is estimated that the vertical tolerance for the derived flood stages may approach plus or minus one foot for the more remote flood events.

37. FLOOD LIMITS. The boundaries of flooding for the selected floods were superimposed on the uncontrolled aerial mosaics by

correlating elevations as indicated by computed flood profiles with elevations on the flood plain as indicated by available topographic data. Topographic data consist of the surveyed cross sections at a limited number of locations and U. S. Geological Survey quadrangle sheets having 10-foot contour intervals. Due to the margin for error caused by the necessity of having to interpolate elevations between the 10-foot contours, and the possibility of those contours being several feet in error, and the inherent degree of distortion in the aerial mosaics, it is again emphasized that actual elevations on the ground may vary considerably from those indicated by the flood lines as shown on plates 2 through 6. The flood lines as shown are intended mainly to serve as a rough guide to potential users of the flood plain. A more exact determination of the limits of flooding can be made by detailed ground surveys, referring to elevations indicated by the computed profiles.

GUIDELINES FOR USE OF FLOOD PLAIN AND FOR REDUCING FUTURE FLOOD DAMAGES

38. GENERAL. Rancocas Creek periodically overflows its banks causing considerable damage in the developed portions of its flood plains. The relative effects of flooding along the creek are illustrated on plates 2 through 6 where flood limit lines for the 20-year, 100-year and standard project floods are shown. It should be noted on these flood plain maps that the area that would be flooded by the 100-year flood is not much greater than that which would be flooded by the 20-year flood. This difference in inundated areas is much smaller than would be expected if only the frequencies of the two events are compared. This is an example of the fact that floods of lesser magnitude do not always show a corresponding decrease in the area of inundation. This frequency versus area inundated comparison is cited to emphasize the fact that recognition should be given to floods of lesser magnitude than the maximum flood of record in flood plain planning to effectuate the prudent use of the flood plain. In addition, it is desirable to emphasize the fact that developed areas subject to frequent periodic flooding are also subject to comparatively rapid deterioration. This occurs because real estate values are decreased, which, in turn, results in residential areas being reduced in status at a faster than normal rate to a less desirable type of neighborhood. Future flood losses can be avoided or reduced by restricting future development in the flood plains to uses that will suffer minimal losses and not aggravate flood conditions by obstructing flood flow. Ways and means of reducing the present flood problem and eliminating possible future flood damages are discussed in the following paragraphs. These matters are presented only as indicative of types of actions or alternatives that may be considered to reduce future flood damages. Additional detailed analysis will be needed by those concerned to decide on a course of action.

39. FLOOD PLAIN REGULATIONS. Flood plain regulations seek to encourage flood plain uses which are compatible with the risks involved and to protect the public from abuse of private rights. These regulations are most effective in avoiding the creation of new flood problems, and in preventing existing problems from becoming more severe. Flood plain regulation refers essentially to the efforts of State and local authorities to achieve the above objectives through the use of their police powers. This involves use of such measures as flood plain zoning, channel and floodway encroachment lines, subdivision regulations, and building codes or standards. Several measures which do not involve the use of police power, but which should be considered as essential to the comprehensive approach to flood damage prevention are: flood

warning, which was discussed in paragraph 16; flood plain clearance; flood proofing; flood plain marking; land acquisition for open space needs; and land treatment. Definitions of these terms are included in the glossary of technical terms in the General Appendix. The need for, desirability, and possible manner of local clarification of policy and planning objectives to recognize flood hazards are apparent from (1) the periodic damage sustained in the past, and (2) the continuing urbanization of the entire watershed, including the flood plain area, which in all probability will result in even greater periodic flood damages in the future unless protection is provided by engineering works, by flood plain regulations, or by a combination of both of these measures.

40. General types of land use compatible with various degrees of flood hazard include those uses which will not cause danger to life or property along the floodway. For example, the Bucks County Planning Commission has proposed to the various political subdivisions along the lower reaches of Neshaminy Creek in Pennsylvania that use of that portion of the flood plain where the velocity of flow is 6 feet or more per second or the depth of flow is 8 feet or more, as determined by the 50-year frequency storm, be restricted to agricultural uses, woodlands, outdoor nurseries, flower and vegetable gardening, parks, playgrounds and golf courses to the exclusion of all buildings. In that portion of the flood plain where the depth of flood flow is less than 8 feet and the velocity of flow is less than 6 feet per second, the Planning Commission has proposed that the uses be restricted to parking and loading areas accessory to commercial use, utility installations, storage of farm equipment, commercial parks, swimming pools, fairs, circus grounds and golf ranges. As a second example, the Montgomery County Planning Commission, after completion of a flood plain information study by the Corps of Engineers for the Wissahickon Creek in Pennsylvania, prepared a model ordinance for consideration with a view to adoption by flood affected municipalities. The proposed ordinance, if enacted, would establish a floodway district along the creek. This floodway district would be limited to certain specified uses such as pastures, nurseries, parks, hunting and fishing reserves, utility transmission lines and other uses that would present a minimum flood damage potential. However, it would also provide for special exceptions under certain circumstances. These examples of flood plain regulations are noted to emphasize the importance of balancing the development of the flood plain with adequate flood carrying capacity to secure optimum use of land resources in the study area.

41. CRITERIA FOR ESTABLISHING CHANNEL AND FLOODWAY REQUIREMENTS. The following guidelines are presented for the purpose of establishing a possible basis from which further regulatory work

might be accomplished. The limits defined by the mean low water mark of the channel establish the area which is permanently under water. The standard project flood lines, as shown on plates 2 through 6, are the approximate maximum limits of the flood hazard and establish the areas which are and could be subject to flooding. The possibility of flooding in areas beyond these limits is considered relatively remote. In those areas subject to periodic flooding, a third limit line can be defined which will segregate areas whose use will have a major effect upon the consequences of flooding from those areas whose use may be considered to have a minor effect on flooding in the flood plain. For example, the Bucks County Planning Commission used this limit line principle in its "Recommended Flood Plain Zoning Regulations" when it proposed the zoning of the lower Neshaminy Creek flood plains into open and modified floodways. The type of floodway was determined by a line which was defined by depth and velocity of water considerations. Consideration should also be given to the general rule that any constriction of the flood plain that now exists will generally result in increasing the flood stages of similar future floods. Exceptions to this rule are along the stream reaches in which the stages of large floods are controlled by downstream obstructions. In these sections the flood plain could be constricted considerably without greatly affecting the stages of the larger floods. However, if increases in flood stages of lesser flows are to be avoided, then the constrictions must be limited by the flood plain required by the lower floods. The increase in velocity of flow resulting from any constriction should be determined to decide the extent of bank protection that may be required. The effect of flood plain encroachment on stages in reaches where overbank flow occurs will vary depending upon the width of the flood plain. If the existing flood plain is broad, limited encroachment will have slight effect on stage. However, where the present flood plain is narrow, a small encroachment may increase the flood stage significantly. Therefore, any contemplated flood plain encroachment should be thoroughly analyzed and its effect determined before it is undertaken. Such practices as dumping and filling operations in the floodway are encroachments and should be prevented in order to maintain adequate channel capacity.

42. The establishment of adequate criteria for the regulation of vertical and horizontal clear openings, minimum elevations for bridges over flood channels, and for highway embankments crossing the flood plain is of the utmost importance. Obstructions of this type increase flood water elevations upstream thereby inundating large areas of the flood plain.

43. Emphasis is also placed on the necessity of limiting and defining channel bottom elevations above which future sewers, other

utility lines, and bridge pier foundations should not be constructed so as to avoid interference with flood flows, damage from floods, or expensive modification if channel improvement is undertaken.

44. ZONING. Flood plain zoning is a means of preventing the creation of future flood problems and the worsening of existing flood problems. Land use studies and community or regional planning are needed to determine the best long-range plan of land use and area development. Planning in the flood plain should be directed at the objective of reducing future flood damages and securing optimum development of the area. Use of the flood plain for parks, recreational uses, agricultural or wooded areas should be considered wherever practicable. Such uses do not adversely affect flood problems and present a minimum damage potential.

45. BUILDING CODES. In areas of the flood plain subjected to only occasional flooding, the establishment of minimum floor and basement elevations and other special building code provisions should be considered. For example, building codes should require that tanks located in flood areas be properly anchored against flotation. This is particularly pertinent for those tanks used for storage of inflammable fluids. Minimum elevations for basements and main floors of buildings or structures without basements may be related to the elevations of a selected flood. The determination of such minimum elevations should be made by the State and local interests. The profiles presented on plates 7 through 10 can be used in conjunction with plates 2 through 6 as guides for the determination of minimum floor elevations.

46. SUBDIVISION REGULATIONS. The existing subdivision regulations for the study area contain no ordinances relating to flood plain zoning. However, the regulations could be amended by local authorities. Such amendments could avoid development of the flood plains for uses which are not compatible with the best interests of the area. Action on this matter and enforcement of regulations is entirely a State and local responsibility.

47. FLOOD PLAIN EVACUATION AND URBAN RENEWAL. A number of studies have been made by the Corps of Engineers on the feasibility of permanently evacuating flood plains as a method of reducing or eliminating future flood losses. The results of these studies indicate that the cost of evacuating entire communities far exceeds the benefits obtained in nearly all cases. However, partial evacuation of urban flood plains shows promise especially if the evacuated land can be utilized for recreational or park purposes of the type that present negligible damage risk. It is suggested that the information presented in this report be considered when an urban renewal project

such as the Water Street (NJ R-47) project is contemplated in the flood plains. 6/ The risks involved in investing in the flood plains should be compared with relocation to more suitable areas, thereby leaving the flood plains for uses compatible with the risk involved.

48. FLOOD PROOFING. Typical flood proofing measures applicable to various types of existing or contemplated property are: (1) the anchoring of tanks and other buoyant objects against flotation; (2) the raising of floor elevations of existing buildings above an anticipated flood damage level where practicable; (3) the construction of basements or floor slabs of contemplated buildings above a flood elevation limit; (4) the water proofing of openings below flood level elevations; (5) the provision of openings equipped with flap valves for structures that have basements or floor slabs that normally can be drained to the outside by gravity (flap valves should be suitable protected to prevent their clogging, for if a flap valve were to be wedged open by foreign material it would defeat its purpose by enabling flood waters to have access to the basement or building); (6) the waterproofing and installation of sump pumps in buildings that cannot be normally drained by gravity; and (7) providing for surrounding site drainage away from buildings wherever possible.

49. OTHER CONTROLS. Financial controls exercised by banks, private lending institutions and by governmental agencies act as deterrents to development in the flood plains where risks are excessive. In addition, Federal agencies involved in urban planning and redevelopment normally seek information regarding flood risks prior to determining whether Federal funds should be provided for urban redevelopment. Another deterrent to development of the flood plains would be the imposition of a special tax on such developments. In the event a developer or land owner does build in the flood plain, the revenue collected from the special tax could be used to compensate the affected community for the cost of providing emergency services during times of floods to those developments in the flood plains.

50. Flood insurance has been proposed as a means of providing coverage against flood losses in unprotected areas. However, neither the private insurance companies nor the Federal government has as yet been able to implement a feasible insurance program. The "Federal Flood Insurance Act of 1956" was enacted following the severe floods of 1955 in the northeastern section of the country and in California. Congress has not yet appropriated funds to carry out

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6/ This urban renewal project is located in Mount Holly, bounded by Washington, Main, Water Streets, and the railroad.

the provisions of that act. However, one of its most important provisions is that the Federal and state governments would share in subsidizing the issued policies. The policy rates would reflect the degree of risk involved. It was therefore in the interest of both the Federal and state governments that imprudent use of the flood plains be discouraged.

51. The State of New Jersey has been encouraging the acquisition of land for open-space preservation. The New Jersey Department of Conservation and Economic Development has a program, known as Green Acres, under which $60 million is provided to reserve open spaces for conservation and outdoor recreation. Under that program $40 million is available for direct state land purchases, and $20 million for grants to counties and local communities on a 50 percent matching fund basis for their open space projects. These grants could be used to acquire flood plain areas for open space purposes.

52. The Fish and Wildlife Service of the U. S. Department of the Interior with the assistance of the New Jersey Division of Fish and Game made an investigation on the fish and wildlife resources in the study area. In a report on its investigation, the Service states that Rancocas Creek and its tributaries contain important fisheries and spawning habitats for certain migratory fish and that the marshes and wooded lands of the flood plains are important habitats for waterfowl, pheasant, grouse, deer, muskrat, and furbearing animals. These lands contain the only major wild habitat in the more intensively cultivated portion adjacent to lower Rancocas Creek and should be preserved for hunting, fishing and wildlife management. The Service recommended that those wetland areas found to be within the flood plain should be preserved either by zoning or by public ownership, and that any bottomland area of 100 acres or more within the flood plain be called to the attention of the New Jersey Division of Fish and Game for consideration as a wildlife management unit. Additional information on that investigation can be obtained from:

Regional Director
Fish and Wildlife Service
U. S. Department of the Interior
Bureau of Sport Fisheries and Wildlife
U. S. Post Office and Courthouse
Boston, Massachusetts 02109

53. Flood warning signs and high water markers should be used in the flood plain, at key locations, for the purpose of informing the public of the susceptibility of the areas to high water stages.

This would enable industrial and commercial firms and the residents located within the flood plain to make plans for reducing future flood damages and would warn the general public of probable dangerous areas.

54. In view of the modern systems of communication, flood forecasting and warning has been recognized as one of the best means of flood damage alleviation. This is especially true in localities, as is typical of the study area, where the terrain is such that flood waters concentrate quickly leaving only little time to take effective precautionary measures. The United States Weather Bureau has developed a system for issuing advanced warnings of impending storms. With the use of radar, the Weather Bureau can detect storms more effectively and thus issue timely warnings of their advancement. The weather station issues these warnings to a designated official of a watershed and apprises him of the forecasted extent and duration of the expected storm. With that information and with data pertaining to the watershed, such as antecedent ground moisture and channel capacity, the local official can determine the possible flooding conditions and disseminate appropriate flood warnings to those concerned. The organization of such a flood warning system for the various reaches of Rancocas Creek is feasible and could be coordinated with the help of the U. S. Weather Bureau.

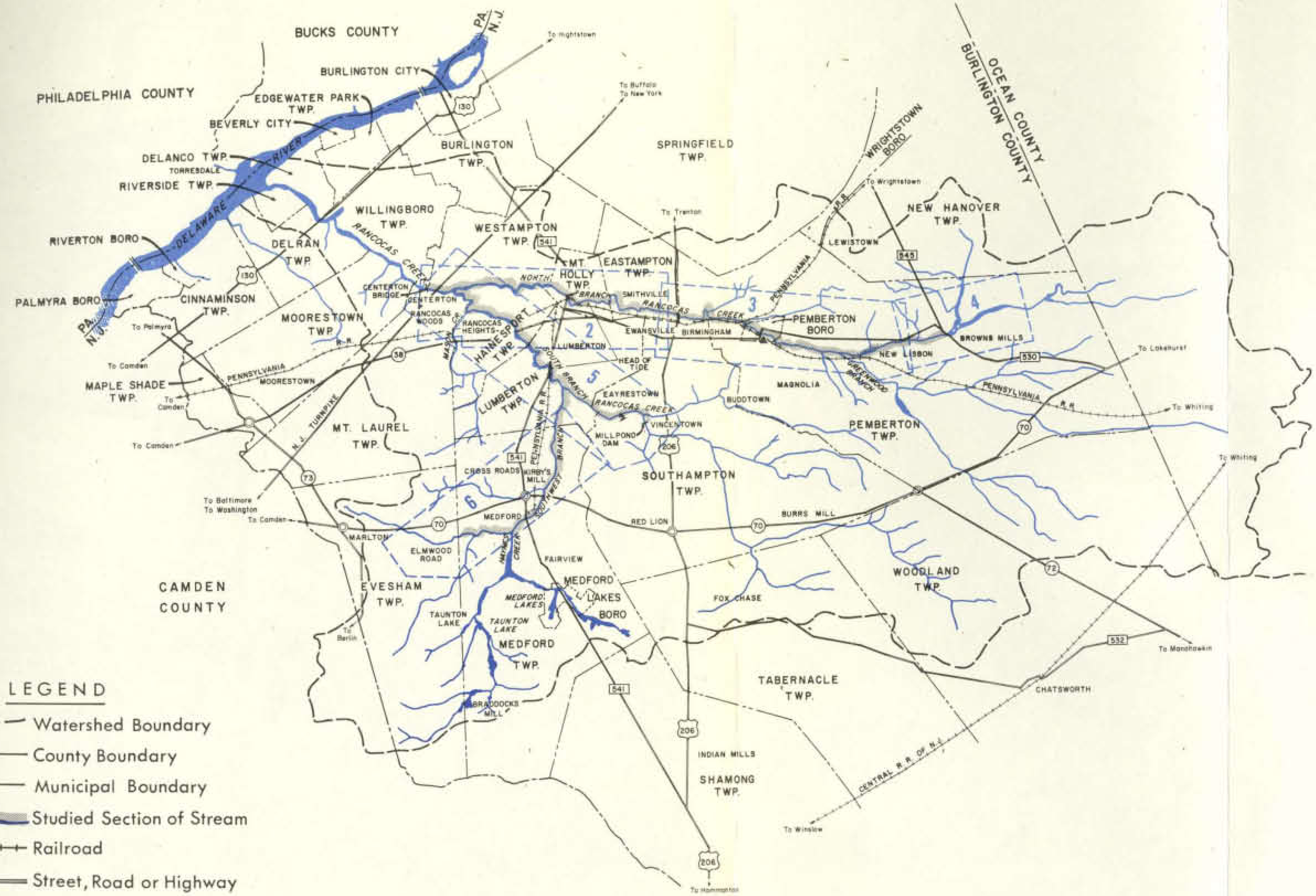
55. It should be noted that the absence of mention of other possible measures in this report should not be construed as eliminating those flood plain regulating measures from future consideration by the local authorities concerned.

56. POSSIBLE DIRECT FLOOD CONTROL MEASURES. There are no planned flood control improvements, Federal or otherwise, which will give positive protection to the flood plain along Rancocas Creek. Such direct measures as channel improvements to increase discharge capacities, flood walls and levees, and dams and reservoirs would definitely reduce flood damages. Such projects are normally authorized only when the benefits obtained from eliminating losses which occur in the absence of the protection are equal to or greater than the cost of providing the protection. Less costly direct measures could be effected by local authorities by maintaining a continuous surveillance of the stream to prevent unauthorized dumping, removing fallen trees that may become temporary debris dams, and keeping bridge and culvert openings clear of debris or vegetative growth.

57. CONCLUSION. Flood damages will continue to occur to existing developments in the flood plains of Rancocas Creek and its tributaries in the absence of adequate flood control improvements.

The guidelines presented in this report for the purpose of reducing flood damages to existing structures, such as flood-proofing, flood-warning and evacuation plans, are undoubtedly of prime importance. However, these guidelines will not prevent additional development in the flood plains and hence the attendant additional flood damages. For this reason, the flood profiles, the flood plain maps, guidelines and other information pertaining to open space, or restricting future use of the flood plains to purposes that are compatible with the risk involved are presented. The primary purpose of this information is to prevent the additional future flood losses that would occur in the absence of such information. These matters are presented only for the purpose of indicating the type of actions or alternatives that may be considered to reduce and/or prevent future flood damages. Additional detailed analysis will be needed by those concerned to decide on a course of action.

W. W. WATKIN, JR.
Colonel, Corps of Engineers
District Engineer



LEGEND

- Watershed Boundary
- County Boundary
- Municipal Boundary
- Studied Section of Stream
- Railroad
- Street, Road or Highway
- 130 U. S. Highway
- 70 State Highway
- 545 Secondary State Highway
- ▲ U. S. G. S. Stream Gage
- Areas Covered by Aerial Maps Plates 2–6

LOCATION MAP

SCALE IN MILES

0 10 20 30 40

FLOOD PLAIN INFORMATION REPORT

RANCOCAS CREEK

BURLINGTON COUNTY, NEW JERSEY

WATERSHED MAP

MILES

0 5 10

PLATE 1


FLOOD PLAIN INFORMATION REPORT
RANCOCAS CREEK
BURLINGTON COUNTY, NEW JERSEY
NORTH BRANCH
MOUNT HOLLY AREA
FLOOD PLAIN MAP
LEGEND
EXTENT OF FLOODING REFLECTING 1964
FLOOD PLAIN CONDITIONS
20-YEAR FLOOD
100-YEAR FLOOD
STANDARD PROJECT FLOOD
LIMIT OF STUDY AREA
SCALE IN FEET
500 0 1000 2000
NEW JERSEY TURNPIKE
NORTH BRANCH RANCOCAS CREEK
CENTERTON
RANCOCAS WOODS
PLATE 1
MATCH LINE
SOUTH BRANCH RANCOCAS CREEK
HAINESPORT
MARNE HIGHWAY ROUTE 537
MOUNT HOLLY
ROUTE 537
BRANCH ST.
MOUNT HOLLY-SMITHVILLE RD.
RANCOCAS-MASONVILLE RD.
CREEK ROAD
RANCOCAS HEIGHTS
PENNSYLVANIA R.R.
ROUTE 38
ROUTE 541
PINE ST.
NORTH BRANCH RANCOCAS CREEK
SOUTH PEMBERTON RD.
PENNSYLVANIA R.R.
MATCH LINE PLATE 3
ROUTE 530
HAINESPORT-MOUNT LAUREL RD.
HAINESPORT-LUMBERTON RD.
PENNSYLVANIA R.R.
MOUNT HOLLY-MEDFORD RD.
MOUNT HOLLY-FAYETTOWN-VINCENTOWN RD.
N

PLATE 2


MATCH LINE PLATE 2
NORTH BRANCH RANCOCAS
PENNSYLVANIA R.R.
N
PEMBERTON
EWANSVILLE
BIRMINGHAM
BIRMINGHAM-ILLINGHAM RD
PENNSYLVANIA R.R.
PEMBERTON-BROWNS MILLS RD
ROUTE 530
MATCH LINE PLATE 4
NORTH BRANCH RANCOCAS CREEK
SOUTH PEMBERTON RD.
ROUTE 530
NEW LISBON
PENNSYLVANIA R.R.
NEW LISBON-MAGNOLIA RD.
MAGNOLIA RD.
U.S. ROUTE 206
PEMBERTON-VINCENTOWN RD
FOUR MILE COLONY RD.
FLOOD PLAIN INFORMATION REPORT
RANCOCAS CREEK
BURLINGTON COUNTY, NEW JERSEY
NORTH BRANCH
PEMBERTON AREA
FLOOD PLAIN MAP
LEGEND
EXTENT OF FLOODING REFLECTING 1964
FLOOD PLAIN CONDITIONS
20-YEAR FLOOD
100-YEAR FLOOD
STANDARD PROJECT FLOOD
LIMIT OF STUDY AREA
SCALE IN FEET
500 0 1000 2000

PLATE 3

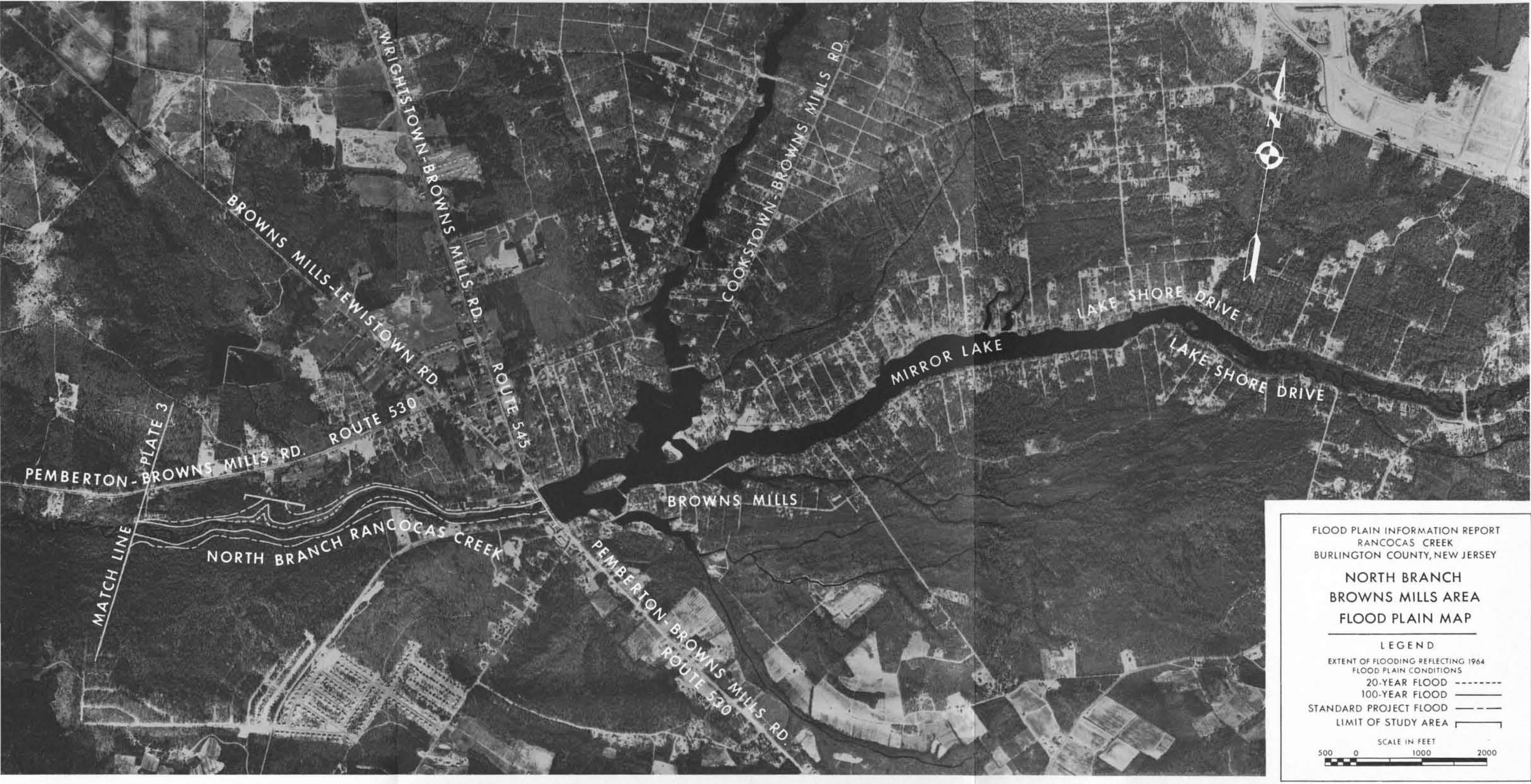
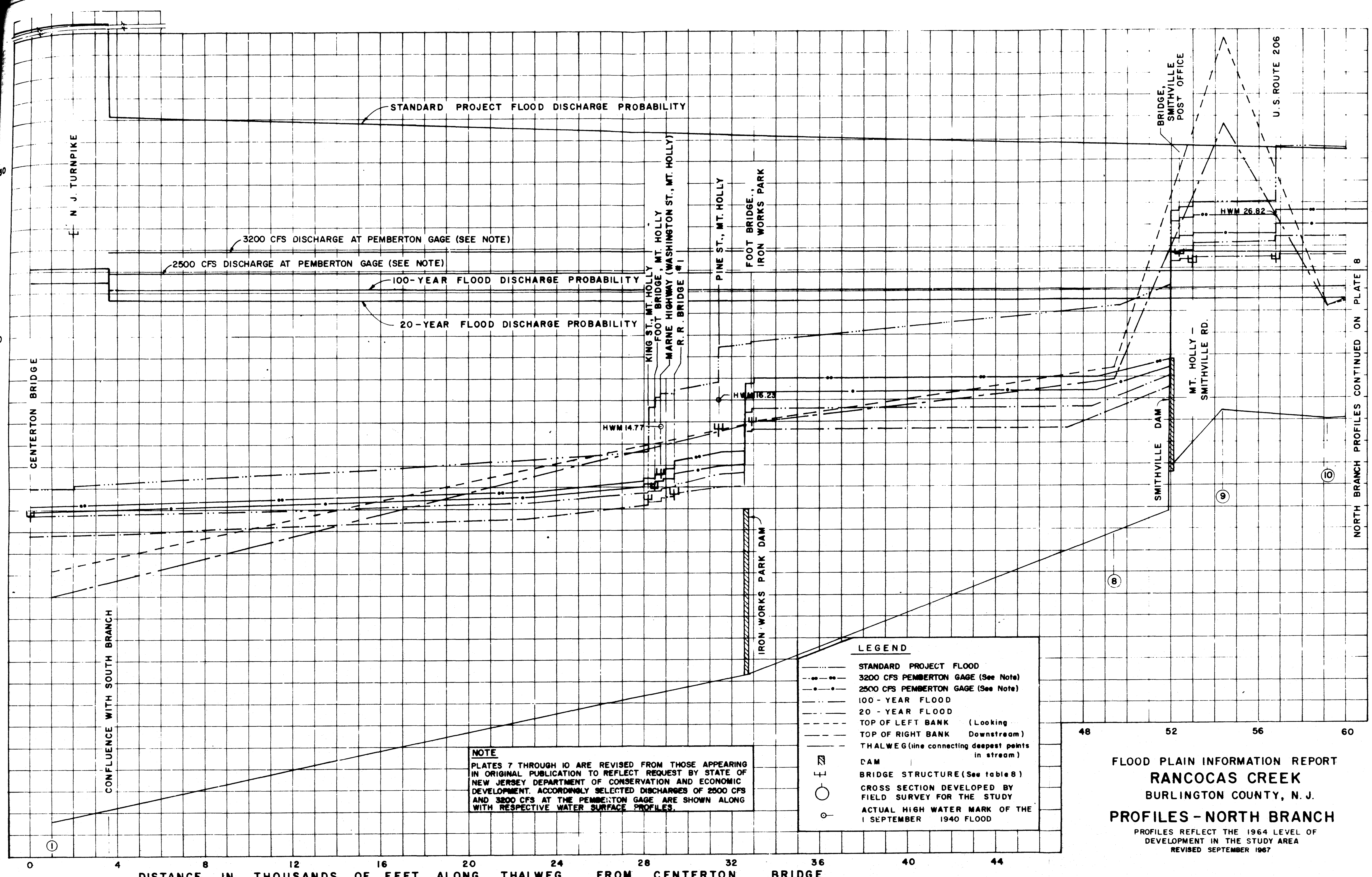

WRIGHTSTOWN-BROWNS MILLS RD.
COOKSTOWN-BROWNS MILLS RD.
BROWNS MILLS-LEWISTOWN RD.
ROUTE 545
LAKE SHORE DRIVE
LAKE SHORE DRIVE
MIRROR LAKE
ROUTE 530
PEMBERTON-BROWNS MILLS RD.
PLATE 3
MATCH LINE
BROWNS MILLS
NORTH BRANCH RANCOCAS CREEK
PEMBERTON-BROWNS MILLS RD.
ROUTE 530
N
FLOOD PLAIN INFORMATION REPORT
RANCOCAS CREEK
BURLINGTON COUNTY, NEW JERSEY
NORTH BRANCH
BROWNS MILLS AREA
FLOOD PLAIN MAP
LEGEND
EXTENT OF FLOODING REFLECTING 1964
FLOOD PLAIN CONDITIONS
20-YEAR FLOOD
100-YEAR FLOOD
STANDARD PROJECT FLOOD
LIMIT OF STUDY AREA
SCALE IN FEET
500 0 1000 2000

PLATE 4


MOUNT HOLLY-BEVERLY RD
NEW JERSEY TURNPIKE
NORTH BRANCH RANCOCAS CREEK
MATCH LINE PLATE 2
RANCOCAS WOODS
RANCOCAS HEIGHTS
HAINESPORT-MOUNT LAUREL RD
ROUTE 38
MARNE HIGHWAY
PENNSYLVANIA R.R.
SOUTH BRANCH RANCOCAS CREEK
NEW RD.
PENNSYLVANIA R.R.
LUMBERTON
HAINESPORT-LUMBERTON RD.
MEDFORD RD.
MOUNT HOLLY-
NEWBOLDS CORNER
MOUNT HOLLY-EAYRESTOWN
VINCENTOWN RD.
FOSTERTOWN-EAYRESTOWN RD.
RANCOCAS CREEK
SOUTHWEST BRANCH
MATCH LINE PLATE 6
EAYRESTOWN
SOUTH BRANCH RANCOCAS CREEK
VINCENTOWN
MAIN ST.
U.S. ROUTE 206
LIGHT DUTY ROAD AT MILLPOND DAM
RED LION-VINCENTOWN RD
CHURCH RD.
EAYRESTOWN-RED LION RD.
FLOOD PLAIN INFORMATION REPORT
RANCOCAS CREEK
BURLINGTON COUNTY, NEW JERSEY
SOUTH BRANCH
TO VINCENTOWN
FLOOD PLAIN MAP
LEGEND
EXTENT OF FLOODING REFLECTING 1964
FLOOD PLAIN CONDITIONS
20-YEAR FLOOD
100-YEAR FLOOD
STANDARD PROJECT FLOOD
LIMIT OF STUDY AREA
SCALE IN FEET
500
0
1000
2000

PLATE 5



FLOOD PLAIN INFORMATION REPORT

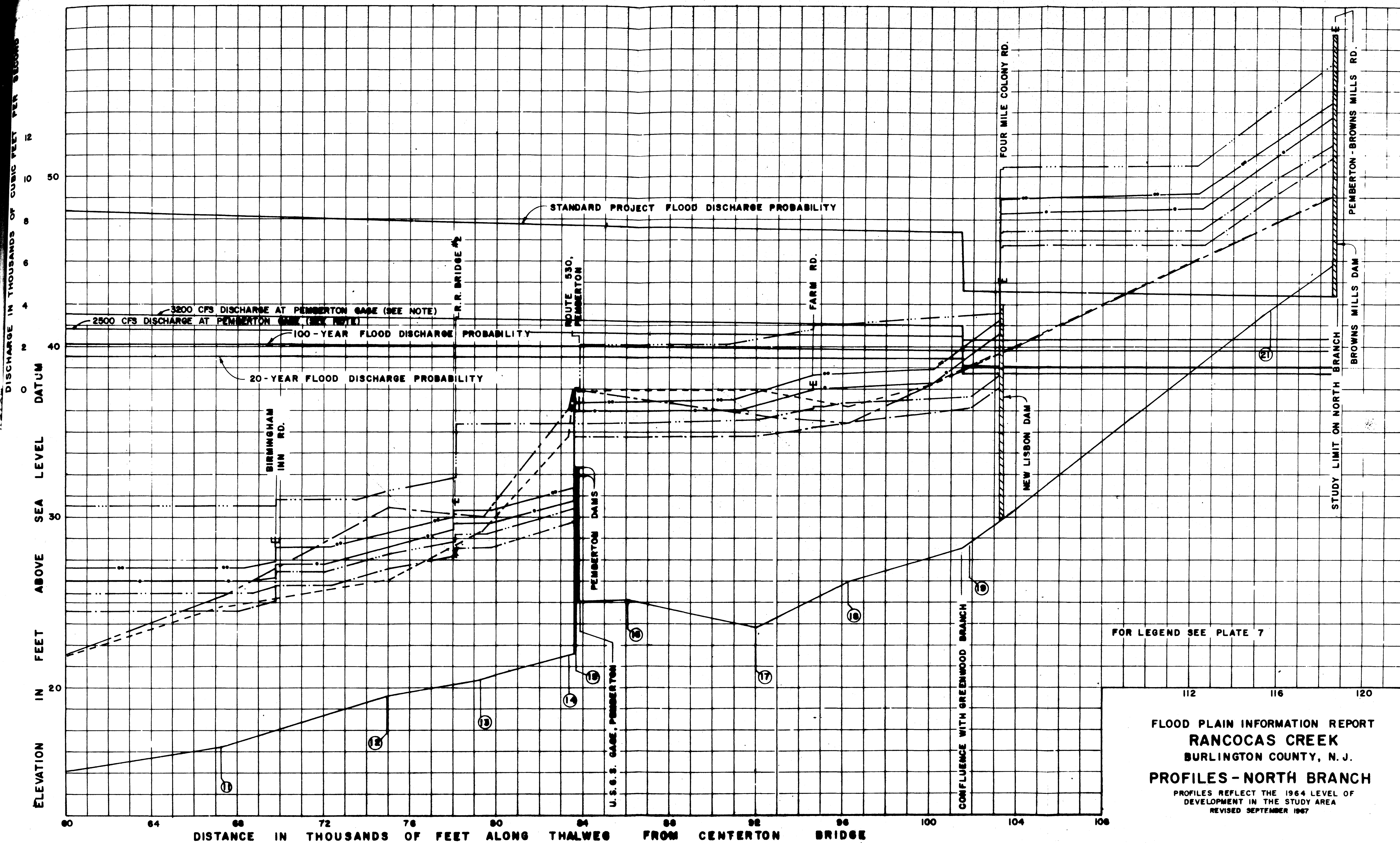
RANCOCAS CREEK

BURLINGTON COUNTY, N. J.

PROFILES - NORTH BRANCH

PROFILES REFLECT THE 1964 LEVEL OF DEVELOPMENT IN THE STUDY AREA
REVISED SEPTEMBER 1967

SHEET 1 OF 4



FLOOD PLAIN INFORMATION REPORT

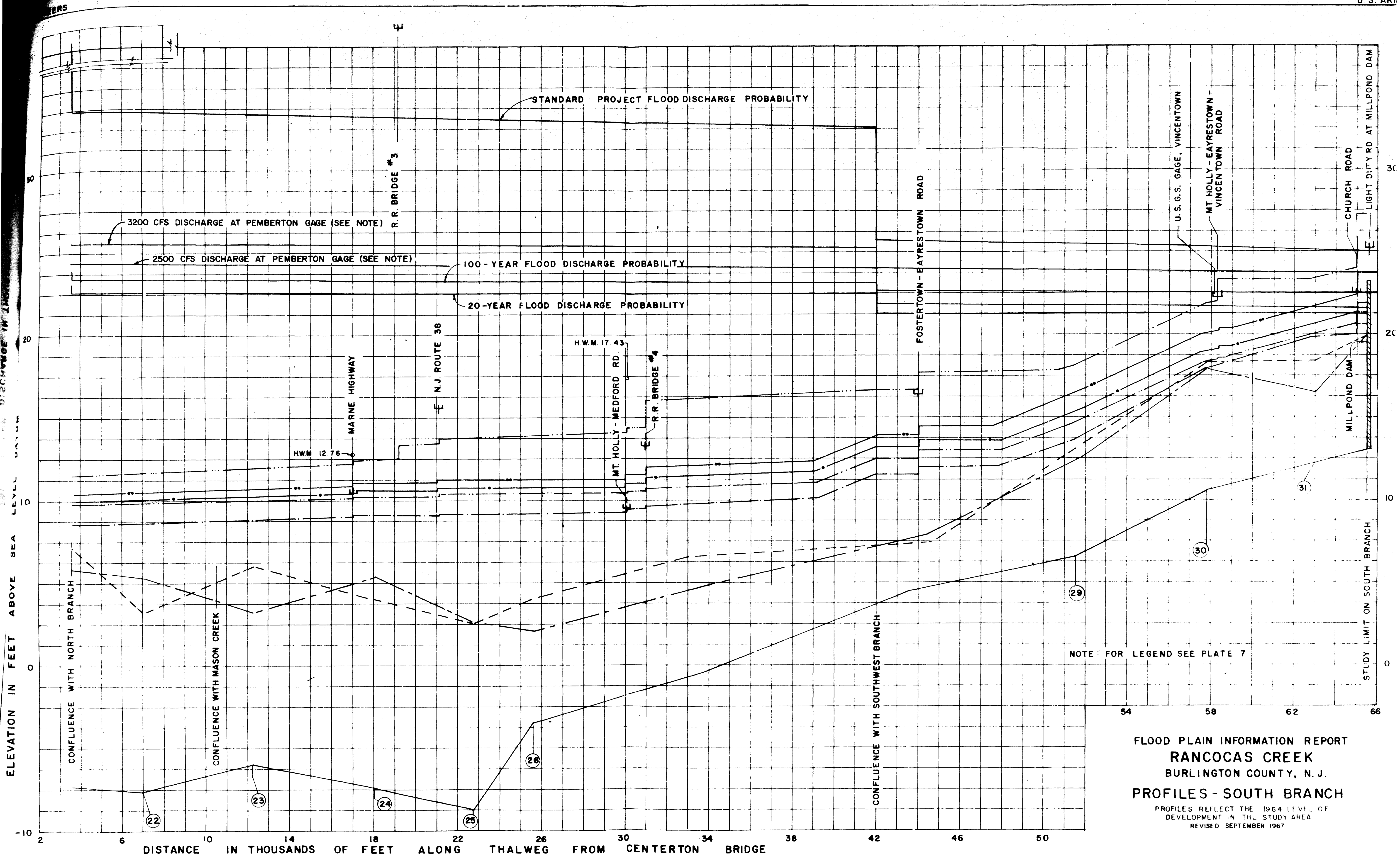
RANCOCAS CREEK

BURLINGTON COUNTY, N.J.

PROFILES - NORTH BRANCH

PROFILES REFLECT THE 1964 LEVEL OF DEVELOPMENT IN THE STUDY AREA
REVISED SEPTEMBER 1967

SHEET 2 OF 4



FLOOD PLAIN INFORMATION REPORT

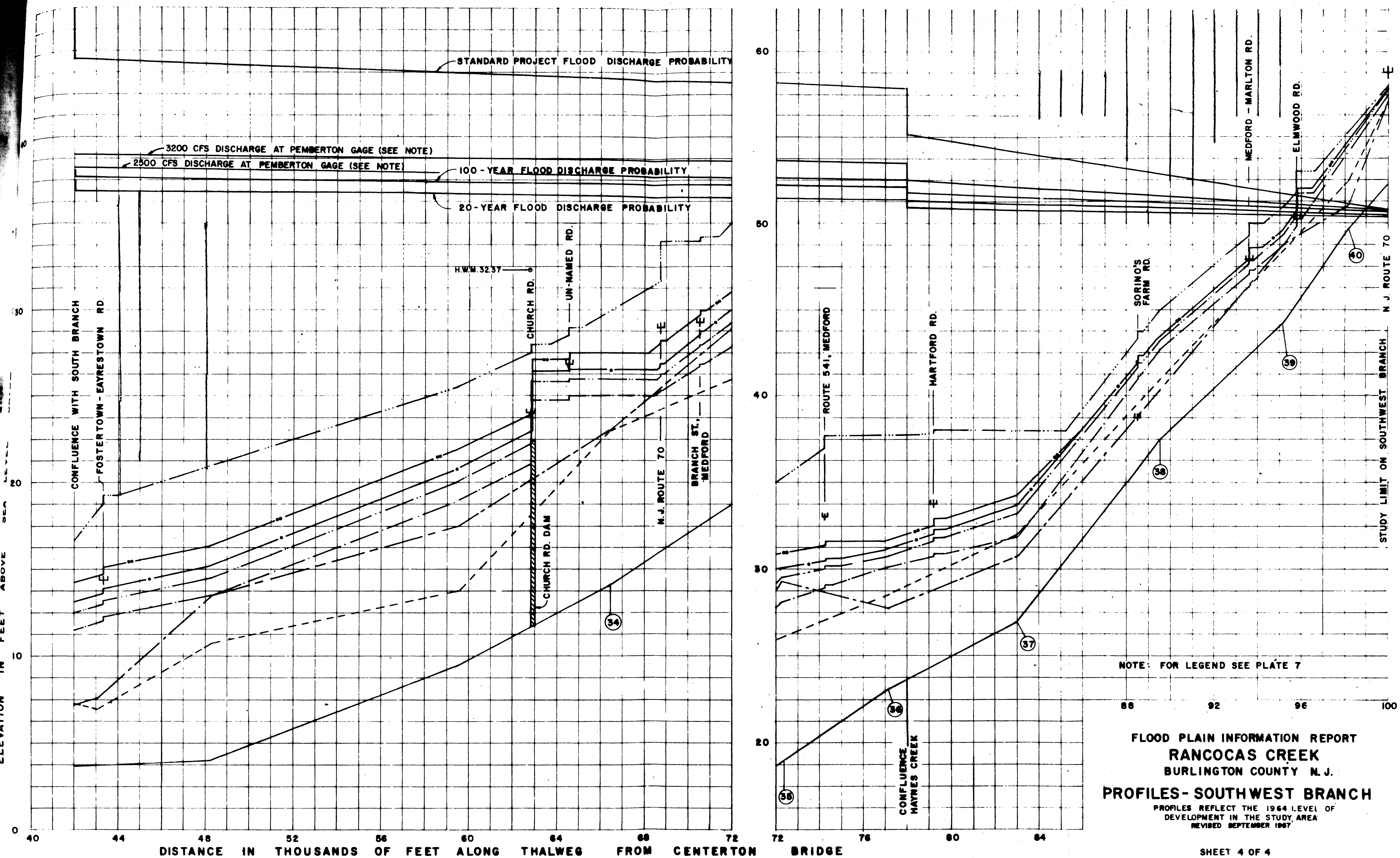
RANCOCAS CREEK

BURLINGTON COUNTY, N.J.

PROFILES - SOUTH BRANCH

PROFILES REFLECT THE 1964 LEVEL OF DEVELOPMENT IN THE STUDY AREA
REVISED SEPTEMBER 1967

SHEET 3 OF 4



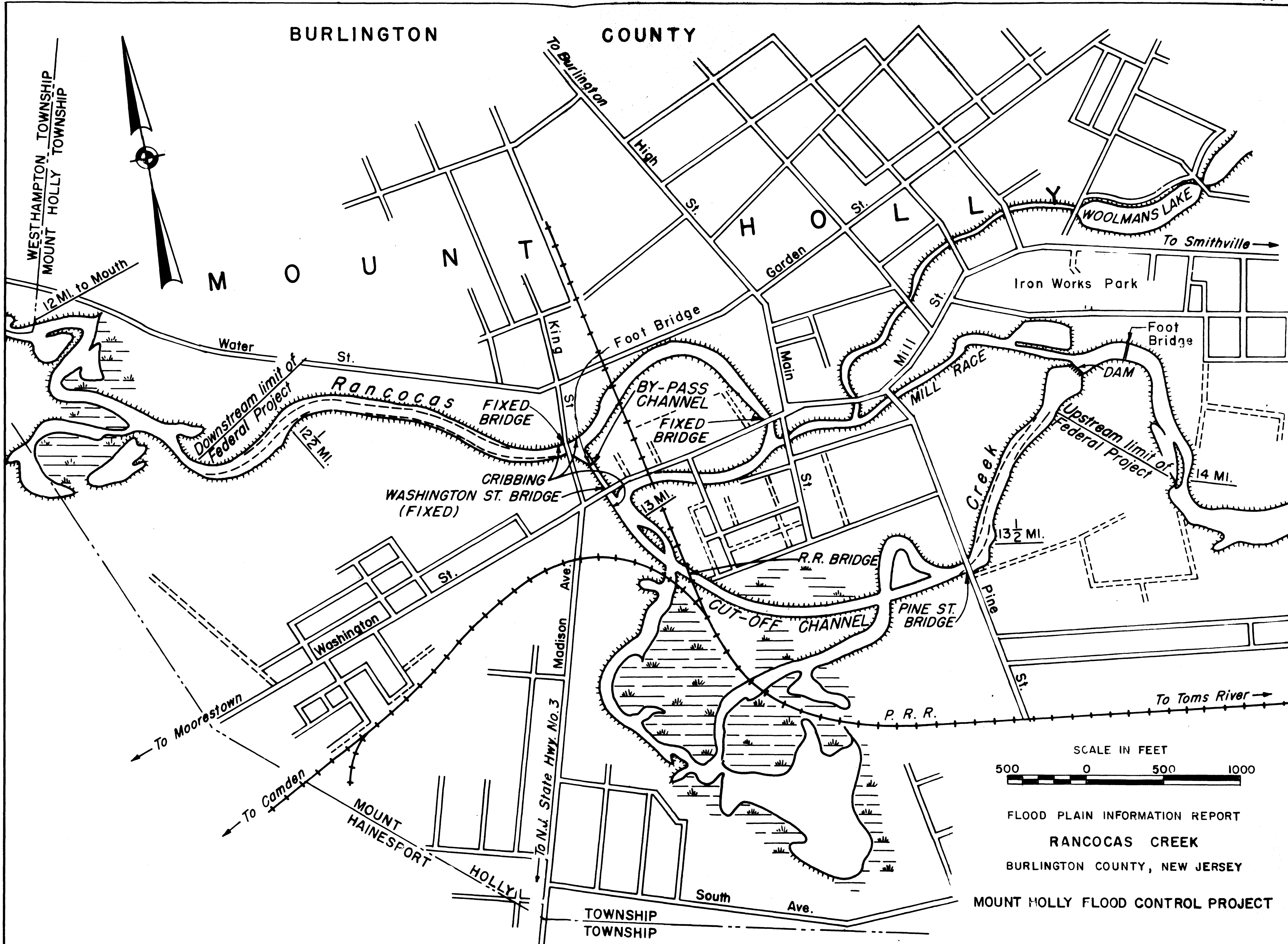
FLOOD PLAIN INFORMATION REPORT

RANCOCAS CREEK

BURLINGTON COUNTY N.J.

PROFILES - SOUTHWEST BRANCH

PROFILES REFLECT THE 1964 LEVEL OF DEVELOPMENT IN THE STUDY AREA
REVISED SEPTEMBER 1967



FLOOD PLAIN INFORMATION REPORT

RANCOCAS CREEK

BURLINGTON COUNTY, NEW JERSEY

MOUNT HOLLY FLOOD CONTROL PROJECT

FLOOD PLAIN INFORMATION REPORT

ON THE

RANCOCAS CREEK

IN

BURLINGTON COUNTY, NEW JERSEY

GENERAL APPENDIX

I

GLOSSARY OF TECHNICAL TERMS
USED IN THE REPORT
AND
REFERENCES

HYDROLOGIC TERMS

1. CHANNEL. A natural or artificial watercourse of perceptible extent, with definite bed and banks to confine and conduct continuously or periodically flowing water.

2. FLOOD.

a. General definition.

(1) In popular usage, a "flood" is commonly interpreted as a temporary overflow of lands not normally covered by water, which lands are used or usable by man when not inundated. In a hydrologic sense, a "flood" associated with a particular stream or other body of water is any relatively high temporary rise in water level or discharge resulting from changes in rates of inflow.

(2) However, in connection with the study area along Rancocas Creek, a "flood" is considered as any temporary rise in stream flow, or stage, that results in significant adverse effects in the vicinity under study. Adverse effects of floods may include damages from overflow of land areas; temporary backwater effects in sewers and local drainage channels; bank erosion or channel shifts; creation of unsanitary conditions or other unfavorable situations by deposition of materials in stream channels during flood recessions; rise of ground water coincident with increased stream flow; interruption of traffic at bridge crossings or fords; and other problems of similar nature.

b. Flood stage. A term commonly used by the U. S. Weather Bureau and others to designate that stage, on a fixed river gage, at which overflow of the natural banks of the stream begins to cause damage in any portion of the reach for which the gage is used as an index.

3. FLOOD FREQUENCY (OR PROBABILITY).

a. General definitions. In statistical analysis, "frequency" means the number of times a specified event occurred in a given series of observations. In general, "probability" determinations associated with hydrology are estimates of average frequencies deemed likely to prevail during an infinitely long period in the future under specified circumstances; observations of actual frequencies during a period of record are used in conjunction with pertinent probability theories and raional analyses to deduce future period (say, 50 years) are not likely to be identical with the "most probable" frequency distribution deduced for a longer period, but unless otherwise specified it is usual practice to assume that the two are identical.

b. Conventional usage of term "frequency". In connection with flood damage analyses and flood control planning, it is customary to estimate the frequency (or probability) in which specific flood stages or discharges (or other elements) are "equalled or exceeded", rather than the freqeuncy of an exact value of stage or discharge. Such estimates are properly designated as "exceedence freqeuncy", or "cumulative frequency" value, but in practice are usually referred to simply as "frequency". Accordingly, unless otherwise specifically indicated, all references to flood frequency values will imply "exceedence frequencies".

c. Alternative forms of expressing estimated frequency (or probability) values. If the term "frequency" refers to "exceedence" frequency as stated in paragraph b, several expressions having essentially the same meaning may be used to specify flood frequency or probability. For example, if a statistical probability study indicates that a discharge of 50,000 cubic feet per second is likely to be equalled or exceeded at a particular stream gaging station once every 20 years, it may be said that this peak discharge value:

(1) is a 20-year frequency flood (or has a frequency of five times in 100 years);

(2) has a probability of 0.05 or 5 percent (i.e., 1/20) chance of occurrence in any year;

(3) has an average "exceedence" interval of 20 years (but this does not imply any regularity in periods between events.)

4. FLOOD HYDROGRAPH. A continuous graph representing stage or discharge at a particular location on a stream, plotted against time during a flood. Stage is usually expressed as elevation in feet above an arbitrary gage datum or above mean sea level; discharge as rate of flow in cubic feet per second; and time in hours or days. Pertinent characteristics related to the flood hydrograph are defined below:

a. Flood wave. A distinct rise in stage culminating in a crest and followed by recession to lower stages. A single flood hydrograph may include more than one "flood wave".

b. Flood peak. The highest value of the stage or discharge attained by a flood; thus, peak stage or peak discharge.

5. FLOOD OF RECORD. Any flood for which there are reasonably reliable data available. (This includes not only U. S. Geological Survey and other official gage records, but also unofficial reliable

records that are documented and complete enough to assure reasonably accurate evaluation.) Ordinarily the term is used to refer to "maximum flood of record".

6. FLOOD PLAIN. The relatively flat low land adjoining a water course or other body of water subject to overflow therefrom.

7. FLOOD PROFILE (BACKWATER PROFILE). The longitudinal profile assumed by the surface of a stream of water flowing in an open channel. (It may be drawn to show surface elevations at a given time, crests during a specific flood, or stages of concordant flows having same frequency of occurrence.)

8. HISTORICAL FLOOD. A known flood which occurred before systematic record keeping was begun for the stream or area under consideration.

9. MAXIMUM KNOWN FLOOD. The largest known flood which has occurred in a region whether it is an historical flood or a flood or record.

10. MAXIMUM PROBABLE FLOOD. As used by the Corps of Engineers, a hypothetical flood representing the most severe flood with respect to volume, concentration of runoff and peak discharge that may be expected from a combination of the most critical meteorological and hydrological conditions that are <u>reasonably possible</u> in the region. The term is used by others with a different meaning. (This concept previously has sometimes been termed "maximum possible flood.")

11. NATURAL FLOODWAY. The channel of the stream or body of water and that portion of the flood plain that is used to carry the flow of the flood.

12. STAGE-DISCHARGE CURVE (RATING CURVE). A graph showing the relation between the stage, elevation or gage height, usually plotted as ordinate, and the amount of water flowing expressed as volume per unit of time, plotted as abscissa. These curves may be used to convert stage hydrographs to discharge hydrographs.

13. STANDARD PROJECT FLOOD. A hypothetical flood, estimated by the Corps of Engineers, representing the critical flood runoff volume and peak discharge that may be expected from the most severe combination of meteorologic and hydrologic conditions that are considered <u>reasonably characteristic</u> of the geographical region involved, excluding extremely rare combinations. It has been found that, in general, standard project flood magnitudes (peak and volume) are equal to 40 to 60 percent of maximum probable flood estimates for the same basins, with an average ratio of about 50 percent.

REGULATORY TERMS

14. BUILDING CODE. A collection of regulations adopted by a local governing body setting forth standards for the construction of buildings and other structures for the purpose of protecting the health, safety, and general welfare of the public.

15. DESIGNATED FLOODWAY. The channel of a stream and that portion of the adjoining flood plain designated by a regulatory agency to provide for reasonable passage of flood flows.

16. ENCROACHMENT LINES. Lateral limits or lines along streams or other bodies of water, beyond which in the direction of the stream of other body of water no structure or fill may be added. Their purposes are to preserve the flood carrying capacity of the stream or other body of water and its flood plain, and to assure attainment of the basic objective of improvement plans that may be considered or proposed. Their location, if along a stream, should be such that the floodway between them including the channel, will handle a designated flood flow or condition. These lines are set by regulatory agencies and may be changed by them.

17. FLOOD PLAIN REGULATIONS. A general term applied to the full range of codes, ordinances, and other regulations relating to the use of land and construction within flood plain areas. The term encompasses zoning ordinances, subdivision regulation, building and housing codes, encroachment laws, open area regulations, and other similar methods of control affecting the use and development of flood plain areas.

18. SUBDIVISION REGULATIONS. Regulations and standards established by a local public authority, generally the local planning agency, with authority from a state enabling law, for the subdivision of land in order to secure coordinated land development, including adequate building sites and land for vital community services and facilities such as streets, utilities, schools and parks.

19. ZONING ORDINANCE. An ordinance adopted by a local governing body, with authority from a state zoning enabling law, which under the police power divides an <u>entire</u> local governmental area into districts and, within each district, regulates the use of land, the height, bulk, and use of buildings or other structures, and the density of population.

OTHER TERMS

20. REDEVELOPMENT AREA. An area designated by the Secretary of Commerce under Public Law 89-136, where persistent unemployment has

existed, and which will be eligible for Federal assistance in developing economic resources for permanent improvement of local economic and working conditions.

21. URBAN RENEWAL. The over-all program of public and private action, growing out of the National Housing Act of 1954, as amended, designed to prevent the spread of blight, to rehabilitate and conserve urban areas that can be economically restored, and to clear and redevelop areas that cannot otherwise be saved from blight.

22. FLOOD PLAIN CLEARANCE. Flood plain clearance involves the purchase and removal from the flood plain of structures subject to frequent and severe inundation or those structures, where economically feasible, which cause upstream inundation due to backwater.

23. FLOOD PLAIN MARKING. Flood plain marking involves conspicuously and permanently identifying high water elevations to emphasize the flood threat. Such provisions are used mainly in areas subject to flash flooding where danger to life may be involved or where no other provisions are made to regulate use of the flood plain.

24. LAND ACQUISITION FOR OPEN SPACE NEEDS. Acquisition of flood plains for open space or park purposes as a method of reducing future flood damages.

25. LAND TREATMENT. Land treatment includes the use of soil conservation practices such as planting of cover crops, contour stripping, woodland improvement, diversions and terraces, pasture improvements, erosion control along stream banks and clearing of debris in stream floodways to prevent flooding upstream of obstructions.

26. WEIR. The opening or channel through or over an obstruction.

27. HARMONIC SLOPE. The square of the harmonic mean of the square roots of slopes of equal segments of stream length. The mathematical expression representing the harmonic slope is as follows:

$$H_s = [n/((1/s_1)^{1/2} + (1/s_2)^{1/2} + (1/s_3)^{1/2} \ldots + (1/s_n)^{1/2})]$$

H_s = harmonic slope of the stream (ft./mile)

$s_{1,2,\ldots,n}$ = the different slopes of equal segments of stream length

n = the number of slopes of equal segments of stream length

28. ENERGY GRADE LINE. A line above the normal water surface a distance equivalent to the velocity heads (the distance a body must fall freely under the force of gravity to acquire the velocity it possesses) at all sections along the stream.

REFERENCES

29. REFERENCES. The following references were used in preparing this report:

Cooter, Harriet Holt, "To Stay Out of Floods," National Civic Review, Vol. L, No. 10 (1961), pp. 534-559.

Dole, Steven, "Flood Damage Alleviation in New Jersey," New Jersey Department of Conservation and Economic Development Water Resources Circular No. 3, 1961.

Murphy, Francis C., "Regulating Flood - Plain Development," University of Chicago Department of Geography Research Paper No. 56, Chicago, 1958.

White, Gilbert F., et al., "Papers on Flood Problems," University of Chicago Department of Geography Research Paper No. 70, Chicago, 1961.

White, Gilbert F., "The Control and Development of Flood Plain Areas", Mathew Bender and Co., New York, 1961.

II

SECTION 206, PUBLIC LAW 86-645

(FLOOD CONTROL ACT OF 1960)

AS AMENDED

II

SECTION 206, PUBLIC LAW 86-645 (FLOOD CONTROL ACT OF 1960) AS AMENDED

The general authority for flood plain information studies by the Corps of Engineers is Section 206, Public Law 86-645 (approved 14 July 1960), as amended by Public Law 89-298, which reads:

"SEC 206(a) That, in recognition of the increasing use and development of the flood plains of the rivers of the United States and of the need for information on flood hazards to serve as a guide to such development, and as a basis for avoiding future hazards by regulation of use by States and municipalities, the Secretary of the Army, through the Chief of Engineers, Department of the Army, is hereby authorized to compile and disseminate information on floods and flood damages, including identification of areas subject to inundation by floods of various magnitudes and frequencies, and general criteria for guidance in the use of flood plain areas; and to provide engineering advice to local interests for their use in planning to ameliorate the flood hazard; Provided, That the necessary surveys and studies will be made and such information and advice will be provided for specific localities only upon the request of a State or a responsible local governmental agency and upon approval by the Chief of Engineers.

"(b) The Secretary of the Army is hereby authorized to allot, from any appropriations hereinafter made for flood control, sums not to exceed $2,500,000 in any one fiscal year for the compilation and dissemination of such information."

III

APPLICATION FROM LOCAL INTERESTS FOR FLOOD PLAIN INFORMATION STUDY

BURLINGTON COUNTY PLANNING BOARD

MOUNT HOLLY, NEW JERSEY

OFFICE OF
EXECUTIVE SECRETARY
LEPHONE, AMHERST 7-3300 EXT. 261

May 25, 1962

Colonel T.H. Setliffe, District Engineer
U. S. Army Engineer District, Philadelphia
P. O. Box 8629
Philadelphia 1, Pennsylvania

Dear Colonel Setliffe:

The Burlington County Planning Board has been authorized by the Burlington County Board of Chosen Freeholders to make application for a flood plain information study of the three main branches of the Rancocas Creek in Burlington County. These branches are the North Branch, South Branch, and Southwest Branch. The authority for the Planning Board, a legally constituted Burlington County Agency, is covered in the laws of 1935, Chapter 251, and known as Revised Statute 40:27-1 to 40:27-12 inclusive, a copy of which is attached as part of this application. Your attention is called to 40:27-2 and 40:27-12.

Detailed study and mapping are desired for the reaches shown in red on the enclosed highway map. The limits of detailed mapping extend from the Centerton Bridge in Westampton Township downstream of the confluence of the North and South Branches, and extend upstream along the North Branch to Browns Mills; on the South Branch upstream to Vincentown; and finally on the Southwest Branch upstream to Route 70.

Burlington County is vitally concerned with the rapid growth of the Fort Dix--McGuire complex in the vicinity of the North Branch of the Rancocas Creek, and its effect thereon; the rapid development pattern in the vicinity of Medford, Medford Lakes and its effect upon the Southwest Branch of the Rancocas Creek; the proposed development in the vicinity of Southampton Township, and its effect upon the South Branch of the Rancocas Creek. We feel that unless immediate attention is given to flood plain zoning by the municipalities, this area will be highly susceptible to increasing flood damage resulting from encroachment and development.

The Burlington County Planning Board therefore requests, that pursuant to the authority granted to the Corps of Engineers under the provisions of Section 206, P.L. 86-645, the Philadelphia District, Corps of Engineers undertake a flood plain information study of the above branches of Rancocas Creek within the limits specified. Upon receipt of this data, the Burlington County Planning Board intends to encourage the adoption of local ordinances designed to provide adequate floodways to prevent the creation of future flood problems. It is therefore requested that the following information be provided:

1. The entire area subject to inundation during a recurrence of the largest flood of record. The flood profile for this flood should also be presented;

2. The areas subject to inundation during the occurrence of floods having frequencies of occurrence of 2.33 (mean annual flood), 15, 25, 50, 75, and 100 years. In addition, the areas subject to inundation during the occurrence of the Standard Project Flood should also be shown. Flood profiles for all of these floods should be shown. In circumstances where it is not practical to provide the information requested above, the Corps of Engineers shall provide as much of the requested information as it considers feasible;

3. The determination of broad guide lines for the establishment of rights-of-way limits for floodways. Particular emphasis should be given to the 50 and 75 year floods: tentative estimates of suggested clear widths for floodways are most urgently needed and would be greatly appreciated. In this connection, the limits of the "flood channel" delineated in Figure K-2 of the New York District's Rondout Creek and Wallkill River Survey Report for Flood Control is essentially what is wanted. We do, however, prefer the use of the term "floodway". It is clearly understood that the establishment of final limits of floodways is a local responsibility;

4. The applicability of utilizing reservoirs or other methods of flood control to minimize future flood losses. It is hoped that this data can be provided under the provisions of EM 1165-2-111, 29 Dec. 1961: App. II page 11, Section 22c.

The Burlington County Planning Board is aware that funds for flood plain information studies are limited. Our original application would have included the request to study all streams within the Rancocas Creek Watershed. Through consultation with the New Jersey Division of Water Policy and Supply, we have, however, limited our application to the three branches noted above.

The Burlington County Planning Board hereby grants assurance of cooperation on the following required items:

1. Available information and data will be furnished for the study.

2. The applicant will publicize the information report in the community and area concerned, and make copies available for use or inspection by responsible interested parties and individuals;

3. Zoning and other regulatory, development and planning agencies, and public information media, will be provided with the flood plain information for their guidance an appropriate action;

4. Survey markers, monuments, etc., established in any Federal surveys undertaken for Sec. 206 studies, or in regular surveys in the area concerned, will be preserved and safeguarded.

In partial fulfillment of item 1 above, please find enclosed:

1. A bridge map of Burlington County showing the designation of each bridge and culvert. From this designation additional information, including description and dimensions of each structure, is available in the files of the County Engineer's Office and will be furnished free upon request.

2. An Engineering Soil Survey of Burlington County made by Rutgers, the State University, in cooperation with the Highway Department and the U.S. Bureau of Public Roads. The area colored may be considered as a rough approximation of the land subject to regular or periodical inundation along Rancocas Creek and its tributaries. The definitions of pertinent symbols are listed in the Soil Survey Report #1, a copy of which is enclosed.

3. Aerial photographs of the April and May 1956 flight by Robinson Aerial Surveys Incorporated at a scale of 1" = 400' will be furnished on a loan basis.

Included in this application are copies of letters of consent received from the various municipalities located adjacent to the three branches of the Rancocas Creek; a copy of the resolution passed by the Burlington County Board of Chosen Freeholders dated October 10, 1961 authorizing the Burlington County Planning Board to make application for the flood plain information study; copies of communications forwarded each municipality from the Board of Chosen Freeholders dated October 13, 1961; copies of communications from the Burlington County Planning Board to each municipality requesting their cooperation and support of the flood plain information study; and copies of communications received from United States Senators Clifford P. Case and Harrison A. Williams, and Congressman Frank Thompson, Fourth Congressional District, New Jersey.

This brochure, together with its several enclosures, is being furnished to Mr. George R. Shanklin, Chief Engineer and Acting Director, Division of Water Policy and Supply, Trenton, New Jersey and to each of the municipalities involved.

Should any questions arise pertaining to this application, please feel free to contact me. I would like to make myself available to you at your convenience on any matter in hopes of expediting the flood plain information study.

Very truly yours,

George R Ballard

GEORGE R. BALLARD
Executive Secretary

GRB:ree

State of New Jersey

DEPARTMENT OF CONSERVATION
AND ECONOMIC DEVELOPMENT

SALVATORE A. BONTEMPO, COMMISSIONER

DIVISION OF
[WATE]R POLICY AND SUPPLY

PLEASE ADDRESS REPLY TO:

32 E. Hanover St.
Trenton, N. J.

May 28, 1962

Colonel T. H. Setliffe, District Engineer
U. S. Army Engineer District, Philadelphia
P. O. Box 8629
Philadelphia 1, Pennsylvania

Dear Colonel Setliffe:

In my letter to you of March 5, 1962 I advised that Commissioner H. Mat Adams of the Department of Conservation and Economic Development had designated our Division to cooperate with you in implementing the flood plain information study program authorized by Section 206, P.L. 86-645. On April 3, 1962 Governor Richard J. Hughes signed into law Chapter 19, P.L. 62. This measure, introduced as Assembly, No. 184, is enclosed and empowers this Division to "delineate and mark flood hazard areas, and to co-ordinate effectively the development, dissemination, and use of information on floods and flood damages that may be available."

We believe the above clearly establishes our responsibility to request flood plain information studies at our own discretion or to sponsor such requests on behalf of various local governmental agencies. Consequently, we hereby sponsor and transmit the enclosed request of the Burlington County Planning Board for a flood plain information study of the North, South, and Southwest Branches of Rancocas Creek within the limits specified in the County's letter of application.

On the second page of the Burlington County Planning Board's letter of application the required assurances of local cooperation have been agreed to. The Planning Board not only has the authority to grant these assurances but we have every confidence that the Board will faithfully carry them out. In order to underscore the great importance and hope with which the State of New Jersey views the flood plain information study program, we also grant assurance on the following items of local cooperation.

(1) Available information and data will be furnished for the study;

(2) The applicant will publicize the information report in the community and area concerned, and make copies available for use or inspection by responsible interested parties and individuals;

(3) Zoning and other regulatory, development and planning agencies, and public information media, will be provided with the flood plain information for their guidance and appropriate action;

(4) Survey markers, monuments, etc., established in any Federal surveys undertaken for Sec. 206 studies, or in regular surveys in the area concerned, will be preserved and safeguarded.

Concerning item one above, this Division will make available to the Philadelphia District Corps of Engineers, upon request and without cost, Riparian and Stream Surveys of (a) the main stem Rancocas Creek from its mouth upstream to the confluence of the North and South Branches; (b) the North Branch Rancocas Creek upstream to Mount Holly; and (c) the South Branch Rancocas Creek upstream to the vicinity of Eayrestown. These stream surveys present data in plan, profile, and cross-section, including details of bridges. A stream survey does not exist for the Southwest Branch. In addition, we will make available all information in our files pertaining to various types of encroachments which have been constructed in, along, or across Rancocas Creek and its tributaries; whatever information that we have on past floods and flood damages will also be made available.

Also enclosed for your perusal are copies of reports prepared by the U. S. Geological Survey in cooperation with this Division dealing with the extent and frequency of the flood plains of the Raritan and Millstone Rivers.

A flood plain information study of Rancocas Creek is considered to have the highest priority.

Very truly yours,

George R. Shanklin

George R. Shanklin
Chief Engineer and
Acting Director

Encls.

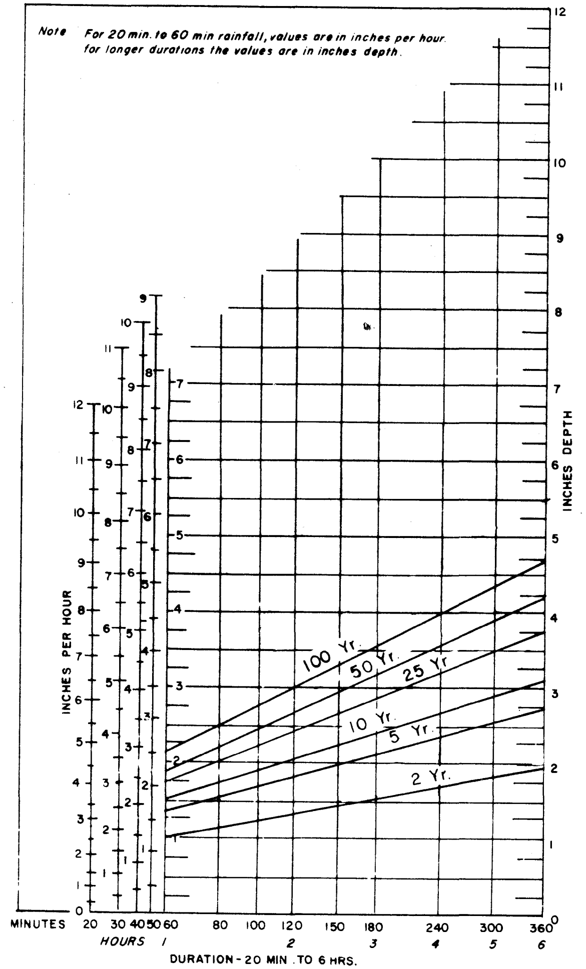
cc: H. Mat Adams, Commissioner
George R. Ballard, Burlington County Planning Board

IV

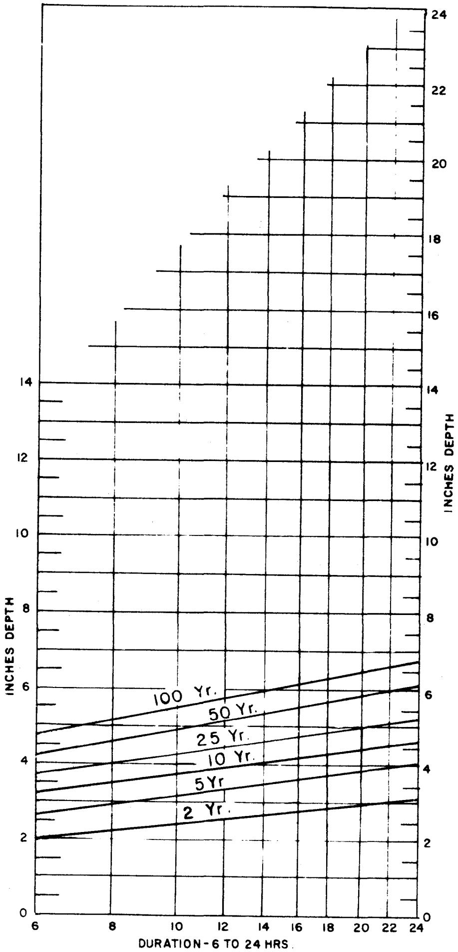
HYDRAULIC AND HYDROLOGIC FIGURES

RAINFALL INTENSITY (DEPTH) DURATION DIAGRAMS

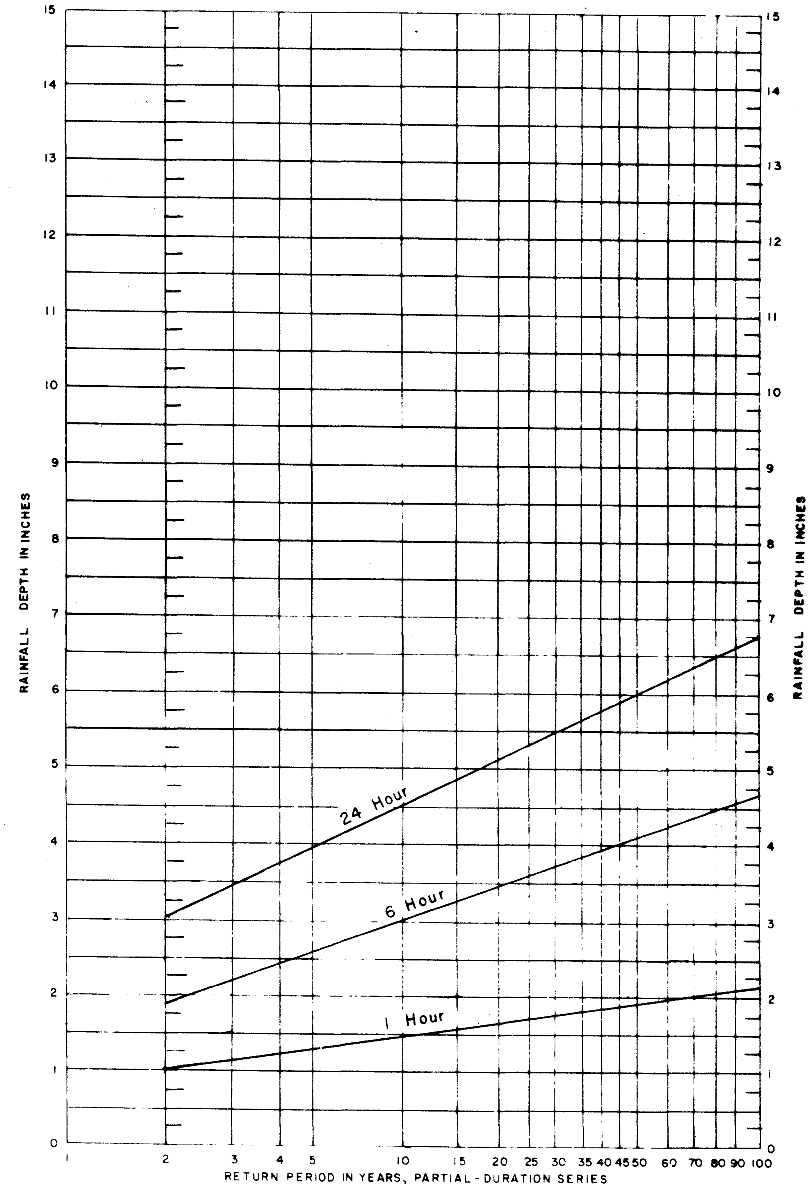
INTENSITY OR DEPTH OF RAINFALL FOR DURATIONS LESS THAN 6 HOURS



DEPTH OF RAINFALL FOR DURATIONS OF 6 TO 24 HOURS



RAINFALL INTENSITY OR DEPTH VS. RETURN PERIOD

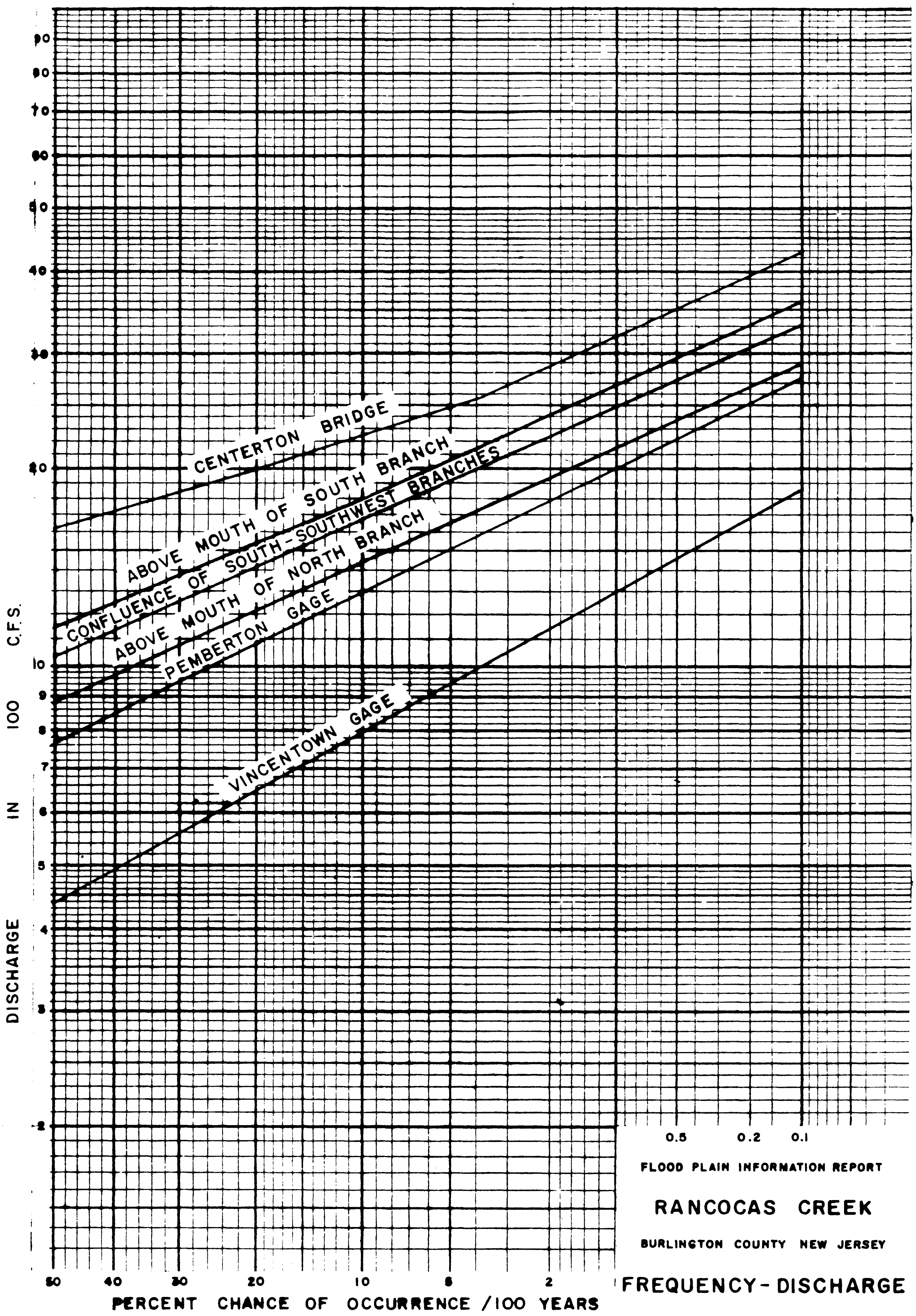


RANCOCAS CREEK WATERSHED

POINT VALUES: RAINFALL INTENSITY - DURATION

RAINFALL INTENSITY - FREQUENCY

FIGURE A-4



CENTERTON BRIDGE
ABOVE MOUTH OF SOUTH BRANCH
CONFLUENCE OF SOUTH-SOUTHWEST BRANCHES
ABOVE MOUTH OF NORTH BRANCH
PEMBERTON GAGE
VINCENTOWN GAGE
DISCHARGE IN 100 C.F.S.
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
50 40 30 20 10 5 2 0.5 0.2 0.1
PERCENT CHANCE OF OCCURRENCE /100 YEARS
FLOOD PLAIN INFORMATION REPORT
RANCOCAS CREEK
BURLINGTON COUNTY NEW JERSEY
FREQUENCY - DISCHARGE

FIGURE A-2