STATE OF NEW JERSEY

MAJOR DRAINAGE BASINS AND REGIONAL BOUNDARIES

SURVEY

OF

NEW JERSEY

WATER RESOURCES DEVELOPMENT

•

LEGISLATIVE COMMISSION ON WATER SUPPLY

STATE OF NEW JERSEY

DECEMBER 1955

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December 31, 1955

Legislative Commission on Water Supply
State of New Jersey
Trenton, New Jersey

Gentlemen:

We are pleased to transmit herewith our Final Report entitled "Survey of New Jersey Water Resources Development" in accordance with the terms of our contract dated May 3, 1955.

Our Preliminary Report entitled "Preliminary Survey of New Jersey Water Resources Development", prepared in a period of ten weeks and submitted to you on July 15, 1955, presented a general review and discussion of all aspects of the New Jersey water supply problem and specific measures and projects to meet short-term needs and a major project to meet the first stage long-term needs of the Northeastern Region.

This, our final report, presents the results of our comprehensive investigation of New Jersey Water Resources. The basic water resources, both surface water and ground water, are covered in detail. Estimates of water demands to the year 2000 have been made and numerous plans and combinations of plans to meet these demands are presented. Legislative action, financial requirements and administration organization necessary to implement these water supply plans are thoroughly discussed. A summary of the report precedes the main body of the report.

Although the Survey determines the requirements of the entire State, we feel that it is in order to make specific mention of the problems of the Northeastern Region. Our recommendation for the first major new supply for the Northeastern Region, the only area of the State in which serious water shortages are developing on a regional basis, remains essentially the same as in the "Preliminary Survey". This recommendation is for the development of the water supply potential of the Raritan River Basin, using initially only the East Branch of the Chimney Rock Reservoir Site for storage. The final report takes cognizance of the testimony brought out at the hearings on the water bills last summer by omitting all diversion of water from the Delaware and Raritan Canal to Chimney Rock, and by the addition of an on-river reservoir for the maintenance of a sustained minimum flow of 130 mgd at Bound Brook.

The retention of the Chimney Rock recommendation in our Final Report is based on the fact that after an exhaustive study of all the water supply possibilities, that site remains, from an engineering and economic standpoint, the most feasible for the development of an additional major water supply which will be available to the entire Northeastern Region. The more detailed studies of the Final Report, show, however, that the capital cost of a new supply of 70 mgd for the Northeastern Region may be held to a minimum if only the eastern portion of the Chimney Rock site (East Branch Reservoir), rather than the full site, were developed in the initial stage. In the second stage, for a 200 mgd supply, the remainder of the Chimney Rock site or the Dock Watch Hollow site may be developed for the additional storage capacity needed. The report provides information on a great many alternative plans, including the use of the Round Valley Reservoir site, Delaware River water and variations on the use of Chimney Rock site.

It has been a pleasure to provide this service for the State of New Jersey and we wish to express our appreciation of the cooperation which we received from the Legislative Commission on Water Supply, and to the many staff members of departments of the State Government who furnished valuable information and assistance to us throughout our work on this investigation.

Very sincerely yours,

TIPPETTS-ABBETT-McCARTHY-STRATTON

James H. Stratton

James H. Stratton

CONSULTANTS

The following Consultants assisted in the investigation and the preparation of the reports:

Leggette, Brashears & Graham	Ground-Water Hydrology, except for costs and engineering aspects, as presented in Chapters III and VII.
Mr. S. Logan Kerr	Mechanical equipment and transmission mains
Mr. Gordon R. Williams	Hydrology
Dr. William Miller	Legislation

Mr. Morton W. Lieberman directed the Survey of New Jersey Water Resources Development for Tippetts-Abbett-McCarthy-Stratton.

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STATE OF NEW JERSEY

MAJOR DRAINAGE BASINS AND REGIONAL BOUNDARIES

SUMMARY

SUMMARY

The general hydrologic information presented in Chapter I and the more specific studies of surface and ground water in Chapters II and III show that there are sufficient potential water resources available to the State of New Jersey to provide for predictable needs. All of the State's water requirements to the year 2000 can be met entirely from resources within the boundaries of the State, which can be developed without interstate agreements or approval of the Supreme Court of the United States. There are, however, economic advantages in using water from the interstate Delaware River to provide the additional supplies which will be needed in the Northeastern Region after 1995. Such out-of-basin diversion will require development of reservoir storage in the Delaware Basin for regulation of the Delaware River to provide a sustained minimum flow as well as for water supply purposes. The preservation of the potable quality of both surface and ground water resources in the lower Delaware Valley may depend on the regulatory works undertaken for the augmentation of low flows in the Delaware River.

Future consumption of water by counties and regions and for the State of New Jersey as a whole is discussed in Chapter IV. The Northeastern Region comprises the most intensely populated and industrialized portion of the State and accounts for the majority of the State's water use. In recent years the practice of supplementing natural rainfall during the summer growing season by the application of irrigation water for vegetable and other high income crops has become widespread in New Jersey and other states in the humid zone of the United States. Expansion of irrigation in the future may be expected to reduce streamflows during the summer months and, therefore, is a factor to be considered in planning water supply projects.

The surface water supplies of existing major systems serving the intensely populated areas of the State are discussed in Chapter II. Particular attention is given to those systems serving the Northeastern Region and to the proposed construction to increase the dependable yields of the Pequannock (Newark) and Rockaway (Jersey City) systems as well as the Point View Project of the Passaic Valley Water Commission. Additional supplies to be provided by these expansions are urgently needed in the region if normal growth is to be encouraged; hence, measures should be taken to encourage the immediate implementation of the three projects by the public owners of the systems. The region-wide need for these increased supplies is of such importance that the State should undertake the projects if the public owners do not proceed within a reasonable time. Arrangements for temporary use of part of the expanded supplies in portions of the Northeastern Region outside of the areas served by the expanded systems, through use of system interconnections, are required in the public interest.

The Raritan River is the largest economically available intra-state source for new water supplies for the Northeastern Region. Numerous plans for utilization of the Raritan River source for new potable water supplies for the Region are discussed in Chapter II. These plans include use of various combinations of on-river reservoirs as well as off-river reservoirs at the Round Valley, Chimney Rock and Dock Watch Hollow sites. As compensation for out-of-basin diversion, provision for maintenance of a sustained minimum flow of 130 million gallons per day below the diversion point at Bound Brook, by use of storage in an on-river reservoir, should be made a part of any water supply plan utilizing Raritan River water.

Twelve plans for the diversion of Delaware River water to the Raritan or Passaic River basins for use in the Northeastern Region are discussed in Chapter II. These plans include both gravity and pumping diversions. Because of the long tunnels required for gravity diversions, those plans are not susceptible of economical stage construction. All of the Delaware diversion plans will require major storage facilities to provide the compensation water necessary to meet anticipated requirements of the U.S. Supreme Court for diversions outside the Delaware River Basin. Such compensation storage could be provided by the Wallpack Bend reservoir or by a reservoir at the Flatbrook site.

Anticipated requirements for potable water in the Northeastern Region to the year 2000 will necessitate the development of 300 million gallons per day from a new source in addition to the proposed expansions of existing supplies. Such a new supply may be obtained from the Raritan River primarily with a supplementary supply from the Delaware River after full economic development of the Raritan, or it may be drawn entirely from the Delaware River. It is recommended that the Raritan source be developed in stages for a new potable supply of 200 million gallons per day with a supplementary supply of 100 million gallons per day obtained from the Delaware River. It is recommended further that the storage needed for the initial 70 mgd Raritan supply, which should be available by 1965, be developed at the East Branch site, with compensation storage for sustained minimum flows obtained at the Spruce Run site. The 200 mgd Raritan supply may be provided by development of reservoir storage in (1) the remainder of the Chimney Rock site or (2) the Dock Watch Hollow site, together with increased pumping and treatment capacity. The supplemental Delaware River supply of 100 mgd, needed by 1955, should be obtained by a pumping diversion to the Delaware-Raritan divide with streambed delivery to Bound Brook, where the supply would be pumped to the East Branch or Chimney Rock reservoirs.

The subject of ground water occurrence and availability is treated in detail in Chapter III. While ground water resources of large magnitude are known to exist—with the Pine Barrens area including the State-owned Wharton Tract, the lower Delaware Valley and the Atlantic coastal area constituting the major locations—insufficient ground water investigations and test pumping have been accomplished to date to establish specific yields, well spacings and other details for efficient development of such supplies. A long range program of ground water investigations is recommended to provide necessary information for planning future developments and for determining the safe yields of areas now being used. Continued use of well fields adjacent to the lower Delaware River, supplied in large part by river infiltration, may be dependent on development of upstream storage for maintenance of sustained minimum flows of the river. Plans for development of new water supplies for the Atlantic City and Camden areas from the Wharton Tract, as well as for other communities in the southern part of the State, are presented in Chapter III. An alternative source of additional supplies for the Camden area from surface flows of Rancocas Creek is presented in Chapter II.

Detailed analysis of future water requirements by Service Areas is presented in Chapter V together with transmission aqueduct requirements to deliver the new supplies to points of interconnection with existing major systems for distribution. Complete project costs for new major supplies needed to the year 2000, including costs of supply development and transmission, are included in Chapter VI.

The engineering objectives and recommendations presented in the report will require a legislative program to provide for their legal, administrative and financial requirements. A State Water Agency is recommended for administering the water supply construction program and to arrange for its financing. Included in Chapter VII are discussions on methods of financing and sources of revenue for the projects as well as recommended additional legislation for strengthening the powers of the Water Supply Council.

INTRODUCTION

INTRODUCTION

AUTHORITY AND SCOPE

This final report as well as the preliminary report submitted on July 15, 1955 was prepared under the terms of a contract entered into on May 3, 1955 between the Legislative Commission on Water Supply of the State of New Jersey (hereinafter referred to as the "COMMISSION"), and the firm of Tippetts-Abbett-McCarthy-Stratton (hereinafter referred to as the "ENGINEER"). The authority under which this contract was executed and the scope of the work to be performed is given in the portion of the contract quoted below:

> WHEREAS: The Legislative Commission on Water Supply of New Jersey has been created, pursuant to Assembly Joint Resolution 4 (1955), for the purpose of making a study of the present and future water resources development of the State, and reporting the results of this study to the Legislature, and
> WHEREAS: The Commission has been authorized by Section 4 of said Resolution to engage the services of competent engineering specialists to make surveys of existing resources and of the potentialities of water supply, and has been empowered to make contracts for the payment of the cost of such services within the limits of appropriations made available, and
> WHEREAS: The Legislative Commission on Water Supply, by resolution adopted at a meeting of the Commission, April 29, 1955 selected the engineering firm of Tippetts-Abbett-McCarthy-Stratton of New York to make the proposed survey, and authorized the Chairman of the Commission to enter into contractual relations with the aforementioned firm on behalf of the COMMISSION.
> Now, THEREFORE, the COMMISSION and the ENGINEER, for the considerations hereinafter named, agree as follows:

A. *SERVICES TO BE RENDERED*

The COMMISSION retains the ENGINEER to make surveys of the potentialities of the water supply resources of the State, including the proposals for the development of the Wharton Tract Water Supply Project, the Round Valley Water Supply Project, the Delaware River Valley Water Supply Project and any other projects or proposals and to report thereon, from time to time, to the COMMISSION with their recommendations as to what areas shall be acquired for water supply purposes and in what order and what type of water supply and storage and conduction and distribution system or systems and facilities shall be constructed in connection with the use of such areas, in the carrying out of an over-all long range plan for the development and use of the water supply resources of the State, together with estimates of the probable cost of the acquisition of such areas and of the facilities required for the development thereof and estimates of the probable demand for water supply from such projects and the probable income to be derived from the sale of water delivered therefrom and to make a preliminary report of the results of this Survey on or before July 15, 1955 and a final report on or before December 15, 1955 in accordance with the following outline:

1. Review of reports and studies previously made by various agencies covering existing and potential water supply projects.

2. A general survey of present safe yield and possible future increases of yield of the statewide existing major water supplies including: The North Jersey Metropolitan Area, including the lower Raritan Valley; the South Jersey Metropolitan Area—particularly in the vicinity of Camden; the East Coast Resort Area.

2A. Will feasible conservation measures (meters, higher rates, reclaiming of industrial water) save substantial amounts of water?

3. Present and future water supply requirements projected to the year 2000 in the various areas of the State, for the purposes of public water supply, industry, agriculture, and regulation of stream flow. Forecasts should estimate when and where the increased water need will occur, and the sequence in which areas will need new water supplies.

4. Studies of the various possible future developments, including but not limited to the Wharton Tract, both as to ground and surface water supply, separately and in combination; the investigation of the possibilities of using scientific ground water recharging methods in areas where excessive pumpage may have produced a serious lowering of the ground water table; the Round Valley Project, impounding waters from either the Raritan River, the Delaware River and its tributaries, or both; the proposed Wallpack Bend Dam on the Delaware River, including consideration of interstate rights, responsibilities and benefits; the Delaware and Raritan Canal as an existing source of water supply operated by the State, and as a future supply facility; other possible developments on the Raritan River and on the Delaware River and its New Jersey Tributaries; and alternative new supplies available to Camden and the Camden industrial area, and to the East Coast area.

5. Study of the possibility of joint and interconnected operation of several systems and the evaluation of increased aggregate dependable yields and economies in the cost of construction that may result from such interconnected operation as compared with the aggregate dependable yields and probable higher construction costs, if water systems are developed and operated independent of each other; study of the possibilities for consolidated operation of two or more existing water systems, indicating which agency or agencies should be given control over any consolidated system.

6. Recommendation of the works most suitable to supply water to the various areas, presenting: safe yield of the supply; quality of water and treatment required including salinity control; effect of the development on the upstream watershed area including the redevelopment needs for roads, railways, bridges, housing and other structures that may be dislocated as a result of reservoir construction and on downstream water rights, including the maintenance of proper downstream flow under conditions of water scarcity and flood and study of the effect of major sanitary trunk sewer construction on the sustained flow in certain streams, particularly the Raritan River; evaluation of the incidental power which may be developed without interference with the major objectives of water supply; evaluation of the incidental flood control benefits that will accrue from the construction of water impounding structures; area to be served by recommended works; general plans of project showing all essential features; estimated cost of construction; construction program; suggested method of financing construction—type and term of bonds and probable interest rate (in association with an approved bond counsel); estimated cost of operation, indicating probable or potential sources of revenue and the possibility of self-liquidation (in what period of time); estimated unit cost of water as delivered, showing operation, maintenance and capital charges separately; suggested form of organizing the financing, construction and operation; and suggestions as to legislation required.

7. Outline and define the most critical short and long range water supply needs of the State, with recommendation of the relative priority of each need.

8. The report shall clearly set forth the nature of the various problems involved and describe the means proposed for solution, indicating the reasoning governing their selection. Drawings and tables shall be used to illustrate recommendations and estimates.

9. One hundred copies of a report shall be submitted to the COMMISSION by July 15, 1955 titled "Preliminary Survey of New Jersey Water Resources Development" presenting a general review and discussion of all aspects of the problem and recommending the facilities immediately to be provided as an appropriate step in the development of a long range plan; and one hundred copies of a final report entitled "Survey of New Jersey Water Resources Development," presenting a complete long range plan, shall be submitted by December 15, 1955.

10. The COMMISSION agrees to use its good offices to assist the ENGINEER in obtaining all reports, data, computations, maps, drawings and other information bearing on the water resources of New Jersey which have been prepared by or for the various State, County or other official agencies.

11. The ENGINEER will submit monthly to the COMMISSION a report indicating scope of work being undertaken and progress accomplished. The ENGINEER agrees to inform the Secretary of the COMMISSION of work in progress and work accomplished from time to time on request, and will undertake to answer inquiries directed to the ENGINEER by the COMMISSION or its Secretary.

CONSIDERATIONS LEADING TO THE INVESTIGATIONS

The development of new water supplies in the State of New Jersey has not kept pace with increasing demands. During the past half century there has rarely been a time, particularly in the populous northeastern part of the State, when there was a safe margin of reserve to take care of emergencies and the expanding use of domestic, commercial and industrial water. Officials of state and local government responsible for water development planning have been aware of this situation and many attempts have been made to implement remedial measures.

Following approval on March 7, 1906 of Joint Resolution No. 2 to investigate the "practicability and probable cost of the acquisition by the State of the title to the potable waters of the State," the New Jersey Potable Water Supply Commission was organized. The Commission's 1907 report urged the appointment of a permanent State Water Commission and recommended that plans for construction of storage reservoirs be referred to the proposed State Water Commission. As a result the New Jersey State Water Supply Commission came into being. All their Annual Reports of 1908 through 1914 expressed concern over New Jersey's water supply problems. These reports included recommendations for a reservoir at Mountain View on the Pompton River, purchase of the Wharton Estate, the development of the Wanaque River supply, and a high level supply from Greenwood Lake. In 1915 legislation was introduced for the purchase of a water preserve in the Wading and Mullica River Basins in South Jersey, but the referendum to authorize the million and a half dollar bond issue needed for this acquisition was defeated by the voters.

The State Department of Conservation and Development retained the engineering firm of Hazen, Whipple and Fuller to make a survey of the water resources of the State which resulted in the issuance of a report in 1922 titled "Water Resources of the State and Their Development." The report emphasized the fact that:

"There are several problems that must be met and solved. Among these may be mentioned:

"First, the engineering problem of selecting the best sources and of deciding what dams, tunnels, reservoirs and other works will best serve to make them available;

"Second, the problem of getting effective cooperation of the thirty-three separate authorities now operating water works systems in the Metropolitan District; or in the absence of such cooperation of finding some way of securing effective action in their behalf;

"Third, the adopting and carrying through of a comprehensive policy of building and operating water works, and of securing control of necessary sites, and holding them for public water supply purposes to make sure that they are not diverted to other uses and lost."

The report recommended the creation of a State Water Board "having very broad powers, including the right to acquire existing sources of supply, and lands and rights for additional sources, and to build water supply works, to sell water at wholesale and to issue bonds to raise money to pay for works bought and built."

Four principal water supply developments were considered in the report:

1. The Passaic Great Reservoir, with the dam on the Passaic River above Little Falls.

2. The Long Hill Reservoir with the dam on the Passaic River above Millington fed by the northern streams (North and South Branches Raritan River, Musconetcong, Pohatcong, and Pequest Rivers, Paulins Kill, and Flat Brook) and the Delaware River.

3. The Raritan Reservoir with the dam on the Raritan River above Somerville with possible diversions from the Delaware River.

4. Joined reservoirs on the Mullica and Wading Rivers in South Jersey.

The Wanaque Project of the North Jersey District Water Supply Commission, described in detail in the 1925 "Report" of the Commission, was constructed and went into operation in 1930.

The 1926 "Report" of the Water Policy Commission was in two parts. Part One discussed the "Compact as to the Water Resources of the Delaware River Between the Commonwealth of Pennsylvania, the State of New Jersey and the State of New York" proposed in 1925 by the Delaware River Treaty Commission. The report recommended that the proposed compact not be ratified in the form submitted and that a commission be constituted to continue the negotiations which resulted in the proposed compact. Part Two of the 1926 "Report" discusses the problem of developing an adequate supply of potable water for the entire state in general with specific discussion of the Long Hill Project proposed in the 1922 Report and a Chimney Rock project that had been suggested by Mr. Morris R. Sherrerd, Consulting Engineer of the North Jersey District Water Supply Commission, in which the Chimney Rock Site would be substituted for the Long Hill Site.

The 1929 Special Report 1 of the New Jersey State Water Policy Commission on "Water Supply Problems of the Northern Metropolitan District" stressed the urgency of the water supply problem and recommended a revolving fund of about 7 million dollars to acquire control of reservoir sites. This recommended bond issue was approved by the voters in 1930. However these funds were diverted to other purposes during the depression. This Special Report 1 suggested that the Long Hill, Dock Watch Hollow, and Round Valley sites be dropped from consideration and that New Hampton on the Musconetcong River, Pleasant Valley and Ravine Lake on the North Branch Raritan River, and Chimney Rock sites be considered for intermediate level supplies and that the Bunnvale and Vernoy sites on the South Branch Raritan River and the Ralston site on the North Branch Raritan River be considered for high level supplies. The Delaware River was also discussed as a future source of water supply for the Northern Metropolitan District.

The 1931 Special Report 3 of the New Jersey State Water Policy Commission on "The South Branch Project, a High Level Water Supply for the Northern Metropolitan District" discussed the Chimney Rock site (using Raritan River water as the supply) as being the best intermediate level project but not as practicable as the recommended high level site at Bunnvale on the South Branch Raritan River utilizing part of the flows of the adjacent Black River, Rockaway Creek, Spruce Run and Musconetcong River drainage basins.

The Delaware and Raritan Canal, deeded to the State of New Jersey in 1937, was dedicated to industrial water supply and recreational use in 1944. In 1949 the law was supplemented to permit the sale of water from the Canal for potable and public use. The Canal was first put to such use in 1951. The State of New Jersey is authorized to withdraw an average of 100 million gallons per day from the Delaware River for use outside the Delaware River water-shed without any requirement for compensating releases.

The Interstate Commission on the Delaware River Basin (INCODEL) plan for the overall development of the water resources of the Delaware River Basin was published in 1950 and included provisions for water supplies for metropolitan areas in New York and New Jersey.

The Round Valley Project as proposed by the North Jersey District Water Supply Commission is covered in detail in their November 1, 1954 report "Round Valley Project for the Metropolitan Section of the North Jersey Water Supply District."

The report to the Commonwealth of Pennsylvania on "Wallpack Bend Dam and Reservoir," dated September 1, 1955, by the consulting engineering firm of Albright and Friel included a complete analysis of the combined effect on Delaware River flows of the operation of the New York City reservoirs and the proposed reservoir at Wallpack Bend.

Of all the major water development proposals made during the last half century, the only two which have materialized are the Wanaque-Ramapo system of the North Jersey District Water Supply Commission benefiting parts of Essex, Passaic, Hudson and Bergen Counties, and the Delaware River Diversion via the Delaware and Raritan Canal. The canal is administered by the State Division of Water Policy and Supply and benefits industries and municipalities in the Raritan River Basin and areas served by the Elizabethtown Water Company.

In 1954 the pressing water needs of northeastern New Jersey were brought to public attention by introduction in the Legislature of a number of bills designed to authorize and finance new water supplies. However, the diverse and conflicting character of the proposals submitted for the northeastern part of the State and the failure, despite the steps taken in acquiring the Wharton Tract, to give adequate recognition to the increased water problems of South Jersey led to a stalemate in legislative action. To clarify this situation the need was indicated for a new study and evaluation of the long range water requirements of the entire state and the resources available to meet these demands. The legislation to achieve this end, Assembly Joint Resolution No. 4(1955), was passed "providing for a commission to study and report to the Legislature as to the acquisition and development of the water supply resources of the State and making an appropriation therefor." Assembly Joint Resolution No. 4(1955) is included in this report as Appendix C. Pursuant to the terms of this resolution the Legislative Commission on Water Supply for the State of New Jersey was organized. On May 3, 1955 the Legislative Commission on Water Supply retained Tippetts-Abbett-McCarthy-Stratton, Engineers, for the purpose of making a study of the present and future water resources of the State and for preparing suitable reports.

THE PRELIMINARY REPORT

The preliminary report, titled "Preliminary Survey of New Jersey Water Resources Development," submitted to the Legislative Commission on Water Supply on July 15, 1955, was prepared in a period of 10 weeks in order to be of use to the Legislature with the following objectives:

1. By a study of the supply and demand to establish the need for additional water supplies in any part of the State.
2. To examine alternate proposals for water projects that have been put forward for the Northeastern Region.
3. To recommend such specific new water supply projects that the study may reveal as essential.
4. To determine the character and cost of recommended projects in some detail in order to facilitate financing.
5. To recommend the necessary legislative program to implement water development recommendations.

The preliminary report presented a general review and discussion of all aspects of the New Jersey water supply problem and outlined specific recommended developments to meet both short-term and long-term needs.

The major recommendations of the preliminary report may be summarized as follows:

1. A new major water supply for the Northeastern Region should be developed on the Raritan River Basin and be supplemented by additional withdrawals from the Delaware and Raritan Canal. The Chimney Rock dams and reservoir site are recommended for the development. The estimated cost of the first stage of development, designed to deliver a safe yield of 70 million gallons per day, is $51,860,000. The completion of the second and final stage of development will result in a total safe yield of 200 million gallons per day with an estimated total cost for both stages of $102,650,000.

2. In order to be assured of an adequate water supply in the Northeastern Region during the period in which the new major water supply is being developed the following additional supplies to existing systems should be developed:

   a. To the City of Newark, Pequannock System, an additional supply of 7.4 million gallons per day at an estimated cost of $8,640,000.

   b. To the City of Jersey City, Rockaway System, an additional supply of 14.6 million gallons per day at an estimated cost of $3,500,000.

   c. To the Passaic Valley Water Commission System, an additional supply of 55 million gallons per day at an estimated cost of $10,000,000.

These three additions will increase the safe yield of the systems by a total of 77.0 million gallons per day at an estimated total cost of $22,140,000.

3. The following legislative action was recommended:

   a. A bill to establish a State Agency with the power to finance and construct new major water supply systems and to encourage the construction of, or to actually construct, additions to existing systems.

   b. A bill providing for a referendum on the bond issues necessary to finance the recommended water supply developments.

   c. A bill which will strengthen the control powers of the Water Policy and Supply Council.

LEGISLATIVE ACTION

Following the receipt of the Tippetts-Abbett-McCarthy-Stratton report, "Preliminary Survey of New Jersey Water Resources Development," on July 15, 1955 the Legislative Commission on Water Supply, pursuant to the requirements of Assembly Joint Resolution No. 4(1955) submitted to the Legislature on August 1, 1955 their report on New Jersey Water Resources Development entitled "A Preliminary Report to the Legislature by the Legislative Commission on Water Supply." This report, included herein as Appendix D, summarizes the findings of the Engineers' Preliminary Report and makes specific recommendations to the Legislature for action. Two bills were introduced to the Legislature for the purpose of carrying out the recommendations of the Legislative Commission on Water Supply. Senate Bill No. 372, "An Act to authorize the creation of a State department . . . for the purpose of acquiring, constructing and developing certain additional water supplies . . ." was introduced August 8, 1955 while Assembly Bill No. 595, "An Act to provide for increased dependable public water supplies . . .; creating a water supply board . . ." was introduced August 15, 1955.

The Senate and Assembly Committees on Revision and Amendment of Laws, Senator John M. Summerill, Jr., Chairman, on August 19, 22 and 24, 1955, held public hearings on the Report of the Legislative Commission on Water Supply together with the Senate (No. 372) and Assembly (No. 595) Bills introduced to supplement that report. The information brought out at these hearings led to the revised bills known as Committee Substitutes. The revisions included the following: The addition of a compensating reservoir on the Raritan River; the addition of a causeway across Chimney Rock Reservoir; changes in financing, administrative, and condemnation procedures; elimination of State participation in the expansion of existing systems; and the addition of 40 million dollars for future work in other areas of the State—particularly South Jersey. The Legislature adopted the Committee Substitutes for Senate Bill No. 372 and Assembly Bill No. 595 on September 19, 1955. This enacted legislation is included in this report as Appendix E.

REFERENDUM RESULTS

In compliance with the provisions of the State Constitution the Committee Substitute for Senate Bill No. 372, adopted September 19, 1955 was submitted to the people of the State of New Jersey at the general election held on November 8, 1955 as follows: "Shall the act entitled 'An act to authorize the creation of a State debt by the issuance of bonds of the State of New Jersey in the aggregate principal amount of

$100,000,000.00 for the purpose of acquiring, constructing and developing dependable public water supplies for domestic and industrial uses and facilities appurtenant thereto, in any part of this State as need appears, and providing the ways and means to pay the interest of such debt and also to pay and discharge the principal thereof,' be approved?"

The act was defeated in the referendum.

ACKNOWLEDGMENTS

Acknowledgment is due to many individuals and organizations who furnished valuable information and helpful cooperation during the conduct of the investigations. The members of the New Jersey Legislative Commission worked in close cooperation with members of this firm throughout the investigations and during the preparation of the reports. Valuable assistance in locating basic data for the investigation was obtained from the New Jersey Taxpayers Association through unlimited access to their comprehensive bibliography and to their files on the New Jersey Water Supply problem. Messrs. Howard T. Critchlow and George R. Shanklin of the Division of Water Policy and Supply were particularly helpful with their comments and files of basic information.

A list of individuals and organizations who were consulted during the course of the work is included as Appendix G. Their assistance is gratefully acknowledged.

LIST OF REFERENCES

A "List of References" used during this study on New Jersey Water Resources Development is included in this report as Appendix H.

CHAPTER I

CHAPTER I

BASIC WATER RESOURCES

The State of New Jersey is fortunate in that it contains within its boundaries ample fresh water supplies capable of sustaining large metropolitan populations, a broadly diversified industry and an intensive agriculture. The recent history of the State indicates a vigorous population growth, a steady increase in the number of established industries and a growing use by agriculture of irrigation to supplement rainfall. Despite these continually increasing demands, the basic water resources of the State are sufficient to supply any foreseeable expansion in population, industry and agricultural irrigation.

Essentially all of New Jersey's fresh water supplies are derived from resources within its own boundaries. Relatively small parts of the Passaic and Hackensack drainage areas lie in New York State and a part of New Jersey (Wallkill River) drains north to the Hudson River in New York. Aside from these minor exceptions and the Delaware River Basin, all of New Jersey's waters are intrastate and may be developed without agreements with bordering states.

The Delaware River Basin, which lies within the four states of Pennsylvania, New York, New Jersey and Delaware, constitutes one of the major water resource areas in the east. The undeveloped potentialities of the Delaware Basin as a source of potable water supply are very large and New Jersey, as one of the Basin States, has inalienable rights to an equitable share of Delaware water.

Because of its importance and interstate character, jurisdiction over the use and diversion of Delaware Basin water is vested in the Supreme Court of the United States. Without prior permission of the Court, Delaware Basin water may not be diverted by any State for use outside of the Basin, even where the water involved rises wholly within the boundaries of a State.

For purposes of identification and ease of discussion New Jersey has been divided into four Regions which have relatively common characteristics based on intensity of urban and industrial development, drainage, geology and topography. These regions are the **Northeastern** comprising the metropolitan area of North Jersey; the **Northwestern** comprising largely the northern Delaware area and typified by a mountainous terrain; the **Coastal Region** consisting of the southern portion of the State bordering on the Atlantic Ocean; and the **Southwestern Region** which includes the lower Delaware and southern metropolitan areas. The boundaries of the Regions are shown on the Frontispiece together with the principal drainage basins of the State. More detailed descriptions of the Regions are given in subsequent chapters.

Whatever the geographical or geological positions of the available water resources of New Jersey are, their derivation and continuance depends solely upon precipitation. All precipitation, whether in the form of rain, sleet, snow or hail, is eventually dissipated in the following ways:

a. Evaporation to the atmosphere.

b. Transpiration by plant life.

c. Infiltration into the ground.

d. Surface runoff.

The proportion of the total precipitation which will go into each of these components will vary widely with geologic, topographic, climatic and seasonal conditions and with the type of vegetal cover. Evaporation to the atmosphere is a relatively small factor except in locations where there are large areas of exposed water surface such as lakes and reservoirs. Evaporation is usually grouped with transpiration, the much larger segment of precipitation used by plant life, and together they are termed evapo-transpiration. These account for the utilization of about *half* of the precipitation in New Jersey. The balance goes into infiltration and runoff. These two inter-related components of precipitation are the basic source of all water supplies.

Where the geological conditions are favorable for infiltration, as in the Pine Barrens area of Central and South Jersey, very large quantities of water will be stored underground. These underground supplies may be tapped by means of wells and eliminate the necessity for creating artificial surface storage facilities. If the amount of ground water withdrawn does not exceed the yearly replenishment by precipitation, the supply will be permanent and dependable under normal circumstances.

Stream runoff consists of excess water that is neither retained in the ground, evaporated, nor transpired. It appears in streams either as immediate sheet runoff during and shortly after a rainfall or as delayed runoff resulting from melting snow and ice. Water that infiltrates into the ground water table also reappears as runoff where stream beds have cut through water-bearing strata or aquifers. The latter constitutes the source of sustained flows in streams after storm waters have subsided.

Water supplies, drawn directly from streams having no storage facilities for flood waters, will be dependable for only the amount of water that can be withdrawn during the period of the lowest flow of the stream. Except in the case of very large rivers with high sustained flows, such supplies are of relatively small volume. With the exception of the Delaware, rivers of this class do not exist in New Jersey and the construction of artificial storage facilities for flood waters is an essential feature in the development of all large surface water supplies. A possible exception to this rule may be made for the withdrawal of supplies of moderate size from the larger streams of South Jersey where the geological conditions contribute to sustained stream flows of relatively greater volume and uniformity.

At the present stage of our technological development, the only economical sources of potable water supply are ground water and surface runoff. Since both of these sources are dependent solely on precipitation, it is imperative that the precipitation and runoff patterns of the State be studied along with the occurrence of ground water as a basis for any statewide water resources planning.

PRECIPITATION

Although New Jersey has experienced occasional periods of low rainfall, the long term average monthly precipitation is remarkably uniform. The average precipitation for each month is about 8% of the annual average. There is a tendency, however, for greater precipitation to occur during July and August in the areas of higher elevation along the topographic divide between the Delaware River and the Atlantic Coast watersheds because of an increased frequency of thunderstorms. The summer monthly precipitation at some of the interior stations reaches about 12% of the annual total. Plate I-1 (Isohyetal Map), which follows this page, shows the distribution of precipitation by lines connecting points of equal average annual precipitation for all of New Jersey. This map was prepared from precipitation records covering the 31 year period from 1923 to 1953. Where station records were for a shorter period, statistical adjustments were made so that all averages are theoretically comparable.

The average annual precipitation in the northern half of the State is about 46 inches and in the southern half about 45 inches. There are two distinct centers of high annual precipitation in the State. The northern center, which reaches an annual total of 51 inches, lies in Morris County in the headwaters of the Passaic and Raritan River Basins. The southern center lies in Burlington and Ocean Counties near the central portion of the Coastal Plain where the annual total precipitation averages 49 inches. In many parts of the United States variations in precipitation are so pronounced that the location of any water development must be preceded by adequate study of the characteristic precipitation and runoff patterns of the specific locale. In New Jersey, however, the distribution of the natural water supply is so relatively uniform that variations in supply are not a major consideration in locating water resource developments. Of greater importance are the topographic and geologic factors. These determine whether collection and storage of water shall be by surface or sub-surface facilities.

During most years the precipitation in New Jersey is adequate to furnish the needs of agriculture and to maintain ground water levels and surface runoff for the present water supply systems. However, there have been periods of drought

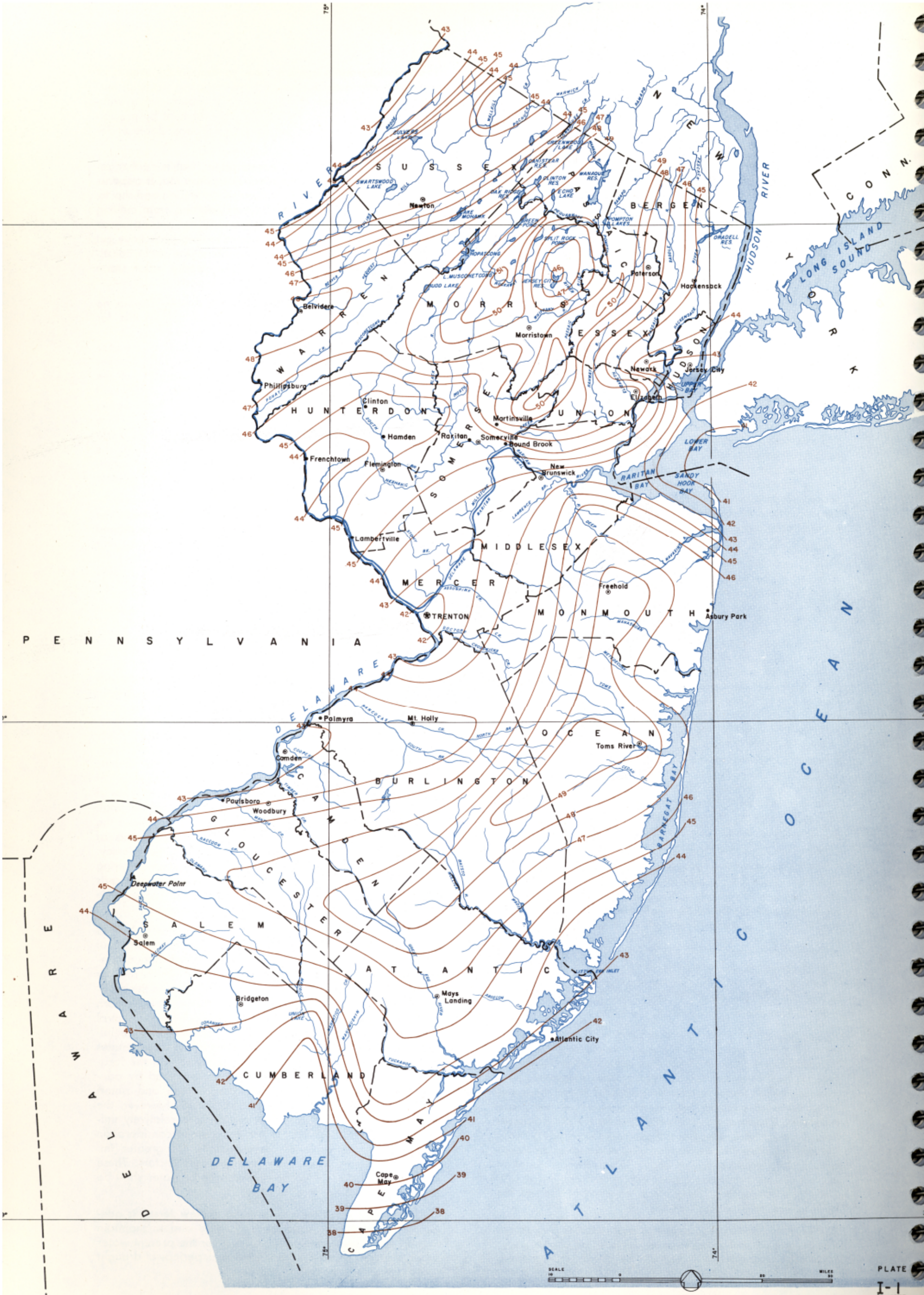


PLATE
I-1
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY

TIPPETTS – ABBETT – McCARTHY – STRATTON
ENGINEERS
NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

AVERAGE ANNUAL PRECIPITATION
(INCHES)

and crop failures have resulted when low rainfall occurred during the growing season. A comparison of Plates I-1, I-2 and I-3 will illustrate the existing variations between the average annual precipitation and precipitation occurring during a typical dry year (1930) and during a typical wet year (1952). Plate I-4 shows monthly distribution of precipitation at selected stations in typical years. Statistical studies indicate that the annual precipitation decreased to 80-85% of normal in the years 1885, 1895, 1910, 1918, 1930-31, 1941 and 1949 or at an average interval of about once in 11 years. These drought conditions were aggravated by the fact that the 15-20 percent reduction in annual precipitation is frequently caused by an almost complete lack of rainfall during one or more months in the summer and fall. Such seasonal decreases in precipitation have resulted in agricultural practices which tend to produce even greater variations in runoff. Summer drought occurrences have led in recent years to a continuously increasing use of irrigation for agriculture. Where considerable irrigation water is drawn from streams, recorded runoffs may be noticeably reduced.

SURFACE RUNOFF—MEASURABLE SURFACE WATER

The term "surface runoff" as used in this report includes all measurable water flowing in streams above tide level. Precipitation, which enters the ground water reservoir, moves through the earth and is discharged to streams either as springs or bank seepages, is considered to be surface runoff as well as the flood water from heavy precipitation and melting snow which moves as a sheet discharge across the earth's surface without entering the ground water reservoir. Surface runoff as defined above is not the total runoff of precipitation. Total runoff would include, in addition to the measurable surface runoff, the discharge of unconfined aquifers into the sea. The quantity of direct sea discharge in New Jersey is unknown and may be considerable. Such discharge cannot be measured by usual stream gaging methods, but the quantity could be estimated if sufficient data on the characteristics of the aquifers were available.

The average annual runoff in inches for all stream gaging stations in New Jersey was also compiled for the same 31-year period used in the precipitation study. Statistical adjustments were likewise made in cases where the records were for less than the complete period. The average runoff for each river basin was plotted in the approximate center of the basin and generalized lines of equal runoff were drawn as shown in Plate I-6 (inches of runoff) and Plate I-7 (millions of gallons per day per square mile). The locations of the stream gaging stations are as shown on Plate I-5.

As might be expected, the centers of high runoff correspond in location to the centers of high precipitation. The greatest runoffs in the State are in Morris and Passaic Counties in the headwaters of the Passaic and Raritan River Basins. Average annual runoff measurements in excess of 29 inches (1.4 million gallons daily per square mile) have been recorded for small areas of New Jersey. Such large runoffs are about 150% of the minimum runoffs of 18-19 inches (0.9 million gallons daily per square mile) which are experienced in areas of low elevation and in the sandy soil areas in the southern part of the State. As was found in the case of precipitation there is also a secondary center of high runoff in the southern half of the State in the Cedar Creek Basin and in the headwaters of the Mullica River Basin. The highest average runoff in this area is 25.5 inches and was recorded from the Cedar Creek Basin.

Extreme variations in runoff from year to year as well as the usual seasonal and daily fluctuations are important in the development of dependable water supplies. A comparison of Plates I-6, I-8 and I-9 will illustrate the variations that occur between the average annual runoff and the runoff for a typical dry year (1930) and for a typical wet year (water year 1951-1952). Plate I-10 shows monthly distribution of runoff at selected stations in typical years.

During the drought periods of 1930-32 and 1949-50 the total annual runoff in many drainage basins fell to 40-50% of the long-term average. In order to meet this type of deviation from the norm, future water storage reservoirs must have adequate capacities to hold and maintain reserves which may be drawn upon only once in 10 to 15 years. Failure to make such provisions will inevitably result in human hardships and even in economic dislocations.

The seasonal supply of runoff in natural basins does not exhibit the uniformity that is shown by precipitation. Plate I-11 indicates the average annual differences between precipitation and runoff. Since runoff is a residual of precipitation—after deductions for transpiration, evaporation and retained ground water—it fluctuates more in comparison to the average than does precipitation. With the necessity to first satisfy the requirements of transpiration, evaporation and infiltration before any runoff can occur, it is obvious that very light rainfalls may frequently produce little or no runoff. It is also obvious that following severe drought periods, even a substantial amount of rainfall may initially produce very little runoff. During drought periods, precipitation for the minimum month may be 30-50 percent of that for the maximum month, but runoff for the minimum month may be only 5 percent or less of that of the maximum month. These short term differences between precipitation and runoff patterns vary seasonally and geographically. Comparison of typical monthly patterns for precipitation and runoff can be made by examining Plates I-4 and I-10. These plates together illustrate the effect of increased evaporation and plant use during the summer growing season in reducing the amount of surface runoff produced from a given precipitation compared with that which would occur in winter months from a similar precipitation. The differences in runoff patterns due to local watershed characteristics are also illustrated by the charts on Plate I-10. These show, for example, that the stabilizing effect of ground water storage in the Coastal Plain results in a noticeably greater sustained dry season runoff in the Batsto River Basin than occurs in the Raritan and Pequannock Basins.

The above comparisons further emphasize the fact that in order to develop major dependable water supplies in New Jersey streams it is essential to have sufficient reserves to augment the low stream flows. Reserve facilities are necessary not only to meet seasonal deficiencies, but must have capacity to meet deficiencies caused by periods of low rainfall that may prevail for a year or more. These reserves may be in the form of impounded flood waters or ground water storage in a developed aquifer of known capacity and yield characteristics. In some instances a combination of surface water storage and ground water may be used to meet stream flow deficiencies as well as fluctuations in demand.

In general the storage of flood waters in reservoirs will be required for all major developments in the Northeastern and Northwestern Regions of the State. Because of the more uniform flow of southern streams and the abundant ground water storage, moderate to large supplies may be developed in the Southwestern and Coastal Regions with only the use of ground water as a regulating reserve.

The amount of runoff is sufficient almost anywhere in the State to develop dependable surface supplies provided that suitable storage sites or underground reserves can be found. The problem, in the north particularly, is, therefore, largely one of locating storage sites of suitable capacity, topography and geology within a reasonable distance from the areas of demand. Relative freedom of development is, of course, also desirable in any proposed reservoir, since otherwise the cost of real estate and the relocation of highways, railroads and utilities may be prohibitive. The cost of transmitting water long distances is also very high. In making economic comparisons, therefore, between the use of remote low evaluation reservoir sites and nearby high evaluation sites it is necessary to carefully balance the cost of transmission lines against the cost of real estate and relocation.

INFILTRATION—GROUND WATER

The amount of water that can be absorbed by infiltration through the earth's surface into the subsurface reservoir, known as the ground water table, is dependent on the following primary factors: The porosity, permeability and transmissibility of the geologic formation at the surface, the depth of this formation, the general topography, the degree of communication between the surface formation and deeper water bearing strata or aquifers, and the character of the vegetal cover. The moisture content of a surface formation at the time of precipitation, the intensity and duration of rainfall, and temperature are additional factors which influence the



PLATE I-2

12-1935

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

TYPICAL ANNUAL PRECIPITATION
DRY YEAR - 1930
(INCHES)



PLATE
I-3
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY

TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS
NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

TYPICAL ANNUAL PRECIPITATION
WET YEAR - 1952
(INCHES)

amount of precipitation that is absorbed into the ground water table at any given time.

In New Jersey there is a pronounced difference between the absorptive capacity and the permeability of the various geologic formations in different parts of the State. These differences influence not only the amount of water the formations contain but also the ease with which water will move through the formations to wells and filter galleries from where it can be withdrawn for use. Although ground water yields, because of geologic differences, may vary considerably even in areas of close geographic proximity, there are three generalized regions or provinces with relatively similar ground water characteristics. These divisions are designated as the Highlands—Appalachian Valley Province in the Northwestern part of the State, the Piedmont Plain Province in the Northeast which extends through to the Delaware River above Trenton, and the Atlantic Coastal Plain Province which comprises the entire southern part of the State below a line from Trenton to Perth Amboy. These provinces with some subdivisions are shown on Plate III-1.

Of the three generalized ground water provinces, the Atlantic Coastal Plain Province has the highest degree of uniformity, the largest area and the greatest potential for ground water development. Large supplies of fresh water can be obtained from wells located in most parts of this province. However, where the province borders on tidal waters, excessive salinity may become a problem if pumping rates are uncontrolled. The amount of water stored in the aquifers underlying the Atlantic Coastal Plain Province is very large and may be considered as a reliable water resource for the Coastal and Southwestern Regions. With proper development this province could yield sufficient water to supply other parts of the State as well.

The Piedmont Plain Province is next in order of ground water abundance and availability. The aquifers of the province lack the relative continuity and uniformity of the Atlantic Coastal Plain. Moderate yields have been obtained from aquifers of limited area, but the occurrences of satisfactory well field locations are spotty and can be found only by extensive test drilling and geological research. The ground water of the Piedmont Plain Province is of greatest value as a source of potable supply for small and medium size municipalities and as an auxiliary regulating supply for surface systems. Extensive development of known aquifers in the province has already taken place and the remaining potential is limited.

The third ground water province made up of the Highlands and Appalachian Valley in the extreme northwestern corner of the State has the least favorable conditions for the occurrence of reliable ground water supplies in sizeable quantities. The character of the geologic formations in the province is such as to form very poor aquifers. Pockets containing unconsolidated sands and gravels of glacial age may be found which will give fair yields, but these are largely undefined and of limited scope. Ground water in the Highlands-Appalachian Valley Province is only of local interest and importance as potable supplies for small municipalities and farms.

TOTAL POTENTIAL WATER RESOURCES

The potential water resources of New Jersey are very large. The natural supply of both surface water and ground water is sufficiently extensive to be theoretically capable of meeting all of the State's foreseeable needs.

The average annual surface runoff of the river systems within the State (not including the Delaware and Hudson Rivers proper) is about 22 inches or 1.05 million gallons per day per square mile of drainage area (see Plates I-6 and I-7). Applying this rate to the entire 7500 square miles of land area in the State indicates a potential water resource of 7.88 billion gallons per day from surface runoff alone. This, of course, is a theoretical maximum quantity which is based on the assumption that all of the runoff can be caught and stored for use before it reaches the sea. This is obviously impracticable as well as unnecessary since the development of only 20% of the total annual surface runoff will supply more than the estimated water requirements of the State as a whole in the year 2000 including an adequate reserve.

After allowances are made for flood runoff, evaporation and transpiration, there is an estimated residual average for the entire State of about 14 inches of precipitation or 0.67 million gallons per day per square mile. This quantity is available for the recharge of aquifers. If the average annual withdrawal by pumping from any given aquifer does not exceed this amount, the supply will be dependable. Theoretically, therefore, the entire State has a ground water potential of 7500 square miles multiplied by 0.67 million gallons per day or approximately 5.0 billion gallons per day. This gross figure assumes the possibility of developing ground water in any part of the State to yield an average of 670,000 gallons per day per square mile. As previously indicated and as will be explained in greater detail in Chapter III pertaining to ground water, there is a very wide difference between ground water yield from the sand formations in South Jersey and from the rock formations in North Jersey. The occurrences of economic ground water areas in the North are, in fact, so irregular and indeterminate as to limit their usefulness to supplying only local areas. On the other hand the Coastal Plain of the South is underlain by water bearing sands and gravels of considerable depth, which form vast underground reservoirs. The interior portion of this plain, in particular, contains water of relatively good quality free from the possibility of salt water contamination. It is within the area of economic feasibility to develop the aquifers in the Coastal Plain and to ultimately utilize the major portion of the water that annually recharges these natural underground reservoirs. The interior part of the Coastal Plain alone has a dependable development potential in excess of 2 billion gallons per day. It is therefore apparent that with the utilization of only the best and most dependable portions of the southern aquifers, more than enough water may be obtained from this source also to meet the entire requirements of the State until the year 2000.

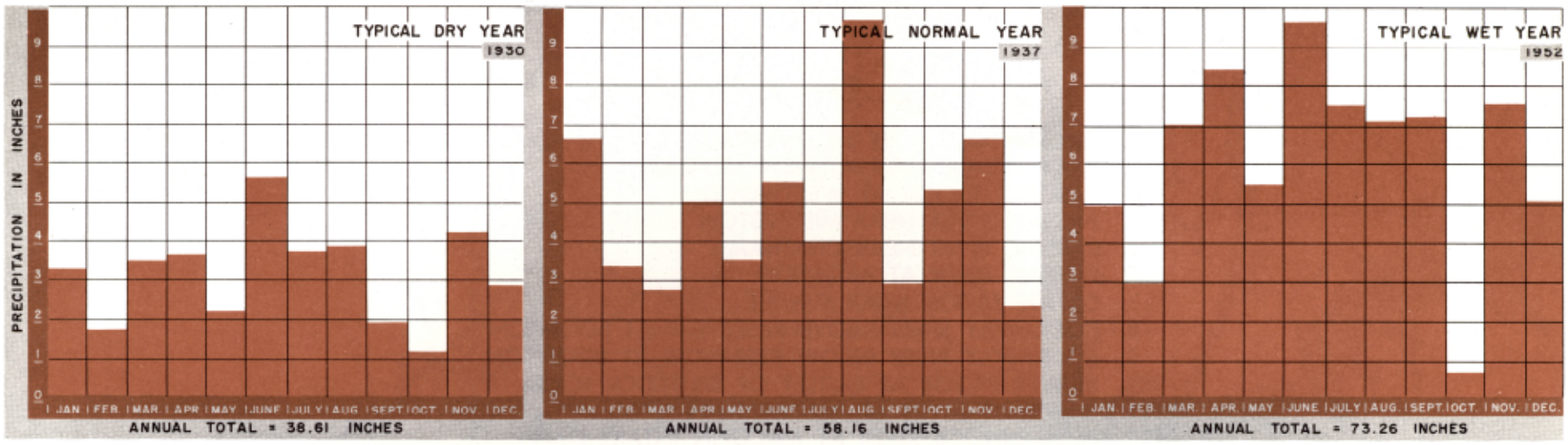
The sum of the above computations of the theoretically maximum surface and ground water developments are not to be taken as the total potential water resources of the State. Parallel development of the maximum quantities indicated for surface and ground water is not possible since extensive ground water development would reduce runoff by an amount comparable to the quantity of water removed by pumping. This overlap, however, does not create any conflict with respect to the feasibility of a parallel and relatively extensive development of surface runoff primarily in the northern part of the State and of ground water located largely in the southern part of the State. Likewise the development of a balanced use of both surface and ground water in a single basin is not precluded.

The water problem in New Jersey is quite obviously not one of the absence of basic resources. It can be said with certainty that enough water is available for development in the State of New Jersey to meet any foreseeable requirement. The problem is that there are concentrations of population and industry located in regions where the demand for water exceeds the natural yield of the surrounding areas even though sources many miles away have been tapped. In such a situation it is necessary to go outside the former limits of supply in order to keep pace with demands resulting from normal economic growth and development.

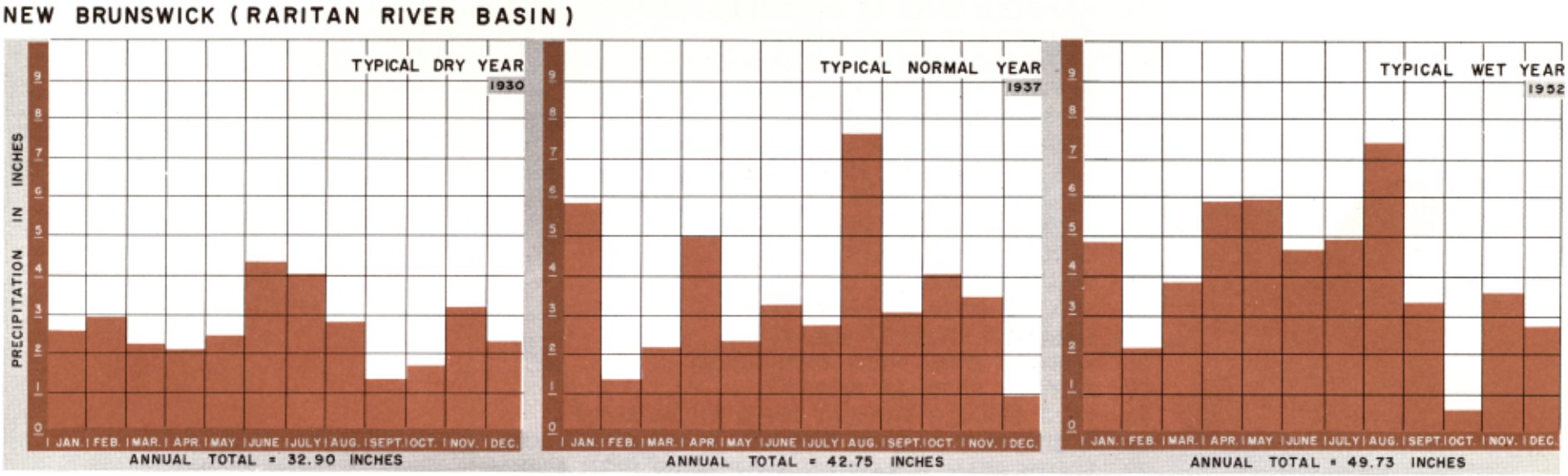
The solution of the problem is one of bringing the available water to the areas of demand on the basis of a long range plan which has been designed to keep pace with the growth of population and industry. Development of additional water supplies for concentrations of population and industry should preferably begin with the resources most readily available and closest to the areas of demand and progressively utilize more remote sources as required.

MONTHLY PRECIPITATION AT SELECTED STATIONS

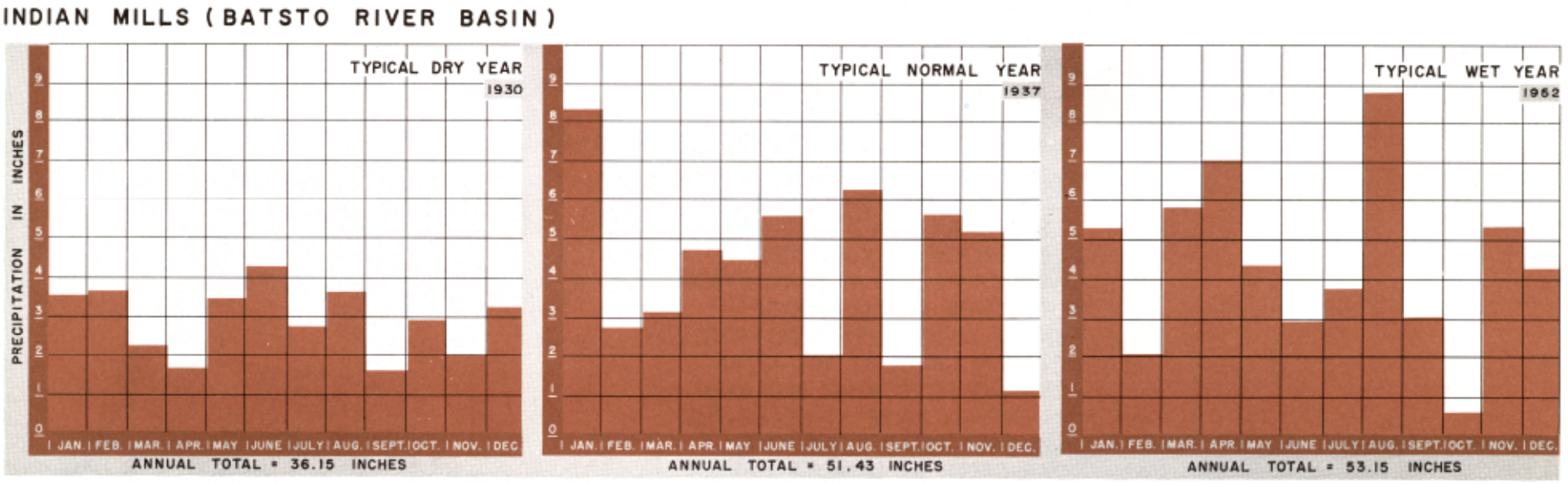
CHARLOTTEBURG (PEQUANNOCK RIVER BASIN)



NEW BRUNSWICK (RARITAN RIVER BASIN)



INDIAN MILLS (BATSTO RIVER BASIN)



AVERAGE AND RANGE OF PRECIPITATION OVER THE STATE

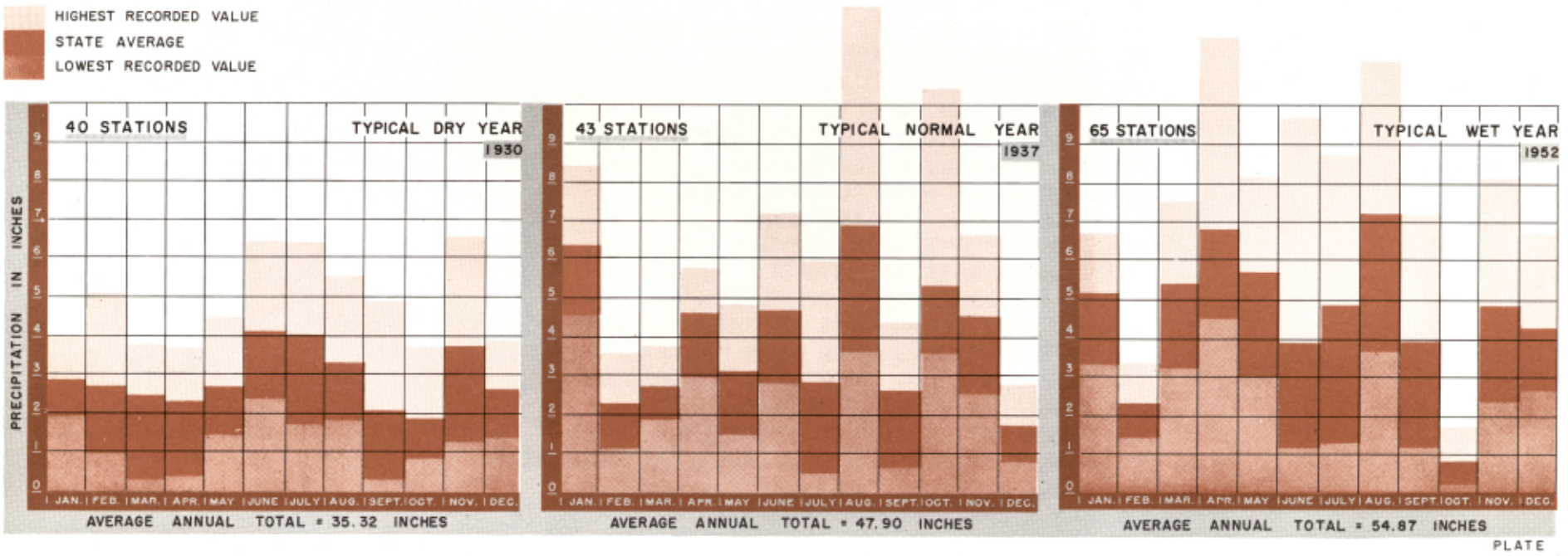


PLATE
I-4
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS
NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

MONTHLY DISTRIBUTION OF PRECIPITATION

Key for Plate I-5

Surface Water Gaging Stations in the State of New Jersey

1. HACKENSACK RIVER AT RIVERDALE
2. HACKENSACK RIVER AT NEW MILFORD
3. PASCACK BROOK AT WESTWOOD
4. PASSAIC RIVER NEAR MILLINGTON
5. PASSAIC RIVER NEAR CHATHAM
6. PASSAIC RIVER AT PATERSON
7. CANOE BROOK NEAR SUMMIT
8. ROCKAWAY RIVER ABOVE RESERVOIR AT BOONTON
9. ROCKAWAY RIVER BELOW RESERVOIR AT BOONTON
10. BEAVER BROOK AT OUTLET OF SPLITROCK POND
11. WHIPPANY RIVER AT MORRISTOWN
12. PEQUANNOCK RIVER AT MACOPIN INTAKE DAM
13. POMPTON RIVER AT POMPTON PLAINS
14. WANAQUE RIVER AT AWOSTING
16. WANAQUE RIVER AT MONKS
17. WANAQUE RIVER AT WANAQUE
18. RINGWOOD CREEK NEAR WANAQUE
19. CUPSAW BROOK NEAR WANAQUE
20. WEST BROOK NEAR WANAQUE
21. BLUE MINE BROOK NEAR WANAQUE
22. RAMAPO RIVER NEAR MAHWAH
23. RAMAPO RIVER AT POMPTON LAKES
24. SADDLE RIVER AT LODI
25. WEASEL BROOK AT CLIFTON
26. SECOND RIVER AT BELLEVILLE
27. ELIZABETH RIVER AT ELIZABETH
28. RAHWAY RIVER NEAR SPRINGFIELD
29. RAHWAY RIVER AT RAHWAY
30. WEST BRANCH RAHWAY RIVER AT MILLBURN
31. ROBINSON'S BRANCH RAHWAY RIVER AT RAHWAY
32. SOUTH BRANCH RARITAN RIVER NEAR HIGH BRIDGE
33. SOUTH BRANCH RARITAN RIVER AT STANTON
34. RARITAN RIVER AT MANVILLE
35. RARITAN RIVER AT BOUND BROOK
36. NESHANIC RIVER AT REAVILLE
37. WALNUT BROOK NEAR FLEMINGTON
38. NORTH BRANCH RARITAN RIVER NEAR FAR HILLS
39. NORTH BRANCH RARITAN RIVER NEAR RARITAN
40. BLACK RIVER NEAR POTTERSVILLE
42. MILLSTONE RIVER NEAR KINGSTON
43. MILLSTONE RIVER AT BLACKWELLS MILLS
44. GREEN BROOK AT PLAINFIELD
45. LAWRENCE BROOK AT FARRINGTON DAM
46. SOUTH RIVER AT OLD BRIDGE
47. TENNENT BROOK NEAR BROWNTOWN
48. MATAWAN CREEK AT MATAWAN
49. SWIMMING RIVER NEAR RED BANK
50. MANASQUAN RIVER AT SQUANKUM
51. TOMS RIVER NEAR TOMS RIVER
52. CEDAR CREEK AT LANOKA HARBOR
53. BATSTO RIVER AT BATSTO
54. EAST BRANCH WADING RIVER AT HARRISVILLE
55. GREAT EGG HARBOR RIVER AT FOLSOM
56. MAURICE RIVER AT NORMA
57. MANANTICO CREEK NEAR MANVILLE
58. LOPER RUN NEAR BRIDGETON
59. DELAWARE RIVER AT PORT JERVIS, NEW YORK
60. DELAWARE RIVER AT MONTAGUE
61. ABSECON CREEK AT ABSECON
64. DELAWARE RIVER AT BELVIDERE
66. DELAWARE RIVER AT RIEGELSVILLE
75. DELAWARE RIVER AT TRENTON
76. FLAT BROOK NEAR FLATBROOKVILLE
77. PAULINS KILL AT BLAIRSTOWN
78. PEQUEST RIVER AT HUNTSVILLE
79. PEQUEST RIVER AT PEQUEST
80. BEAVER BROOK NEAR BELVIDERE
82. MUSCONETCONG RIVER AT OUTLET OF LAKE HOPATCONG
83. MUSCONETCONG RIVER NEAR HACKETTSTOWN
84. MUSCONETCONG RIVER NEAR BLOOMSBURY
85. ASSUNPINK CREEK AT TRENTON
86. CROSSWICKS CREEK AT EXTONVILLE
87. NORTH BRANCH RANCOCAS CREEK AT PEMBERTON
88. MANTUA CREEK AT PITMAN
89. SALEM CREEK AT WOODSTOWN

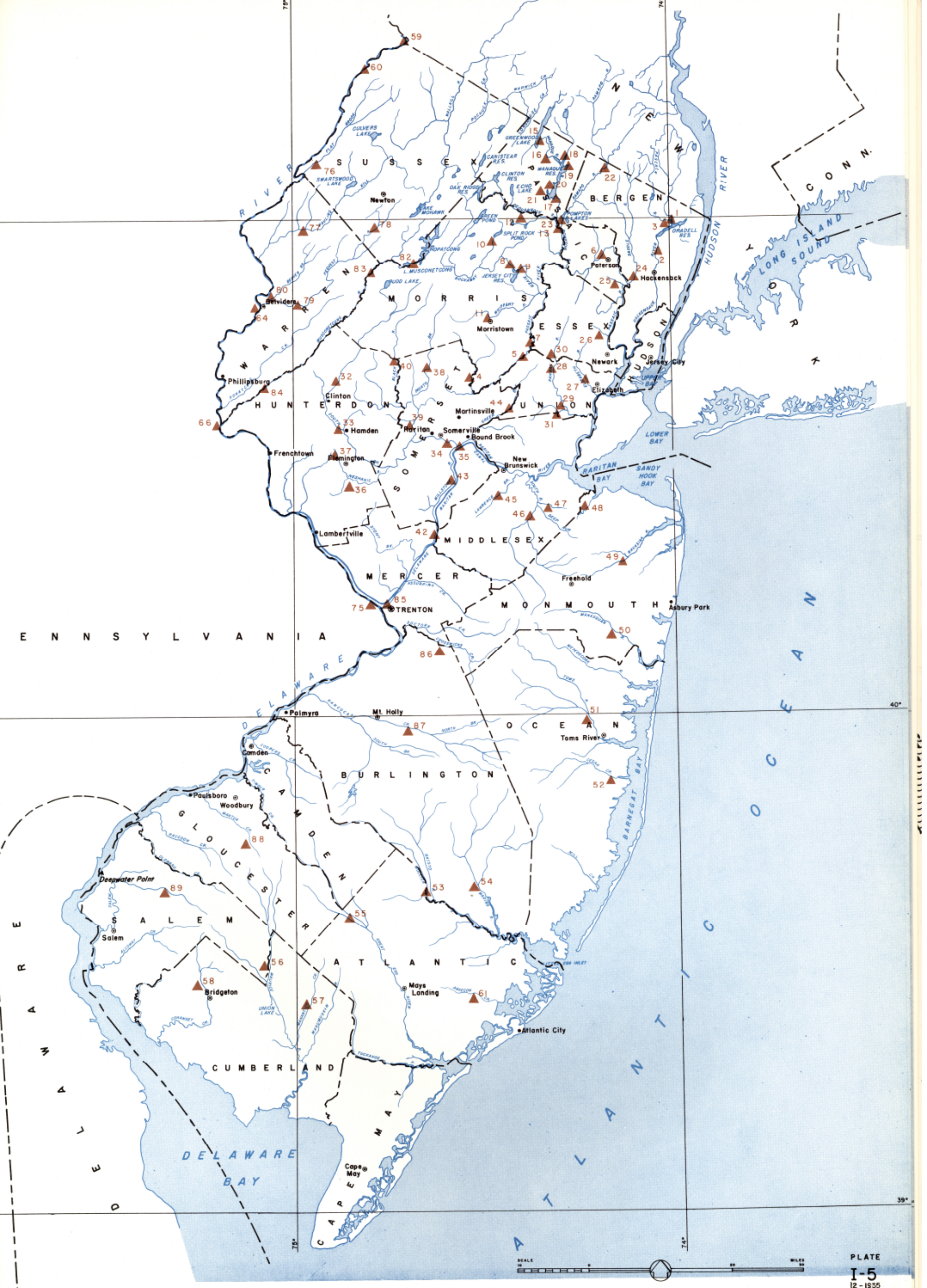


PLATE I-5
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY

TIPPETTS – ABBETT – McCARTHY – STRATTON
ENGINEERS NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

LOCATION OF SURFACE WATER GAGING STATIONS



PLATE I-6

12-1935

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS – ABBETT – McCARTHY – STRATTON
ENGINEERS
NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

AVERAGE ANNUAL SURFACE RUNOFF

(INCHES)



PLATE
I-7

12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

AVERAGE ANNUAL SURFACE RUNOFF

(MILLION GALLONS PER DAY PER SQUARE MILE)

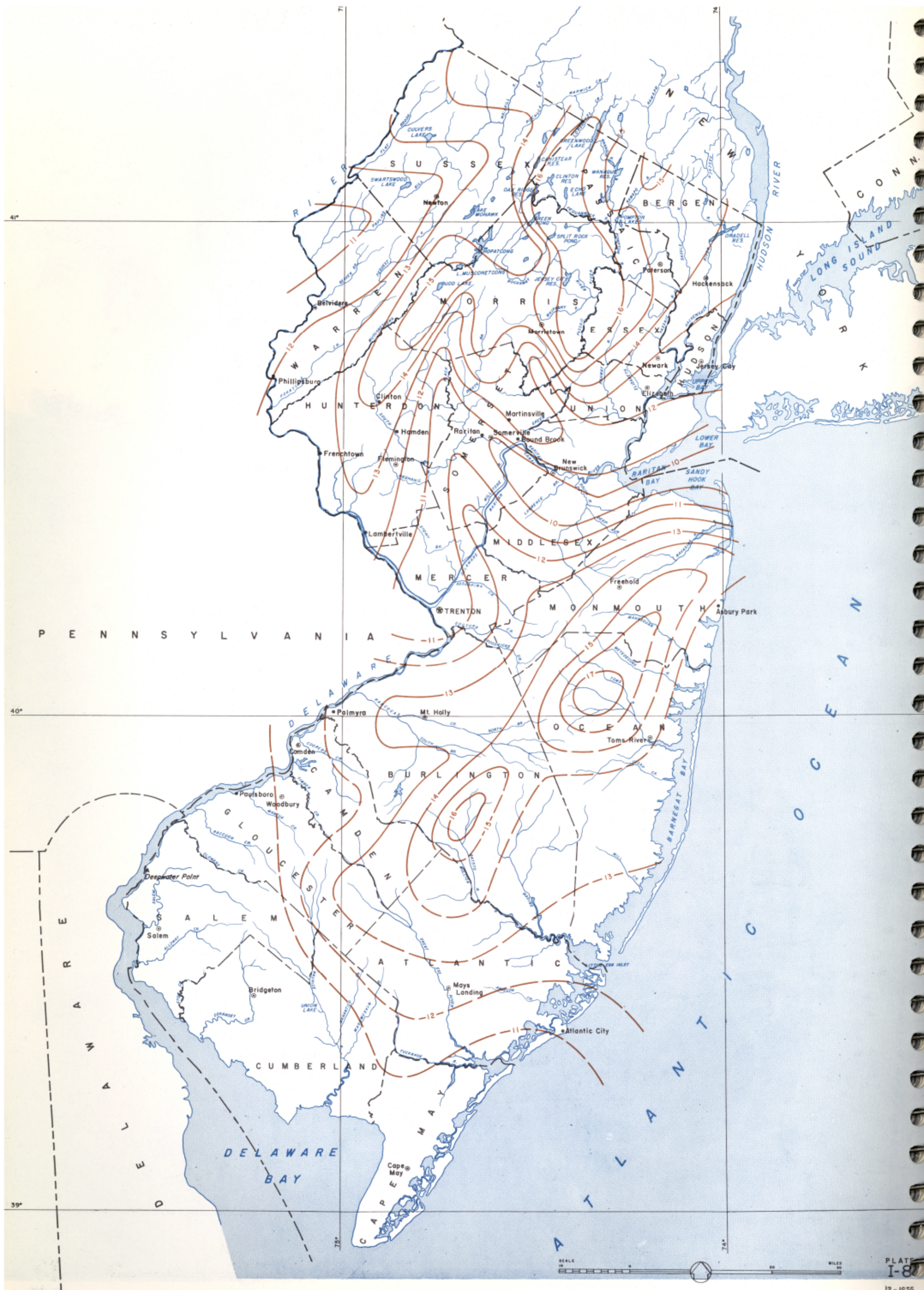


PLATE I-8

12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY

TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS
NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

TYPICAL ANNUAL SURFACE RUNOFF
DRY YEAR - 1930
(INCHES)



PLATE I-9

12-1955

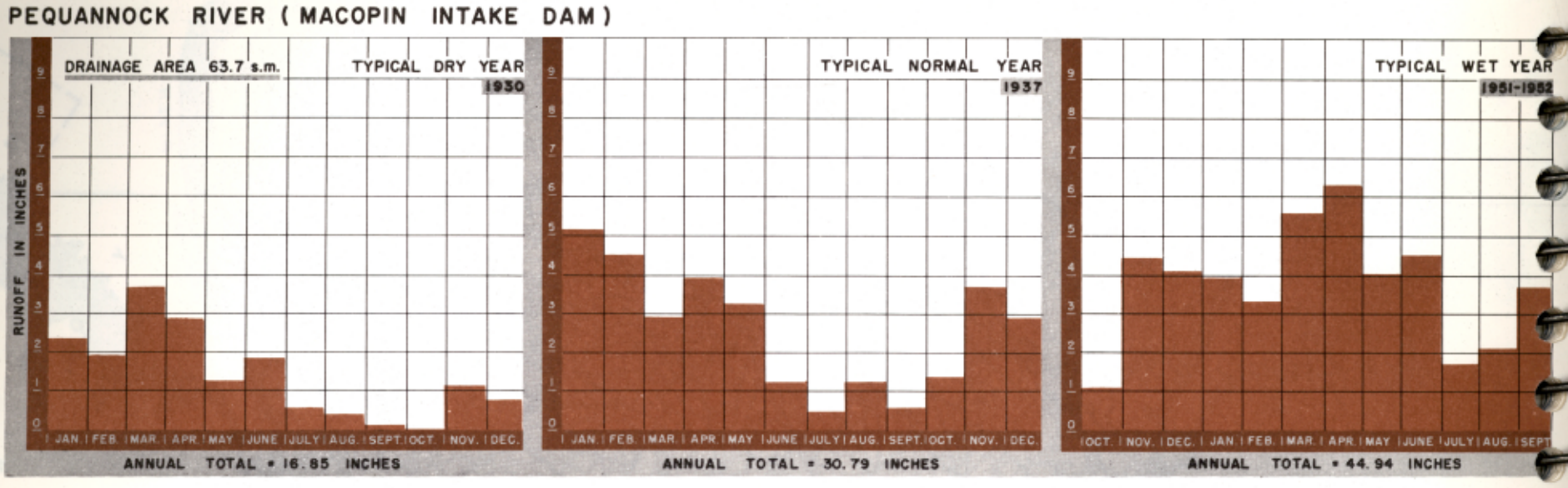
STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

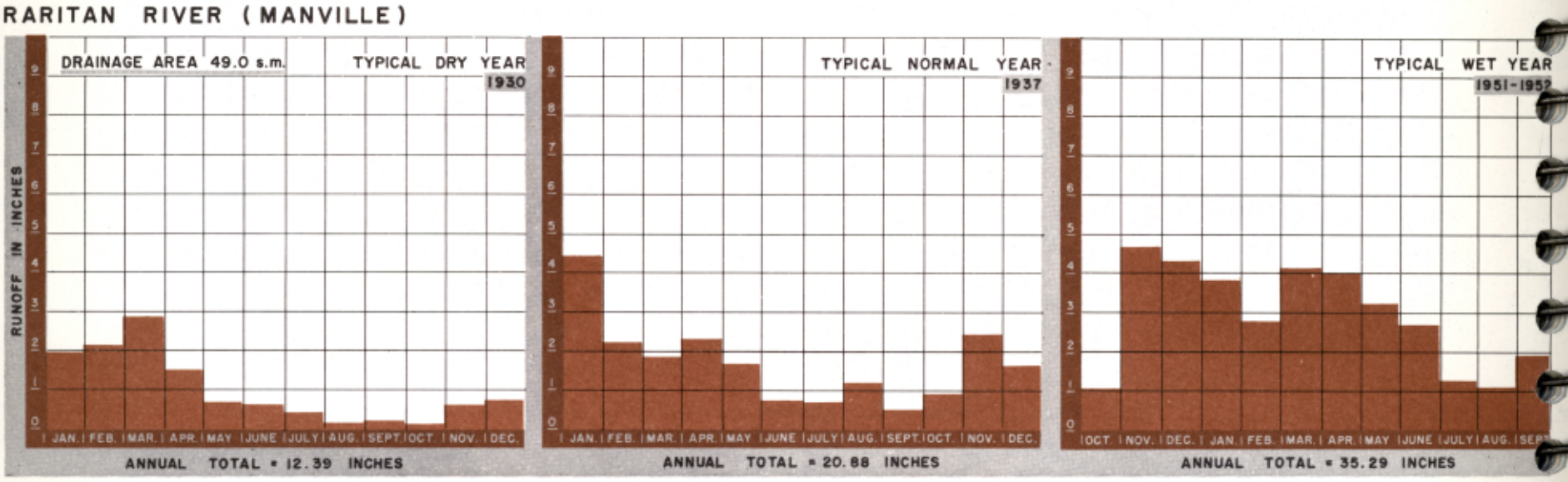
TYPICAL ANNUAL SURFACE RUNOFF
WET YEAR - WATER YEAR 1951-1952
(INCHES)

MONTHLY RUNOFF AT SELECTED STATIONS

PEQUANNOCK RIVER (MACOPIN INTAKE DAM)



RARITAN RIVER (MANVILLE)



BATSTO RIVER (BATSTO)

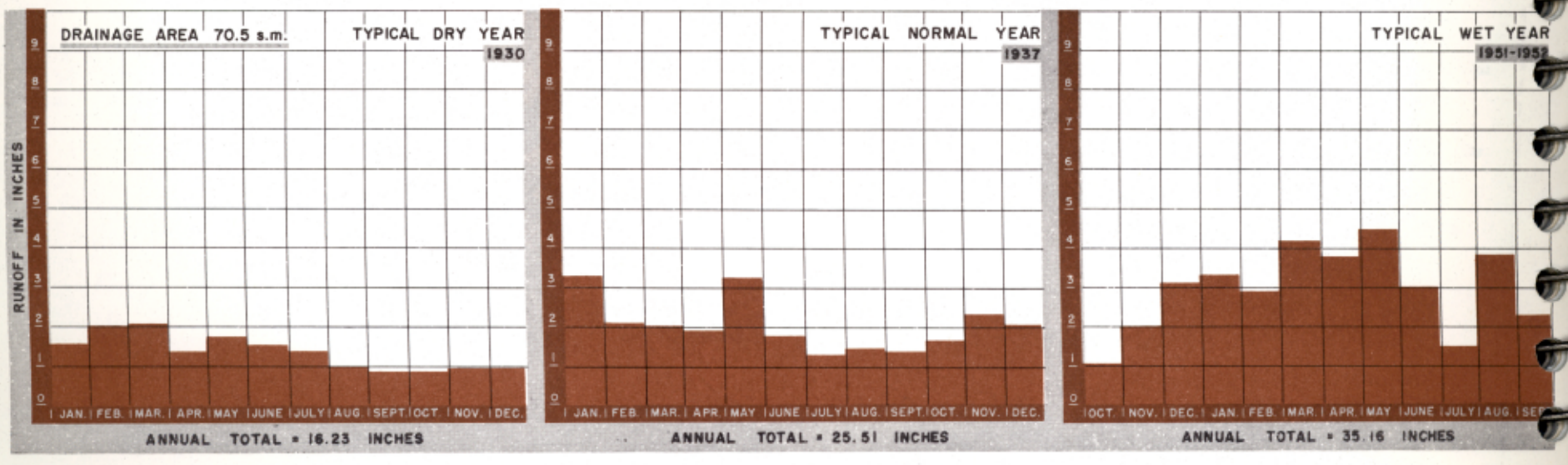


PLATE
I-10
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS
NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT
MONTHLY DISTRIBUTION OF SURFACE RUNOFF



PLATE I-11

12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS – ABBETT – McCARTHY – STRATTON
ENGINEERS NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

AVERAGE ANNUAL DIFFERENCE BETWEEN
PRECIPITATION & SURFACE RUNOFF
(INCHES)

CHAPTER II

CHAPTER II

SURFACE WATER

MAJOR RIVER SYSTEMS—GENERAL DESCRIPTION

The principal drainage basins in New Jersey and their location within the four regional divisions are shown on the Frontispiece. In general, the eastern part of the State drains directly to the Atlantic Ocean, the western part to the Delaware River and a small area in the northern part (the Wallkill River Basin) to the Hudson River.

NORTHEASTERN REGION

The Passaic, Hackensack and Raritan are the major river systems in the Northeastern Region. The Raritan, however, is the only basin which is entirely within the boundaries of New Jersey since the Passaic and Hackensack systems have some of their head waters in New York State. These three rivers together with two minor ones, the Elizabeth and Rahway Rivers, drain the most populous areas in New Jersey and enter tidewater at either Newark or Raritan Bays.

On the whole, the streams in the Northeastern Region are highly erratic with wide variations in flow between wet and dry periods. As a result of this characteristic, water supplies taken from unregulated streams in the region including the main rivers, have relatively low dependable yields. On the other hand, comparatively small streams can be developed to yield sizable supplies with a high degree of dependability when adequate storage facilities are provided for flood flows.

There has been a considerable development of potable water supplies in the Passaic and Hackensack Basins through the construction of storage facilities. Although additional development is still feasible in these basins, the possibilities are limited largely to the expansion of existing systems. The Raritan Basin, on the other hand, is entirely unregulated and present withdrawals of water from the river for both potable and industrial uses are limited in dependability to the lowest dry weather flow. The Raritan River together with its principal tributary, the Millstone River, represents one of the most important undeveloped water resources in New Jersey. It is the closest as well as the most readily available source for additional large water supplies for the Northeastern Region.

COASTAL REGION

In the Coastal Region the principal streams are the Shrewsbury-Navesink, Manasquan, Metediconk, Toms, Mullica-Wading, Great Egg Harbor and the Maurice. These streams flow in a southeasterly direction across the eastern slope of the Coastal Plain and reach tidewater either at the Atlantic Ocean or in Delaware Bay. They drain a region which is largely agricultural and recreational and includes the major portion of the sparsely developed area known as the "Pine Barrens".

The topography of the Central Region has relatively low relief. Most of the Region lies between sea level and the 200 foot contour and a large part of its surface is composed of sands and light permeable soils. As a result of these two factors the run-off characteristics of the area are quite different from those of northern New Jersey. The rivers of the Coastal Plain do not have the erratic characteristics of the more northerly streams since the retention of a large part of the precipitation in the porous ground and the movement of this water through the ground to stream beds at a relatively uniform rate, tends to minimize the difference between wet and dry weather flows.

Because of the more uniform flow of the Coastal Region streams and the large quantity of water stored underground, surface storage of flood flows is not so essential for the development of large dependable water supplies as in the Northeastern Region. Surface supplies may be developed either by direct diversion from streams or by inducing flow from streams to filter galleries or wells located in the permeable formations along the river banks.

In most of the Coastal Plain relatively little use has been made of surface water for potable supplies because of the ease with which ground water supplies may be utilized. There are a few locations, however, where small surface supplies have been developed, such as in the Shrewsbury-Navesink Basin where ground water conditions are not so favorable as in the other parts of the Region.

Potentially the Mullica-Wading Basin is the most important surface water resource area in the Coastal Region because of the relatively large size of the drainage area, its proximity to the two largest areas of demand in the southern part of the State (Camden and Atlantic City) and because of the large State owned preserves within the Basin (Wharton Tract, Green Bank, Bass River, Lebanon and Penn State Forests).

NORTHWESTERN REGION

The Northwestern Region contains most of the mountainous areas of New Jersey. The principal rivers are the Musconetcong, Pohatcong, Pequest, Paulins Kill and Flat Brook all of which drain to the Delaware River, and the Wallkill which flows into the Hudson River in New York State. This region also contains the headwaters of the North and South branches of the Raritan River and the New Jersey headwaters of the Passaic River.

Surface run-off of storm water in the Northwestern Region is typical of run-off in mountainous terrain composed of relatively impervious rocks. The rapid delivery of precipitation to streams results in the rivers having a flashy character. However, some natural regulation of runoff is effected by the large number of lakes and ponds in the region. The principal rivers, particularly those in the Delaware Basin, have relatively small drainage areas limited to narrow valleys between succeeding ridges of mountains. The Musconetcong River with 157 square miles of watershed is the largest in the Region. Comparatively minor utilization of surface water for potable supply has been made in this part of the State except for the Passaic Basin runoff to the Pequannock, Rockaway, and Wanaque systems which serve parts of the Northeastern Region.

Considerable potential for potable water supply development exists in both the Delaware and Hudson drainage areas. Although the Northwestern Region is neither urban nor industrial in character, there are very few good reservoir sites which do not require considerable relocation of highways and railroads, and the disturbance of industry and rural residential communities. The sites requiring a minimum of disturbance of existing facilities appear to be located on Flat Brook and on Beaver Brook, a tributary of the Pequest River. Both of these streams, however, have insufficient drainage areas for the development of a major water supply and, as a consequence, supplemental supply from the Delaware River would be required.

Direct diversion of considerable quantities of water from the Delaware River for potable supplies in Northeastern New Jersey is also feasible provided adequate storage to supplement the low flow of the river is constructed in accordance with established legal requirements for out-of-basin diversion. Such compensating storage could be provided either on the main river at the proposed Wallpack Bend Reservoir or on one of the Delaware tributaries. Diversion from the Delaware River should preferably be made above the confluence with the Lehigh River in order to avoid pollution from the latter stream. A number of diversion routes, both gravity and pumping, may be used to deliver water from the Delaware River into the Raritan Basin. The comparative economy of these diversions is given later in this chapter under the section on the use of Delaware River water.

Any major water development for New Jersey in the Delaware Basin in the foreseeable future would be for the benefit of New Jersey areas lying outside of the Basin and, as a consequence, would be subject to agreement between the Delaware Valley States and to review by the United States Supreme Court. Except for permission presently granted to the State of New Jersey to divert 100 million gallons per day from the Delaware Basin, all additional diversions are likely to require the construction of compensating reservoirs in order to provide releases to the river during periods of low flow.

SOUTHWESTERN REGION

The Southwestern Region is comprised of the western or Delaware Slope of the coastal plain. The principal streams are Crosswicks Creek, Rancocas Creek, Salem Creek and Cohancy Creek. These creeks together with a large number of lesser streams drain the Region to the Delaware River. Most of the streams in this region are subject to some tidal action where they join the Delaware River. With the exception of the Delaware River proper, Rancocas Creek is the largest source of surface water in the Region and has a drainage area of 335 square miles.

The topography and the runoff pattern of the Southwestern Region is similar to that of the Coastal Region. Flat natural gradients and a pervious surface formation are common to most of the area and produce a more uniform stream flow than in the northern part of the State. Most of the tributary streams, however, before reaching the Delaware River, flow through an area with underlying geological formations of poorer water transmitting qualities than in the Coastal Region. For this reason the condition is not so favorable as in the Coastal Region for inducing surface flow from streams into subsurface collecting structures. This condition does not apply to the area adjacent to the Delaware River itself since there is ample evidence that wells located near the river in the vicinity of Camden are fed to a considerable degree by an induced infiltration of river water.

The lack of good reservoir sites in the Southwestern Region makes the development of large water supplies from surface sources alone impracticable except for the use of the Delaware River proper. The lower Delaware River, even though unregulated, constitutes a large water resource but it is subject to tidal action and receives pollution from large quantities of sewage and industrial wastes. These factors may become serious in connection with the use of the lower Delaware as a source for potable water.

As in the Coastal Region, the ease of developing underground supplies has resulted in negligible use of surface waters in the Southwestern Region. The two greatest uses of surface water in the region are made at Trenton and Camden; the first is by a direct diversion from the Delaware River and the second by an induced diversion through the pervious strata along the river. Rancocas Creek, because of its size and proximity to the Camden metropolitan area, is probably the most important surface water resource in the Region with the exception of the Delaware River.

PRINCIPAL SURFACE WATER DEVELOPMENT POSSIBILITIES

The Northeastern Region has the following surface water resources available for the development of additional potable supplies:

1. Additional development of the Hackensack River Basin.
2. Additional development of the Passaic River Basin.
3. Development of the Raritan River Basin.
4. Diversion from the Delaware River Basin.
5. Diversion from the Wallkill River Basin.

At the present time the major water supplies for the Northeastern Region are obtained from the surface waters of both the Hackensack and Passaic River Basins. Greatest reliance is placed on stored water in the upstream tributaries of the Passaic Basin; namely the Wanaque, Pequannock and Rockaway Rivers. A portion of the Ramapo River, another Passaic tributary, is diverted to storage in Wanaque Reservoir and diversion without storage is made directly from the Passaic River at Little Falls. The Hackensack Basin above Oradell is the principal source of supply for the Hackensack Water Company and additional works providing for greater utilization of the river are under construction. Despite this concentration of water development in the Hackensack and Passaic Basins, additional expansion of these sources of supply is still practicable.

HACKENSACK RIVER BASIN

The Hackensack Water Company has been the principal developer of public water supplies in the Hackensack Valley. This privately owned water utility serves areas in both Bergen and Hudson Counties in New Jersey and its wholly owned subsidiary, the Spring Valley Water Works and Supply Company, serves portions of Rockland County in New York State. Regulation of the runoff from 116 square miles of the Hackensack River drainage basin is provided at present by two reservoirs; the Oradell Reservoir, constructed in 1922 with a capacity of 3,080 million gallons; and the Woodcliff Reservoir on Pascack Creek, with a capacity of 890 million gallons. The dependable supply of the company's existing surface water system is 45 million gallons per day. Additional storage capacity is currently under construction in New York State by the Spring Valley Water Works and Supply Company. The capacity of the new reservoir—to be named "deForest Lake Reservoir"—will be 5.6 billion gallons. This reservoir will control a drainage area of about 26 square miles in the upper reaches of the Hackensack River and the new project will develop a dependable yield of 20 million gallons per day. The division of this additional Hackensack River supply between the New York and New Jersey supply areas is discussed in detail below.

The approval granted by the New York State Water Power and Control Commission for the construction of deForest Lake Reservoir contains the following conditions:

1. Of the daily yield of the watershed, at least 10 million gallons are to be forever reserved for needs of the inhabitants of Rockland County.
2. No part of the water may be conducted across the New York State line through pipes, conduits or artificially constructed ditches or canals.
3. An amount of at least 9.75 million gallons daily is to be released from the deForest Reservoir in order to maintain this minimum flow at the intake of the Village of Nyack water works located downstream from the reservoir. Of this 2.0 million gallons per day is to be reserved for the Village of Nyack, which diverts water completely out of the Hackensack Basin.

From the findings and rulings of the New York State Water Power and Control Commission, it appears likely that the amount of water available to New Jersey consumers from the "deForest Lake" development could be officially reduced to 7.75 million gallons per day.

After completion of the "deForest Lake Reservoir," the water available to the Spring Valley Water Works and Supply Company will be 20 million gallons per day plus its present dependable well supply of 4 million gallons per day or a total of 24 million gallons per day. The Company's estimated maximum requirement for its service area in 1980 is 17 million gallons per day. This leaves a net surplus in 1980 of 7 million gallons per day assuming that the sources of supply remain constant. On this basis it is within the range of reasonable probability to assume that the minimum release of 9.75 less 2.00 million gallons per day for Nyack, or 7.75 million gallons per day, will be the dependable supply available to New Jersey in 1980 from the deForest Reservoir. Initially, about twice this amount of water may be available daily from the deForest Lake Reservoir for the New Jersey service area of the Hackensack Water Company. To this should be added whatever return drainage may reach the Hackensack River from the water consumed in the service area of the Spring Valley Water Works and Supply Company.

In addition to the deForest Lake Reservoir supply of 20 million gallons per day in New York and the 45 million gallons already developed in New Jersey, there is a further potential of 10 million gallons per day which may be obtained from the New Jersey portion of the Hackensack Basin. This will make a total of 75 million gallons per day which represents the limit of economic feasibility for surface water supply development in the Hackensack Basin. It is probable, however, that through coordinated operation of the Oradell and deForest Lake Reservoirs, a dependable yield somewhat higher than 75 million gallons per day may be achieved. Except for such ground water resources as may be exploited without affecting surface supplies, the service area of the Hackensack Water Company will require additional supplies originating outside of the Hackensack Basin when the average daily water demand plus a reasonable reserve reaches 62.75 million gallons (75.00 million gallons per day less

12.25 million gallons per day for Rockland County). See mass hydrograph and yield vs. storage curve for Hackensack River on Appendix Plate A-1.

The Hackensack Water Company has interconnections with both the Jersey City system and the Passaic Valley Water Commission system. Under short-term agreements, up to 8 million gallons per day may be obtained from the Passaic Valley Water Commission and 4 million from Jersey City. Pending completion of Hackensack River developments, present deficiencies in the Hackensack supply are met by drafts on these two Passaic Basin systems.

PASSAIC RIVER BASIN

Four major systems and several minor ones serving the Northeastern Region draw their supplies from the surface water of the Passaic Basin. A description of these systems and the extent of feasible expansion follows:

Pequannock System

This system is owned and operated by the City of Newark and supplies water to that City, to the Towns of Bloomfield and Belleville and to a number of other municipalities and consumers located along the aqueduct. Construction of the key works commenced in 1889 and was completed in 1896 by the East Jersey Water Company. The City acquired these properties in 1900 and made major improvements and additions in both 1904 and 1943.

The supply is impounded in four storage reservoirs, namely—Canistear, Oak Ridge, Clinton and Echo Lake—located in the Pequannock River Basin, a tributary of the Passaic River. These reservoirs deliver water via natural stream channel to the Macopin Intake Reservoir. The water is taken by gravity from there through an aqueduct to Newark and the other municipalities. The Pequannock River has a drainage area of 63.7 square miles above Macopin Dam.

The Pequannock Aqueduct extends from the gate house at Macopin Intake to Belleville Reservoir, a distance of 21.2 miles. A distributing reservoir with a capacity of about 700 million gallons is located near Cedar Grove. Under normal operating conditions, all water is delivered to consumers from the Cedar Grove Reservoir, but this reservoir can be bypassed through the trunk mains in the event of an emergency or an exceptionally large draft. A second distributing reservoir located in Belleville, has a capacity of 14 million gallons and serves a high level district in that town.

The greatest average rate of delivery for the Pequannock system occurred in 1951 and averaged 63 million gallons per day during the year as compared with an average delivery of 50 million gallons per day during the more typical year 1954. The greatest monthly draft occurred in June 1950 and averaged 71.5 million gallons per day for that period. Of this amount, 13.4 million gallons per day were delivered to the Wanaque system. The greatest daily delivery to the Newark system alone occurred on June 26, 1952 and totaled 95.5 million gallons. The greatest total daily delivery from the Pequannock system occurred during May 1953 and was 99.4 million gallons, of which the Wanaque system received 35.0 million gallons.

Operation studies made for the most critical dry period on record indicate that the dependable yield of this system with existing reservoirs is 46 million gallons per day. This figure is based on the assumption that 25 percent of the storage capacity would be held as reserve. Additional studies show that the dependable yield of this system may be increased by construction of Charlotteburg Reservoir and by the diversion of flows from Farber Brook to Canistear Reservoir.

A report has been prepared for the City of Newark on a new reservoir at Charlotteburg Pond having a storage capacity of 2.9 billion gallons and for the diversion of flows from Farber Brook to the existing Canistear Reservoir. The maximum economic development of the Pequannock basin would be achieved with the construction of these two additions, which are estimated to cost about $8,640,000. Included in the estimated cost are funds for construction of a new treatment plant and pipe lines from Charlotteburg and Echo Lake Reservoirs to the existing Pequannock Aqueduct. Independent operation studies prepared for this survey show that with the addition of these proposed projects and with 25 percent of the total storage capacity considered as reserve, the yield of the system during the most severe drought of record for the Pequannock Basin (1900-1901), could be increased from 46 to 53.4 million gallons per day. The proposed arrangement for the delivery of water from Charlotteburg and Echo Lake Reservoirs will increase the aqueduct capacity from 81 to 90 million gallons per day by increasing the hydraulic gradient.

The report on the expansion of the Pequannock water supply has been thoroughly reviewed and an independent check was made of the engineering findings and cost estimates. Except for a difference in the increased yield which may be expected from the Farber Brook diversion the findings of the report were found to be in accord with the known hydrological data for the basin and with current costs for similar work.

A field inspection of the proposed Charlotteburg dam site was made by an engineering geologist who also studied the core boring results presented in the report of Parsons, Brinckerhoff, Hall and Macdonald. It was found that this site is underlain by hard granitoid gneiss which will form a good foundation for a concrete gravity dam. However, considerable excavation will be required to expose the gneiss bedrock, since glacial deposits of sand and gravel overlay the rock and in the left abutment attain a thickness of 95 feet. It is believed, therefore, that consideration should be given to the use of an earth fill or rock fill dam at the proposed Charlotteburg site. A more economical site geologically for a dam founded on rock, would be about 300 feet downstream from the junction of the Wharton and Northern Railroad with the New York, Susquehanna and Western Railroad, where the glacial deposit is not involved. This move, however, would involve additional costs for highway and railroad relocation which may offset the saving in construction cost.

Plate II-1 shows the location of the Pequannock system and the proposed additions. Area and capacity curves for the Charlotteburg and other proposed reservoir sites in the Passaic River basin are shown on Appendix Plate A-14.

Rockaway River System

This system is owned and operated by the City of Jersey City and derives its supply from storage developed in the Rockaway River Basin which is tributary to the Passaic River. The system presently operates with two main storage reservoirs. The larger one with a capacity of 7.5 billion gallons is located at Boonton on the Rockaway River, where the drainage area is 121.5 square miles. The smaller, known as Split Rock Reservoir, which was completed in 1948 with a capacity of 3.3 billion gallons, impounds the flow of Beaver Brook, a tributary of the Rockaway River. The supply from the latter reservoir is delivered to Boonton Reservoir by gravity flow through natural channels.

An aqueduct 22.8 miles in length extends from Boonton Reservoir to the Jersey City distribution system. Interconnections located along this aqueduct permit interchange of water from the Wanaque, Pequannock (Newark) and Passaic Valley Water Commission systems. The Jersey City system also supplies water to the City of Hoboken, the Township of Lyndhurst and the Borough of North Arlington as well as to eight major and a number of smaller industrial consumers located outside the boundaries of Jersey City. The average delivery rate for the system in 1954 was 62.8 million gallons per day. Operation studies made for the most critical dry period of record indicate the dependable yield of the existing systems to be 68 million gallons per day.

Additional operation studies show that expansion of the Rockaway River system to its practicable maximum may be accomplished by the construction of the proposed Longwood Valley Reservoir on the upper Rockaway River and by the installation of bascule type gates on the spillway at Boonton Reservoir to increase its capacity. The addition of bascule gates to Boonton dam will raise the reservoir level by 2.0 feet and will increase the storage capacity from 7.5 to 8.3 billion gallons. A contract for the installation of the gates has recently been awarded. The proposed Longwood Valley reservoir would add 4.5 billion gallons of storage to the system if constructed with a flow line at elevation 760.0. Water from this reservoir would be conducted to Boonton Reservoir by natural stream channel. Through coordinated

operation of the enlarged Boonton Reservoir, Split Rock Reservoir and Longwood Valley Reservoir, the expanded Rockaway River system could provide a dependable total yield of 82.6 million gallons per day, representing a gain of 14.6 million gallons per day over the present safe yield of 68 million gallons per day. These yields are based on a study of the most critical dry periods of record and assume a reserve reservoir capacity of 25% of the total storage.

A field reconnaissance of the site of the proposed Longwood Valley dam on the Rockaway River discloses that the area is underlain by granitoid gneiss, conglomerate, limestone and shale with a major fault line generally separating the igneous rocks on the western side of the Valley from the sedimentary rocks on the eastern side. The fault appears to be stable with no evidence of recent movement. The site, with proper design consideration and foundation treatment, is suitable for an earth dam 80 or 90 feet high. A cutoff of some depth beneath the dam will be required to prevent excessive leakage and damage to the dam. Specific cutoff requirements will have to be defined by exploratory borings and tests. There will be no advantage, from a geological standpoint, in moving the dam upstream or downstream, since conditions are generally similar over a considerable distance.

The estimated cost of the proposed Longwood Valley Reservoir development is $3,500,000.

The aqueduct from Boonton Reservoir to Jersey City has a design capacity of 100 million gallons per day. In order to provide adequate service during peak demand periods at the maximum delivery capability of the expanded system, it is probable that increased balancing reservoir capacity will be required.

Wanaque-Ramapo System

This system is administered by the North Jersey District Water Supply Commission and was placed in operation in March 1930. Water is obtained from the Wanaque and Ramapo Rivers in the Passaic Basin. Storage is provided at Wanaque Reservoir which is located on Wanaque River near the northern boundary of New Jersey. This reservoir drains an area of 94.4 square miles and is formed by Raymond Dam and seven dikes. The nominal storage capacity is 28 billion gallons, but it can be increased to 29.5 billion gallons by the operation of flashboards which raise the flow line of the reservoir from elevation 300.3 to 302.25. The Ramapo Diversion Project was placed in service in December 1953 and provides facilities for diverting water to Wanaque Reservoir by pumping from the Ramapo River at Pompton Lake (drainage area, 160 square miles). This additional facility increases the dependable yield of the system from about 82.5 million gallons per day to 106 million gallons per day.

The North Jersey District Water Supply Commission was created by the New Jersey Legislature in 1916 (Chapters 70 and 71 Public Laws of 1916). The system is administered by the Commission and is owned by the participating municipalities in the following proportions:

City of Newark	40.50%
Passaic Valley Water Commission for Passaic, Paterson and Clifton	37.75%
Town of Kearny	12.00%
Town of Montclair	5.00%
Town of Bloomfield	4.00%
Borough of Glen Ridge	0.75%
TOTAL	100.00%

In addition to furnishing the owner municipalities, water is also supplied by contract to Bayonne and Elizabeth from Newark surpluses, to the Hackensack Water Company through the Passaic Valley Water Commission and to small communities along the route of the aqueduct. The Town of Bloomfield is under an agreement with the City of Newark to exchange its 4% allotment of Wanaque water for the higher level Pequannock supply.

The transmission system extends from Wanaque Reservoir to Belleville Reservoir, a distance of 20.6 miles, and has interconnections along the way to (1) the Pequannock Aqueduct of the Newark system, (2) the Little Falls pumping station of the Passaic Valley Water Commission, (3) the Jersey City Aqueduct, (4) the Montclair pumping station, (5) Bloomfield and (6) Belleville. Glen Ridge is supplied through meters from the Montclair distribution system.

The greatest annual delivery on this system occurred in 1948 and averaged 95.4 million gallons per day as compared with the average delivery of 89.3 million gallons per day during 1954, a typical year. The greatest monthly delivery occurred during September 1953 and averaged 107.2 million gallons per day for that period. The greatest single day draft during that month was 137.6 million gallons.

Operation studies were made for this system for the most critical dry period of record (1930-33). It was found that, with 25 percent of the storage capacity held as a reserve, the dependable yield was 82.5 million gallons per day from Wanaque flows only and 106 million gallons per day for the present system including the Ramapo Diversion.

The diversion of water from the Ramapo River to the Wanaque River was authorized in 1950 by the Water Policy and Supply Council with the following conditions:

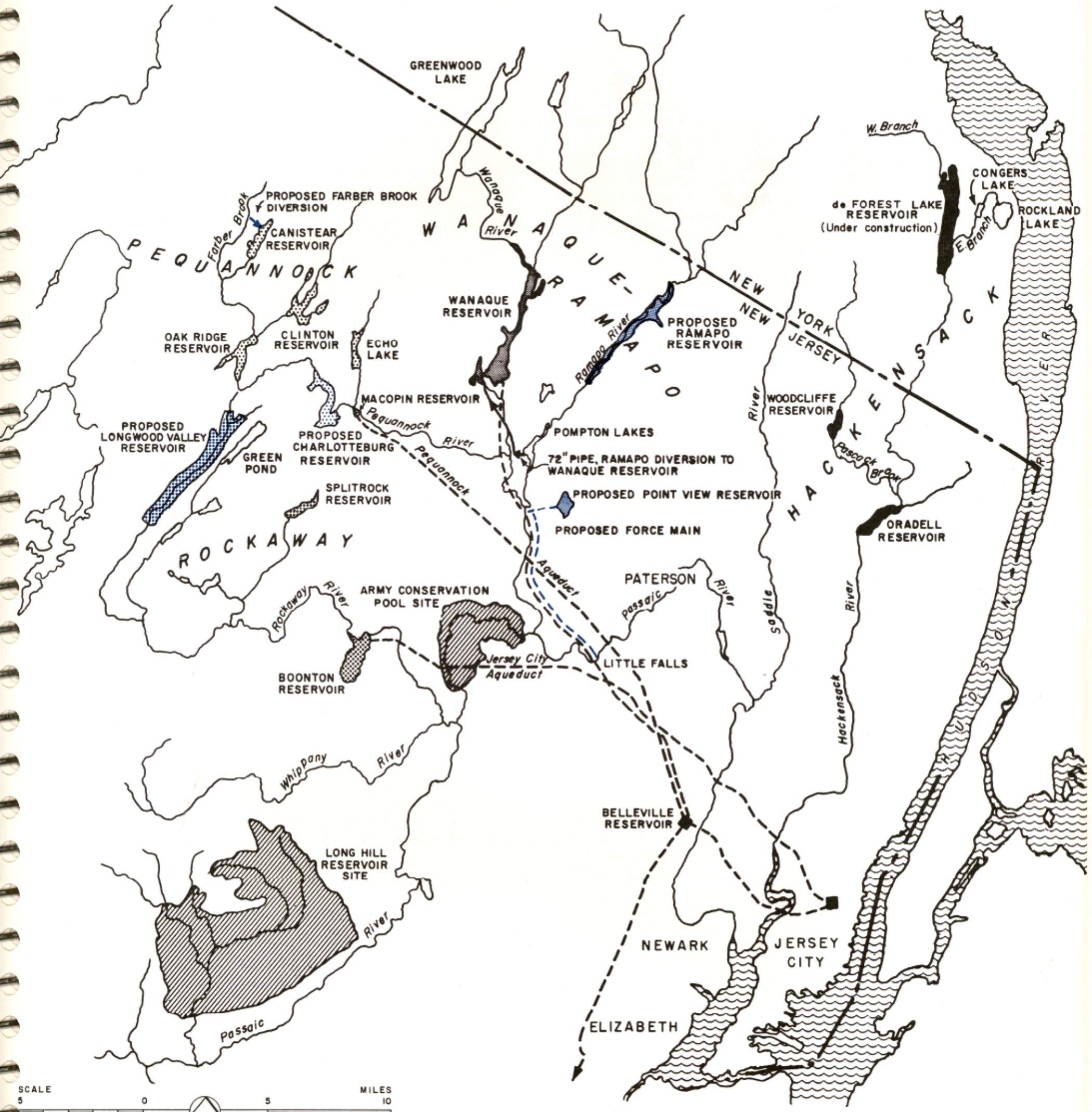
1. Average daily pumping rate shall not exceed 100 million gallons in any calendar month.
2. On an annual basis the total quantity of water pumped shall not exceed an average daily rate of 25 million gallons (9.125 billion gallons per year).
3. The above pumpage may be increased as necessary to provide water for compensating releases from storage to maintain a minimum flow of 10 million gallons per day below the diversion point. Required releases, however, are limited to 60 days in a calendar year.
4. No diversion from the Ramapo River shall be made when the net flow below the point of diversion is less than 40 million gallons per day.
5. No pumping shall be done during the months of June, July, August and September.
6. The water level at Pompton Lakes shall not be materially lowered by the pumping diversion.

These restrictions on the Ramapo Diversion were made, after hearing all objections to the diversion, in order to protect the water rights of downstream riparian owners. The conditions imposed have fully provided this protection. They have, in fact, raised the question as to whether they are not too restrictive in view of the considerable quantity of water which still goes to waste in the Ramapo River over and above the 40 million gallons per day minimum downstream flow during periods of diversion. In order to determine the effect of a greater Ramapo Diversion on the dependable yield of the system, an analysis of the flow of the Ramapo River was made for the severe drought period of 1931-32 with the following assumed modifications in the diversion restrictions:

1. Pumping to be permitted during the entire year of flows above a minimum of 40 million gallons per day measured below the diversion point.
2. Pumping to be permitted up to the full capacity of the pumps at all times when water is available above the minimum downstream flow of 40 million gallons per day without restrictions on the annual total.

On the basis of using the existing pumping capacity of 100 million gallons per day, it was found that the adoption of these eased diversion restrictions would increase the dependable yield by 16 million gallons per day, making the total dependable yield of the system 122 million gallons per day. It was further found that an additional increase in the safe yield of 2 million gallons per day was possible for each 10 million gallons per day increase in pumping capacity until the yield of the total system became 130 million gallons per day. This would require a basic pumping capacity at the Ramapo Pumping Station of 140 million gallons per day. These increased Ramapo diversions could be carried out without any injury to the water rights of downstream owners although power production at the hydro-electric plant of the Passaic Valley Water Commission would be affected. However, in view of the relative values and availability of water and power in the Northeastern Region, the production of hydro-power should be subordinated to potable water needs.

The increase in the yield of the Wanaque-Ramapo system by 16 million gallons per day to a total of 122 million gallons



PUBLIC WATER SUPPLIES

RIVER BASIN	SUB-BASIN	NEW DEVELOPMENT	INCREMENTAL YIELD	ESTIMATED COST	OPERATOR
SSAIC	PEQUANNOCK	CHARLOTTEBURG RESERVOIR – 2,900 mg FARBER BROOK DIVERSION	7.4 mgd	$ 8,640,000	CITY OF NEWARK
	ROCKAWAY	LONGWOOD VALLEY RESERVOIR – 4,500 mg±	14.6	3,500,000	CITY OF JERSEY CITY
	PASSAIC–POMPTON	POINT VIEW RESERVOIR – 2,800 mg	55	10,000,000	PASSAIC VALLEY WATER COMMISSION

PRIVATE WATER SUPPLIES

CKENSACK	HACKENSACK	de FOREST LAKE RESERVOIR – 5,600 mg	20	UNDER CONSTRUCTION	HACKENSACK WATER CO. AND SUBSIDIARY SPRING VALLEY WATER WORKS AND SUPPLY CO.

OTHER PREVIOUSLY SUGGESTED PLANS

SSAIC	PASSAIC	LONG HILL RESERVOIR – 328,000 mg	600±	NOT ESTIMATED
	PASSAIC	ARMY CONSERVATION POOL – 90,600 mg	120	NOT ESTIMATED

PLATE
II-1
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

PROPOSED EXPANSIONS TO EXISTING WATER SUPPLY SYSTEMS
PASSAIC AND HACKENSACK RIVER BASINS

per day through the easing of restrictions on the Ramapo Diversion, may be made with the existing installation and without any expenditure for capital improvements. If such an increased diversion is permitted, operating experience at the higher rate may indicate the future desirability of adding reserve pumping units of smaller capacity. These new units would provide both greater flexibility and dependability to the diversion. The delivery of the increased yield through the existing aqueduct may require operation of the Wanaque booster pumps during times of peak demand.

The economic value of increasing the yield of the present Wanaque-Ramapo system to 130 million gallons per day by the addition of pumping capacity is doubtful. It would require extensive changes in the pumping equipment in order to deliver the increased volume through the existing 72 inch force main between Pompton Lake and the Wanaque Reservoir and the Wanaque Aqueduct may not be able to deliver the peak load requirements of the increased yield.

The full water supply potential of the 94.4 square miles of drainage area of the Wanaque River has been realized by the storage provided at Wanaque Reservoir. Increasing the storage capacity of Wanaque Reservoir will, therefore, serve no useful purpose unless water is diverted into the Wanaque Basin from other drainage areas.

The only major potable water supply use being made of Ramapo River with 160 square miles of drainage area above Pompton Lakes (most of which is in New York State) is the 25 million gallon annual average daily diversion to the Wanaque Reservoir. This diversion, as indicated above, may be increased to 41 million gallons per day with existing facilities through a change in diversion rules. The Ramapo River has a water supply potential of about 140 million gallons per day providing suitable storage sites for its flood flows can be found and developed. A part of this potential could be utilized without storage on the Ramapo River by the construction of pumping facilities and force mains large enough to handle high, short duration flood flows and by the enlargement of Wanaque Reservoir to hold this additional diversion. Careful consideration of this possibility has resulted in the following conclusions:

1. With the need to first satisfy the minimum flow requirements of 40 million gallons per day and with a diversion of 41 million gallons per day possible using only existing facilities, very little additional pumping could be done during a critical period equivalent to that of June 1930 through April 1933 (1050 days). Therefore, any increase in Wanaque Reservoir storage for additional Ramapo water will have to be uniformly spread over the 1050 day critical period in computing the increase in dependable yield. Thus an increase in storage capacity of 1 billion gallons would result in an approximate increase in the dependable yield of only 1 million gallons per day.

2. The existing Wanaque Reservoir is formed by Raymond Dam across the Wanaque River and by seven dikes across low saddles around the periphery of the reservoir. This construction very nearly utilizes the reservoir basin to its topographic limit. In order to increase the capacity of the reservoir, the dam and seven dikes would have to be raised and lengthened, causeways across the reservoir raised, highways and railroads relocated and new property acquired. The cost of these alterations would be disproportionate to the value of the storage volume gained.

3. On the basis of the considerations in 1 and 2 above, additional development of the Ramapo River by storing an increased amount of pumped flood waters in an enlarged Wanaque Reservoir is not economically feasible.

Other reservoir sites, both on the Ramapo River proper and sites for pumped storage such as the Point View site (See Plate II-1), may be utilized to develop additional water supply for use in conjunction with the Wanaque-Ramapo system. The impounding of water on the Ramapo River above Pompton Lakes in sufficient volume to serve the regulation requirements of the river would involve extensive road relocation and inundate very costly industrial, commercial and residential properties. Point View is a high off-river reservoir site located on a small stream which flows into Pompton Lake. It may be filled by pumping from either the Ramapo or the Pompton Rivers. This reservoir could be used to augment the Wanaque-Ramapo supply by varying amounts depending upon the elevation to which Point View was flooded, the pumping capacity installed and the diversion rules established. The amount of added capacity, however, would be small compared to the potential of the river. The use of Point View Reservoir was covered in considerable detail in a report to the Passaic Valley Water Commission by Bogert-Childs Engineering Associates in 1950. This report concluded that the Point View Reservoir was far more valuable for the regulation of the Passaic River supply at Little Falls. On the basis of independent studies made during this survey the above conclusion is confirmed. The use of the Point View Reservoir site in conjunction with the Passaic River is discussed in the next subsection on the Passaic Valley Water Commission System.

Studies of both the Ramapo water supply potential and the existing conditions in the basin in comparison with other areas do not indicate this to be a favorable location for the development of a major additional supply for North Jersey. However, supplies of relatively small size from this source may be feasible for a future localized demand within the drainage area of the Ramapo. It may also be possible to develop, on the river above Pompton Lake, the moderate storage needed to regulate the Passaic River Diversion at Little Falls as an alternate to the Point View site. (See Passaic Valley Water Supply Commission System.) Proposals for the further development of potable water supplies from the Ramapo River should be considered with the following conditions in view:

1. That approval of the construction of one or more storage reservoirs on the Ramapo River will probably contain a provision which requires the maintenance of a minimum sustained flow. This sustained flow may be the present required amount of 40 million gallons per day which is less than 0.4 cu. ft. per second per square mile of drainage area (csm), or it may be increased to the Delaware Basin standard of 0.5 csm. In the latter case the required sustained flow will be 52 million gallons per day.

2. The present diversion on an annual basis is 25 million gallons per day and as explained above may be increased to 41 million gallons per day with existing equipment and facilities by changing the diversion restrictions.

3. The water which can be diverted by the present installation plus the required minimum flow accounts for 81 million gallons per day out of a maximum potential of 140 million gallons per day. This leaves a balance of 59 million gallons per day which may be developed. This may be reduced to 47 million gallons per day if the interstate Delaware Basin standard for sustained flow is adopted.

4. The Ramapo is an interstate River with approximately 70% of its entire basin in New York State. Future diversions by New York State could appreciably reduce the quantity of water available to New Jersey.

5. A water supply based on impounded water above Pompton Lakes would require a new aqueduct to the areas of demand unless the impounded water was used only to regulate a larger dependable diversion from the Passaic River at Little Falls. In the latter case water could be transmitted to Little Falls by natural stream bed.

6. The recreational interests of the Ramapo area will probably bring strong opposition to diversion of any water above Pompton Lakes even though adequate measures are taken to improve dry weather flows over natural conditions.

Passaic Valley Water Commission System

The Passaic Valley Water Commission was organized in 1927 by the cities of Paterson, Passaic and Clifton to acquire and operate a water supply system for the benefit of these municipalities. This system at the present time also furnishes all or part of the water supplies for Harrison, Nutley, Prospect Park, Totowa, Garfield, Haledon, East Paterson and Lodi. The Town of Little Falls is supplied through the North

Jersey Water Service Company and the supplies of a number of municipalities in Bergen and Hudson Counties are supplemented through sales of water to the Hackensack Water Company.

The Commission draws its supplies from the following two sources:

1. The Wanaque-Ramapo System in which the Commission holds rights of 37.75% of both the original Wanaque supply and the Ramapo Diversion. This source provides the Passaic Valley System with a dependable daily supply of 40 million gallons. Under certain restrictions and depending upon the availability of water, the Commission may make short term overdrafts on the Wanaque-Ramapo supply.
2. The Commission acquired the properties of the Passaic Consolidated Water Company in 1930 together with the right to divert up to 75 million gallons of water per day from the Passaic River, whenever such quantity was available. This diversion is made directly from the Passaic River at Little Falls without storage. The dependability of this supply, consequently, is limited to the low flow of the river. There are recorded flows of the Passaic River at Little Falls as low as 27 million gallons per day, but these are of short duration and can be supplemented by a temporary overdraft on the Wanaque-Ramapo supply. It is reasonable, on the basis of the flow records, to apply a value of 35 million gallons per day to the dependable yield of the unregulated Passaic River at Little Falls.

The combined dependable water supply available to the consumers of the Passaic Valley Water Commission on an average annual basis is 75 million gallons per day made up of 40 million gallons per day from the Wanaque-Ramapo System and 35 million gallons per day from the Passaic River. The average daily water demand on Passaic Valley System is now very close to the dependable supply. Peak demands occurring simultaneously with extreme low flows in the Passaic River, can only be met by overdrafts on the Wanaque-Ramapo supply and from the storage in three reservoirs, located on the distribution system which have a total capacity of 262.9 million gallons. Interconnections with the Newark and the Jersey City Aqueducts can undoubtedly be used, subject to the requirements of these cities, to supplement Passaic Valley water supplies during short term peak demands and during emergencies. However, this system is presently operating with practically no reserve and could face a serious shortage should a high demand period in its service area occur simultaneously with a low stream flow in the Passaic River coupled with correspondingly high demands and low reservoir levels on the Newark and Jersey City systems. The present condition provides no dependable margin for future growth.

The precarious balance that currently exists between supply and demand can be changed to an ample reserve by providing sufficient storage to compensate for the deficiency occurring in the Passaic River flow when it falls below the Commission's diversion rights of 75 million gallons per day. The storage-yield curve (Plate A-1) indicates that a relatively small amount of storage is needed to provide a dependable supply of 75 million gallons per day from the Passaic River at Little Falls. It is, in fact, not necessary from a hydrologic standpoint, to limit the Passaic River supply to the present diversion rights of the Passaic Valley Water Commission.

The Report on an Additional Dependable Supply made to the Passaic Valley Water Commission in 1950 recommended that the storage needed to increase the safe yield of the Passaic River supply to the full 75 million gallons per day diversion rights be obtained by construction of a reservoir at Point View. This storage site is located on a small tributary of the Ramapo River about 6 miles north of the Little Falls pumping station. For the purpose of regulating the Passaic River flow at Little Falls it may be filled by pumping either from the Pompton River or the Passaic River. With a flow line at elevation 383 and a total storage capacity of 2.8 billion gallons (2.2 billion gallons useable) it would provide a dependable Passaic River yield of 75 million gallons per day.

The 1950 report gives the estimated cost of the Point View project, based on pumping from the Passaic River and including additions to the Little Falls Treatment Plant, as $6,320,000. This cost was revised in November 1953 to $7,500,000.

An application for the Point View project was approved as early as 1934 by the State Water Policy Commission subject to the following diversion restrictions:

1. A maximum daily diversion of 25 million gallons.
2. No diversion when the flow in the Passaic River at Little Falls is less than 800 cfs (517 million gallons per day).
3. Total annual pumping to be limited to 150 days at an average rate of 20 million gallons per day (3.0 billion gallons).

The findings on the Point View project contained in the 1950 Report are based on continuance of the above restrictions. The report, however, points out the fact that the 800 cfs flow requirement in the Passaic River was probably made to favor power production which is now considered to be "of secondary importance to potable water supply."

Since the Passaic Valley Water Commission has the right to take the complete flow of the river, for water supply purposes, whenever the flow is less than 75 million gallons per day, the limitation on pumping for the Point View Diversion to 25 million gallons per day and to times when the river flow is more than 800 cubic feet per second (517 million gallons per day) appear to be unwarranted restrictions. An operation study was, therefore, made to ascertain what yield could have been obtained for the critical 1932 period with the permissible pumping rate increased to 50 million gallons per day and the 800 cfs flow requirement removed. It was found that these conditions, plus an increase in the useable Point View Reservoir storage to 2.6 billion gallons (3.1 billion gallons total storage), it was possible to obtain a dependable water supply yield of 90 million gallons per day from the Passaic River at Little Falls.

A geological examination of the proposed dam site was made in the field by an engineering geologist. The site is suitable for an earth fill dam structure of the height contemplated. A cutoff of some depth beneath the dam will be required to prevent excessive leakage. Cutoff requirements should be determined by thorough exploratory borings. Consideration should be given to the use of an impervious clay core rather than a concrete core wall as proposed.

The estimated cost of increasing the dependable yield of the Passaic River at Little Falls from 35 to 90 million gallons per day including enlargement of the treatment plant is $10,000,000.

The proposal to expand the dependable Passaic River yield by 40 million gallons per day to a total of 75 million gallons per day at a cost of $7,500,000 would result in a cost per million gallons per day of additional system capacity of $187,500.

If the supply was expanded by an additional 55 million gallons per day to a dependable yield of 90 million gallons per day at an estimated cost of $10,000,000 it would have an average cost per million gallons per day of additional system capacity of $181,800. This is by a considerable margin the lowest unit cost for any potable water development investigated in detail for the Northeastern Region. However, an alternative site for the regulation of the Passaic River Diversion at Little Falls appears to be available on the Ramapo River above Pompton Lake which may have even greater economy of construction and operation. This reservoir site was investigated in the field and its capacity computed from the existing Geological Survey topographic maps. By the use of a very economical dam structure located in a narrow gorge on the Ramapo River about one mile north of Oakland, it was found that 3.5 billion gallons of water could be impounded with a flow line elevation of 255 feet. This development would create a lake on the river about 5.5 miles long, but there would be no major problems in highway relocation or in displacement. The flooded area would cover 775 acres and approximately 900 acres should be acquired. The area and capacity curves for this site are shown on Appendix Plate A-14.

The advantages of the alternative are the elimination of the need for a long force main and high lift pumps, better regulation of stream flow in the Ramapo and Pompton Rivers and independence of pumping diversion restrictions. The

principal disadvantage would be the somewhat greater control difficulty in regulating the Passaic River Diversion at Little Falls by releases into the natural channels of the Ramapo and Pompton Rivers as compared with a pipe line from Point View to Little Falls. There should be little objection to this development by downstream riparian owners, since low stream flows would be improved by its operation.

No cost estimate was prepared for this alternative although it is fairly obvious that barring some very unusual conditions at the dam site which must, of course, be thoroughly explored, construction costs would be lower than for the Point View Project. However, in view of the likewise economical costs of the latter and the better operating control that can be exercised by a direct pipeline from the Point View Reservoir to the Little Falls Treatment Plant, this project is considered to be of first priority for the increase in the dependable water supply that can be diverted from the Passaic River at Little Falls. The alternative reservoir location at Oakland could assume importance, if the construction of Point View should become impracticable because of housing development within the proposed reservoir or if the need arose for greater regulation of the Passaic River Diversion than can be accomplished by Point View alone.

Other Water Supply Projects Proposed For the Passaic Basin

In addition to the proposals discussed above for the expansion of existing Passaic Basin water supply systems, two proposals have been made in the past for the development of major new supplies. These are the Long Hill Reservoir first discussed by Hazen, Whipple & Fuller in their 1922 Report on Water Resources of the State and the so called "Army Conservation Pool" contained in the Corps of Engineers Survey Report on Flood Control for the Passaic River made in 1948.

Long Hill Reservoir. This reservoir known as the Great Swamp Reservoir would be created by the construction of a dam across the upper Passaic River at the point where it emerges from the Great Swamp and passes through Long Hill in a narrow gorge above Millington. The site is located largely in Morris County south of Morristown. The plan proposed in the 1922 Report was to construct a dam 110 feet high, which would have created a lake with a water surface at full pool of 15,000 acres (24 square miles) and with tremendous storage capacity (328 billion gallons). The drainage area above the dam site is only 55 square miles and in order to fill the reservoir, the 1922 report proposed to make large diversions from the Raritan River Basin, from the New Jersey tributaries of the Delaware and from the Delaware River itself. Supplies ranging up to 1500 million gallons per day were suggested as possible with the diversions from other basins. These proposals were made before the compensation requirements for Delaware Basin diversions had been established by the United States Supreme Court, before New York City proceeded with an independent development of a Delaware supply and also before a number of major supplies for Northeastern New Jersey were developed. Apparently little consideration was given to minimum stream flow releases now required by the Water Policy and Supply Council. Because of these present day factors, the construction of Long Hill for a water supply of the proportions proposed in the 1922 report is no longer feasible or essential.

The question remains as to whether the Long Hill Reservoir site may be economically utilized for a supply more in line with the present and projected requirements for the Northeastern Region. On the basis of the runoff of the Passaic River above Long Hill a safe yield of only 44 million gallons per day can be obtained from this source. The very large storage capacity of the Long Hill Reservoir is entirely disproportionate to a supply of the size that can be developed from the Passaic River alone.

By a complete diversion of the North and South Branches of the Raritan River including the Black River and Peapack Brook into the Long Hill Reservoir, it would be possible to increase the yield to 178 million gallons per day. Such complete diversions, however, are likely to be strenuously contested by property owners in the Raritan Basin and would probably not be approved. Furthermore, the topography of the Long Hill Reservoir is such that, even with a greatly reduced flow line elevation there will not be a proportionately large reduction in the flooded area. As a result of this topographic characteristic the reservoir, for a supply of 178 million gallons per day, would have undesirably shallow storage, high evaporation losses and would require large and costly land takings with many hundreds of residential dislocations.

In view of the conditions described above the use of the Long Hill reservoir cannot be considered feasible for the development of a water supply of the size presently required for the Northeastern Region of the State. Consideration could be given, however, to the construction of a low dam at the Long Hill site designed to raise the water level of the Great Swamp wasteland. This would improve the natural regulation of run-off already provided by the Great Swamp and facilitate the control of mosquito breeding.

Corps of Engineers Conservation Pool. This proposed project, primarily designed for flood control, would create a multi-purpose reservoir called the "Conservation Pool" on the Passaic River just above the junction with the Pompton River and a nominally dry flood detention reservoir on the Passaic, Pompton, Rockaway and Whippany Rivers. Water from the Pompton River would be diverted into the Conservation Pool, which would be separated by dikes from the flood detention reservoir. The Passaic River would be diverted around the Conservation Pool permitting the better quality Pompton water to be separately stored in the Conservation Pool and utilized for potable purposes. At the spillway elevation of 176.5, the Conservation Pool would have a storage volume of 23 billion gallons and would provide a dependable yield of 120 million gallons a day for potable water supply from the Pompton River source only. The project would also regulate a dry weather flow for the Passaic River of 300 cubic feet per second (195 million gallons per day). By use of the lower quality Passaic water in conjunction with Pompton water a higher dependable yield than 120 million gallons per day could be obtained for water supply.

The cost of the Corps of Engineers combined conservation and flood control project was estimated in 1948 for reservoir and diversion work only to be $96,300,000 of which $28,600,000 was to be allocated to conservation (waste supply). At present day prices these costs would be $137,700,000 and $41,000,000 respectively to which would have to be added an indeterminate but sizeable sum for increase in real estate values due to the considerable development which has taken place in the area since 1948. Construction of both the flood control and water supply features of this project would require major financial contributions by the federal and state governments toward which end there has apparently been little progress since the project was reported in 1948.

The conservation portion of this plan could be undertaken separately as a water supply project without federal aid. In this case, however, in order to obtain the quality advantage of separating the Ramapo and Passaic waters, it will be necessary to add to the water supply cost considerable portions of the costs previously allocated to flood control. To these increased reservoir costs must be added the cost of pumping, treating and transmission. The total cost of the project developed for water supply alone has not been estimated in detail because of a number of indeterminate factors, but will on the basis of known items alone be in excess of $110,000,000. This would make the project less economical than others which have been studied for a new Northeastern Region supply.

Despite the highly desirable benefits of flood control, water supply and stream regulation provided by the proposed Corps of Engineers project, there has been a great deal of local opposition to its implementation because of the excessive dislocation of residential, commercial and industrial properties. This dislocation numbered 1250 individual establishments in 1948 and is considerably higher today. Additional objections to the project other than cost are loss of tax ratables by Municipalities, the low quality of water that would result from the shallow storage of the conservation pool and pollution due to the increasing urbanization of the area. The installation of the Ramapo Diversion to the Wanaque Reservoir has also reduced the total quantity of water available to the Conservation Pool. For the reasons given, it is not likely that interest in the Corps of Engineers project

streamflow, even though a large part of the supply may be pumped from wells. For this reason, a repetition of past precipitation conditions may be expected to produce less streamflow in the future during the growing season (May through October), at points downstream from irrigated areas, than was experienced prior to irrigation. It is possible that had irrigation, as now practiced or expected in the future, been in effect in 1932 (the year of least growing season runoff) the streamflow from the watershed tributary to the Raritan River at Bound Brook (principally from the Millstone drainage area) might have been reduced in that critical year by the following amounts:

Estimated Maximum Reduction of Reported Flows at Bound Brook by Irrigation Use During Growing Season

Year	Millions of Gallons
1950	392
1955	1,100
1960	1,560
1980	1,920
2000	1,920

It should be understood that the estimates given above represent the probable maximum reductions of experienced surface flow at Bound Brook assuming no restrictions on use of water for irrigation. Such reductions would apply only to extremely dry growing seasons, such as 1932, assuming that all of the estimated irrigated acreage was provided adequate supplemental water to sustain optimum plant growth at all times. Actually, such complete supplemental irrigation would probably not be achieved and streamflow depletions would be somewhat less than the maximum values estimated.

Assuming, conservatively, that irrigation use in the Raritan Basin above Bound Brook during the critical dry period would equal the values tabulated above, the storage requirements at one or more on-river reservoir sites to maintain a regulated minimum flow downstream from the junction of the Raritan and Millstone Rivers of 150 mgd (130 mgd after diversion of 20 mgd by Elizabethtown Water Company) would be as follows:

Useable Storage Needed for Minimum Sustained Flow

Year	Millions of Gallons
1955	7,600
1960	8,100
1980	8,400
2000	8,400

To provide dependably for stream flow regulation requirements as stipulated above, including present maximum irrigation usage, will necessitate a reservoir with a storage capacity of 10.1 billion gallons in order to have a 25% reserve over the indicated usable storage of 7.6 billion gallons. This would allow for some capacity loss due to sedimentation by flood carried silt and an emergency supply for possible droughts more severe than any experienced during the 34 year period of record. It would also permit, through a relatively small draft on the reserve, to meet increasing reductions of stream flow due to irrigation requirements until about 1970. After this, conditions may indicate the necessity to increase the storage capacity of the reservoir or to provide additional storage at another location.

The reservoir for stream flow regulation should preferably be located on the river or one of its main tributaries so that it may be filled directly by flood water and the delivery of necessary make-up water be made by natural channels. Reservoir sites of large capacity with deep storage and high elevation are not available on-river in the Raritan basin. However, these characteristics which are highly desirable for a potable supply, are not essential for stream regulation storage and a number of sites may be used to accomplish this purpose.

Further development of the potentialities of the Raritan River Basin may also be accomplished by the construction of a series of on-river reservoirs as well as through the use of reservoir locations within the basin but not located on the main river or any of its principal tributaries (off-river reservoirs). These latter reservoirs are at a considerable elevation above the main streams and must be filled by pumping.

There are presented below the alternate projects and combinations of projects in which these reservoir sites may be used to regulate the stream flow and develop the potential water supply of the Raritan River Basin. This presentation includes the following studies:

Using On-River Reservoir Sites—OR Plans

For regulation of the minimum stream flow (Plan OR-1).

For additional regulated flow or water supply (Plan OR-2).

For maximum economic on-river development of Raritan Basin (Plan OR-3).

Using Off-River Reservoir Sites—RV and CR Plans

For the development of a 70 million gallons per day potable water supply using Round Valley Reservoir (Plan RV-1).

For the development of a 150 million gallons per day potable water supply using Round Valley Reservoir with stream bed delivery to Bound Brook (Plan RV-2).

For the development of Plan RV-2 plus high level emergency storage in Dock Watch Hollow (Plan RV-3).

For the development of a 200 million gallons per day potable water supply using Round Valley and Dock Watch Hollow (Plan RV-4).

For development of a 70 million gallons per day potable water supply using Chimney Rock Reservoir (Plan CR-1).

For the development of a 200 million gallons per day potable water supply using Chimney Rock Reservoir (Plan CR-2).

For the development of a 70 million gallons per day potable water supply using the East Branch of Chimney Rock Reservoir (Plan CR-3).

For the development of a 200 million gallons per day supply using East Branch of Chimney Rock Reservoir and Dock Watch Hollow Reservoir (Plan CR-4).

These sites are shown on Plate II-2.

A summary of the results of these studies together with tabulations of comparative costs is given in Chapter VI on Findings and Recommendations.

Development of the Raritan Basin with On-River Reservoirs

Plan OR-1—For Regulation of a Minimum Sustained Flow

The storage capacity needed to regulate a minimum flow of 130 million gallons per day in the Raritan River at Bound Brook can be developed at any one of four on-river reservoir sites. The general locations of these sites are shown on Plates II-2 and II-3 and on stream profiles presented on Plate A-2 in the Appendix. Surface-area and storage capacity data for the sites are included on Plate A-3 in the Appendix. Each of the sites was examined by an engineering geologist experienced in all phases of dam site foundation and reservoir seepage problems. On the basis of these field examinations and available published data on the geology of New Jersey, it appears that the dam sites, with proper structural designs, are suitable for the construction of earth or earth and rock fill dams of the heights contemplated. No unusual foundation or seepage problems are expected. Detailed foundation explorations by core drilling or test pits will be required before construction designs can be prepared.

The **North Branch Reservoir site** is situated on the North Branch of the Raritan River upstream from the village of North Branch. A reservoir at this site with a flow line at elevation 105.3 will flood an area of 2720 acres of river bottom and farm land and will inundate the village of Burnt Mills. A compacted earth dam with a crest length of about

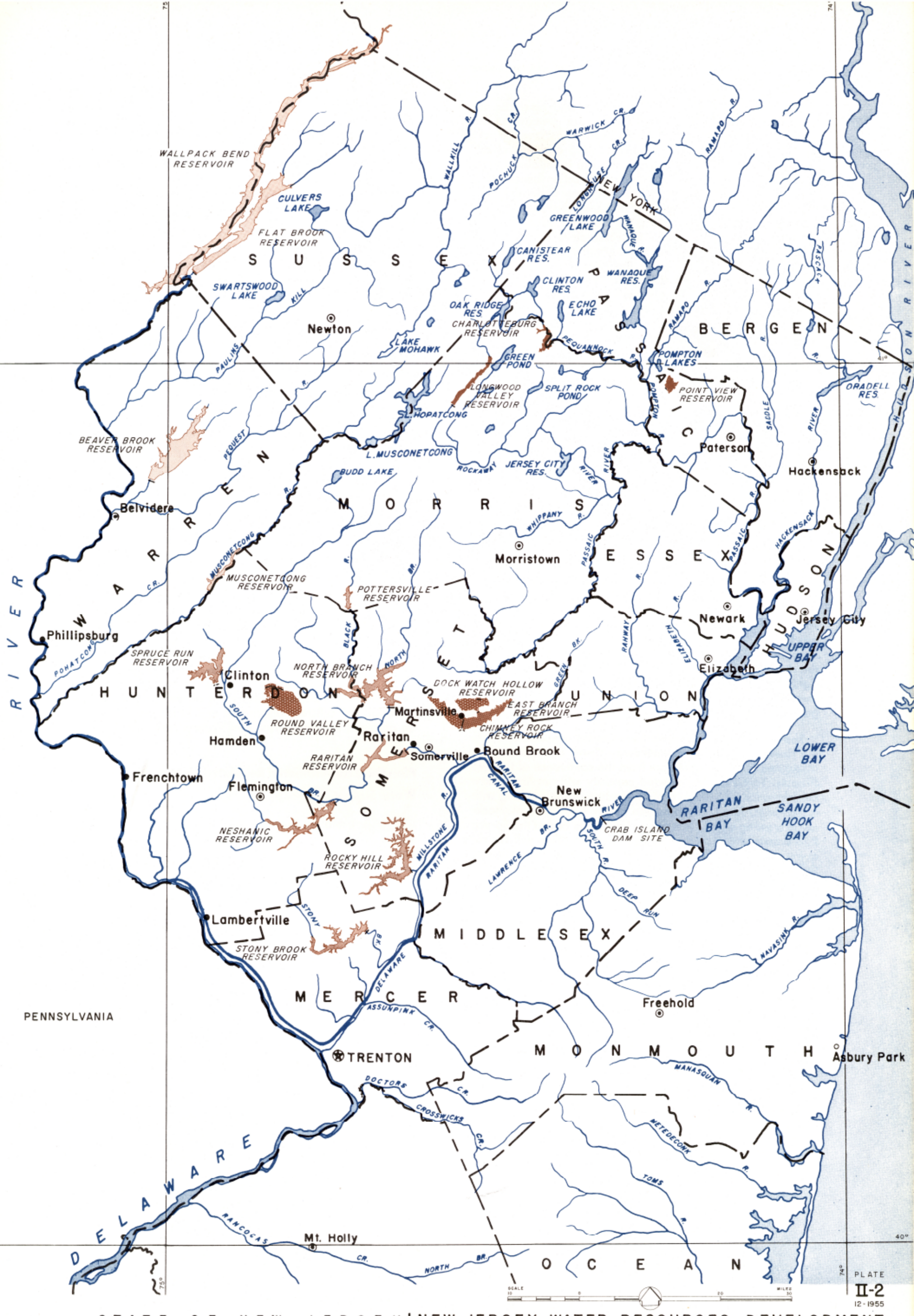


PLATE II-2
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS
NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

LOCATION MAP FOR RESERVOIR SITES
IN
NORTHERN AND CENTRAL NEW JERSEY

3,600 feet and a total height of about 52 feet above stream bed will be required.

The proposed North Branch dam site and reservoir are underlain by red shales of the Brunswick formation. The stream bed contains deposits of recent alluvium, and terraces or benches of older deposits of silt, sand and gravel are found above the present stream. The site is suitable for an earth fill dam. The cutoff in the stream section beneath the dam required to prevent percolation of water under the dam, may be a trench back-filled with impervious material, or sheet piling. The shales forming the reservoir basin are relatively tight and leakage from the reservoir will not be more than might be expected for any normal reservoir. The terraces of older alluvium along the river will offer suitable sources of borrow for an earth dam. Rock for concrete and slope protection may be obtained from nearby trap rock quarries or from proposed tunnel excavation if the site is used in conjunction with a potable water development. Sand for concrete must be transported to the site as the river bed sand would not be suitable.

An attractive feature of the site is that it could serve also as a forebay for a pumping plant to deliver water to the Chimney Rock Reservoir site. By pumping to Chimney Rock Reservoir from the North Branch Reservoir, the pump lift would be about 80 feet less than that required for a pumping plant near Bound Brook and the water would be of better quality. However, the discharge line would be longer from the North Branch and approximately 7000 feet would be in tunnel, necessitating a greater construction cost. The North Branch site commands a drainage area of about 174 square miles, and the runoff is adequate to supply the necessary compensation water in addition to water required for development of an initial potable supply of 70 million gallons per day with Chimney Rock Reservoir. Thus, the site is desirable for development in conjunction with plans for potable supplies involving Chimney Rock Reservoir. Disadvantages of the site compared wth the other three are the larger area of valuable agricultural land which would be removed from production, the greater residential displacement, and the somewhat higher costs involved. Table II-1, which follows the discussion of the Rocky Hill site, summarizes many of the significant details concerning the four possible sites for a reservoir to regulate a minimum sustained flow of 130 million gallons per day at Bound Brook.

The **Spruce Run Reservoir** near Clinton would necessitate the damming of both Mulhockaway Creek and Spruce Run about one half mile upstream from the confluence of the two streams. To obtain the needed capacity will require a flow line elevation 276.7 and a dam structure 3600 feet long with a section 90 feet high above the stream bed at the Mulhockaway crossing and 83 feet above the stream bed at the Spruce Run crossing. In addition three low earth dikes will be required to close saddles along the ridge at the southeast of the main dam. About 1240 acres would be flooded at the proposed flow line elevation.

The Spruce Run dam site and reservoir area are underlain by limestones and shales. These rocks have adequate bearing capacity to support a compacted earth dam of the proposed height. Curtain grouting or a drainage system will be required to prevent damage to the structures by seepage. It is not expected that loss of water by seepage through the reservoir floor will be excessive. Construction materials are available in the area.

Selection of the Spruce Run site would result in the displacement of fewer persons and flooding of less agricultural land than at the other sites.

The **Stony Brook site** is situated on Stony Brook west of Princeton, in the upper part of the Millstone River watershed. The dam, with a flow line at elevation 152.3, would be approximately 1900 feet long at the crest, with a maximum height of about 80 feet above the stream bed.

The Stony Brook dam site and reservoir area are underlain by red shales of the Brunswick formation. The foundation rocks are adequate to support an earth dam of the required height. The reservoir basin is relatively tight and loss of water from the reservoir through leakage will not present a problem. Borrow material can be obtained in the vicinity of the dam site. The flooded area of 1520 acres would be larger than that at the Spruce Run site, but would be less than at the North Branch or Rocky Hill sites.

The **Rocky Hill site** is located on Bedens Brook about 0.3 mile upstream from the confluence with the Millstone River near the village of Rocky Hill. The site is relatively undesirable since in addition to the large area that would be inundated (2180 acres) it would be extremely irregular with numerous shallow fingers. The dam, with a flow line at elevation 82.2 would have a length of about 2,600 feet and a maximum height of about 53 feet above the stream bed.

The Rocky Hill damsite and reservoir area are underlain by the relatively soft shales of the Brunswick formation. The dam site offers suitable foundation for an earth dam of the contemplated height. The Brunswick formation shales and overlying soil are relatively tight and it is expected that leakage from the reservoir would be minor. Stream terraces along lower Bedens Brook and the Millstone River would provide suitable borrow material for an earth dam. Suitable materials for concrete aggregate and bank protection may be obtained locally or from nearby trap rock quarries.

Plan OR-2 for Additional Regulated Flow or Water Supply

It is possible to develop additional regulated flows at Bound Brook, over and above the 130 mgd which could be provided by any one of the four reservoir sites discussed under Plan OR-1, by the construction of additional on-river reservoirs. Such additional regulated flow could be left in

TABLE II-1

DATA ON PROPOSED REGULATING RESERVOIRS IN THE RARITAN RIVER BASIN

Item	Unit	RESERVOIR SITE			
		North Branch	Spruce Run	Stony Brook	Rocky Hill
Flow line elevation	feet	105.3	276.7	152.3	82.2
Reservoir water area	acres	2,730	1,240	1,520	2,180
Reservoir capacity	million gallons	10,100	10,100	10,100	10,100
Suggested taking line elevation	feet	113	284	160	90
Area to be acquired	acres	4,050	1,500	2,310	3,300
Houses or farm units to be taken	number	45	60	22	35
Drainage area above damsite	square miles	174	41	38	48
Reservoir cost	$ million	2.29	1.52	1.59	2.17
Dam construction cost	$ million	3.02	2.60	2.51	1.37
Engr., legal and adm. costs	$ million	.45	.35	.35	.30
Interest during construction	$ million	.24	.19	.19	.16
Total initial cost	$ million	6.00	4.66	4.64	4.00

STATE OF NEW JERSEY
NEW JERSEY WATER RESOURCES DEVELOPMENT
LEGISLATIVE COMMISSION ON WATER SUPPLY
BASIC FEATURES OF PLAN OR-1 WITH DETAILS OF NORTH BRANCH DAM
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS
NEW YORK

II-13

PLATE
II-3
12-1955

OR-1B
SPRUCE RUN RESERVOIR

Capacity

Usable ..... 7.6 b.g.
Total ..... 10.1 b.g.
Flow line elevation ..... 276.7 ft.

OR-1A
NORTH BRANCH RES.

Capacity

Usable ..... 7.6 b.g.
Total ..... 10.1 b.g.
Flow line elevation ... 105.3 ft.

OR-1C
ROCKY HILL RESERVOIR

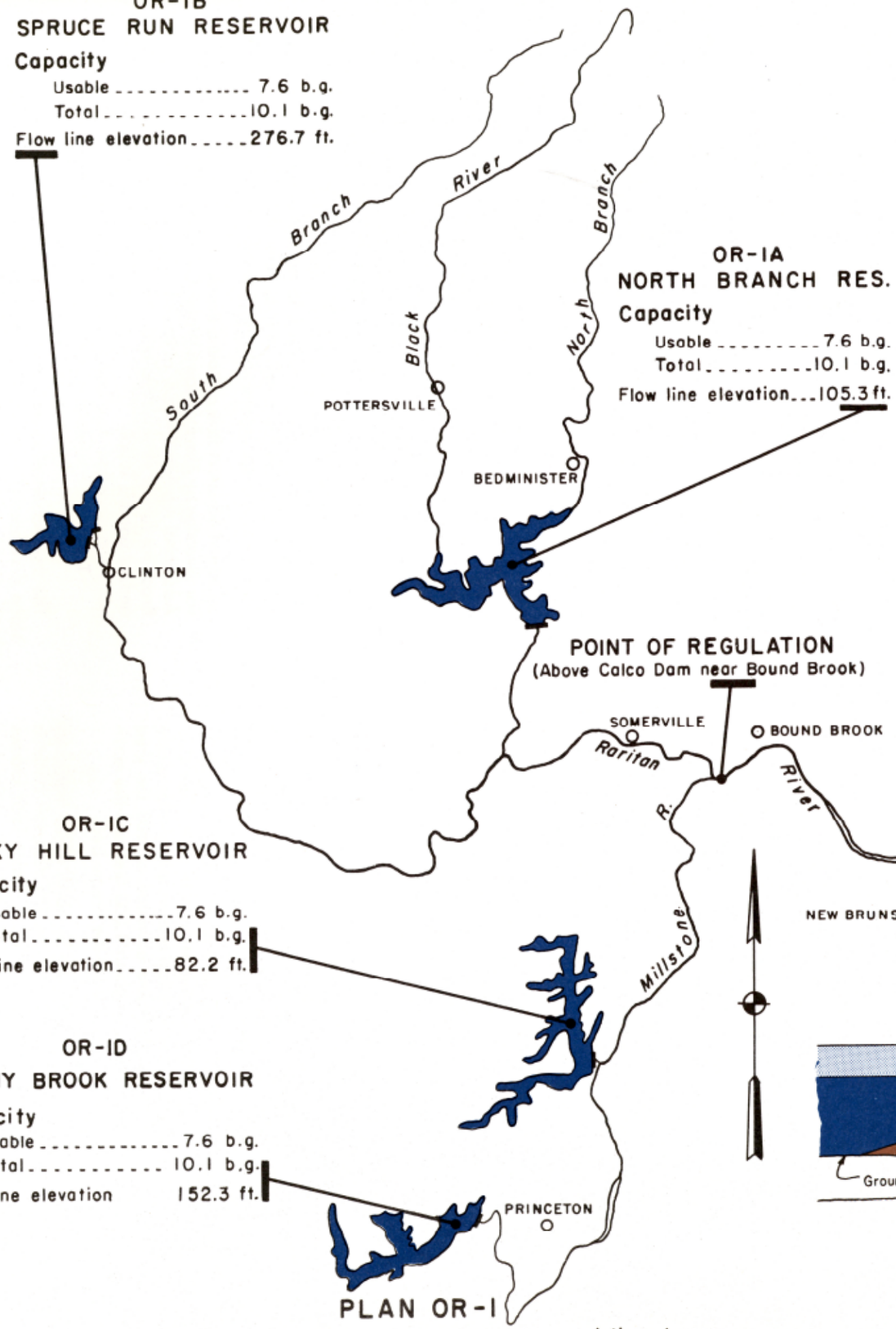
Capacity

Usable ..... 7.6 b.g.
Total ..... 10.1 b.g.
Flow line elevation ..... 82.2 ft.

OR-1D
STONY BROOK RESERVOIR

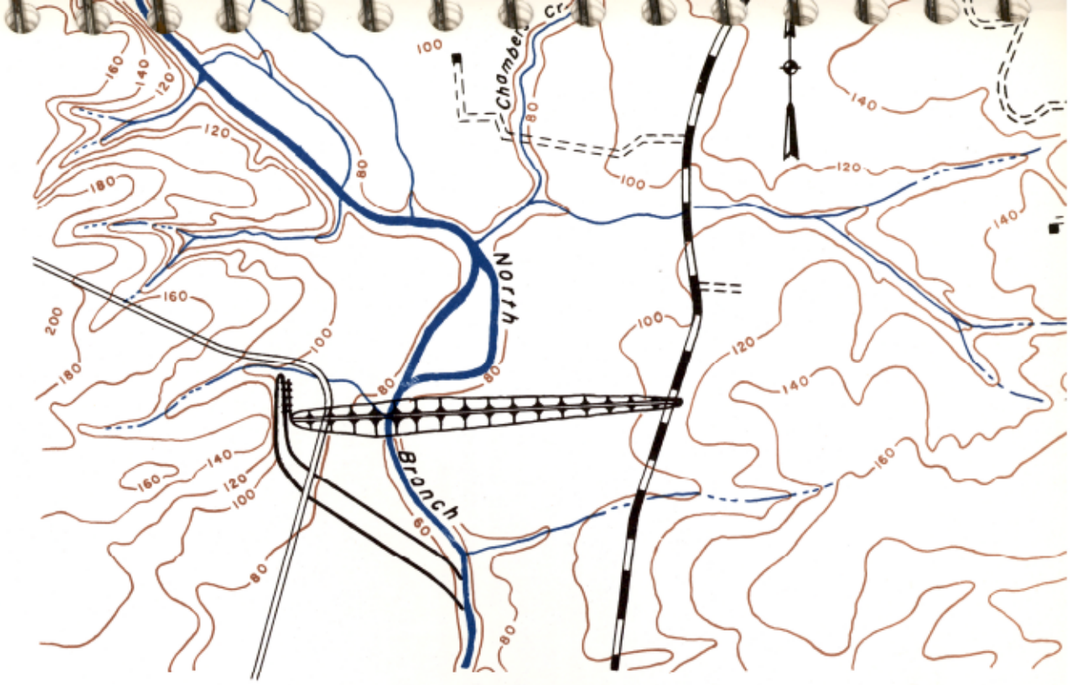
Capacity

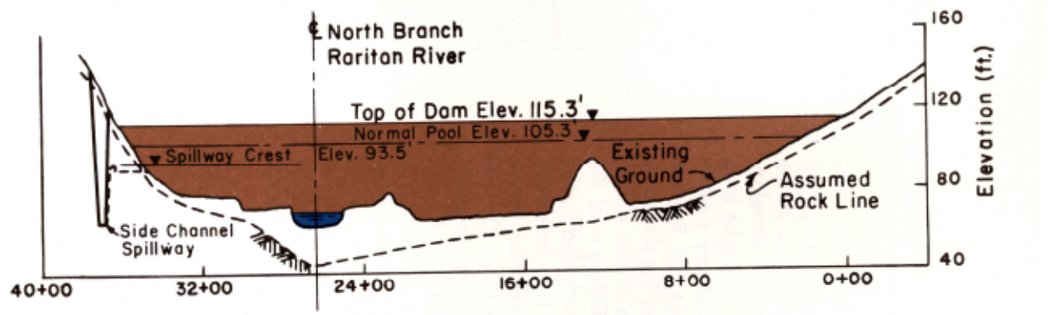
Usable ..... 7.6 b.g.
Total ..... 10.1 b.g.
Flow line elevation 152.3 ft.



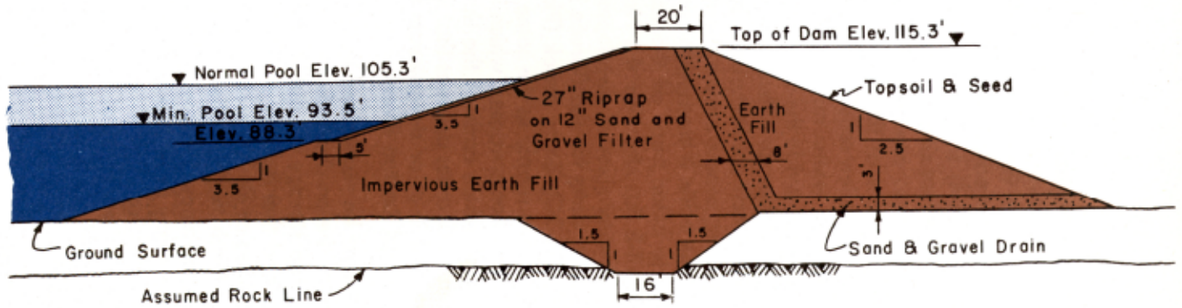
PLAN OR-1

Alternate on-river reservoir sites adequate to provide regulation storage needed to maintain a minimum flow of 150 mgd (including 20 mgd for Elizabethtown Water Co.) at Bound Brook.





PROFILE



DAM SECTION

the river channel for the benefit of downstream interests or it could be diverted by pumping from the Raritan River channel upstream from the existing Calco dam at Bound Brook for use as a potable water supply. Plan OR-2 is presented (see Plate II-4) to indicate the yield and probable cost of each of the four sites included in Plan OR-1 on the assumption that each was constructed as the second on-river development, with one of the other sites being utilized to take care of compensation requirements. It is assumed that any project for potable water supplies to be used outside the Raritan Basin must provide the compensation features of the minimum regulated flow described. To take advantage of the difference in runoff characteristics between the Millstone and the main river, compensation storage should be provided in the Millstone basin if storage for potable supplies is to be developed in other parts of the Raritan Basin, and vice versa. Table II-2 lists data for the North Branch site (Plan OR-2A) for different sizes of development. Table II-3 includes pertinent cost data for the Spruce Run (Plan OR-2B), Rocky Hill (Plan OR-2C), Stony Brook (Plan OR-2D) sites if developed for potable supply to the same capacity as that required for compensation purposes, which is about the practicable maximum for which each of the three sites is suitable. The yield given in all cases assumes that the point of regulation and/or diversion is at or downstream from the junction of the Millstone and Raritan Rivers.

It must be recognized that potable supplies obtained with any of the on-river schemes would not have the advantage of deep storage for quality improvement and low temperature and that delivery of the supply will be dependent upon pumping at all times. The shallow depth of all of the on-river sites (with the possible exception of Spruce Run), and the many swampy areas which would probably be unavoidable in the many arms and branches of the reservoirs, would not be conducive to water of the most desirable quality. Furthermore, natural channel delivery to Bound Brook from Spruce Run would detract from any quality advantages which might otherwise accrue to that site.

Plan OR-3—Maximum Economic Development of Raritan Basin with On-River Reservoirs

In addition to the four on-river reservoir sites previously discussed in connection with plans OR-1 and OR-2, there are three smaller on-river sites for which development appears to be practicable. Plates II-2 and II-5 show the general location of these sites in relation to other sites in the Raritan Basin. Pertinent information and comments about the three additional sites follow and are summarized on Table II-4.

The **Neshanic site** is situated on the Neshanic River about one-half mile upstream from the confluence with the South Branch of Raritan River. With a flow line elevation of 120, the dam structure would have a crest length of about 1300 feet and a maximum height of about 57 feet above the stream bed. The flooded area of the reservoir would be approximately 920 acres and the total storage 4.2 billion gallons.

The damsite and reservoir area are underlain by shales of the Brunswick Formation. These rocks will offer a suitable foundation for an earth dam of the contemplated height. The formation is sufficiently tight to prevent any serious leakage around a dam of proper design and construction. Construction materials are available from nearby deposits of recent and older alluvium.

The **Pottersville site** is situated on the Black River about one-quarter of a mile upstream from Pottersville. The dam site is situated in a narrow gorge section suitable for a concrete structure. For a flow line elevation of 400 the crest length of the dam would be about 1,200 feet and the maximum height about 150 feet above the stream bed.

The Pottersville site is underlain by hard, dense metamorphic rocks of the Franklin Formation. The reservoir basin is formed by the Losee granite gneiss. A major fault crosses the Black River about 1,000 feet downstream from the dam site. Field evidence indicates that the fault is inactive and the area stable. The site with proper design and foundation treatment is well adapted to the use of a concrete gravity dam of the desired height. Rock aggregate for concrete can be obtained from nearby trap rock quarries. Stream terraces and glacial drift may yield suitable sand after washing and grading, otherwise fine aggregates for concrete will have to be brought into the site.

Although the storage capacity of the Pottersville site is limited, it appears that a desirable hydro-electric power installation, which might produce revenues adequate to defray part of the cost of the dam and reservoir, could be constructed to utilize the hydraulic head available at the damsite (about 150 feet). If the Pottersville and North Branch Reservoirs were designed and constructed to function as a unit, it would appear feasible to operate a generating plant at Pottersville on a low load factor for peak load assistance to the electric utility company serving the area. The North Branch Reservoir could re-regulate the concentrated water releases for power generation at Pottersville. Detailed studies beyond the scope of this report will be required to determine the design capacity and economics of such a power feature. However, power for peak load assistance will probably be readily salable since power companies have indicated an interest in this type of development.

The **Raritan site** is situated on the main river about 2,000 feet upstream from the highway bridge at the Borough of Raritan. A flow line elevation of 52 feet—which is the maximum possible without encountering excessive property costs—will provide a total storage capacity of about 1.5 billion gallons, and will require a dam with a height of about 30 feet above the stream bed. The dam would consist of a concrete spillway section containing gates of adequate capacity to pass the combined flood flows of the North and South Branches of the Raritan River, and earth dike sections near the abutments. Because of the depth of river bottom deposits at this site, a design utilizing steel sheet piling cutoff walls and other features required for such foundation conditions would be indicated. Embankment materials are available nearby. Aggregates for concrete can be obtained from nearby commercial sources.

The capacity of the Raritan Reservoir is insufficient to be of much consequence as a storage reservoir, but the advantageous location of the site in the main river near the point of regulation or diversion makes its construction desirable to facilitate efficient operation of an on-river reservoir system.

Table II-4 summarizes pertinent details regarding the three additional on-river reservoir sites discussed above.

Development of all of the seven on-river reservoirs shown on Plates II-2 and II-5 would provide a dependable regulated flow of 400 million gallons per day at Bound Brook. Various combinations of these reservoirs may be used for the stage development of a large range of yields up to the maximum of 400 mgd. Such flows may be diverted for potable water supply or left in the river for the benefit of downstream interests or may be partially utilized for each of the two purposes.

The full on-river development shown on Plate II-5 would provide a dependable regulated flow of 400 mgd at Bound Brook under the drought conditions of 1931-32 and 1955 conditions of irrigation use, through utilization of only 75% of the total reservoir capacity. When the estimated maximum rate for the use of irrigation water has been reached—about 1970—a greater amount of stored water would be required to maintain the regulated flow of 400 mgd during critical drought periods than under present conditions, but the stored water requirement would not exceed 85 percent of the total storage capacity. Thus, the full on-river reservoir would be capable of supplying dependable flows as follows:

Sustained minimum flow at Bound Brook	130 mgd
For diversion by Elizabethtown Water Co.	20 mgd
Additional regulated supply at Bound Brook for further stream regulation and/or potable supply	250 mgd
Total	400 mgd

The on-river development would be admirably suited to stage development as required to keep pace with increasing water supply requirements. For example, by the construction of any two of the reservoirs described under Plans OR-1 and OR-2, a dependable supply of approximately 70 mgd could be made available at Bound Brook for potable water supply use in addition to 20 mgd for the Elizabethtown Water Company, and the minimum sustained flow of 130 mgd for the lower river.

TABLE II-2

PERTINENT DATA AND ESTIMATED COSTS —PLAN OR-2A (North Branch Site)

(Exclusive of transmission aqueduct)

Units—Millions of dollars except as indicated

Item	Flow Line Elevation—Ft. 105.3	120
Dependable yield in million gallons per day	69	165
Reservoir water area, acres	2730	5400
Suggested taking line elev., feet	113	130
Area to be acquired, acres	4050	7500
Approx. No. of houses or farm units to be taken	45	85
Reservoir cost	2.29	3.90
Dam construction cost	3.02	4.16
Diversion dam, intake, coagulation, and pumping plant cost	3.20	5.80
Treatment plant cost	3.50	7.50
Adjustment to point of common transmission	1.70	2.50
Adm. & control bldg., shop	.65	.65
Subtotal	14.36	24.51
Engr., legal & adm. costs	1.22	2.08
Interest during construction	.62	1.10
Initial cost of potable supply at Bound Brook	16.20	27.69
Cost of regulating reservoir	4.66(1)	4.66(1)
Cost of project, exclusive of transmission aqueduct	20.86	32.35
Total annual cost, including operation and maintenance	1.47	2.40
Annual cost per mgd	$21,200	$14,500
Cost per million gallons of supply	$ 58	$ 40

(1) Assuming construction of the Spruce Run Site

TABLE II-3

ESTIMATED COST DATA—PLANS OR-2B, OR-2C, AND OR-2D

(Exclusive of transmission aqueduct)

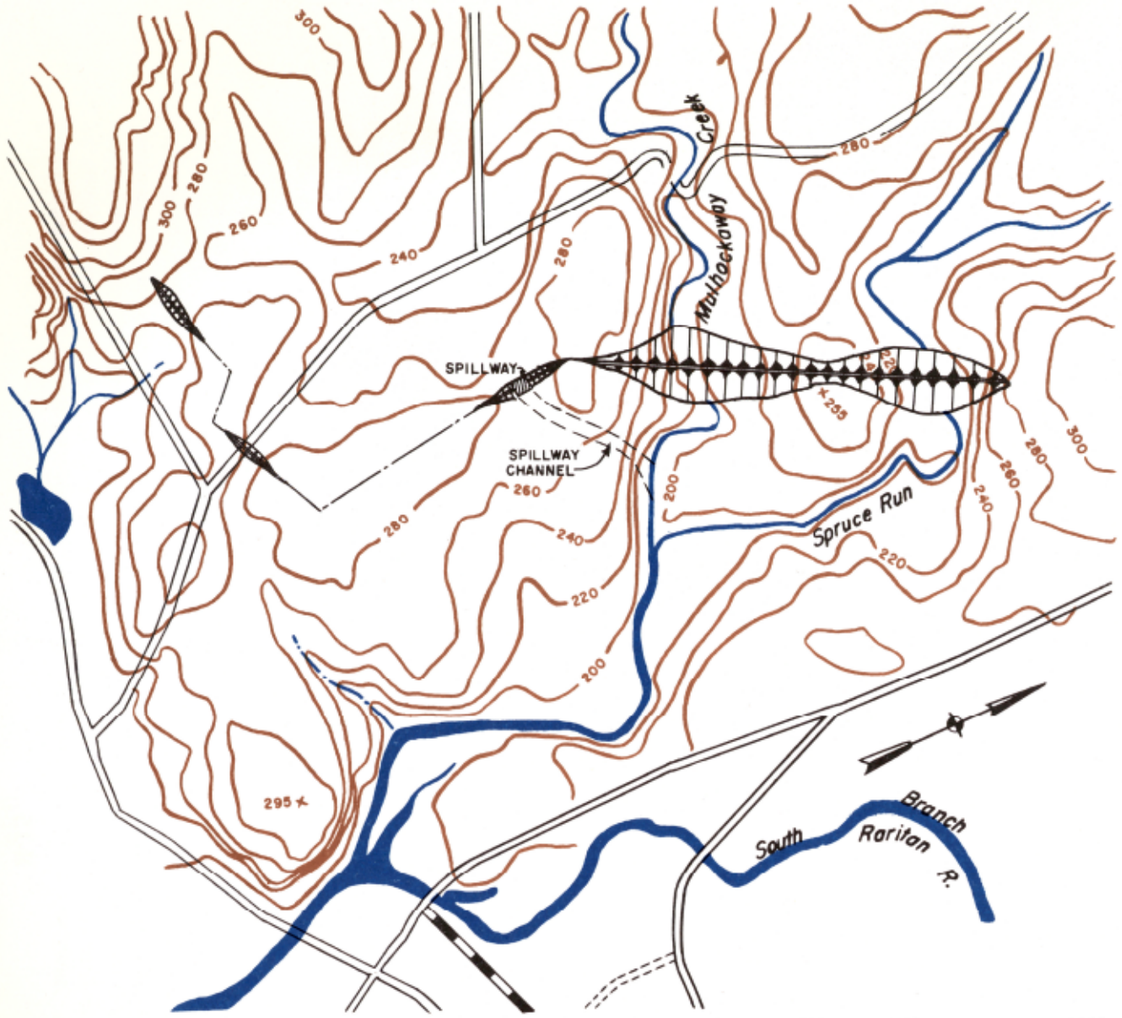
Units—Millions of dollars except as indicated

Item	OR-2B (Spruce Run)	OR-2C (Rocky Hill)	OR-2D (Stony Brook)
Dependable yield—mgd	69	69	69
Reservoir cost	1.52	2.17	1.59
Dam construction cost	2.60	1.37	2.51
Div. dam, intake, gates, coagulation and pumping plant costs	3.20	3.20	3.20
Treatment plant cost	3.50	3.50	3.50
Adjustment to point of common transmission	1.70	1.70	1.70
Administration & Control Bldg., Shop	.65	.65	.65
Subtotal	13.17	12.59	13.15
Engr., legal & adm. costs	1.12	1.07	1.12
Interest during construction	.60	.54	.60
Initial cost of potable supply at Bound Brook	14.89	14.20	14.87
Cost of regulating reservoir	4.00(1)	6.00(2)	4.66(3)
Cost of project, exclusive of transmission aqueduct	18.89	20.20	19.53
Total annual cost, including operation and maintenance	1.38	1.44	1.41
Annual cost per mgd	$20,000	$20,800	$20,000
Cost per million gallons of supply	$ 55	$ 57	$ 56

(1) Assuming construction of the Rocky Hill site

(2) Assuming construction of the North Branch site

(3) Assuming construction of the Spruce Run site



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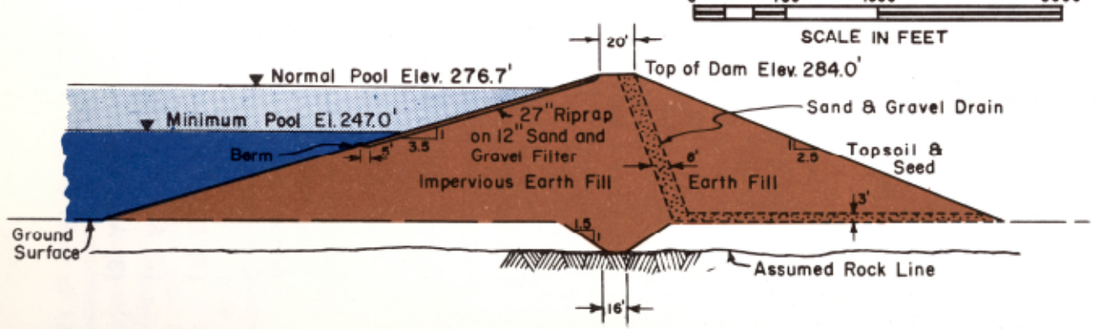
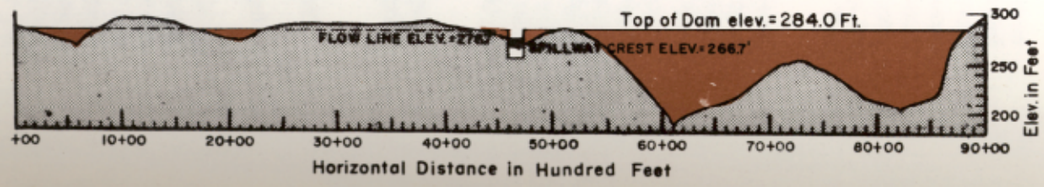
SCALE IN FEET

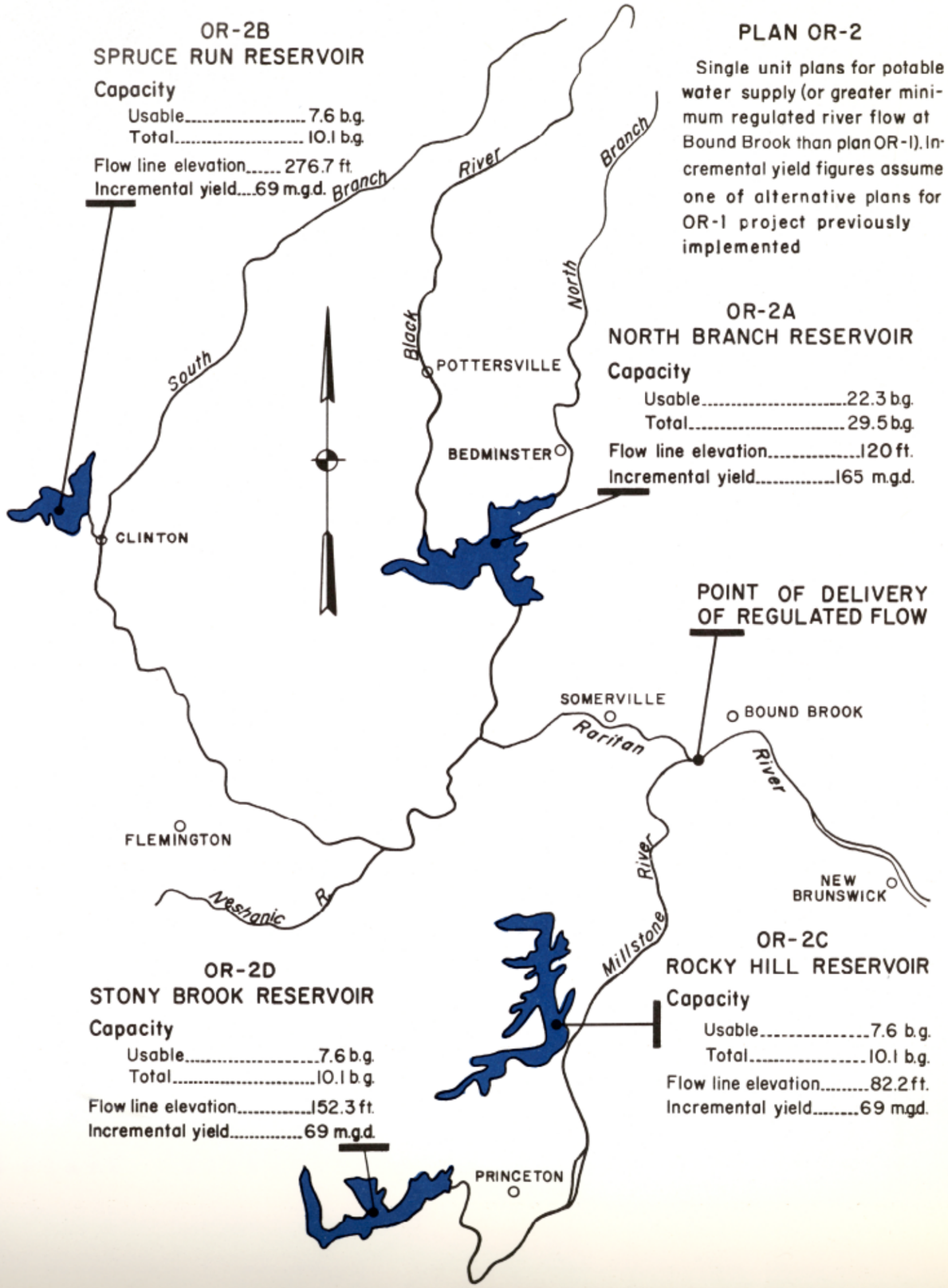


DAM SECTION

Scale: 1" = 100'



PROFILE



PLAN OR-2

Single unit plans for potable water supply (or greater minimum regulated river flow at Bound Brook than plan OR-1). Incremental yield figures assume one of alternative plans for OR-1 project previously implemented

OR-2B
SPRUCE RUN RESERVOIR

Capacity
- Usable ..... 7.6 b.g.
- Total ..... 10.1 b.g.

Flow line elevation ..... 276.7 ft.
Incremental yield ..... 69 m.g.d.

OR-2A
NORTH BRANCH RESERVOIR

Capacity
- Usable ..... 22.3 b.g.
- Total ..... 29.5 b.g.

Flow line elevation ..... 120 ft.
Incremental yield ..... 165 m.g.d.

POINT OF DELIVERY OF REGULATED FLOW

OR-2D
STONY BROOK RESERVOIR

Capacity
- Usable ..... 7.6 b.g.
- Total ..... 10.1 b.g.

Flow line elevation ..... 152.3 ft.
Incremental yield ..... 69 m.g.d.

OR-2C
ROCKY HILL RESERVOIR

Capacity
- Usable ..... 7.6 b.g.
- Total ..... 10.1 b.g.

Flow line elevation ..... 82.2 ft.
Incremental yield ..... 69 m.g.d.

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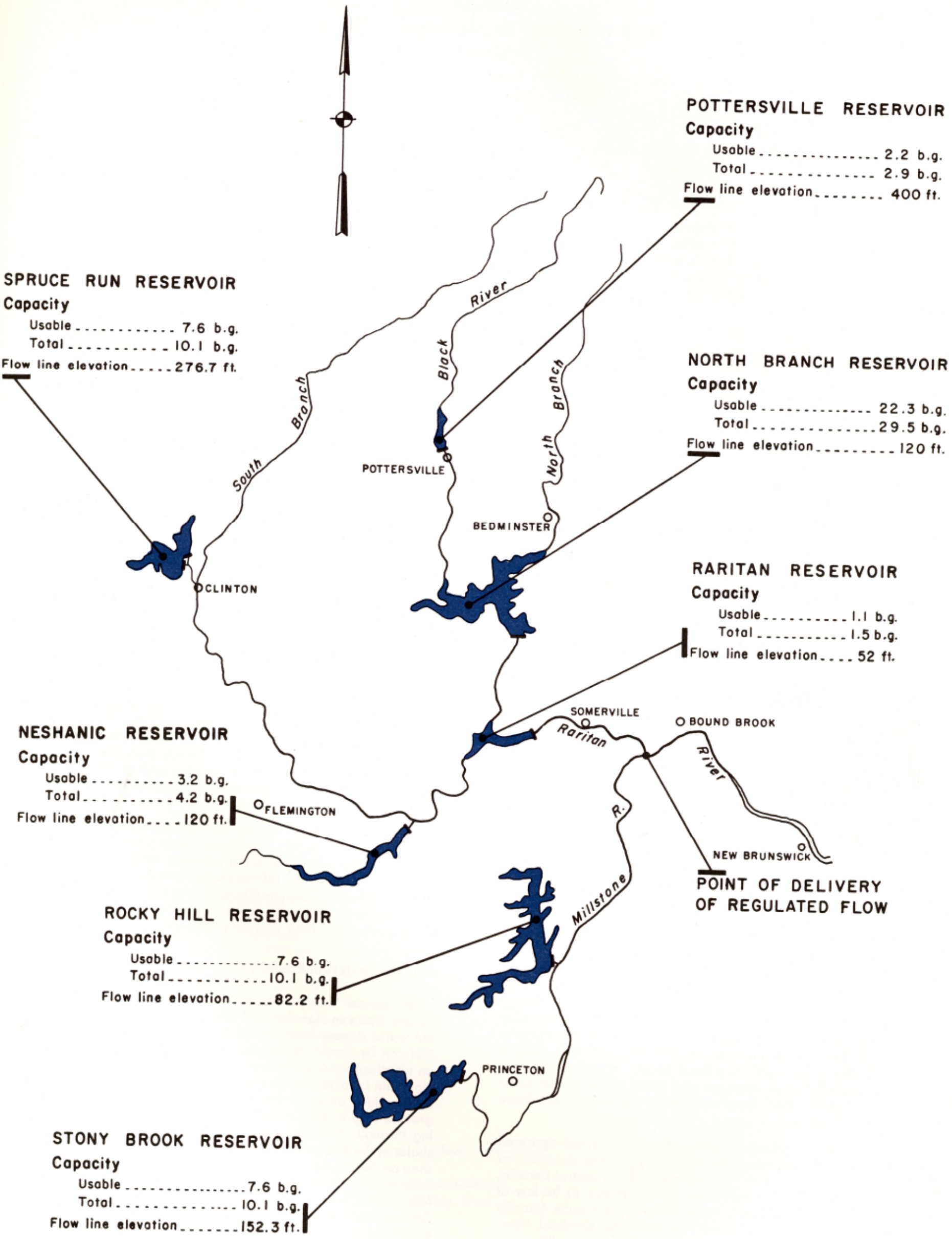
NEW JERSEY WATER RESOURCES DEVELOPMENT
BASIC FEATURES OF PLAN OR-2 WITH DETAILS OF SPRUCE RUN DAM

PLATE II-4
12-1955



PLAN OR-3

MULTIPLE UNIT ON-RIVER RESERVOIR SYSTEM provides regulated flow at Bound Brook of 400 mgd. Usable for diversion or sustained river flow.

PLATE II-5
12-1955

STATE OF NEW JERSEY
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NEW JERSEY WATER RESOURCES DEVELOPMENT

BASIC FEATURES OF PLAN OR-3

TABLE II-4

DATA PERTAINING TO ADDITIONAL ON-RIVER RESERVOIRS

Item	Unit	Neshanic	Pottersville	Raritan
Flow line elevation	feet	120	400	52
Reservoir water area	acres	920	182	786
Capacity	million gal.	4,200	2,900	1,500
Suggested taking line elevation	feet	130	410	60
Houses or farm units to be taken	number	21	2	20
Area to be acquired	acres	1,450	210	1,300
Reservoir site cost	$ million	1.28	0.12	1.03
Dam construction cost	$ million	1.86	3.46	1.62
Engr., legal & adm. costs	$ million	.27	.31	.23
Interest during construction	$ million	.14	.15	.12
Initial Cost	$ million	3.55	4.04	3.00

It must be recognized that the on-river developments discussed here would not be capable of furnishing water of equivalent quality and temperature to that which could be supplied by certain off-river developments described in following sections of this chapter and which have the advantage of deep storage. During periods of flood runoff sediment deposits would be accumulated in the upstream portions of the on-river reservoirs. These delta areas, because of the flat slopes in most of the Raritan Basin, may result in swamp conditions. This would cause increasing water losses due to evaporation and transpiration, a gradual deterioration in water quality, and a decrease in reservoir capacity. In addition, the full on-river reservoir development would inundate or remove from production and taxation a total area of approximately 17,000 acres of land. Provision for a new 200 million gallons per day potable supply, in addition to the Elizabethtown Water Company's diversion and stream regulation, will require land takings of 13,600 acres. By comparison, the proposed Chimney Rock Reservoir site, operated in conjunction with the Spruce Run Site, would provide the same total water supply and river regulation with the use of only 4800 acres.

A further consideration is the fact that a potable water supply obtained by pumping from the river channel at Bound Brook would depend at all times upon pump operation for the pressure necessary for water transmission and delivery. Although many water systems operate under such conditions, the supply is subject to interruption due to power failure and breakdowns and is, therefore, not as dependable as a system capable of gravity delivery under ordinary circumstances. Improved dependability in the water delivery of an on-river system may be achieved by providing a high level storage reservoir at the Dock Watch Hollow site for emergency use. Such a feature is discussed later in this chapter, as a part of Plan RV-3.

In the preliminary designs made for the on-river studies in this survey, the criteria were established for spillways to cause a surcharge above the normal reservoir operating level while passing a flood. This surcharge was computed to be equal to the natural valley storage which existed in the reservoir site prior to construction of the reservoir. Without this provision on-river reservoirs operated primarily for water supply and flow regulation could actually cause an increase in the flood levels downstream from the reservoirs. Such a condition would result if a flood occurs when the reservoirs are already full or nearly so and gated spillways are operated to pass flood flows without an increase in maximum reservoir levels.

Contrary to popular belief, on-river reservoirs operated without storage space reserved solely for the detention of flood water will contribute only minor flood control benefits. If the water level in reservoirs should happen to be low at the time of flood there would naturally be some benefits derived from the flood water that would be detained. However, a benefit that relies upon this accidental condition can not be considered as dependable.

The estimated initial costs of developing potable supplies of 200 mgd (Plan OR-3A) and 250 mgd (Plan OR-3B) at transmission pressure at Bound Brook, in addition to providing a regulated flow of 130 million gallons per day at Bound Brook plus 20 million gallons per day for the Elizabethtown Water Company are shown by typical groupings of on-river reservoirs in Table II-5. The cost estimates given therein do not include required expenditures for transmission lines, balancing reservoirs and distribution facilities. Transmission of water and related problems are discussed together with estimated costs in Chapter V.

Development of the Raritan Basin with Off-River Reservoirs

There are three off-river reservoir sites in the Raritan Basin which have sufficient capacity and other desirable characteristics to warrant consideration for water supply development. These sites are located at Round Valley in Hunterdon County, and at Chimney Rock and Dock Watch Hollow in Somerset County. A fourth possibility is a variation of the Chimney Rock site using only the eastern half drained by the east branch of Middle Brook. This use of Chimney Rock is hereafter referred to as the "East Branch" reservoir site. These sites are shown on Plate II-2 in this chapter and the area-capacity data for the reservoirs shown on Plate A-4 in the Appendix.

Although considerable residential and agricultural use is made of the three off-river sites, the acquisition of any of these for water supply purposes is considered economically feasible. The development of the Cihmney Rock site would displace the greatest number of persons and on the other hand the use of Round Valley would inundate the largest area of productive agricultural land.

It is assumed that all off-river developments will be solely for potable water supply, except for minor releases to local brooks. Stream regulation for a minimum sustained flow at Bound Brook, frequently referred to as "compensation water" when considered in conjunction with a potable supply to be used outside of the basin, would be achieved by use of one of the on-river reservoir sites described under Plan OR-1.

Alternative Uses of Round Valley—RV Plans

The Round Valley reservoir site, located in Hunterdon County between Hamden and Lebanon, is the largest potential water storage basin in the Raritan River drainage area that can be considered as economically feasible. The site is an elliptical bowl-like valley formed in the top of Cushetunk Mountain by a horseshoe-shaped ridge. The rock mass forming the ridge on the north, east and south consists of coarse-grained trap rock (diabase) and is probably a dike protruding through the valley floor which is underlain by soft red shales of the Brunswick Formation. The open end of the horseshoe on the west is cut by a north-south trending fault. Rock adjacent to the fault plane has been quite extensively disturbed, but there is no evidence of recent movement along the fault and it is probable that the area is stable. Foundation conditions at the site for the three dams required to enclose the reservoir were investigated in 1954 by 19 diamond drill holes made for the North Jersey District Water Supply Commission. Examination of the drill logs, made available by the North Jersey District, and field examinations by an engineering geologist, support the conclusion that the foundations are adequate to support dams of the proposed design. Faulted foundation conditions at the south dam site will re-

quire construction of an impervious cutoff to a depth of 50 feet or more in the central part of the dam and grouting below the backfilled cutoff to an additional depth of about 70 feet. Similar foundation treatment, but of a lesser magnitude, will be required at the north and west damsites and with such treatment it is believed the reservoir leakage will be minor. It is recommended, however, that additional damsite investigations by borings and pressure tests be made to determine actual cutoff requirements prior to preparation of detailed designs. Due to the perched position of Round Valley and the steep gradient from its entire perimeter to the surrounding lower valley, further drilling and geophysical exploration of Cushetunk Mountain around the diabase ridge is recommended to obtain more accurate data on the character of the formation and the necessity, if any, for additional grouting to prevent leakage at locations other than the dam sites.

The topography of the Round Valley site, together with damsite profiles and typical dam sections used for estimating purposes, is shown on Plate II-6.

The area of Round Valley within the surrounding ridge consists of approximately 3,500 acres of farm and forest lands which are worked by the 50 farm families that inhabit the valley. The entire farming area would be taken out of production wth the flooding of the valley, and all farm dwellings and other buildings would have to be moved or destroyed. The inundation will also necessitate the relocation of two 2-lane macadam highways and a power transmission line.

The three dams necessary to close the basin consist of the north and south dams across the natural drainage outlets of the valley and the west dam or dike which is across a low saddle at the open end of the horseshoe ridge. By building these dams to develop a flow line elevation of 420, eighty billion gallons of water can be stored in this reservoir. The surface area of the pool formed at that elevation would be about 2600 acres. Storage volume of this magnitude is far greater than can be economically filled by pumping from the unregulated flow of the South Branch of the Raritan River at Hamden where the flow is from a drainage area of only 140 square miles. The development of the practicable potential of the South Branch of the Raritan River may be accomplished by using a flow line elevation in Round Valley of 380, which would have a water surface area of approximately 2,200 acres. Greater use of the potential storage capacity of Round Valley may be made by the diversion of flood flows from the Delaware River. These possibilities are dealt with in a later section of the chapter devoted to Delaware River diversion plans. Four plans using the Round Valley Reservoir for the development of potable water from Raritan River sources are discussed below.

Plan RV-1—70 Million Gallons per Day Project

This project is essentially the first stage of the development of Round Valley as proposed by the North Jersey District Water Supply Commission in the report by that agency dated November 1, 1954. Water would be diverted by pumping from the South Branch of the Raritan River near Hamden. A dependable supply of 70 million gallons per day can be developed using a flow line elevation of 380.0 at which level 48.6 billion gallons of water would be stored. Under the North Jersey District Plan, water would be delivered largely by gravity through a 72 inch transmission main to Elizabeth, a distance of 38 miles. The details of this plan with some minor modifications made as a result of this study are shown on the upper half of Plate II-7.

No provision was made in the Round Valley plans as developed by the North Jersey District for augmentation of the low flows of the river as "compensation to downstream interests for diversion of water out of the Raritan Basin." A small let-down of water from the reservoir to maintain a constant flow in the larger of two brooks draining Round

TABLE II-5

ESTIMATED COSTS FOR ON-RIVER PLANS

OR-3A and OR-3B

Units—Millions of Dollars except as indicated

Item	OR-3A	OR-3B
Potable water yield—mgd	200	250
North Branch site (Flow line 120 ft.)		
Reservoir cost	3.90	3.90
Dam construction	4.16	4.16
Spruce Run site		
Reservoir cost	1.52	1.52
Dam construction	2.60	2.60
Stony Brook site		
Reservoir cost		1.59
Dam construction		2.51
Rocky Hill site		
Reservoir cost	2.17	2.17
Dam construction	1.37	1.37
Neshanic site		
Reservoir cost		1.28
Dam construction		1.86
Pottersville site		
Reservoir cost		0.12
Dam construction		3.46
Raritan site		
Reservoir cost	1.03	1.03
Dam construction	1.62	1.62
Diversion dam, intake, pumping plant, coagulation	6.40	7.30
Treatment plant	8.90	11.30
Adjustment to point of common transmission	2.80	3.40
Administration and Control Building, shop	.65	.65
Subtotal	37.12	51.84
Engineering, Legal and Adm. costs	3.15	4.42
Interest during construction	1.68	2.34
Cost of project, exclusive of transmission mains	3.12	4.17
Total annual cost, including operation and maintenance	41.95	58.60
Annual cost per mgd	$15,600	$16,700
Cost per million gallons of supply	$43	$46

Valley is contemplated and no pumping from the river is proposed when the flow below the point of diversion is 35 million gallons per day or less.* This arrangement would add nothing to stream flow improvement in the lower river. To be consistent with the premise that augmentation of the low flows of the Raritan River will be an integral part of any plan to develop the water supply potentialities of the river, and also to place the Round Valley plans on a comparable basis with others, the cost estimates for these plans include the construction of the Spruce Run reservoir to provide a sustained flow of 130 million gallons per day at Bound Brook.

The estimated construction cost for Plan RV-1 including the reservoir, 200 million gallons per day Hamden pumping station, diversion dam and intake works, force main, booster pumps for use when the reservoir level is too low for gravity delivery, treatment plant near Lebanon and transmission line to Bound Brook only is given in Table II-6 following the presentation of Plan RV-4.

Plan RV-2—150 Million Gallons per Day Project Using Stream Bed Delivery to Bound Brook

The salient features of this plan are shown on the lower half of Plate II-7. It provides for the pumping of water from the South Branch of the Raritan River into storage at Round Valley essentially as in Plan RV-1. However, instead of delivery by transmission main from the reservoir, the water would be let down the natural stream channels to Bound Brook. At a point between the confluence of the Raritan and Millstone River and the Calco dam the water would be diverted to a pumping station, treated and delivered to the transmission mains.

With Plan RV-2, it is possible to use the storage in Round Valley to regulate the natural runoff from the entire 779 square miles of drainage area at Bound Brook instead of the 140 square miles above Hamden. The maximum usable storage in Round Valley that can be refilled in a reasonable length of time by pumping diversions from the South Branch is 36.5 billion gallons. This can provide a dependable flow for water supply diversion at Bound Brook of 150 million gallons per day. In addition to this yield for potable supply a sustained minimum flow of 130 million gallons per day would be maintained below the diversions at Bound Brook by one of the on-river reservoirs of Plan OR-1.

In this plan the treatment works near Lebanon and the transmission main to Bound Brook are omitted and are replaced by a diversion dam, a low lift pumping station, treatment plant and high pressure pumping station at Bound Brook, all with a capacity of 190 million gallons per day to handle 125% of the average dependable yield. Costs for Plan RV-2 are given in Table II-6.

Plan RV-2 has the advantage of providing a much larger dependable yield than Plan RV-1 from the South Branch diversion with the same amount of storage in Round Valley. It has the disadvantages, however, of being completely dependent on power for the delivery of water, of being subject to partial or complete interruption to service due to equipment breakdown, and the quality improvement gained by storage in Round Valley would be lost by the stream bed delivery to Bound Brook.

Plan RV-3—150 Million Gallons per Day Project Plus High Level Emergency Storage

This plan is the same as RV-2 except that in order to overcome the serious disadvantage of complete dependence on electrical and mechanical equipment for continuous service, emergency high level storage is provided capable of delivering by gravity for seven days a supply of 190 million gallons per day (125 percent of the average yield). The features of the plan are shown on Plate II-7.

The high level storage would be provided in the Dock Watch Hollow reservoir site located in the Watchung Mountains due north of Bound Brook. A total storage of 1.77 billion gallons will be required for the net usable storage of 1.33 billion gallons necessary for an emergency 7-day supply. The flow line elevation for this volume of storage would be 389 and the flooded area 250 acres. Although the elevation is greater than needed for gravity delivery, Dock Watch Hollow is the best site available for the purpose. Since water from this reservoir would only be used in emergencies the amount of water pumped to the excess elevation in Dock Watch Hollow would be very small compared to the total used and, therefore, operating economy would not be greatly affected. A complete description of the Dock Watch Hollow site is given under Plan RV-4 which makes more complete usage of the reservoir site.

Utilization of the Dock Watch Hollow Reservoir as envisaged under Plan RV-3 will require an addition of 50 million gallons per day capacity to the pumping station at Bound Brook, a 50 million gallons per day booster pump, and a force main adequate to deliver 50 million gallons per day to the reservoir and return 190 million gallons per day by gravity to the transmission main, by a connection through the pressure filters.

Plan RV-3 also depends on one of the on-river sites of OR-1 to provide a sustained flow of 130 million gallons per day below diversions at Bound Brook.

Plan RV-4—200 Million Gallons per Day Project Using Round Valley and Dock Watch Hollow Reservoirs

This plan would develop a dependable yield of 200 million gallons per day of potable water from the Raritan Basin by using the Round Valley Reservoir with stream bed delivery to Bound Brook as in Plans RV-2 and RV-3 together with the full capacity of the Dock Watch Hollow Reservoir at flow line elevation 455. As in all other plans, regulation of a sustained flow of 130 million gallons per day at Bound Brook will require one of the on-river reservoirs described under Plan OR-1.

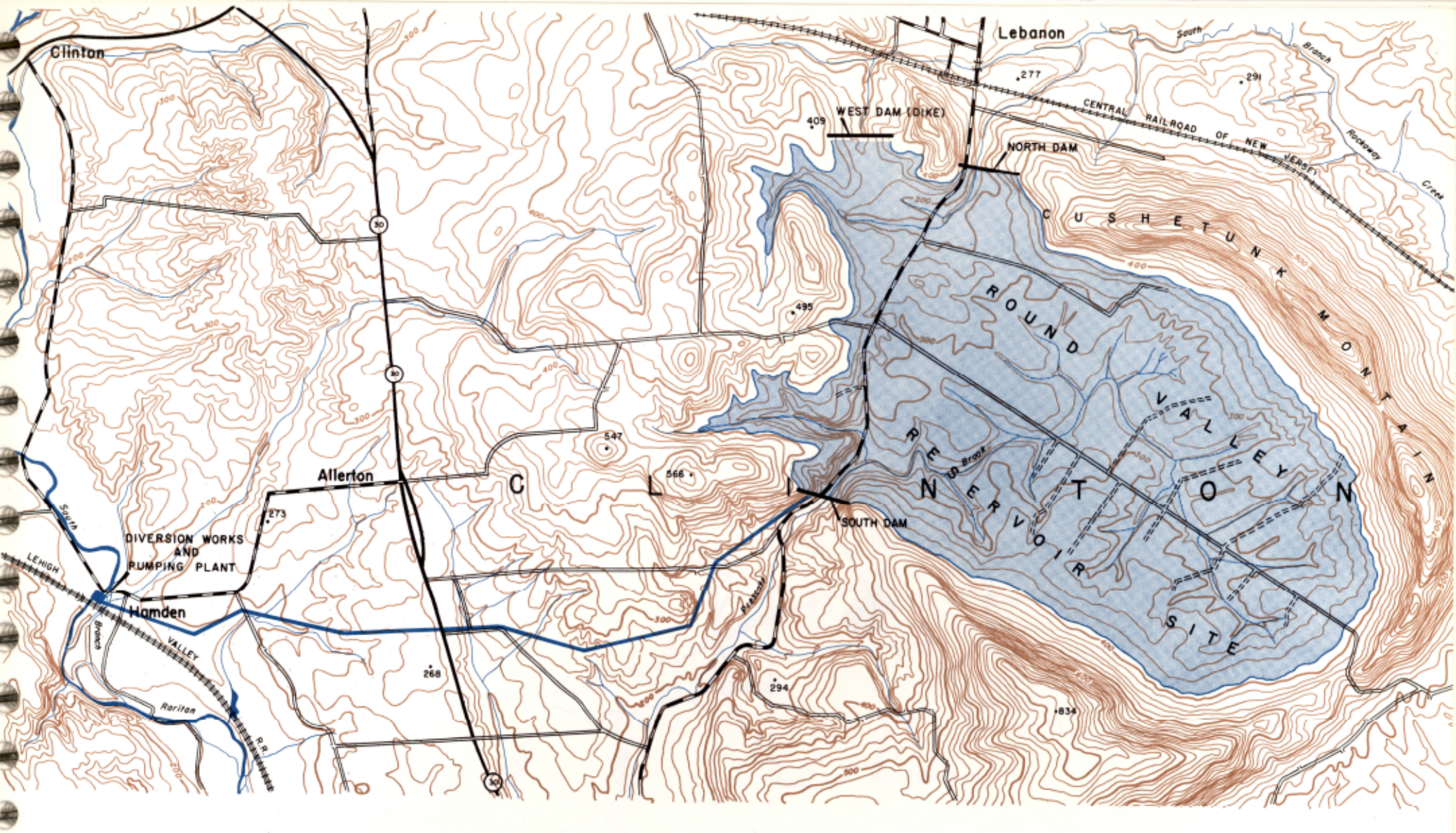
In addition a small distribution reservoir is needed to aid in the operation and improve the economy of this plan. This reservoir would be located at Warrenville in the extreme eastern tip of Washington Valley (Chimney Rock Reservoir) with a flow line elevation of 306.5 which will permit gravity delivery of the water. A second small reservoir is an optional feature and would be located on the South Branch of the Raritan River just below Hamden at Sunnyside to provide the low level pondage necessary to economically recover energy from the water stored in Round Valley and released for stream bed delivery to Bound Brook. Plate II-8 shows the pertinent features of the plan. Additional data on the use of Dock Watch Hollow Reservoir and the energy recovery plan (pumped-storage) are given below and in Appendix F.

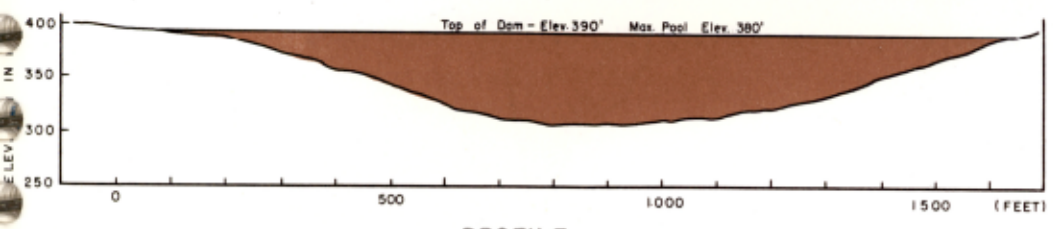
The natural depression in the top of the Watchung Mountains about 3 miles due north of Bound Brook known as Dock Watch Hollow may be closed off for a reservoir by the erection of a single dam. A dam 131 feet high above the outlet brook with a spillway at elevation 455 would flood an area of 1,060 acres and develop a storage volume of 15.8 billion gallons. Land takings should include the full topographic basin—a total of 1,200 acres. Approximately 80 one-family dwellings would have to be moved from the reservoir site. Road and utility relocations are a minor consideration at the site.

The dam would be founded on sound basaltic trap rock adequate for any type of structure. Curtain grouting will be required to prevent leakage under the dam and around the abutments. The reservoir basin is underlain with relatively tight shales and leakage through the floor will be very slight. A combination earth and rock fill dam may be used at the site as shown by the typical section on Plate II-11. However, more detailed studies may reveal the desirability and economy of a concrete dam in view of the rock foundation.

The Warrenville Distribution Reservoir would have a total capacity of 750 million gallons with a flow line elevation of 306.5. An impervious core earth dam 2,300 feet long and having a maximum height of 44 feet will be required across the eastern end of Washington Valley to create the reservoir. Approximately 140 acres will be flooded and a total of 170 acres should be acquired. Approximately 45 families will be displaced.

*This restriction is not mentioned in the November 1, 1954 Report on Round Valley but was brought out at hearings before the Water Policy and Supply Council during the summer of 1955.





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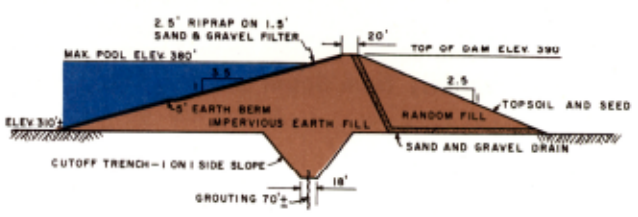
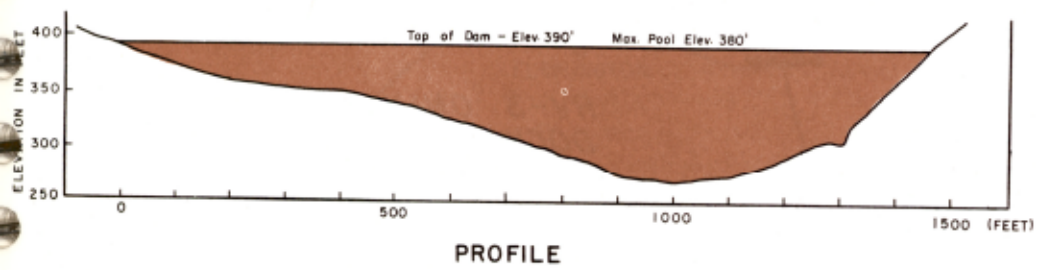


DAM SECTION
SCALE: 1 IN. = 200 FT.

WEST DAM (DIKE)



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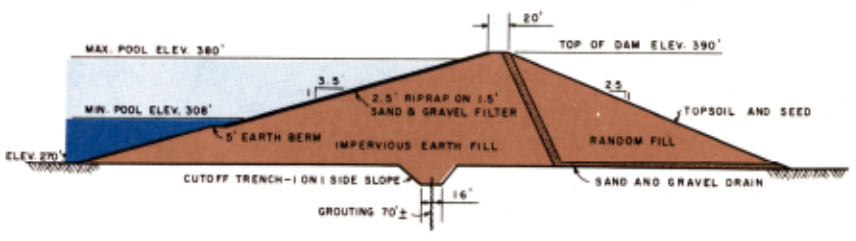
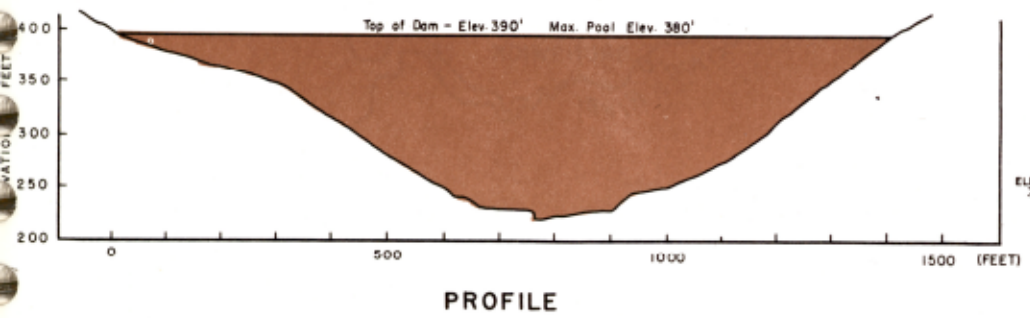


DAM SECTION
SCALE: 1 IN. = 200 FT.

NORTH DAM



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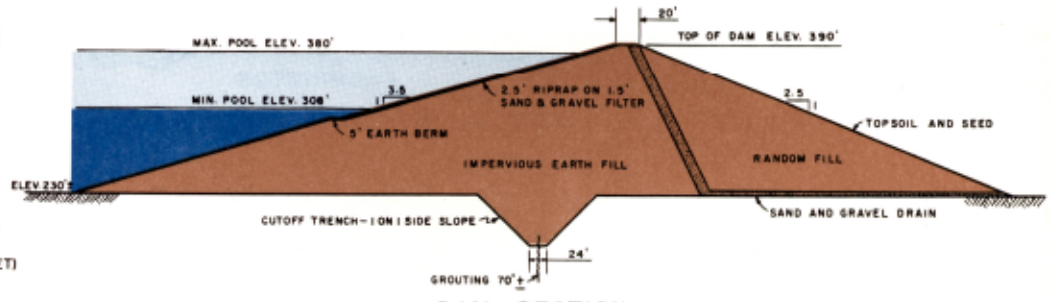

DAM SECTION
SCALE: 1 IN. = 200 FT.

SOUTH DAM



PLATE
II-6
12-1955

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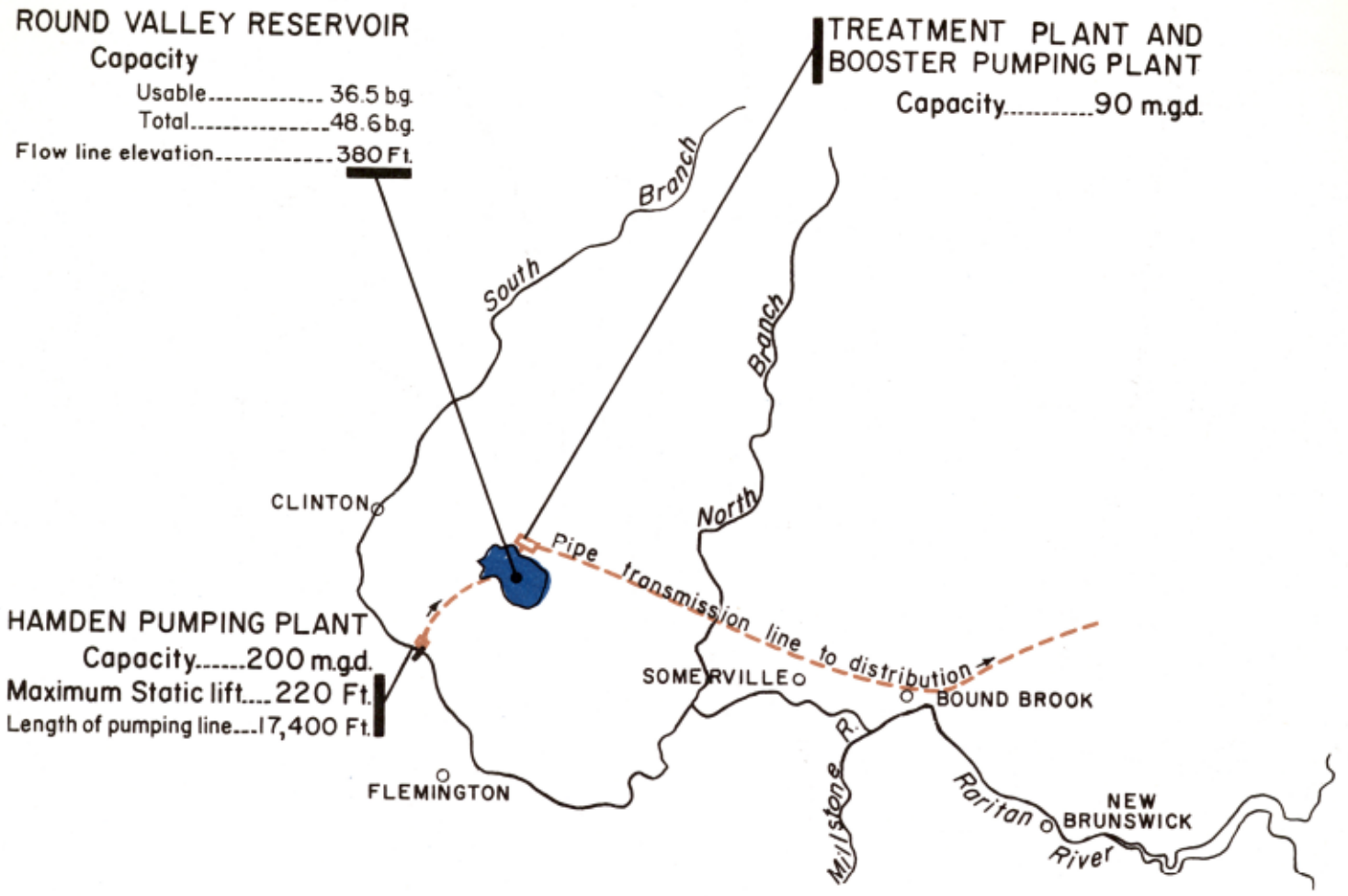
NEW JERSEY WATER RESOURCES DEVELOPMENT

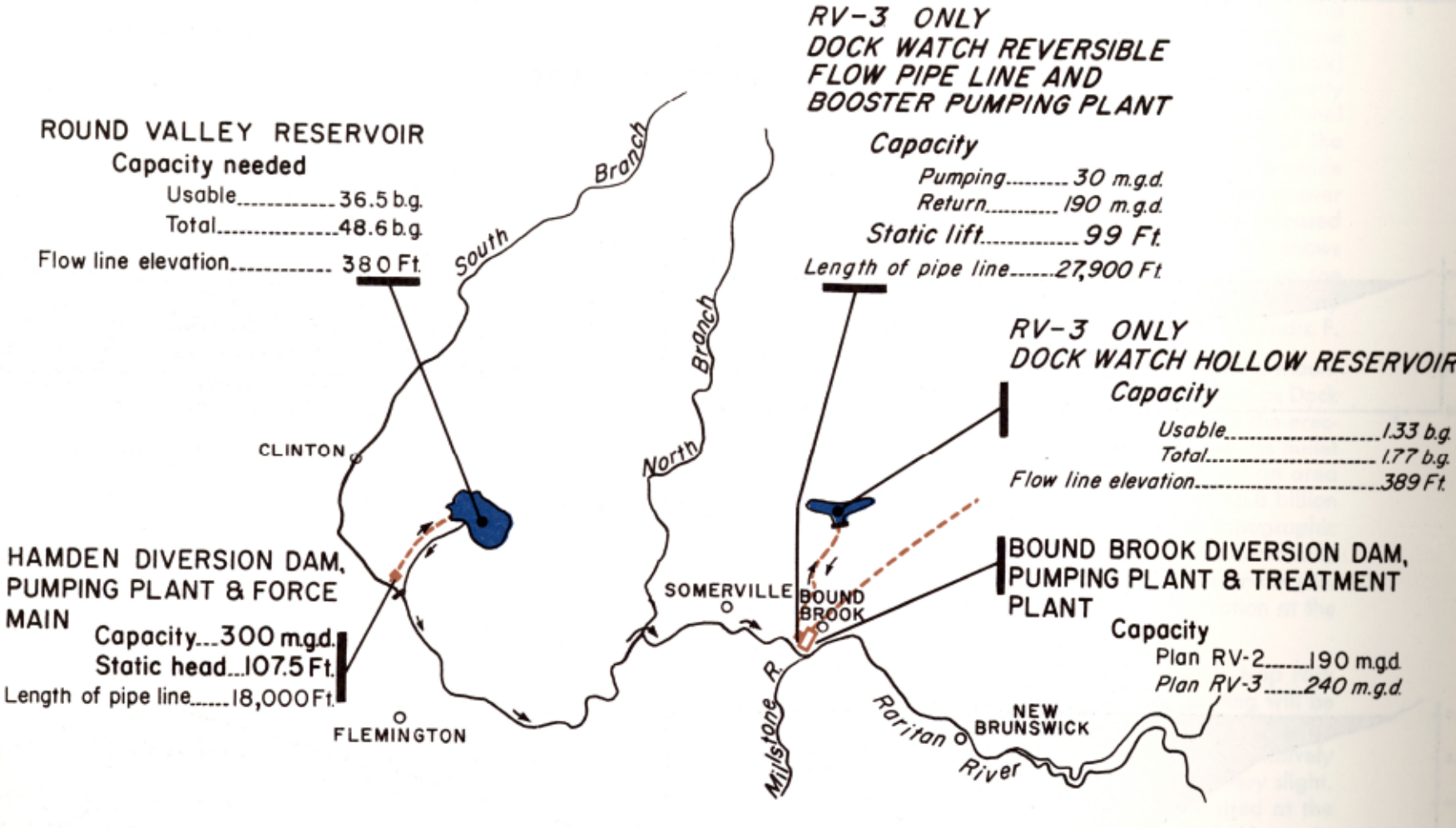
ROUND VALLEY AREA
ELEVATIONS AND SECTIONS - ROUND VALLEY DAMS



PLAN RV-1

North Jersey District Water Supply Commission plan for 70 m.g.d. project using storage in Round Valley Reservoir site, pumping entirely from South Branch Raritan River at Hamden.

RV-3 ONLY



PLANS RV-2 AND *RV-3*

BASIC PLANS UTILIZING ROUND VALLEY SITE WITH STREAM BED DELIVERY TO BOUND BROOK

Dependable yield of 150 m.g.d. regulated flow in Raritan River at Bound Brook, over and above 150 m.g.d. supply at same point, to be provided by 1 of 4 on-river sites, for regulated minimum (compensated) flow, including 20 m.g.d. for Elizabeth Water Company.

Plan RV-3 is the same as RV-2 *plus 7 day reserve supply in Dock Watch Hollow Reservoir to permit gravity delivery during emergencies.*

PLATE II-7
12-1955

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NEW JERSEY WATER RESOURCES DEVELOPMENT

BASIC FEATURES OF PLANS RV-1, RV-2 & *RV-3*

DOCK WATCH HOLLOW RESERVOIR

Capacity

Usable ..... 13.4 b.g.
Total ..... 15.8 b.g.
Flow line elevation ..... 455 ft.

BOUND BROOK PUMPING PLANT AND DIVERSION DAM

Capacity ..... 400 mgd
Max. Lift ..... 435 ft.
Length of discharge line ... ±27,900 ft.

WARRENVILLE PUMP-STORAGE PLANT

Capacity needed for withdrawal of water from Dock Watch Hollow ..... 250 mgd
Static head range ..... 90 to 169 ft.
Length of reversible flow force main – penstock, approx. 13,800 ft.

HAMDEN PUMP-STORAGE PLANT

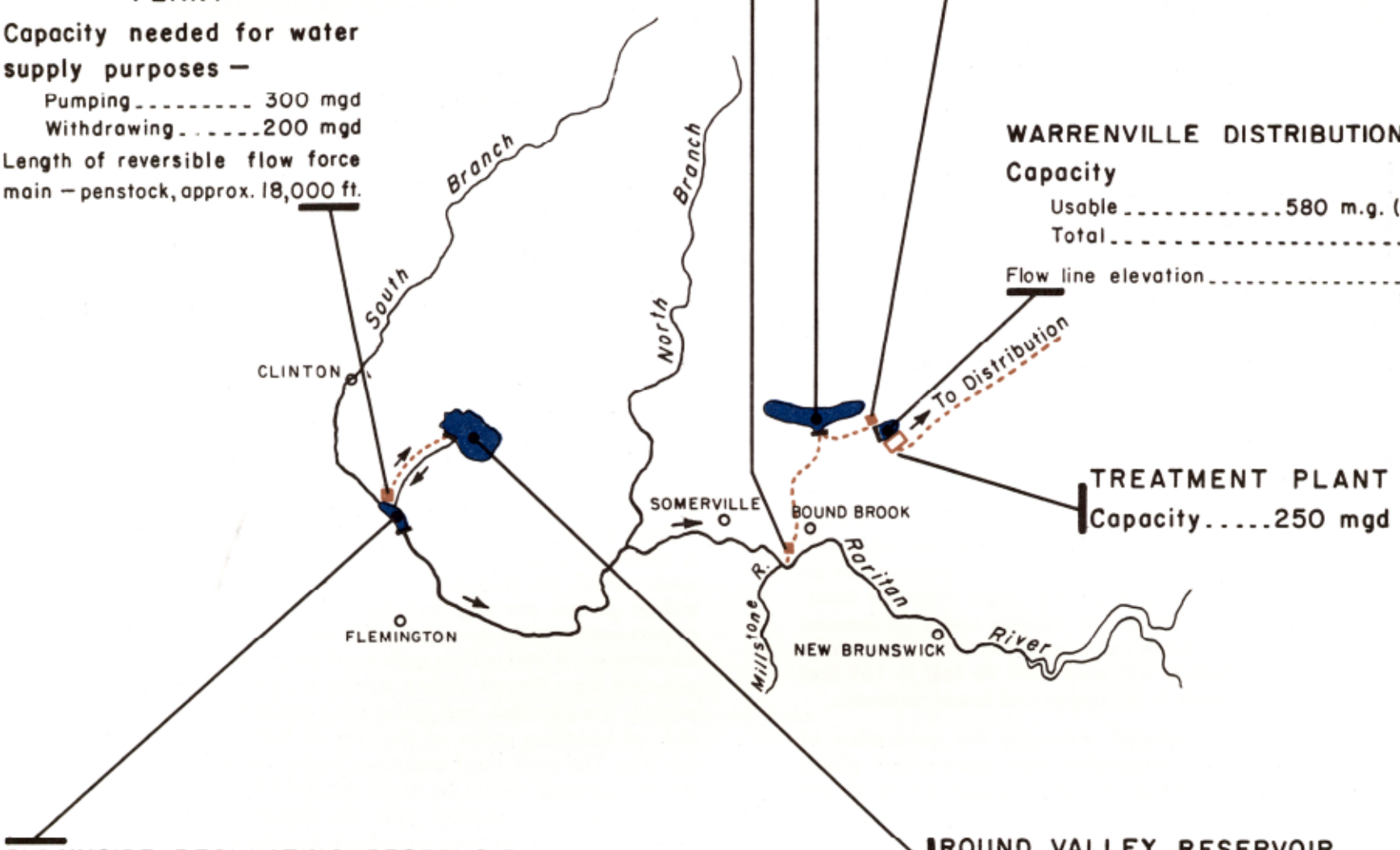
Capacity needed for water supply purposes –

Pumping ..... 300 mgd
Withdrawing ..... 200 mgd
Length of reversible flow force main – penstock, approx. 18,000 ft.

WARRENVILLE DISTRIBUTION RESERVOIR

Capacity

Usable ..... 580 m.g. (above elev. 286)
Total ..... 750 m.g.
Flow line elevation ..... 306.5 ft.



TREATMENT PLANT

Capacity ..... 250 mgd

SUNNYSIDE REGULATING RESERVOIR

Capacity

Usable ..... 750 m.g. (above 156')
Total ..... 1,000 m.g.
Flow line elevation ..... 166 ft.

ROUND VALLEY RESERVOIR

Capacity

Usable ..... 36.5 b.g.
Total ..... 48.6 b.g.
Flow line elevation (min.) ..... 380 ft.

PLAN RV-4

200 mgd plan utilizing storage in Round Valley and Dock Watch Hollow Reservoirs – with Dock Watch Hollow used for quality improvement and gravity delivery – and with energy recovery at Round Valley and Dock Watch Hollow.

PLATE
II-8
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS
NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

BASIC FEATURES OF PLAN RV-4

The Sunnyside Reservoir located on the South Branch below Hamden would be adequate for short term regulation of stream flow as required for economical recovery of energy from Round Valley releases, and would store 1,000 million gallons of of water (1.0 bg) with a flow line elevation of 166.0. An earth dam 1,950 feet long with a maximum height of 39 feet above the stream bed will be required. The flooded area will be about 450 acres and a total area of about 600 acres should be acquired. Approximately 15 farm units would be inundated. The Sunnyside Reservoir would only be required in connection with a pumped-storage generation installation at Round Valley.

The first steps in the operation of Plan RV-4 will be similar to RV-2 and RV-3. Water will be pumped from the South Branch to Round Valley and delivered to Bound Brook by natural stream channels. At Bound Brook, however, instead of being pumped directly into the transmission mains, the water will be pumped to Dock Watch Hollow Reservoir. The additional storage in this reservoir is adequate to increase the dependable yield from 150 to 200 million gallons per day. It also removes the danger of service interruptions due to electrical and mechanical failure. Although the average storage period in Dock Watch Hollow will be much shorter than in Round Valley, the storage provided will be deep and the quality improvement and low temperature lost by stream bed delivery should be largely recovered.

Plan RV-4 effectively provides a dependable 200 million gallons per day supply, from the Raritan Basin alone, using Round Valley as the key reservoir without building the expensive 18 mile long transmission mains to Bound Brook and without sacrificing gravity delivery or quality. An excessive amount of pumping, however, is required in order to accomplish this, which would have a considerable effect on the cost of water. In order to overcome this disadvantage, the recovery of electrical energy from the pumped water has been made a feature of the plan.

The recovery of electrical energy can be accomplished at two places in Plan RV-4: First between Round Valley and the South Branch, where a head of approximately 200 feet can be utilized to generate electricity with the stored water as it is returned to the river for stream bed delivery to Bound Brook; Secondly, the elevation of Dock Watch Hollow being higher than is necessary for gravity delivery of the water, a portion of the static head between the Raritan River and Dock Watch Hollow may be recovered by dropping the water into a distribution reservoir at Warrenville which still has sufficient elevation for delivery by gravity except during periods when extreme peak water demand coincides with low reservoir levels. Booster pumping at such times would be more economical than to provide the larger diameter transmission mains required for gravity delivery under all demand conditions. The recoverable static head between Warrenville and Dock Watch Hollow will vary from 90 feet to 169 feet depending on the levels in the upper and lower reservoirs.

Installations using pumped water for the generation of electricity are called "pumped-storage generation" plants or simply "pumped-storage" plants. Modern plants of this type use a unit known as a pump-turbine. This unit acts as a motor driven pump when water is being lifted to the upper reservoir. The pump becomes a turbine and the motor a generator when the flow of water is reversed. This dual service unit performs with hydraulic and mechanical efficiency practically equal to single purpose units and has a much lower overall cost than separate pumping and generating facilities. The force main on these installations also serves a dual purpose by acting as a penstock during the generating cycle. Successful installations of this type are in operation in the United States and in Europe, many of them for the primary purpose of electric power generation for peak load assistance.

Where water supply rather than electric generation is the primary purpose it is possible to limit the installation and to operate it solely from the standpoint of water supply requirements. In other words, water would be pumped on a random schedule as available in the stream and would be released for power generation only as needed to meet the requirements of water supply. Such an operational method, while requiring the minimum capital investment, would not, in all probability, show sufficient economic advantage to warrant even the minimum installation. The reasons for this are, first, that power recovery with pumped water is only about 65% of power input and, secondly, because the recovered energy may not be generated at a time when it can be used or is most valuable.

The power recovered from pumped-storage could be used by the water supply system or could be fed by contractural arrangement into the power grid of the electric utility company serving the area. In the first case it would be essential to have a nearby installation of the water system which could use the power at any time that it is generated. If such an installation were not in close proximity to the point of generation, the cost of transmitting the power might be more than its economic value. If the power is sold to utility companies, it will be necessary, in order to be of real interest to these companies, to design the installation to consume power for pumping at specific times when the general consumption of power on their systems is low (off-peak hours) and to deliver a dependable power output at specific times when the general consumption of power is high (peak load hours). Such an arrangement is known as "peak load assistance" and with it comes the advantage of buying electrical power for the minimum price during off-peak hours (usually night and early morning) and selling power at a higher price during the peak load hours. The economy of the installation will depend on whether the differential in price between off-peak and peak load power is sufficient to overcome the 35% loss between the input and output of the pump-turbine and the additional cost of the installation designed for peak load assistance. It is also essential that the installation be located in an area where the electric utility has need for additional peak load power.

In order to properly operate a pumped-storage plant for peak-load assistance it is necessary to have upper and lower pools or reservoirs between which water may be exchanged freely without regard for and without interference with the requirements of water supply. Given this condition an almost infinite variety of pumping and generating arrangements may be set up, limited only by the storage volume of the two pools and the capacity of the pumped-turbine and supplementary generating units installed. The two pool requirement is the reason for adding the short term on-river regulating reservoir at Sunnyside to operate in conjunction with Round Valley and the distributing reservoir at Warrenville to form a pumped storage unit with Dock Watch Hollow.

An example of how the generation of peak load assistance would work at the Round Valley location under Plan RV-4 is as follows: The maximum pumping requirement at Round Valley for water supply is 200 million gallons per day. If it is desirable to pump this amount during an eight hour off-peak period, the pumping capacity necessary would be 600 million gallons per day and the maximum pumping power requirement would be about 23,000 kilowatts or 30,000 horsepower. If 200 million gallons of the pumped water were released from Round Valley during a two hour peak load period, the penstock and generating facilities must be capable of handling water at the rate of 2400 million gallons per day. The peak load assistance power generated by such an arrangement would be about 50,000 kilowatts or 67,000 horsepower. It is obvious that the dependability and the opportunity for expansion in such an installation rests largely on the capacities of the upper and lower reservoirs. The economical structure of the installation is also improved where both reservoirs are essential parts of the water system and therefore do not enter into the cost of additional installation for peak load generation.

In Plan RV-4 the Sunnyside-Round Valley pumped-storage plant would be in the franchise area of the New Jersey Power and Light Company and the Warrenville-Dock Watch Hollow plant in the area served by the Public Service Electric and Gas Company of New Jersey. Officials of both of these companies were contacted with respect to the potentialities for pumped-storage generation and both expressed an interest and willingness to seriously explore the possibilities at the appropriate time. The correspondence on the subject with both companies is reproduced in Appendix F together with further data on "Pumped Storage Generation." Plate A-10 shows a section through a typical pump-turbine installation.

On Plate II-8, showing the general arrangement of Plan RV-4, the capacities given are those required for water supply only and do not limit the variety of arrangements that can be made for pumped-storage generation.

Table II-6, which follows, gives the cost of Plans RV-1, RV-2, RV-3 and RV-4. As previously stated the cost of all plans include an on-river reservoir to provide a minimum sustained flow at Bound Brook of 130 million gallons per day after potable water diversions. Costs include all pumping and treatment plants and gravity transmission mains to Bound Brook only or transmission by stream bed to Bound Brook with pressure head added equivalent to a gravity line from Round Valley.

Alternative Uses of Chimney Rock—CR Plans

The Chimney Rock reservoir site, situated between the First and Second Watchung Mountains north of the Borough of Bound Brook in the area known locally as Washington Valley, has long been recognized as an advantageous location for a water supply reservoir. Due to its geographic position near the lower portion of the Raritan River Basin and within reasonable transmission distance of the Metropolitan Region, it has many advantages over other sites. Extensive residential development along the southern slope of the Second Watchung Mountain makes it economically infeasible to utilize the entire topographic basin for water storage; hence the practicable limit of reservoir capacity at the Chimney Rock site is 40.8 billion gallons, corresponding to a flow line elevation of 290. The storage capacity at Chimney Rock is, therefore, considerably less than that which can be developed at Round Valley. The effect of this limitation is offset by the fact that the source of water for Chimney Rock is at Bound Brook where surface runoff from a drainage area of 779 square miles (including all of the Millstone River and both North and South Branches of the Raritan River) is available, whereas the Round Valley site has convenient access to the runoff from only 140 square miles of the drainage area of the South Branch of the Raritan River.

The Chimney Rock Reservoir would have a flooded area of 2880 acres at the flow line elevation of 290 and with an average taking line at elevation 300 approximately 3230 acres would have to be acquired. The reservoir site, below the taking line at elevation 300, is presently occupied by about 450 suburban and farm residences. There are no important highways or railroads in the site but relocations and improvement of existing roads across or around the east and west extremities of the reservoir will be required. A direct road from Martinsville to U.S. Highway 22 and Bound Brook would be provided by a causeway across the reservoir site to replace the present Chimney Rock Road. The causeway would be parallel to the present road and would furnish convenient access for the residents of Martinsville and adjacent areas to schools, shopping centers, hospitals and places of employment.

The construction of the Chimney Rock Reservoir would eliminate the two small reservoirs of the Bound Brook Water Company which now serve the community of Bound Brook. Consequently, the inundated property and diversion rights of that company, which delivers water at an average annual rate of about 1.25 million gallons per day from its Chimney Rock source, would have to be acquired. Informal discussions with officials of the Bound Brook Water Company indicate a full realization of the much greater importance of the Chimney Rock site for a major water supply than for the minor use made by the local water company. The company's treatment plant would not be affected by the proposed Chimney Rock development and it is believed that a mutually satisfactory compensation agreement for loss of the company's storage can be worked out which would include the

TABLE II-6

ESTIMATED COSTS FOR RARITAN DEVELOPMENTS
WITH ROUND VALLEY SITE

Units—Millions of dollars except as indicated

Item	Plan RV-1	RV-2	RV-3	RV-4*
Yield of Potable Water-mgd	70	150	150	200
Spruce Run Site				
Reservoir Costs	1.52	1.52	1.52	1.52
Dam Construction	2.60	2.60	2.60	2.60
Round Valley Site				
Reservoir costs	3.91	3.91	3.91	3.91
Dam Construction	12.95	12.95	12.95	12.95
Hamden intake and pumping plant	2.01	2.01	2.01	2.01
Force main-Hamden to Round Valley	2.50	2.50	2.50	2.50
Lebanon Treatment plant and booster pumps	4.88			
Transmission main-Round Valley to Bound Brook Area	9.70			
Bound Brook intake and pumping plant		2.85	2.85	4.80
Bound Brook treatment plant		8.00	10.30	
Adjustment to point of common transmission		2.20	2.20	
Dock Watch Hollow Site				
Reservoir Costs			1.32	3.59
Dam Construction			.75	2.41
Booster pumping plant to Dock Watch Hollow			1.20	
Force main-Bound Brook to Dock Watch Hollow			3.07	10.60
Warrenville distribution reservoir				
Reservoir cost				1.37
Dam construction				1.21
Warrenville power plant				.88
Aqueduct-penstock, Dock Watch Hollow to Warrenville				2.50
Warrenville treatment plant				8.90
Subtotal	40.07	38.54	47.18	61.75
Engr., legal & admin. costs	3.40	3.27	4.01	5.25
Interest during construction	2.98	2.92	3.58	4.60
Cost of project, exclusive of transmission mains beyond Bound Brook Area	46.45	44.73	54.77	71.60*
Total annual cost, including operation and maintenance	2.75	3.20	3.74	5.24
Annual cost per mgd	$39,300	$21,300	$24,900	$26,200
Cost per million gallons of supply	$108	$58	$68	$72

*Costs for Plan RV-4 include only basic facilities required for water supply. Optional features, shown on Plate II-8, for pumped-storage development not included as extent of such developments will depend upon negotiations with utility companies.

furnishing of raw water to the treatment plant from Chimney Rock Reservoir.

The Bound Brook quarry of the North Jersey Quarry Company is operating in an area about 1000 feet downstream from the west dam site. Although some concern has been expressed by local residents, analyses of data obtained from seismograph records of operations at the Bound Brook quarry show conclusively that blasting will have no effect on the dams. Modern designs used for dams result in structures able to withstand earthquake shocks which are hundreds of times more severe than those produced by quarry blasting. It will be necessary to maintain a rock plug between the south shore of the reservoir and future quarry operations. This plug or barrier will require purchase of a strip of quarry property outside of the reservoir limits, about 400 feet wide adjacent to the flow line of the pool. The 400 foot wide barrier together with the additional insurance of curtain grouting will be adequate to preclude any escape of water from the reservoir into the quarry. Lands owned by the North Jersey Quarry Company at the Bound Brook site exclusive of that which would have to be taken for reservoir purposes, provide rock reserves adequate for operation of the quarry for more than one hundred years, assuming future rock removal to be at a greater rate than that of recent years.

The Chimney Rock area (Washington Valley) is drained by the East and West Branches of Middle Brook through a gap in the First Watchung Mountain into the Raritan River. Two dams will be required to form the reservoir; one each over the East and West Branches of Middle Brook and are called hereafter the East Dam and West Dam. Both dams will be located in the southern ridge or First Watchung Mountain which is composed of fine grained, hard basalt (trap rock).

At the West Dam site hard rock is exposed in the bed of the stream but on the slopes approximately five feet of material would have to be removed to expose sound rock. The East Dam site will require the removal of approximately five feet of material from the stream channel and ten feet from the slopes. The amount of foundation preparation at both sites is nominal and will expose rock suitable for any type of dam structure. Grout curtain cutoffs, about 60 feet deep at the West Dam and of somewhat greater depth at the East Dam (since there is evidence of a small fault in the East Branch gorge) should be provided. More detailed investigation of the rock in the canyon walls may reveal the desirability of additional grouting beyond the abutments. With these precautions leakage under and around the dam should be minor. The valley floor is underlain by the soft red shales of the Brunswick Formation with some interbedding of fine-grained sandstone. Jointing in this formation is not extensively developed and it in turn is underlain by the basaltic formation of First Mountain. It is anticipated that leakage from the reservoir will be negligible.

Several types of dam structures were investigated and although the rock fill type proved to be the most economical, the concrete gravity dam was selected since the cost differential was relatively small and this type of dam would appear to be psychologically more acceptable. The trap rock available at the site is excellent coarse aggregate for the concrete dam structure. Sand for fine aggregate will have to be brought in from other sources. Plate II-9 shows the proposed dam locations, spillway and typical dam sections.

The protection of the reservoir against pollution is not expected to be a major problem even though the entire watershed area of Chimney Rock is not included in the proposed real estate takings. The majority of water supply systems do not own the complete watershed areas draining to their reservoirs and operate without detrimental results providing the existing State and local laws on the disposal of sanitary wastes are observed. In connection with the Chimney Rock development it is proposed to construct a sanitary sewerage system for the populated area around Martinsville. After a high degree of treatment, sewage from the Martinsville area would be piped across the reservoir in the proposed causeway and discharged into Middle Brook. Residences located outside of the Martinsville area are generally on plots of sufficient size to provide efficient underground disposal with the use of properly designed septic tanks and subsoil irrigation. As a final protection all water delivered from Chimney Rock will be coagulated, filtered and chlorinated to insure purity and safety.

Four plans are presented below for the development of the water supply potential of the Raritan River Basin using the Chimney Rock Reservoir site as the principal storage area. In all of these plans it is assumed that river regulation to obtain a sustained minimum flow at Bound Brook of 130 million gallons per day, after diversions for potable supply, will be achieved by an on-river reservoir and will be an integral part of the development.

Plan CR-1—70 Million Gallons per Day Project

The upper half of Plate II-10 illustrates the pertinent features of this plan, which is for a first stage development of Chimney Rock and will provide a dependable yield of 70 million gallons per day. Two alternates using different locations for water diversions are possible with Plan CR-1. In Alternate 1, water is taken from the North Branch of the Raritan River at a point about one mile upstream from the village of North Branch. In Alternate 2 the diversion would be at Bound Brook on the main river downstream from the confluence with the Millstone River.

Alternate 1 will require a larger pumping plant than Alternate 2 (150 mgd instead of 110 mgd) and a costlier force main because of some necessary tunnel construction. It will, however, have the advantage of a smaller pumping head and a better initial water quality. The use of Alternate 1 may be further subdivided into two parts. With Alternate 1A, the North Branch site would be used for the storage of water for stream flow regulation (compensation) as in Plan OR-1 as well as for the pumping diversion to Chimney Rock. In this case the static lift would vary from 132 to 186 feet, depending on the water levels in the two reservoirs. With Alternate 1B, the North Branch site would be used for diversion only with compensation storage for a sustained flow at Bound Brook provided in one of the other sites described in Plan OR-1. In this case the static lift between North Branch and Chimney Rock would vary from 137 to 205 feet.

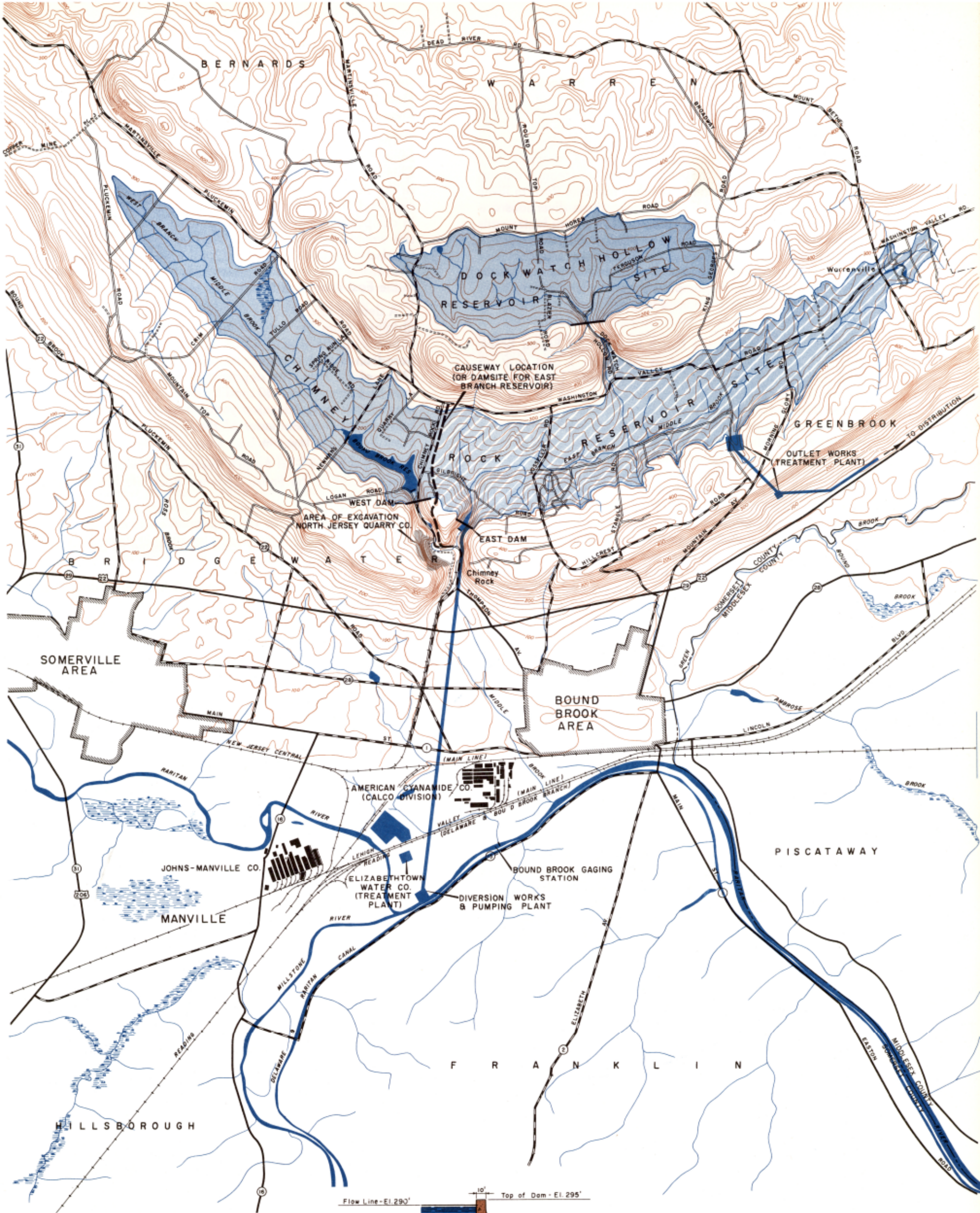
In Alternate 2 Chimney Rock would be supplied from a pumping station on the Raritan River commanding the entire drainage area of the North and South Branches and the Millstone River (779 square miles). Because of the larger stream flow available the pumping capacity required is only 110 mgd, but the station lift will vary between 248 and 270 feet.

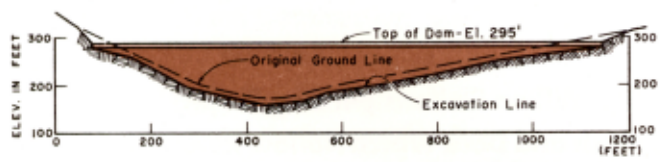
The monthly hydrograph of the flow of the Raritan River at Bound Brook under unregulated conditions and as modified by Plan CR-1 is shown on Plate A-5 in the Appendix. On Plate A-6 in the Appendix are graphs showing the percent of time that water levels in the Chimney Rock and North Branch Reservoirs would be at or above various elevations in their respective operating ranges. These elevation vs. frequency curves show that on a long term basis (34-year study period) the Chimney Rock Reservoir operated under plan CR-1 will be full fifty percent of the time and for 95% of the time will be fluctuating only within the top 12 feet.

Daily operation studies made for Plan CR-1 for critical drought periods are summarized in Plates A-7 and A-8 in the Appendix. These studies, together with the mass hydrographs for the Raritan River at Bound Brook, show that the drought periods of 1930-33 and 1949 were the most critical during the entire 34-year record from 1922 to 1955.

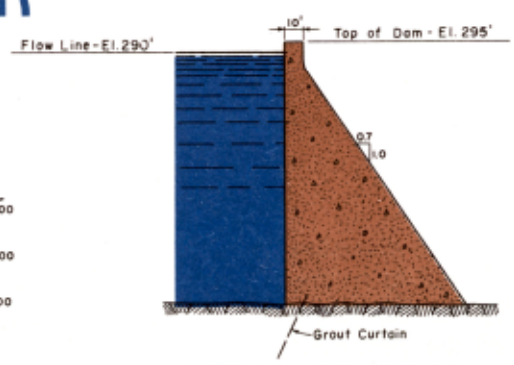
The usable storage capacity at Chimney Rock required to maintain an average annual delivery rate of 70 million gallons per day is only 18.1 billion gallons. However, by raising the operating level to the flow line elevation of 290.0 (total storage 40.8 billion gallons) delivery to distribution point can be made by gravity a large percentage of the time. With Plans CR-1 and a normal operating level of 290.0, a recurrence of 1930-33 runoff conditions would cause a minimum level in the Chimney Rock Reservoir of 268.0.

Plates A-7 and A-8, in the Appendix, illustrate the operation of the North Branch Reservoir to maintain minimum flow requirements of 28 mgd in the North Branch of the Raritan River downstream from the damsite and 150 mgd in the Raritan River at Bound Brook (including 20 million gallons per day for the Elizabethtown Water Company).

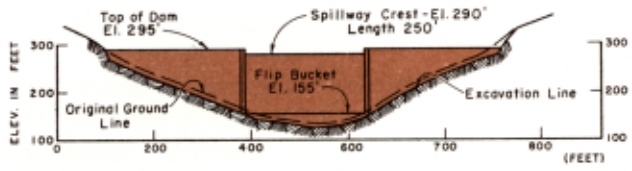




DOWNSTREAM ELEVATION OF WEST DAM



TYPICAL DAM SECTION



DOWNSTREAM ELEVATION OF EAST DAM

SCALE 4000 0 4000 FEET 8000

PLATE II-9
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

CHIMNEY ROCK AREA
ELEVATIONS AND SECTIONS - CHIMNEY ROCK DAMS

Plan CR-2—200 Million Gallons per Day Project

This is the second stage of the Chimney Rock development. The important units of this plan are shown on the bottom half of Plate II-10. As in Plan CR-1 there are two locations from which water may be diverted into the reservoir, one on the North Branch of the Raritan River upstream from the village of North Branch, and the other from the Raritan River at Bound Brook. In Plan CR-2, however, these diversions are not entirely alternate to each other since enough water cannot be obtained from the North Branch to supply an average yield of 200 mgd and, therefore, this diversion must be used in conjunction with an additional diversion at Bound Brook. By providing sufficient pumping capacity at Bound Brook this diversion point may be used independently for the entire supply.

The plan using both the North Branch and Bound Brook diversion points is designated as Alternate 1 and may be used in two different ways. Under Alternate 1A the North Branch Reservoir would be used to store water for the sustained flow of 130 mgd at Bound Brook (compensation water) and would also provide an additional 1.8 billion gallons of storage needed for more efficient utilization of the 150 mgd pumping diversion to Chimney Rock reservoir from this point. The total storage including reserve in the North Branch Reservoir would be 11.9 billion gallons. For Alternate 1B the North Branch Reservoir would be used only for diversion and for minor regulatory storage of 2.4 billion gallons (1.8 billion gallons usable) needed in connection with the diversion. The flow line elevation of the reservoir in this case will be only 93.0. With both Alternates 1A and 1B the pumping capacity required at North Branch will be 150 mgd and will operate in conjunction with a pumping station at Bound Brook with 350 mgd capacity.

It appears most probable that Alternate 1 would not be executed with Plan CR-2 unless this Alternate had been initiated under Plan CR-1. In this event the only construction required at North Branch for the continued use of Alternate 1 would be the raising of the North Branch dam to impound the additional 1.8 billion gallons of water.

Alternate 2 uses a diversion point at Bound Brook to supply all of the water needed for the 200 million gallons per day supply. In this case pumping capacity of the Bound Brook Station must be 500 mgd or equal to the combined capacities of the North Branch and Bound Brook pumping stations under Alternate 1.

Plate A-5 in the Appendix shows the monthly hydrograph of the Raritan River at Bound Brook both unregulated and as modified by the operation of Plan CR-2. The elevation vs. frequency curves on Plate A-6 in the Appendix show that for the period of record (1922-1955) the Chimney Rock Reservoir operated under Plan CR-2 would have been full 60% of the time and for 95% of the time the change in reservoir level would have been confined to the top 27 feet.

Daily operation studies for the most critical periods of record with the average 200 mgd delivery rate of Plan CR-2 show that the minimum reservoir level would be elevation 236.0. During the entire 34 year period of record the hypothetical operation of Plan CR-2 would have lowered the Chimney Rock Reservoir below 25% of its capacity only twice: in 1930-31 and in 1949. The maximum withdrawal from the reservoir would have been 33.1 billion gallons on February 8, 1931, leaving a reserve of 18.7 percent of the total reservoir capacity. Plate A-9 in the Appendix shows the storage fluctuation under Plan CR-2 operating conditions in Chimney Rock Reservoir during four serious drought periods: 1923-24, 1930-31, 1949-50, 1953-54.

Plan CR-3—70 Million Gallons per Day Project Using the East Branch of Chimney Rock

This plan presents an alternate to Plan CR-1 with diversion from Bound Brook. A reservoir hereafter referred to as the "East Branch Reservoir" could be formed by the East Dam proposed for Chimney Rock and a dam at the proposed causeway site on the divide between the East and West Branches of Middle Brook, see Plate II-11. The East Branch Reservoir could be used either as the 70 mgd first stage of Plan CR-2, or in the event that the entire Chimney Rock site were not acquired, it could be used in conjunction with the Dock Watch Hollow site to develop 200 mgd from the Raritan River as presented in Plan CR-4.

The total capacity of the East Branch Reservoir, with the same flow line of elevation 290.0 as used in the complete Chimney Rock plan, is 26.0 billion gallons. The flooded area at the flow line will be 1690 acres and the total area to be acquired with a taking line elevation of 300 is 1900 acres. In comparison with the whole Chimney Site, the East Branch site would have 64% of the storage capacity, 57% of the flooded area and 59% of the total area. Slightly more than half of the residential occupancy of the whole site is located in the East Branch section.

A dependable yield of 70 million gallons per day may be obtained from the East Branch Reservoir with a pumping capacity at the Bound Brook diversion point of 110 mgd. Based on a usable storage capacity of 22.1 billion gallons (75% of 26.0 bg) the dependable yield from the reservoir may be increased to 140 mgd by adding pumping and force main capacity. To develop yields beyond 140 mgd will require either the remainder of the Chimney Rock site or the Dock Watch Hollow site.

The use of the East Branch Reservoir without the eventual development of the entire Chimney Rock site has a number of advantages:

1. It would displace fewer people.
2. Only 1900 acres of land would have to be taken as against 3230 acres.
3. The West Dam over the West Branch of Middle Brook would not be required.
4. It would remove the necessity for the purchase of any land owned by the North Jersey Quarry Company or the installation of a grout curtain along the reservoir's boundary with the Quarry Company.
5. The principal storage reservoir and diversion works of the Bound Brook Water Company could continue to function without interference.
6. The need for a sewerage system for the Martinsville area would be eliminated.
7. If used in conjunction with Dock Watch Hollow for the eventual development of 200 mgd it could serve as a perfect lower pool for a pumped storage generation scheme.

The principal disadvantages of using only the East Branch Reservoir are:

1. The East Branch Reservoir would not be as flexible as the complete Chimney Rock Reservoir for the development of intermediate supplies between 70 and 200 million gallons per day.
2. If the Chimney Rock Reservoir were constructed after a first stage development with the East Branch Reservoir, the total cost of construction would be higher because of the costlier construction needed for a dam than for a causeway and the need to install an opening through the dam under operating conditions in order to convert it to causeway use. This would add between two and three million dollars to the overall cost of the project.
3. If land for expanding the supply to 200 mgd is not acquired at the same time as the land for the first stage, it may be very costly and difficult to acquire at a later date.
4. The average water storage period would be shorter for the East Branch Reservoir than for the larger Chimney Rock Reservoir. However, the storage in the East Branch Reservoir is sufficient for a large quality improvement in the water.

Plan CR-4—200 Million Gallons per Day Project Using East Branch and Dock Watch Hollow Reservoirs

Plate II-11 shows in outline how a dependable yield of 200 million gallons per day from the Raritan River Basin may be developed with the joint use of the East Branch Reservoir and the Dock Watch Hollow Reservoir.

ALTERNATE NO. 1A
NORTH BRANCH RESERVOIR
Capacity needed (compensation)
Usable - 7.6 b.g.
Total - 10.1 b.g.
Flow line elevation - 105.3

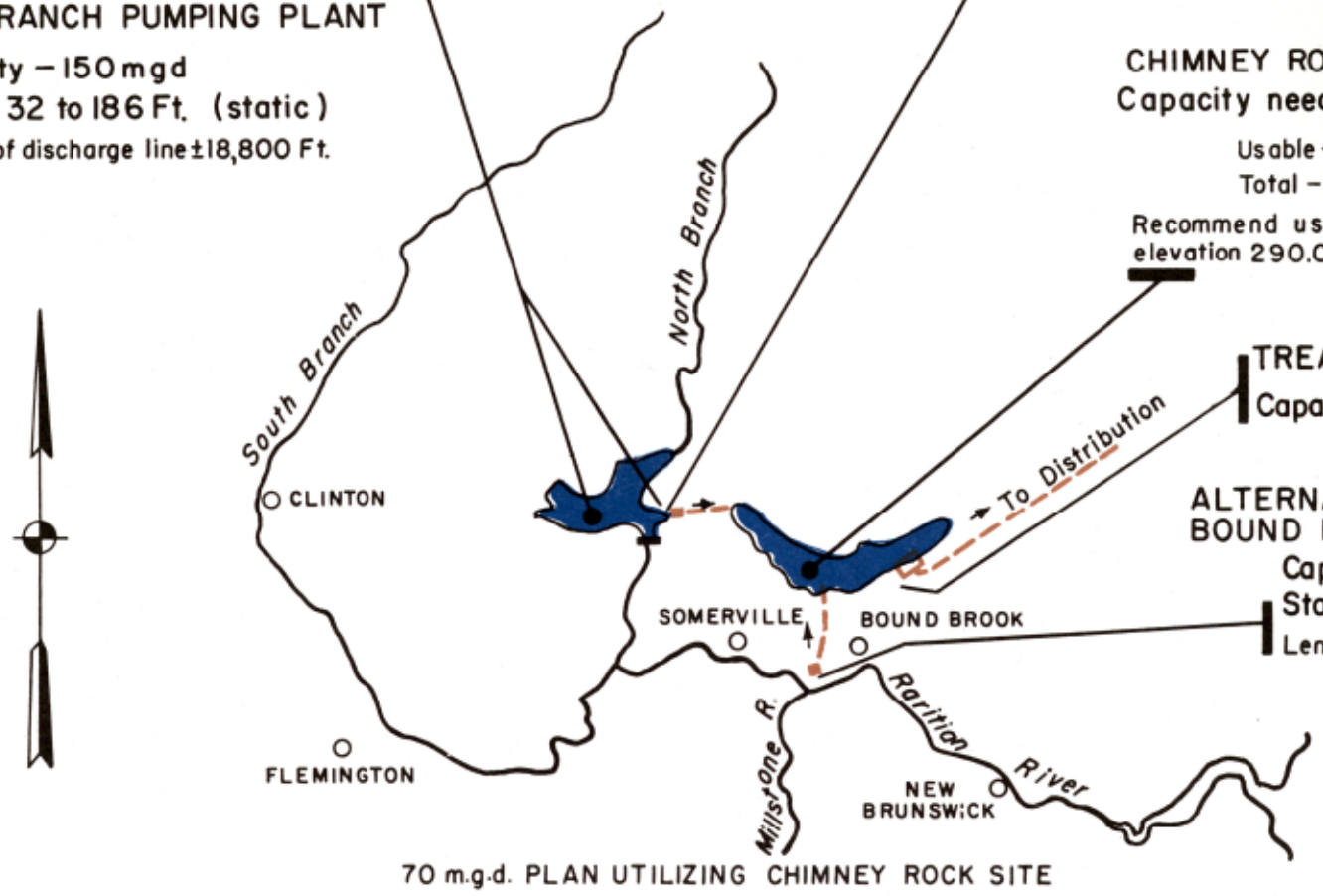
NORTH BRANCH PUMPING PLANT
Capacity - 150 mgd
Lift - 132 to 186 Ft. (static)
Length of discharge line ±18,800 Ft.

ALTERNATE NO. 1B (With N. Branch diversion dam only)
NORTH BRANCH PUMPING PLANT
Capacity - 150 mgd
Lift - 137 to 205 Ft. (static)
Length of discharge line ±18,800 Ft.

CHIMNEY ROCK RESERVOIR
Capacity needed (minimum)
Usable - 18.1 b.g.
Total - 24.0 b.g.
Recommend use of flow line elevation 290.0 - capacity 40.8 bg

TREATMENT PLANT
Capacity - 90 m.g.d.

ALTERNATE NO. 2
BOUND BROOK PUMPING PLANT
Capacity - 110 mgd
Static lift - 248 to 270 Ft.
Length of discharge line - 16,800 Ft.



70 m.g.d. PLAN UTILIZING CHIMNEY ROCK SITE
Alternate 1 - Pumping from North Branch only
Alternate 2 - Pumping from Bound Brook only

PLAN CR-1

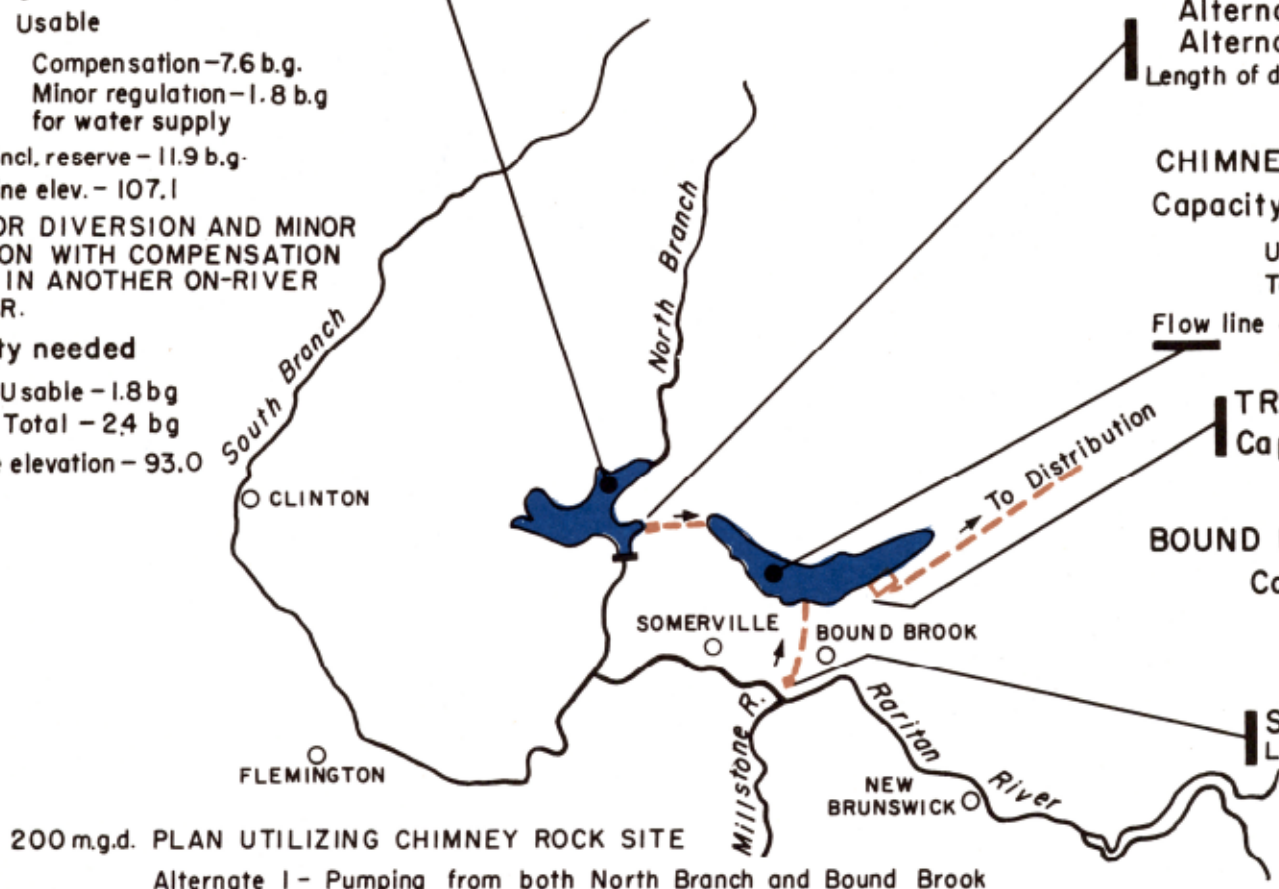
ALTERNATE NO. 1
NORTH BRANCH RESERVOIR
1A - IF USED FOR COMPENSATION, MINOR REGULATION AND DIVERSION.
Capacity needed
Usable
Compensation - 7.6 b.g.
Minor regulation - 1.8 b.g for water supply
Total incl. reserve - 11.9 b.g.
Flow line elev. - 107.1
1B - IF USED FOR DIVERSION AND MINOR REGULATION WITH COMPENSATION PROVIDED IN ANOTHER ON-RIVER RESERVOIR.
Capacity needed
Usable - 1.8 bg
Total - 2.4 bg
Flow line elevation - 93.0

ALTERNATE NO. 1
NORTH BRANCH PUMPING PLANT
Capacity - 150 mgd
Static lift
Alternate 1A - 132 to 186 Ft.
Alternate 1B - 137 to 205 Ft.
Length of discharge line ± 18,800 Ft.

CHIMNEY ROCK RESERVOIR
Capacity needed
Usable - 34.7 b.g.
Total - 40.8 b.g.
Flow line elevation 290.0

TREATMENT PLANT
Capacity - 250 m.g.d.

BOUND BROOK PUMPING PLANT
Capacity
Alternate 1A or 1B - 350 m.g.d.
Alternate 2 (without North Branch) - 500 m.g.d.
Static lift - 216 to 270 Ft.
Length of discharge line ±16,800 Ft.



200 m.g.d. PLAN UTILIZING CHIMNEY ROCK SITE
Alternate 1 - Pumping from both North Branch and Bound Brook
Alternate 2 - Pumping only from Bound Brook with compensation storage provided by any one of four on-river sites presented in connection with Plan OR-1

PLAN CR-2

PLATE II-10
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT
BASIC FEATURES OF PLANS CR-1 & CR-2

C R - 4 ONLY
DOCK WATCH HOLLOW RESERVOIR

Capacity

Usable	13.4 b.g.
Total	15.8 b.g.
Flow line elevation	455 ft.

C R - 4 ONLY
DOCK WATCH PUMPING PLANT

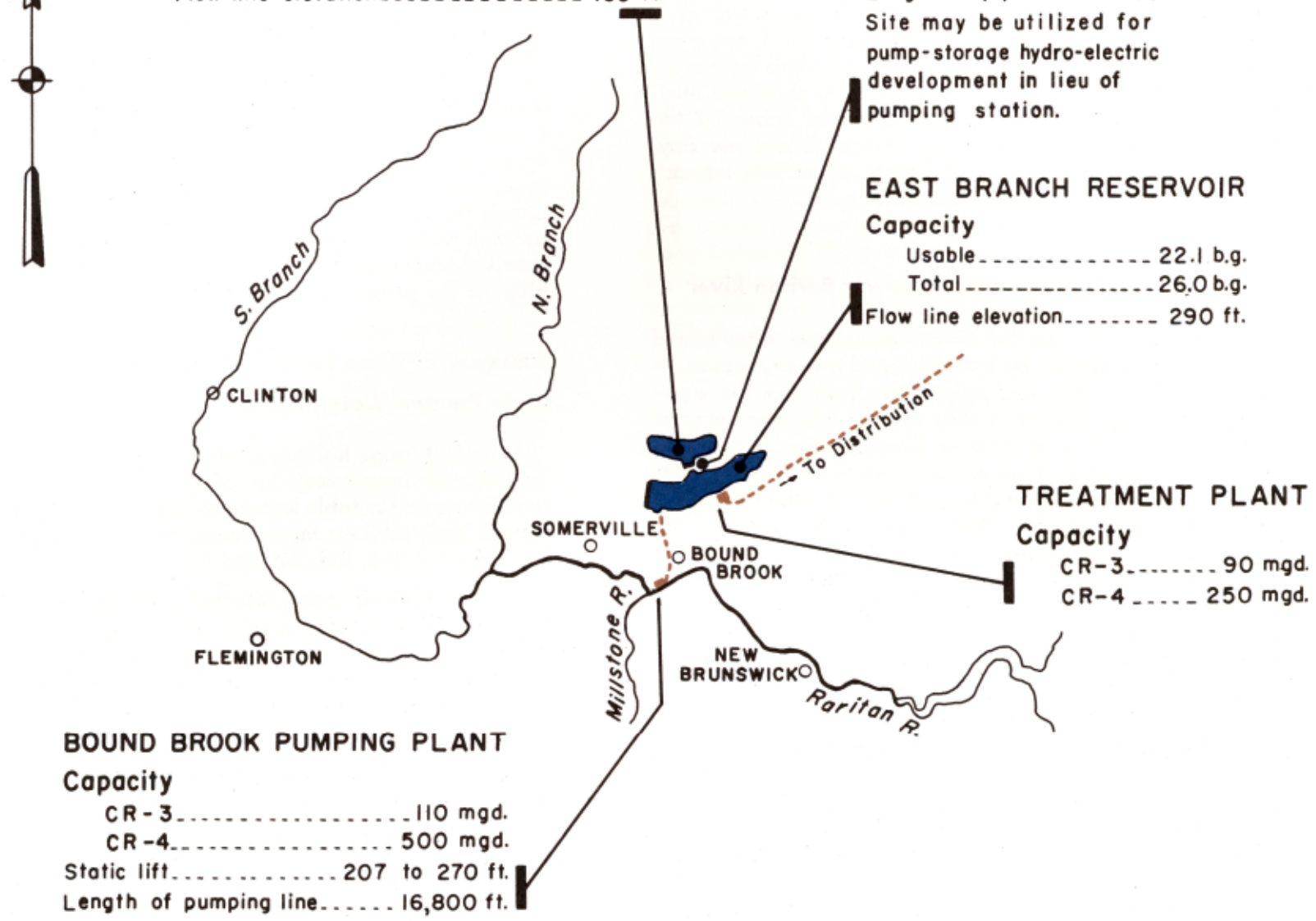
Capacity	100 mgd.
Static head	Approx. 165 ft.
Length of pipe line	1900 ft.

Site may be utilized for pump-storage hydro-electric development in lieu of pumping station.

EAST BRANCH RESERVOIR

Capacity

Usable	22.1 b.g.
Total	26.0 b.g.
Flow line elevation	290 ft.



TREATMENT PLANT

Capacity

CR-3	90 mgd.
CR-4	250 mgd.

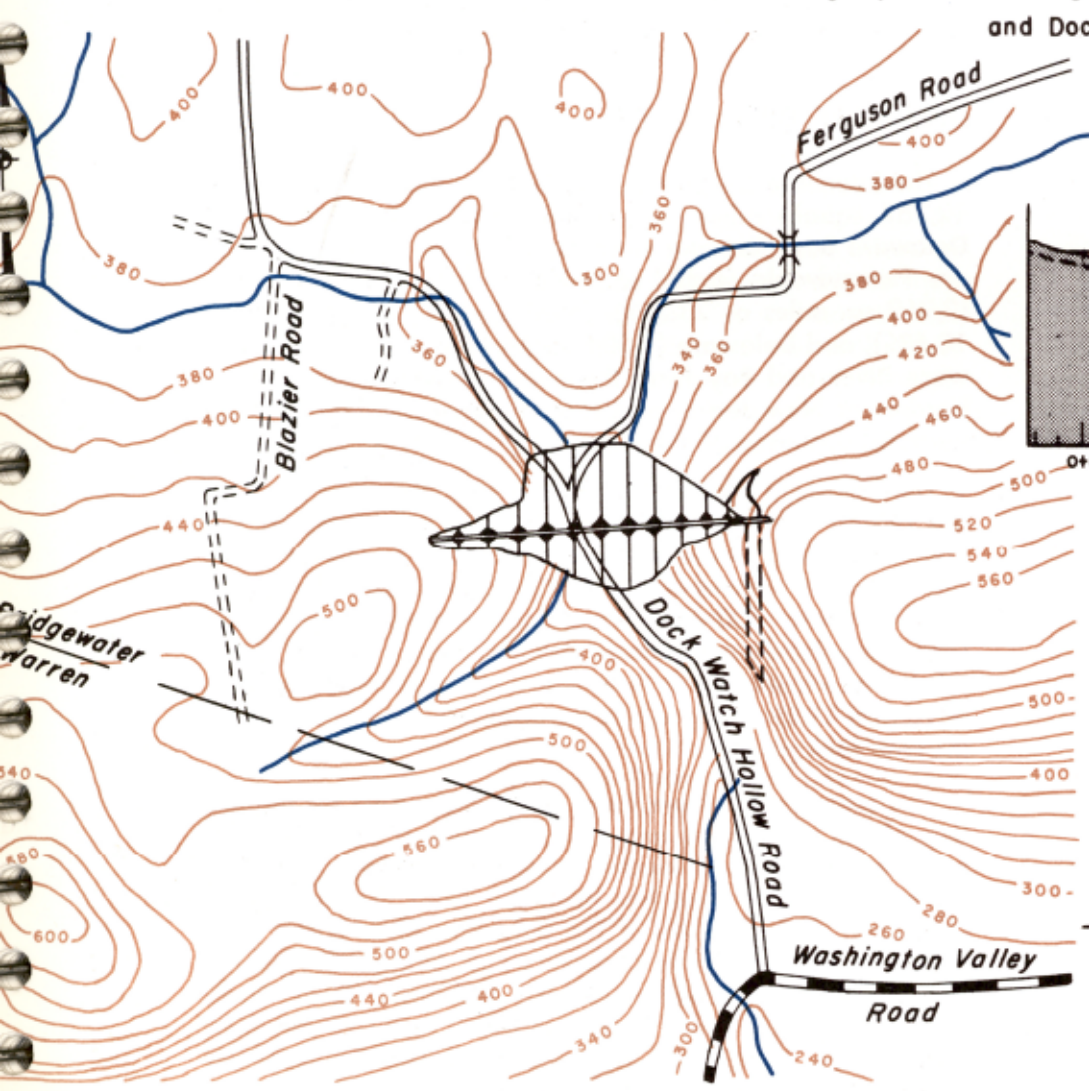
BOUND BROOK PUMPING PLANT

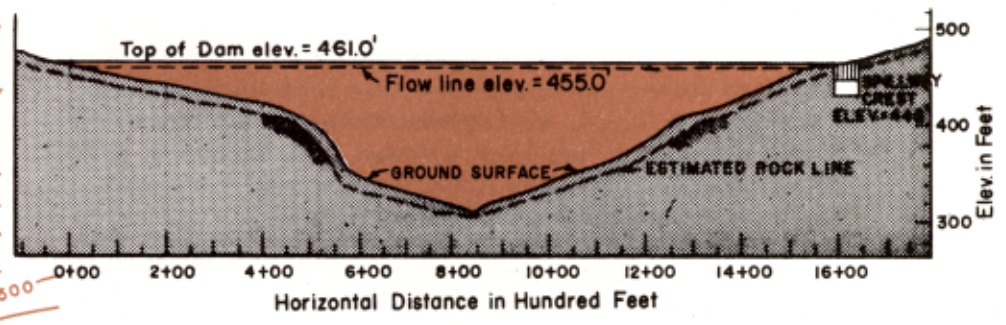
Capacity

CR-3	110 mgd.
CR-4	500 mgd.
Static lift	207 to 270 ft.
Length of pumping line	16,800 ft.

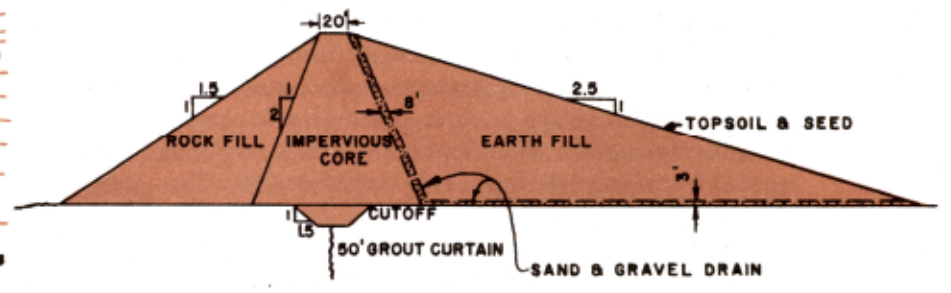
PLANS CR-3 AND CR-4

CR-3 ___ 70 mgd yield - storage in East Branch Reservoir.
CR-4 __ 200 mgd yield - storage in East Branch Reservoir and Dock Watch Hollow Reservoir.





PROFILE



DAM SECTION

0 750 1500 3000
SCALE IN FEET

PLATE
II-11
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

BASIC FEATURES OF PLANS CR-3 & CR-4,
WITH DETAILS OF DOCK WATCH HOLLOW DAM

selected as the means of developing the water supply potential of the Raritan River Basin.

The estimated costs for Raritan River Basin water supply developments using the Chimney Rock reservoir site as a whole or in part (Plans CR-1, CR-2, CR-3 and CR-4) are given in Table II-7 which follows. The costs for all plans include an on-river reservoir for the maintenance of a sustained minimum flow at Bound Brook. At the bottom of Table II-7 the total annual cost, annual cost per million gallons per day, and cost per million gallons of supply all include interest, amortization, operation and maintenance.

Surface Water Developments on Lower Raritan River

The water of the Raritan River downstream from Bound Brook, due to pollution by industrial and sanitary wastes, is not of potable quality, and below New Brunswick the water becomes progressively more salty as tidal influence becomes stronger than the flow of the river. Considerable use or re-use of the river water in these areas is made by industries for cooling and other non-potable purposes. In addition, industrial and limited potable water supplies are obtained by pumping from wells situated near the river. In general, such well pumping has lowered the ground water table below river levels resulting in a potential being established for the infiltration of water from the river into the ground water table. It is understood that the intrusion of salt water and other pollution substances into wells has been experienced in some areas along the lower Raritan River.

The proposed Middlesex County Trunk Sewer will remove many of the sources of present pollution along the lower Raritan, but it will also reduce the river flow. Unless storage facilities as herein recommended for maintenance of a sustained minimum flow of 130 mgd at Bound Brook are provided, it is probable that during dry periods the river flow will be insufficient for industrial needs and for the dilution necessary to maintain an acceptable condition in the lower river. Expansion of industrial water use, if allowed to continue normally, will aggravate this situation.

A surface water reservoir on the lower Raritan River formed by a low dam at the Crab Island site about five miles below New Brunswick (see Plate II-2), has been advocated for the following purposes:

1. To form a link in the inland waterway along the Atlantic seaboard for the benefit of small boat navigation and recreational uses.

2. To limit the zone of salt water influence in the Raritan River to the channel downstream from Crab Island, thereby providing a supply of non-brackish water for industrial sites adjacent to the river between New Brunswick and Crab Island.

3. By raising the low-water level of the Raritan River and substituting a fresh water reservoir for the tidal zone between New Brunswick and Crab Island, the fresh water recharge of the ground water table along the lower Raritan River would be increased. Saline invasion of the ground water table would thereby be arrested and water bearing sands underlying the lower Raritan valley may continue to be useable as a limited source of ground water of reasonably good quality.

The desirability of satisfying the objectives listed is evident and efforts to implement the project should be continued and encouraged. Unless some means are found to increase the ground water recharge, it is possible that pumpage of existing wells used for industrial and potable supplies may have to be curtailed or the wells abandoned. The proposed reservoir, which would have a flow line elevation somewhat higher than high tide level, would be effective in repelling salt water invasion of ground water above Crab Island and the increased elevation of the river above the dam would have a beneficial influence on ground water for recharge. In connection with this, the maintenance of a sustained minimum Raritan River flow of at least 130 mgd as herein recommended, is of utmost importance.

Practicable designs and realistic cost estimates for Crab Island dam cannot be made without the results of extensive investigation of the dam site by borings. In the absence of such data, it must be assumed that bedrock suitable as a foundation for the necessary spillway and lock structures of the dam would be found at great depth at the Crab Island site. Since the eastern coastal area of the United States has been undergoing settlement during recent geologic times, deep canyons eroded in the bedrock at the mouths of rivers during earlier geologic times have become filled with river-borne sediments. Such sediments, which may have attained a thickness of as much as 200 feet at the Crab Island site, would not furnish adequate support for the major concrete structures required. Removal of such a depth of sediment to permit the concrete structures of the dam to be founded on bedrock would undoubtedly be very costly and would require detailed investigation and study before the economic feasibility of the project can be determined.

Summary of Plans for Development of Raritan River Basin Potable Water Supplies

Table II-8 (page II-41) presents for convenient comparison, capital and annual costs for all of the plans presented for development of potable water supplies from the Raritan River source. Basic costs for the various plans have been presented in Tables II-2, II-3, II-5, II-6 and II-7.

The summarized costs presented in Table II-8 reflect only development of potable supplies at the point of common delivery at or near Bound Brook, and do not include costs of transmission and distribution facilities which are developed in Chapter V. Complete project costs, including the transmission system are presented in Chapter VI.

Costs in Table II-8 include the treatment of water and either the delivery of the water to off-river storage in Round Valley, Chimney Rock or East Branch Reservoirs or delivery at a pressure head equivalent to the flow line elevation of the Chimney Rock Reservoir (290 feet). In order to place all plans on a more equitable basis of comparison, the on-river plans and the Round Valley plans using stream channel delivery to Bound Brook have had included in Table II-8 the costs of a reserve storage in the Dock Watch Hollow Site for emergency deliveries to the transmission system by gravity. This reserve volume is computed on the basis of 125 percent of the average yield for a period of seven days.

DELAWARE RIVER BASIN

The interstate Delaware River Basin comprises an area of 12,757 square miles not including the water surface of Delaware Bay. The four states in which the basin is located are Pennsylvania (6,422 sq. miles or 50.3%), New Jersey (2,969 sq. miles or 23.3%), (New York 2,362 sq. miles or 18.5%), and Delaware (1,004 sq. miles or 7.9%). The Delaware River and Bay form the entire western and southern borders of New Jersey and receive approximately 40% of the total drainage of the state.

The Delaware River carries a large annual volume of water but during the late summer and early fall, flows at the Trenton gaging station have been recorded as low at 1,200 cubic feet per second or 780 million gallons per day. Flood flows of nearly 300 times this amount have been recorded. Damaging floods, particularly on the tributary streams, have taken place from time to time. The most recent was the flood of August 1955 during which the greatest recorded flows of the river took place.

Numerous studies have been made in the past for regulation of the river flows and the utilization of its waters for potable supplies and electric power generation. The most comprehensive of these has been the 1950 "Report on the Utilization of the Waters of the Delaware River Basin" prepared by Malcolm Pirnie Engineers and Albright & Friel for the Interstate Commission on the Delaware River Basin (INCODEL). This report recommended a series of developments which would have appreciably raised the minimum flows in the river and provided major additions to the water supplies of the Northeastern New Jersey, New York and Philadelphia Metropolitan areas.

The failure of the Commonwealth of Pennsylvania to ratify a compact for interstate development of the Delaware River led to unilateral development of the portion of the basin

within New York State by the City of New York for its potable water supply. The City has completed or has under construction in the upper Delaware Basin three large reservoirs, Neversink, East Branch, and Cannonsville, with a reported usable capacity of 275 billion gallons of water. From these reservoirs the City will be able to divert 800 million gallons per day for potable use and in addition supply compensation releases to augment the low flows of the river in accordance with decrees of the United States Supreme Court.

Since the Delaware River is an interstate stream, jurisdiction over the use of its water has been assumed by the Supreme Court of the United States and no water may be diverted outside of the basin, from the river or any of its tributaries, without prior approval of that judicial body. In the case of the New York City diversion, a principle of compensation releases known as the "Montague Formula" has been established, which requires the City to release water at the rate of 0.66 cubic ft. per second per square mile of drainage area above the Neversink Reservoir whenever the flow falls below 1,750 cubic feet per second at the Montague, N. J. gaging station, or below 3,400 cubic feet per second at Trenton, N. J. After completion of the East Branch and Cannonsville Reservoirs, the City will be required to release sufficient water to maintain a minimum basic rate of flow of 1,750 cubic ft. per second (1,131.1 million gallons per day) at Montague. In addition to the releases for maintaining the basic minimum flow, the City must release a variable amount of water depending upon the estimated yearly requirement of the City and the quantity of water available.

New Jersey has been authorized by the U.S. Supreme Court to divert 100 million gallons of water per day from the Delaware River Watershed without compensation releases. The diversion is limited to a monthly average of 100 mgd with a daily maximum of 120 mgd. Diversions by the State of New Jersey of Delaware Basin water for use outside of the watershed in excess of an average of 100 mgd shall not, in accordance with the 1954 Supreme Court decision, be made during the months of July, August, September, and October and shall require compensating releases. The extent of the compensating releases is not specifically stated but may be assumed to be of the same order of magnitude as required for New York State.

Following the unilateral action by New York for the development of its Delaware Basin water resources, the State of New Jersey and the Commonwealth of Pennsylvania started negotiations toward a cooperative development of the river which forms a continuous border between the two States. In 1953 New Jersey enacted legislation (Chapter 443 of the Public Laws of 1953) empowering Pennsylvania to construct a dam and reservoir on the Delaware River at Wallpack Bend. The State of New Jersey retained the right to participate in the cost of and acquire a proportionate interest in the project up to 30%. This act was to become effective if concurred in by the Commonwealth of Pennsylvania before July 1, 1955, and if construction was to be authorized by Pennsylvania within fifty years of the effective date. The General Assembly of Pennsylvania passed concurring legislation in 1955 (House Bill No. 582, Session of 1955).

On September 1, 1955, the consulting engineering firm of Albright & Friel submitted a report to the Commonwealth of Pennsylvania on the Wallpack Bend Dam and Reservoir. This report gives a complete analysis of the combined effect on the river flows of the compensating releases by New York City and the operation of the proposed reservoir at Wallpack Bend. The report also covers the flood control benefits that may be derived from the operation of the reservoir, power generation possibilities, recreational facilities, and up-to-date cost estimates of the project.

The report shows that if the reservoir is operated primarily for river regulation, it can sustain a minimum flow of 3,400 cfs at Trenton during a dry period equal to the longest recorded period of low flows on the Delaware River (1930-32). The flood control benefits to be derived from the project are largely incidental and would depend on the storage volume available in the reservoir at the time of a flood and on the amount of water that can be released from the reservoir in advance of a flood, based on weather forecasting. The project is estimated by Albright & Friel to cost $70,454,125.50 including the hydro-electric generating plant and recreational facilities on the Pennsylvania side.

The Wallpack Bend project would provide many benefits to New Jersey and Pennsylvania. The augmentation of the low river flows would improve the downstream quality of the water for potable and industrial uses, would prevent the encroachment of saline waters in the tidal portion of the river, help to maintain optimum conditions for oyster growing in the Delaware Bay, improve navigation and provide the compensating water necessary for increased diversions of Delaware water outside of the watershed.

From the standpoint of water supply the Wallpack Bend Reservoir, through quality improvement and salinity retardation, would prevent the deterioration of well supplies in the lower Delaware Valley which depend on induced river water infiltration and may put off for an indefinite period the need to develop new inland sources for this area. It would also facilitate the diversion of water to the Northeastern Region.

The basic minimum flow of 3,400 cfs at Trenton, which can be regulated with the Wallpack Bend Reservoir is 60% higher than the minimum flow that could have been provided during the record low flow of 1930 with New York City releases alone. The additional augmentation of low flows of the Delaware River by Wallpack Bend Reservoir releases should, therefore, be equivalent to compensation releases necessary for a diversion greater than that made by New York City, assuming that the Supreme Court requirement would be the same as for New York City. The anticipated growth of the Northeastern Region of New Jersey will require in addition to the expansion of existing water systems, approximately 300 mgd of major new water development before the year 2000. Even if this requirement were met entirely with Delaware water, it is reasonable to assume that New Jersey's proposed share of the Wallpack Bend Development would furnish the compensation necessary for a diversion of this size.

In the studies made of the diversion of Delaware Basin water for use in the Northeastern Region of New Jersey to the year 2000, it was assumed that development would take place in accordance with one of the following two basic programs:

1. Diversion from the Delaware Watershed to meet all of the estimated water requirements after expansion of existing systems or 300 million gallons per day, hereafter referred to as a primary supply.

2. Diversion from the Delaware Watershed to meet the estimated water requirement after expansion of existing systems and full economic development of the Raritan River Basin or 100 million gallons per day, hereafter referred to as supplementary supply.

Existing Delaware River Diversions

Delaware River water is being used for potable purposes in New Jersey by the cities of Trenton and Camden and most of the other towns and cities adjacent to the river. Diversion is made either directly from the river, as at Trenton, or indirectly from wells and filter galleries fed largely by infiltration of river water. Such use of Delaware River water within the drainage basin does not require the approval of the Supreme Court because practically all of the water is returned to the river. So long as water of potable quality is available in the Delaware River or in adjacent ground water such supplies may be tapped as needed for use in the Delaware Basin subject only to the laws and regulations of the State of New Jersey.

In general the water of the main Delaware River upstream from the mouth of Lehigh River is of good quality. Efforts have been made recently to reduce the industrial pollution in the Lehigh, and some quality improvement has been achieved. See Appendix J for the analysis of water samples taken at various locations along the Delaware and Raritan Rivers.

Delaware and Raritan Canal

At present the Delaware and Raritan Canal is the only facility in New Jersey used for diverting Delaware River water outside the Delaware drainage basin. This canal, originally constructed in 1830 as a navigation canal, was deeded to the State of New Jersey by its private owners in 1937. In 1944, by enactment of Chapter 172, the canal was dedicated

to industrial water supply and recreation use. That law was supplemented in 1949 by Chapter 168, to include sales to water supply systems for potable and public use. Rehabilitation of the canal to restore carrying capacity permitted water deliveries to consumers to begin in 1951. Existing contract entitlements for water deliveries from the canal are listed below:

For Potable Use	*mgd*
Elizabethtown Water Company	22.500
City of New Brunswick	7.500
Lambertville (Pending)	.450
	30.450
For Industrial, Non-Potable Use	
American Cyanamid	11.000
Johnson and Johnson	2.326
Bakelite Div. of Union Carbide	2.000
Public Service Electric and Gas	1.600
Other	1.550
	18.476

The canal has sufficient capacity to carry the permitted diversion of 100 mgd of water from the point of diversion at Raven Rock to the divide between the Delaware and Raritan watersheds. Losses from the canal between that point and New Brunswick amount to about 25 mgd. Thus, a total of 75 mgd can be delivered to connections along the canal after it leaves the Delaware Basin. Of the total of 48.926 mgd of canal water now under contract or pending applications, 47.676 mgd are subject to the 100 mgd restriction on diversions from the basin, leaving 27.324 mgd of canal capacity presently unallotted.

The Elizabethtown Water Company has recently made application for an increase in its contractual allotment to Delaware and Raritan Canal waters. Action on this application has not been taken; however, it may be assumed that opposition will be voiced by interests in favor of reserving the presently unused canal capacity to supply normal expansion by existing industries or to supply cheap non-potable water for future industrial locations along the canal route.

Preliminary studies have been made of improvements to the canal such as enclosing the waterway or replacing portions of it by pipelines. Such improvements are desirable to prevent pollution of the canal water and damage to the canal itself by flood flows which occur from time to time in the Trenton area, and to reduce canal losses. It would be possible by these improvement measures to increase the carrying capacity of the canal to about 150 mgd. However, diversions in excess of 100 mgd from the Delaware River basin cannot be made without the approval of the Supreme Court of the U.S. and provisions for compensation of low water flows according to criteria to be established by that court. It is probable that the compensation flow requirements would be similar to those decreed by the Supreme Court for operation of the New York City reservoirs.

Further consideration should be given to improvement of the canal since industry is establishing along the highway and railroad lines between Trenton and New Brunswick, which is an area with relatively meagre water resources. The canal could be an important factor in the industrial development of this area.

Delaware River Diversion Plans Investigated

Twelve plans for the diversion of Delaware River water to the Raritan or Passaic River basins have been investigated. These plans consider using various combinations of Wallpack Bend, Flatbrook, Round Valley or Chimney Rock reservoirs to provide the storage needed for water supply and Delaware River Regulation. Diversion plans are divided into groups in accordance with the reservoir combinations used;

Diversions using Wallpack Bend and Flatbrook Reservoir.
This group is subdivided into:
DG plans in which water is diverted by gravity tunnels either to the Raritan Basin or the Passaic Basin.
DP plans in which water is diverted by pumping into the Raritan Basin.

Diversions using storage in Round Valley Reservoir.
DRV plans for diversions of 130 and 300 million gallons per day.

Diversion using Flatbrook Reservoir only.
DG plan for diversion of 100 mgd.
DP plan for diversion of 100 mgd.

The following presentation describes each of the plans studied and gives their advantages and disadvantages.

Diversions Using Wallpack Bend and Flatbrook Reservoirs

Eight of the diversion plans studied contemplate the combined use of Wallpack Bend and Flatbrook Reservoirs. These two reservoirs would be adjacent to each other, the first being formed by a dam on the Delaware River just above the conjunction of Flatbrook and the main river, and the second by a dam on Flatbrook just before it joins the Delaware River. Both reservoirs are described in the 1950 INCODEL Report and the Wallpack Bend Dam and Reservoir Report of 1955 treats this site in more detail.

In connection with water supply diversion for Northeastern New Jersey, the Wallpack Bend Reservoir would be used to provide the water necessary to meet anticipated requirements of the U.S. Supreme Court as compensation for diversions outside of the Delaware Basin. The reservoir would be formed by a concrete dam approximately 170 ft. high above bedrock. The maximum water level of the reservoir would be at elevation 420 and would be controlled by a row of 17 Tainter gates 24 feet high. The height of the structure from average water elevation below the dam to the top of the Tainter gates would be 95 feet. A reservoir 26 miles long would be created, extending from Bushkill, Pennsylvania to Port Jervis, New York, with a total capacity of 121 billion gallons and a usable capacity of 91 billion gallons. The volume of the storage held between the top and bottom of the Tainter gates would be 62 billion gallons. The total estimated cost of the dam and reservoir including road relocation, hydro-electric generating plant, fishway and recreational areas in Pennsylvania is $70,500,000. In the use of the river regulation afforded by the Wallpack Bend Reservoir to compensate for out-of-basin diversion by New Jersey, it has been assumed that the State of New Jersey would participate in this project to the extent of 30% as provided in the legislation passed by both New Jersey and Pennsylvania.

The Flatbrook Reservoir would be used to impound water from the Flatbrook Watershed in New Jersey (65 square miles) and to store Delaware River flood waters by pumping from Wallpack Bend Reservoir when permissible under the U.S. Supreme Court Decree of 1954. Flatbrook Reservoir would be created by an impervious core earth dam about four-fifths of a mile upstream from the junction with the Delaware River. By constructing a dam approximately 185 feet high with a flow line elevation of 520, the reservoir would have a total storage capacity of 84 billion gallons and a usable storage of 63 billion gallons. This is a greater storage capacity than can normally be filled from the drainage area of Flatbrook alone, and hence the necessity to pump from the Delaware River.

Geological and engineering inspections of the Wallpack Bend and Flatbrook Dam and Reservoir sites were made. These inspections confirm the suitability of the sites for the types of dams proposed. Considerable exploratory boring will have to be carried out at each of the sites to determine cut-off requirements and other design details.

Of the eight plans considered which use Wallpack Bend and Flatbrook Reservoirs, six divert water into the Raritan River Basin and two into the Passaic River Basin. Three of the six diversions to the Raritan Basin are by gravity tunnel from the Delaware River into a tributary of the Raritan River, and three are pumping diversions from the Delaware River to Raritan tributaries. The two diversions into the Passaic Basin are by gravity tunnels from Flatbrook to existing Passaic Basin reservoirs.

A common condition of five of the six diversions to the Raritan Basin using Wallpack Bend and Flatbrook Reservoirs is the delivery of water by natural stream channels to Bound Brook, from which point it is pumped directly to the transmission mains. All cost estimates for these systems include

pumping equipment to make delivery at a pressure head of 290 feet or equivalent to the flow line elevation of Chimney Rock Reservoir. The sixth diversion in the group is a direct pumping line from the Delaware River to Bound Brook with a pressure level delivery of 290 feet at the transmission main.

A disadvantage of all six of the above Delaware to Raritan diversions is the complete dependence on power for the maintenance of service. To overcome this, there has been added to the basic cost of delivering water to Bound Brook at a pressure level of 290 feet, the cost of providing a seven day, high level, emergency storage in Dock Watch Hollow. This provides a degree of safety against interruption to service due to electrical power failure and mechanical breakdown, but is not the equivalent, either in dependability or water quality improvement, of full scale, high level, deep storage such as provided by Chimney Rock, East Branch or a fully developed Dock Watch Hollow Reservoir.

The eight diversions using Wallpack Bend and Flatbrook Reservoirs may all be developed for the full 300 million gallons per day required if Delaware River water is used as the major primary source for future Northeastern Region water supplies, and they may also be developed as a supplementary Northeastern Regional supply of 100 mgd. Several of the diversions of this group may be developed with relative economy in stages corresponding in growth requirements. The special characteristics of each diversion is brought out in the following presentation for the individual plans. Plate II-12 shows the location and general features of the plans.

Plan DG-1—300 Million Gallons Per Day Gravity Diversion to Raritan Basin. This plan calls for the construction of a tunnel from Frenchtown on the Delaware River to a point below Three Bridges on the South Branch of the Raritan River. The tunnel would be concrete lined, 144 inches in diameter and 76,000 feet (14.4 miles) long. A low diversion dam would be required on the Delaware at Frenchtown to channel the flow into the tunnel head.

Water would flow by gravity from the Delaware River to the South Branch of the Raritan River and hence by natural stream channels to Bound Brook. A low diversion dam on the Raritan River at Bound Brook would channel the flow to a low lift pumping station which would lift the water for passage through coagulation tanks. Water would then be pumped by a high lift station through pressure filters directly to the transmission mains. If a seven day emergency supply is stored in Dock Watch Hollow Reservoir, an additional pumping plant, a force main and the development of the reservoir would be required. Through proper valve arrangement the force main to Dock Watch Hollow can be used to feed the emergency supply back to the transmission system.

Plan DG-1 is for the delivery of a basic supply of 300 million gallons per day. Since storage is at Flatbrook in the Delaware Basin, the necessity for carrying flood water through the tunnel for storage is eliminated. The capacity of the tunnel as well as of the pumping and treatment works at Bound Brook has been computed at 125% of average flow or 375 million gallons per day.

The principal advantage of the diversion route used in Plan DG-1 is that it is the shortest gravity diversion from the Delaware River into the Raritan Basin. (76,000 feet compared with 81,000 feet for Plan DG-3, the next shortest route studied.)

The Frenchtown diversion has the disadvantage of being located below the discharges of the Lehigh River and other streams carrying polluting matter. The quality of water at Frenchtown is, therefore, likely to be poorer than some of the other diversions studied. Plan DG-1 has a further disadvantage in that it cannot be economically constructed in stages or for a 100 mgd supply. The major portion of the project cost is in the tunnel which must be constructed for its full length, and savings in cost by reduction in the size of the tunnel to carry 100 mgd is small compared with the reduction in capacity. Accordingly, cost data presented on Table II-9 does not reflect stage construction.

Plan DG-2—300 Million Gallons Per Day Supply by Gravity Diversion to Raritan Basin. This plan would divert water from the Delaware River at Stockton and convey it by gravity tunnel to Beden's Brook, a tributary of the Millstone River. The water would then flow by natural stream channels to the Bound Brook diversion treatment and pumping plant, from where it would be delivered to the transmissions mains at a pressure head of 290 feet. The diversion works on the Delaware and Raritan Rivers, low lift pumps, coagulation basin, treatment plant and high lift pumping station would all be similar to those required for Plan DG-1.

The tunnel from the Delaware River at Stockton to Beden's Brook would be 156 inches in diameter after lining with reinforced concrete and 86,000 feet (16.3 miles) long.

This plan has no advantage over the others studied. Water quality may be somewhat better than at Frenchtown, but the difference is not likely to be of sufficient significance to influence the selection of the diversion route in preference to the others considered. The tunnel would be nearly two miles longer than in DG-1 and costlier per unit of length because of its greater size. The terminus of the Stockton-Beden's Brook tunnel would be in a stream with a limited waterway and would require some channel enlargement and bridge reconstruction in order to carry the tunnel discharge to the Millstone River.

The diversion location of Plan DG-2 is the lowest downstream point on the Delaware River that is practicable for a gravity delivery of water to the Raritan River at Bound Brook. The route was studied primarily as an alternate to the use of the Delaware and Raritan Canal for an increased diversion from the Delaware River. The DG-2 tunnel, as contemplated, would start about three-quarters of a mile downstream from the intake of the canal and possibly some savings could be effected by making the diversion from the canal instead of directly from the river. This would require an increase in the capacity of the short length of canal above the point of intersection with the tunnel. The change, however, would not alter the relative desirability of Plan DG-2 as compared with others.

Plan DG-2 is basically for a 300 million gallons per day supply. It has the same inflexibility as Plan DG-1 with respect to stage construction and is even less desirable from a cost standpoint for a supplementary 100 mgd supply. Cost estimates for this plan given in Table II-9 do not reflect the increased costs which would apply to stage development.

Plan DG-3—300 Million Gallons Per Day Diversion to Raritan Basin. This plan contemplates the construction of a tunnel to deliver water by gravity from the Delaware River above Belvedere to Spruce Run, a tributary of the South Branch of the Raritan River. The tunnel would be concrete lined, 132 inches in diameter and 81,000 feet long (15.3 miles). From the terminal point of the tunnel at Spruce Run, water would be carried by natural stream channels to Bound Brook and pumped to the transmission system in the same manner as described for Plan DG-1.

All requirements for the Belvedere-Spruce Run diversion will be similar to those for the Frenchtown diversion described under Plan DG-1. Although the length of the tunnel in Plan DG-3 is approximately one mile longer than for DG-1, the tunnel size required is smaller because of the greater head available between the tunnel intake at the Delaware River and the tunnel discharge at Spruce Run. This factor practically equalizes the cost between the two plans.

The Belvedere diversion has the advantage of being located above the Lehigh River, and the water diverted would therefore not be subject to the polluting influences that are encountered at lower points.

The basic plan for the Belvedere diversion is for a 300 mgd primary supply. This diversion route would appear to have favorable possibilities for stage construction since the tunnel passes under the Musconetcong River, the Pohatcong Creek, and the Pequest River. By creating storage on these streams and diverting them into the tunnel, it would be possible to build and operate this plan for progressively increasing yields without constructing the entire length of tunnel to the Delaware River in the first stage. The net yields that may be expected from the three Delaware Basin streams at the intersection with the tunnel route, after allowances for compensation of Delaware flows and for minimum flows below the dams, are approximately 40 mgd for the Musconetcong River, 5 mgd for Pohatcong Creek and 48 mgd for the Pequest River including Beaver Brook. In order to tap the 40 mgd from the Musconetcong will require a tunnel 4.8 miles in

length. The next increase would necessitate 3.3 miles of additional tunnel to the Pohatcong for only about 5 mgd of additional supply. The next step to the Pequest River will require a total tunnel length of 14.5 miles which is only 0.8 miles short of going to the Delaware River.

It is obvious from the above that the spacing of the water sources along the Belvedere-Spruce Run tunnel and the sizes of the resources available are too uneven for economic stage planning. If the diversion was being developed as a primary source with a desirable first stage of 70 mgd and an ultimate stage of 300 mgd, it would be necessary to drive the tunnel to the Pequest or within 0.8 miles of the Delaware River in order to obtain sufficient water for the first stage. Since the tunnel would have to be the full size for the ultimate stage, the reduction in capital expenditure for the first stage would be relatively small. For the development of the Belvedere-Spruce Run tunnel for a supplementary supply of 100 mgd the same conditions would apply.

Stage construction of Plan DG-3 to utilize flows of the intercepted Delaware tributaries would need dams and reservoirs to store water for compensation, minimum releases and water supply on the Musconetcong River, Pohatcong Creek, Pequest River and Beaver Brook. The construction of these four reservoirs will be considerably more costly than the construction of a single large capacity reservoir at the Flatbrook site. Since the tunnel would in any event have to be driven to the Delaware River or within 0.8 miles of the river, greater economy can be achieved through the use of Flatbrook Reservoir with a diversion from the Delaware at Belvedere as compared with individual diversions from the Delaware tributaries. Stage construction of the Belvedere-Spruce Run diversion tunnel does not appear to be economically feasible either for a primary water supply of 300 mgd or a supplementary supply of 100 mgd. Plan DG-3 is, however, the most favorable gravity diversion from the Delaware Basin to the Raritan Basin, both as to location and cost of construction.

Plan DG-4—300 Million Gallons Per Day Gravity Diversion to Passaic Basin. This plan would take water by gravity tunnel from Flatbrook Reservoir to the Boonton Reservoir of the Jersey City System, located on the Rockaway River in the Passaic Basin. A concrete-lined tunnel 165,000 feet (31.2 miles) long and 120 inches in diameter would be required. Water would be delivered at elevation 305, the flow line elevation of the Boonton Reservoir.

The tunnel would be designed to carry 125% of the average yield or 375 mgd. Boonton Reservoir would act only as the eastern terminus for the tunnel and would not be utilized for storage purposes for the new supply. Changes to increase the capacity of the Boonton Reservoir are, therefore, not contemplated as a part of this plan. New treatment works and transmission facilities to the demand areas would be required as a part of the total development.

A diversion tunnel from Flatbrook Reservoir directly into the Northeastern Region could be constructed without the use of Boonton Reservoir as a terminus. This, however, would considerably increase the length of tunnel required. Also the use of Boonton Reservoir would provide a certain amount of balancing, even though the storage of the reservoir was not increased, which would be beneficial in the operation of the system.

Plan DG-4 for the diversion of Delaware water into Boonton Reservoir would be an excellent solution for an immediate or near future demand for additional supplies of 300 million gallons per day. Such a supply would be of high quality and could be fed by gravity to most of the service area. The large storage at Flatbrook Reservoir would insure dependability even though the reservoir is filled by pumping from the Delaware. Although the capital cost for this plan as well as for DG-5, is much higher than for other plans studied, operating costs are lower and therefore the cost of water on the basis of a 300 mgd supply does not vary greatly from Delaware diversion plans with less desirable characteristics.

Plan DG-4, however, cannot be constructed in stages. It will require the full tunnel length and both Wallpack Bend and Flatbrook Reservoirs for its proper operation. These items constitute practically the entire construction cost. Since the demand studies indicate that, following the expansion of existing supplies, the need for adding a total of 300 million gallons per day to the Northeastern Region's water supplies would not take place until 1995 (see Plate V-2), the necessity to carry the full capital cost of the plan on a partial usage of the water for so long a period, makes it economically unfeasible.

In view of the above, a detailed study of water transmission from Boonton Reservoir to demand areas in the entire region was not made. The general transmission requirements from Boonton were compared with the transmission system from Bound Brook, and this comparison indicates that the cost of the two systems would not differ greatly on final cost. Supplies from Bound Brook, however, are closer to areas of early demand which would not normally be supplied from the proposed expansion of existing systems. Therefore the early capital expenditure for transmission favors a supply from the Bound Brook area.

Plan DG-5—300 Million Gallons Per Day Gravity Diversion to Passaic Basin. This plan is similar to DG-4, except that the terminal point of the tunnel from Flatbrook Reservoir would be in the Wanaque Reservoir of the North Jersey District Water Supply Commission. The tunnel required for this route would be 120 inches in diameter, the same as in DG-4 and the length would be 155,000 feet (29.3 miles) or about 2 miles less than the Flatbrook-Boonton tunnel.

For the same reasons discussed under Plan DG-4, the Flatbrook-Wanaque diversion cannot be economically developed in stages approximately equal to the growth in water usage in the Northeastern Region.

Plan DP-1—300 Million Gallons Per Day Pumping Diversion to the Raritan Basin. This plan calls for the construction of a pumping station on the Delaware River north of Lambertville (see Plate II-12), and a force main from this location directly into the Bound Brook headworks of the transmission system. The force main for stage development would require three pipes (1 of 72 inches and 2 of 84 inches diameter) each approximately 144,000 feet (27.3 miles) long. The pumping plant in the final stage would have a rated capacity of 375 million gallons per day.

In delivering 375 million gallons of water per day over the DP-1 route a total head of 384 feet, including a static head of 240 feet would have to be overcome. A study of the profile of the force main route indicates that this plan would present many operational problems. This condition, together with high construction and operation costs, makes the plan unattractive compared with other plans for both pumping and gravity diversions. (See Table II-9.)

Plan DP-1 was studied primarily to determine the economics of a pumping diversion route between the Delaware River and the Raritan Basin which avoided the use of natural stream channels for any part of the delivery to Bound Brook. This offered some advantages in operational control and avoided any possibility of added pollution from Raritan Basin water. However, since treatment will in any event be essential for Delaware water diverted at Lambertville, these advantages are not sufficient to warrant the higher capital expenditure required for Plan DP-1.

The pumping diversions from the Delaware Basin to the Raritan Basin are more adaptable to stage development than the gravity diversions. The costs in Table II-9 for Plan DP-1 and other pumping diversions is for the ultimate development cost of 300 mgd using two preliminary stages of 70 mgd and 200 mgd.

Plan DP-2—300 Million Gallons Per Day Pumping Diversion from Lambertville to Back Brook. The Diversion point in this plan is also north of Lambertville, but water would be pumped only over the divide between the Delaware and Raritan Basins into a tributary of Back Brook south of Ringoes. From the end of the force main, water would flow in natural stream channels via Back Brook, the Neshanic River, South Branch and the Raritan River to Bound Brook. Approximately six miles of channel improvement will be required in the streams used for conveyance in order to handle the increased flow.

The force main from Lambertville would include one 72 inch and two 84 inch diameter pipes each 26,200 feet (5 miles) long. The pumping station would have the same capacity as for Plan DP-1 but would only be required to overcome a total dynamic head of 191 feet. The Bound Brook diversion

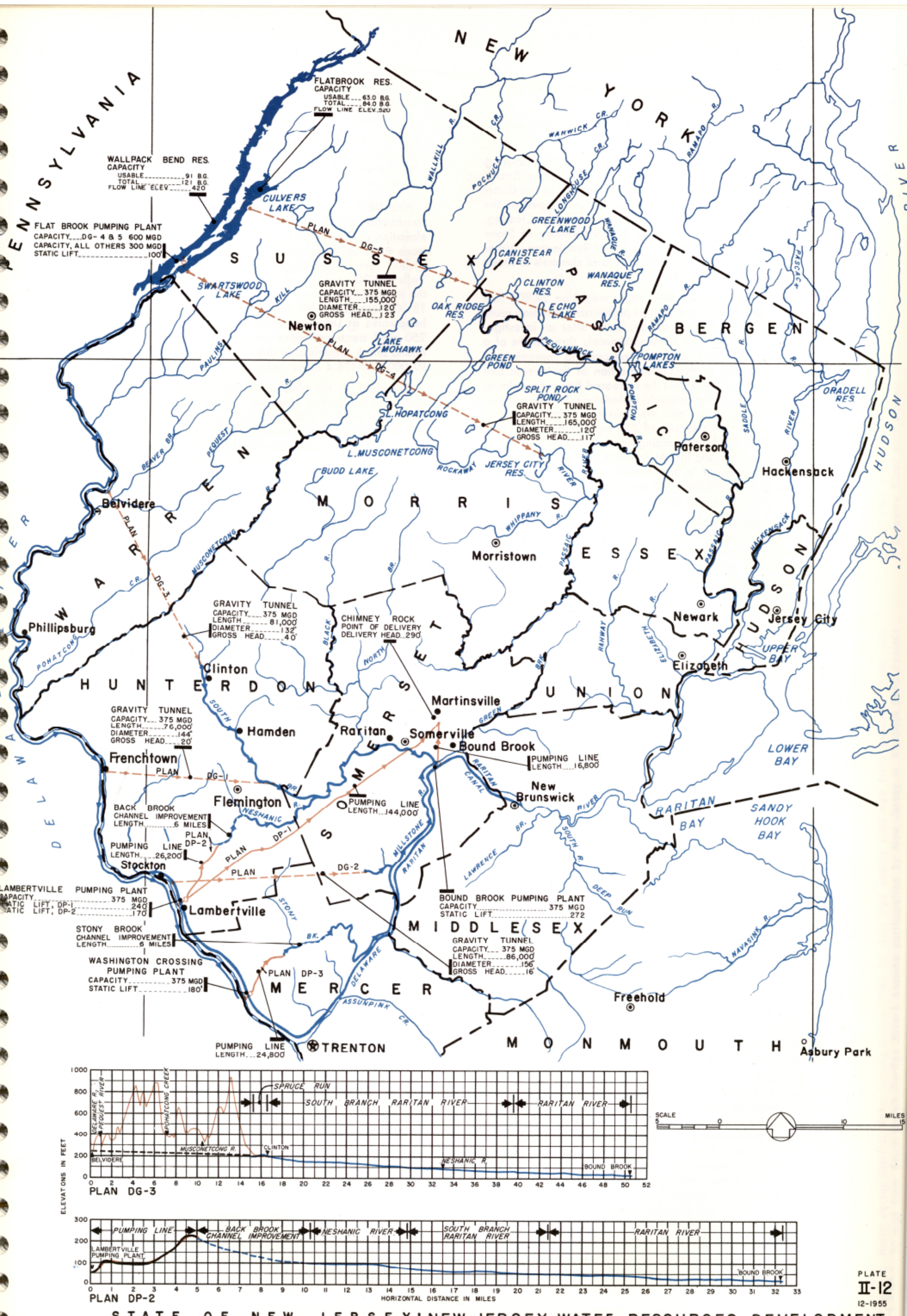


PLATE
II-12
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
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NEW JERSEY WATER RESOURCES DEVELOPMENT

GENERAL LOCATION FOR DIVERSIONS FROM THE DELAWARE RIVER WITH STORAGE AT FLATBROOK RESERVOIR

works, treatment plant and pumping station would be the same as described for Plan DG-1.

On Table II-9 costs are given for the 70 mgd, 200 mgd and 300 mgd development stages of Plan DP-2.

Plan DP-3—300 Million Gallons Per Day Pumping Diversion from Washington Crossing to Raritan Basin. This plan differs from DP-2 only in the location of the diversion route. In Plan DP-3, the diversion is from a point on the Delaware River about a mile below Washington Crossing. The force main would discharge into a tributary of Stony Brook at Baldwins' Corners just south of Pennington. Water would flow to Bound Brook via the natural channels of Stony Brook and the Millstone River.

The force main on the DP-3 route would be 24,800 feet (4.7 miles) long. This is the shortest practicable pumping route over the Delaware-Raritan divide, found after an investigation of the entire area. It is approximately three-tenths of a mile shorter than DP-2. Channel and crossing improvements on about six miles of the upper portion of the stream bed route will be required to pass the increased flows at maximum diversion. The force mains would include one 72 inch and two 84 inch diameter pipes and the Delaware pumping station would have a rated capacity of 375 mgd, both the same as for Plan DP-2. The total pumping head would be 200 feet of which 180 feet is static lift. At Bound Brook, water would be treated and pumped in the manner previously described. The total cost of DP-3 for a 300 mgd diversion based on stage development is given on Table II-9.

The pumping diversion plans with dependence on pumping at two different locations (Delaware River and Bound Brook) are particularly susceptible to service interruptions due to power failure and mechanical breakdown. A seven day emergency supply stored at Dock Watch Hollow for gravity delivery when needed is considered a minimum requirement for improving the dependability of the pumping diversion plans. The cost of adding this feature to the DP plans is given in Table II-9.

In the above pumping diversion plans presented, there is little difference in cost between DP-2 and DP-3, and no difference in the quality of the Delaware water. Plan DP-2 which would deliver water via the South Branch of the Raritan River has a slight preference over Plan DP-3 which would utilize the stream channel of the Millstone River for delivery to Bound Brook. For this reason, Plan DP-2 has been selected to illustrate stage development costs on Table II-9.

Delaware Diversion Plans Using Round Valley Reservoir

Two basic plans were studied in detail for the use of the Round Valley Reservoir Site in connection with the diversion of Delaware Basin Water. The first designated as Plan DRV-1 was for a pumping diversion of 130 million gallons per day from Frenchtown. This would be used in conjunction with Plan RV-1, which utilizes 70 mgd from the South Branch of the Raritan River, making a total yield for the plan of 200 million gallons per day. Two alternatives of the basic plan were studied—Alternate 1 uses the Wallpack Bend Reservoir to provide compensation for the diversion of Delaware water out of the watershed, and Alternate 2 uses the Flatbrook Reservoir for the same purpose. The second basic plan, DRV-2, is for the development of 300 million gallons per day, utilizing the Wallpack Bend Reservoir with the Round Valley Reservoir. The following presentation and Plate II-13 describes the principal features of these diversion plans.

Plan DRV-1—130 Million Gallons Per Day Pumping Diversion to Raritan Basin (200 mgd Total Yield). This plan is essentially the second stage of the Round Valley project proposed by the North Jersey District Water Supply Commission in their report of November 1, 1954. In this presentation it has been found necessary to make the following additions and changes to the basic North Jersey Project, in order to fully meet conditions for compensation releases to the Delaware River, as established by the U.S. Supreme Court, and requirements for pumping and transmission as determined by this investigation:

1. Wallpack Bend Reservoir or Flatbrook Reservoir are considered essential to the project for storage of compensation water.
2. Pumping capacity at the Delaware River diversion is increased to 300 mgd in order to comply with diversion restrictions.
3. Transmission of the full yield to the Bound Brook area to conform with distribution requirements and for the comparison with other plans using Bound Brook as a common point.

Plan DRV-1 as illustrated on Plate II-13 would require the construction of the Round Valley Reservoir with a flow line elevation of 380, a 300 mgd pumping station on the Delaware River at Frenchtown, a 96-inch diameter force main 71,000 feet (13.4 miles) long from Frenchtown to Round Valley, a 200 mgd pumping station on the South Branch of the Raritan River near Hamden, an 84" diameter force main 18,000 feet (3.4 miles) long from Hamden to Round Valley, headworks at Lebanon consisting of booster pumps and a 250 mgd treatment plant and a transmission aqueduct to Bound Brook comprised of three 72" diameter pipe lines each 97,000 feet (18.4 miles) long.

The yield for the plan would be 70 mgd from the South Branch of the Raritan River and 130 mgd from the Delaware River or a total of 200 mgd. It is assumed that Plan DRV-1 will be carried out as a second stage of Round Valley development after the completion of Plan RV-1 as the first stage. Under Plan RV-1 the reservoir, Hamden pumping station and force main, booster pumps and treatment plant capacity for 90 mgd and one 72" transmission main to Bound Brook would have been constructed. (See Raritan River Basin.)

There are two alternatives of Plan DRV-1 depending on whether Wallpack Bend Reservoir or Flatbrook Reservoir is used to augment the low flows of the Delaware River by compensating releases of stored water in accordance with the requirement of the U.S. Supreme Court.

Alternate 1—Using Wallpack Bend Reservoir for Compensation. This assumes that the Wallpack Bend Reservoir, as described at the beginning of the section on the Delaware River Basin, would have been constructed by the time Plan DRV-1 is developed and that the State of New Jersey participated in the project to the extent of 30 percent. Seventy-five percent of New Jersey's share of the Wallpack Bend capital cost is allocated to out-of-basin water supply benefits. This cost is reflected in Table II-9.

Alternate 2—Using Flatbrook Reservoir for Compensation. The Wallpack Bend Reservoir is an interstate undertaking and intended for a much larger regulation of the Delaware River than required for compensation releases for Plan DRV-1. In the event that the Wallpack Bend Reservoir is not in operation when DRV-1 is built it will be possible to provide sufficient storage for compensation water with a partial construction of the Flatbrook Reservoir. This may be accomplished with a considerable saving in cost as shown in Table II-9. Under Alternate 2 only sufficient compensation is provided for a diversion of 130 million gallons per day outside of the Delaware Basin. This would be far less than the regulation and incidental flood control benefits that would be provided by Wallpack Bend Reservoir.

Plan DRV-2—300 Million Gallons Per Day Gravity Diversion to Raritan Basin. This plan calls for the construction of the Round Valley Reservoir with a flow line elevation of 415.0 for the storage of Delaware water. At this elevation Round Valley would have a flooded area of 2,530 acres and would store 76.0 billion gallons of water. The plan would operate normally with Delaware water only. Storage of excess water for the regulation of the water supply would be in Round Valley Reservoir instead of Flatbrook, and compensation for the out-of-basin diversion would be provided by the Wallpack Bend Reservoir.

Diversion of Delaware water would be by gravity using the Belvidere to Spruce Run tunnel route described under Plan DG-3. Since the plan does not provide for water supply storage in the Delaware Basin, it is necessary for the tunnel to have sufficient capacity to convey the average daily requirement of 300 mgd plus the additional quantity needed for storage in Round Valley to regulate the supply when the permissible diversions from the Delaware are less than the demand. To meet these requirements will necessitate a concrete-lined tunnel 15 feet in diameter with a capacity of 750 million gallons per day.

STATE OF NEW JERSEY | NEW JERSEY WATER RESOURCES DEVELOPMENT

LEGISLATIVE COMMISSION ON WATER SUPPLY

BASIC FEATURES OF PLANS FOR DELAWARE RIVER DIVERSIONS

USING STORAGE AT ROUND VALLEY SITE

TIPPETTS - ABBETT - McCARTHY - STRATTON
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II-39

PLATE II-13
12-1955

PLAN DRV-1

WALLPACK BEND RESERVOIR
Flow line elevation.....420 ft.

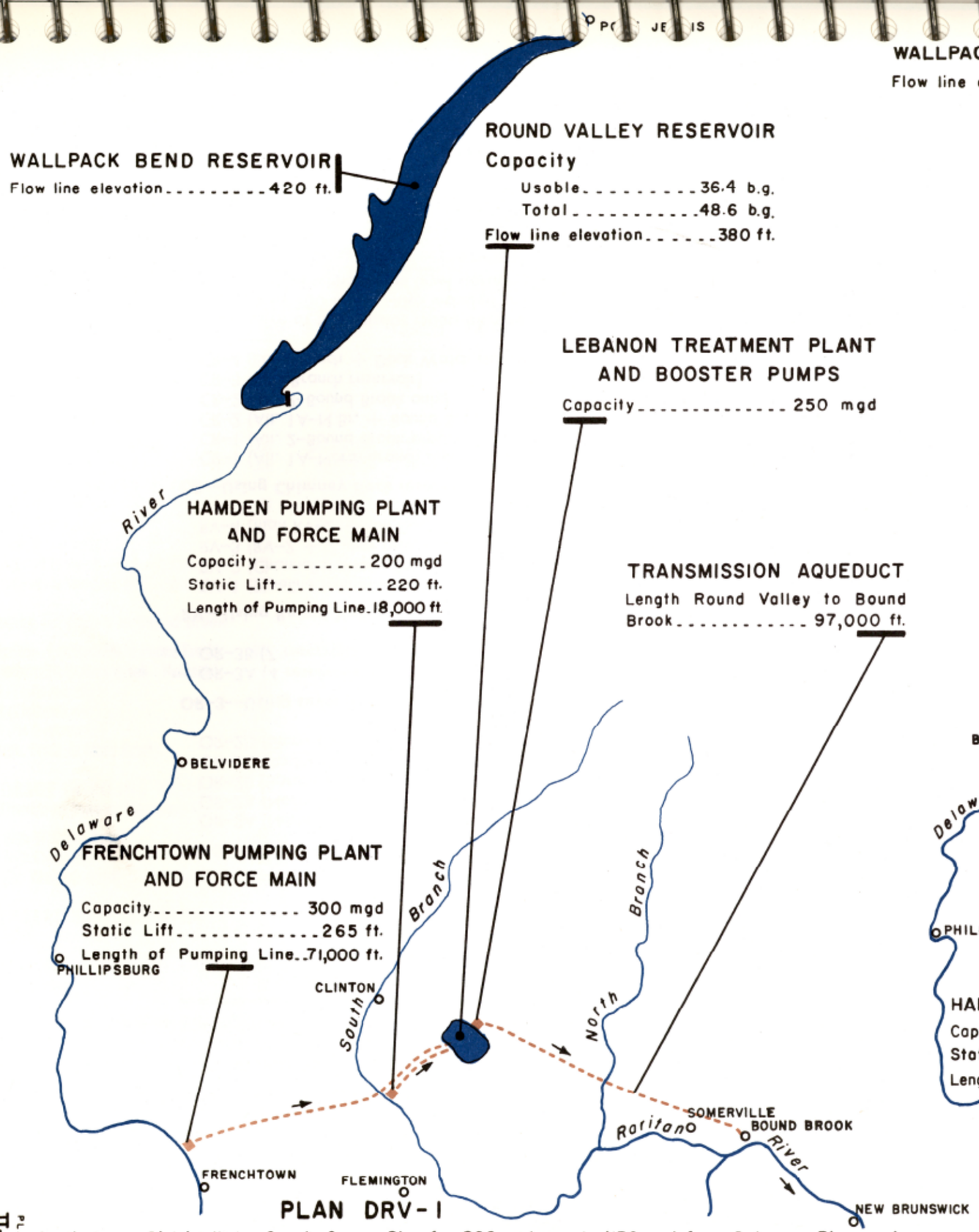
ROUND VALLEY RESERVOIR
Capacity
Usable.....36.4 b.g.
Total.....48.6 b.g.
Flow line elevation.....380 ft.

LEBANON TREATMENT PLANT AND BOOSTER PUMPS
Capacity.....250 mgd

HAMDEN PUMPING PLANT AND FORCE MAIN
Capacity.....200 mgd
Static Lift.....220 ft.
Length of Pumping Line..18,000 ft.

TRANSMISSION AQUEDUCT
Length Round Valley to Bound Brook.....97,000 ft.

FRENCHTOWN PUMPING PLANT AND FORCE MAIN
Capacity.....300 mgd
Static Lift.....265 ft.
Length of Pumping Line..71,000 ft.



North Jersey District Water Supply Comm. Plan for 200 mgd supply (130 mgd from Delaware River and 70 mgd from South Branch Raritan River). Assume participation by New Jersey in Wallpack Bend Project to satisfy compensation requirements on Delaware River.

PLAN DRV-2

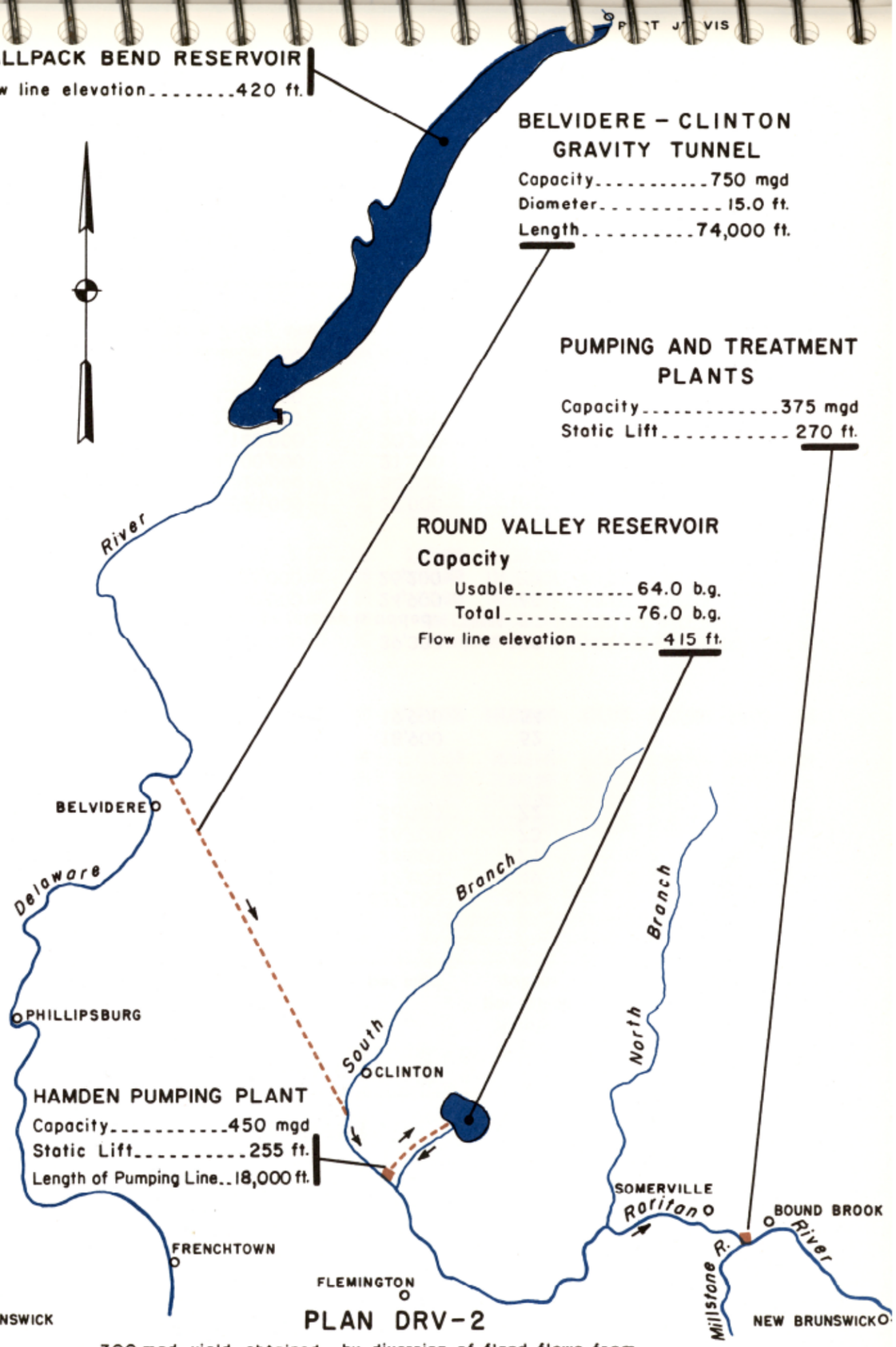
WALLPACK BEND RESERVOIR
Flow line elevation.....420 ft.

BELVIDERE – CLINTON GRAVITY TUNNEL
Capacity.....750 mgd
Diameter.....15.0 ft.
Length.....74,000 ft.

PUMPING AND TREATMENT PLANTS
Capacity.....375 mgd
Static Lift.....270 ft.

ROUND VALLEY RESERVOIR
Capacity
Usable.....64.0 b.g.
Total.....76.0 b.g.
Flow line elevation.....415 ft.

HAMDEN PUMPING PLANT
Capacity.....450 mgd
Static Lift.....255 ft.
Length of Pumping Line..18,000 ft.



300 mgd yield obtained by diversion of flood flows from Delaware River with storage in Round Valley.

TABLE II-8

COST COMPARISON—PLANS FOR DEVELOPMENT OF RARITAN RIVER BASIN POTABLE WATER SUPPLY*

Plan	Potable Yield mgd.	Capital Cost		Annual Cost		Cost of Supply* per million gallons
		Total	Per million gallons of Capacity	Total	per mgd	
OR–2—Using 2 on-river reservoirs						
OR–2A (North Branch + Spruce Run)	69	$26,730,000	$387,400	$1,872,000	$27,100	$74
OR–2A (North Branch + Spruce Run)	165	42,350,000	256,700	2,940,000	17,800	49
OR–2B (Spruce Run + Rocky Hill)	69	24,760,000	358,800	1,782,000	25,800	71
OR–2C (Rocky Hill + North Branch)	69	26,070,000	377,800	1,842,000	26,700	73
OR–2D (Stony Brook + Spruce Run)	69	25,400,000	368,100	1,812,000	26,300	72
OR–3—Using several on-river reservoirs						
OR–3A (4 reservoirs)	200	52,550,000	262,800	3,771,000	18,900	52
OR–3B (7 reservoirs)	250	71,825,000	287,300	4,962,000	19,900	54
RV—Using Round Valley Reservoir						
RV–1 (Pipeline transmission from Round Valley)	70	46,450,000	663,600	2,750,000	39,300	108
RV–2 (Channel delivery Round Valley to Bound Brook)	150	Same as RV–3 after 7-day gravity reserve is added.				
RV–3 (RV–2 + 7 day reserve in Dock Watch Hollow)	150	54,770,000	365,100	3,740,000	24,900	68
RV–4 (Plan RV–2 + full Dock Watch Hollow res.)	200	71,600,000	358,000	5,236,000	26,200	72
CR—Using Chimney Rock reservoir						
CR–1 (Alt. 1A–North Branch supply)	70	46,530,000	664,700	2,590,000	37,000	101
CR–1 (Alt. 2–Bound Brook supply)	70	42,730,000	610,400	2,520,000	36,000	99
CR–2 (Alt. 1A–N Br. + Bound Brook)	200	66,400,000	332,000	4,300,000	21,500	59
CR–2 (Alt. 2–Bound Brook only)	200	60,800,000	304,000	4,140,000	20,700	57
CR–3 (East Branch reservoir)	70	32,970,000	471,000	2,090,000	29,800	82
CR–4 (East Branch + Dock Watch Hollow)	200	60,040,000	300,200	4,200,000	21,000	58

*Exclusive of transmission mains beyond common point near Bound Brook and including facilities for regulating minimum flows below diversions at Bound Brook to 130 mgd. Also included are costs for Dock Watch Hollow reservoir and appurtenant facilities for a 7-day emergency gravity supply for those plans without high level storage (OR–2, OR–3 and RV–2).

TABLE II-9

COST COMPARISON—DELAWARE RIVER DIVERSION PLANS (1)

Plan	Potable Water Yield mgd	Delaware R. Storage and Compensation(2)	Pumping and Intake Facilities	Tunnels or Pipelines	Raritan R. Storage and Compensation	Bound Brook Intake and Pumping Facilities	Treatment Facilities	CAPITAL COST Total	CAPITAL COST Per mgd of Capacity	ANNUAL COSTS Fixed	ANNUAL COSTS Operation and Maintenance	ANNUAL COSTS Total	ANNUAL COSTS Per mgd	Basic Cost Per Million Gallons	COST OF PLAN WITH 7-DAY GRAVITY RESERVE SUPPLY — CAPITAL COST Additions	CAPITAL COST Total	CAPITAL COST Per mgd	ANNUAL COST Total	ANNUAL COST Per mgd	Cost of Supply Per Million Gallons
USING WALLPACK BEND AND FLATBROOK																				
DG—Gravity Tunnel Diversions																				
DG-1 (Frenchtown to S. Br. Raritan)	300	$47,150,000	$2,400,000	$46,000,000		$15,760,000	$15,260,000	$126,570,000	$ 421,900	$5,817,000	$1,475,000	$7,292,000	$24,310	$67	$14,000,000	$140,570,000	$ 468,570	$8,098,000	$26,990	$74
DG-2 (Stockton to Bedens Brook)	300	47,150,000	2,400,000	55,700,000		15,760,000	15,260,000	136,270,000	454,200	6,237,000	1,475,000	7,712,000	25,710	70	14,000,000	150,270,000	500,900	8,518,000	28,390	78
DG-3 (Belvidere to Spruce Run)																				
Stage 1 (Flatbrook only)	70	14,750,000	1,940,000	45,600,000		6,270,000	3,950,000	72,510,000	1,035,900	3,231,000	470,000	3,701,000	52,870	145	5,870,000	78,380,000	1,120,000	4,103,000	58,610	161
Stage 2 (Flatbrook only)	200	31,300,000	5,460,000	45,600,000		11,350,000	10,060,000	103,770,000	518,900	4,702,000	1,030,000	5,732,000	28,660	79	10,590,000	114,360,000	571,800	6,383,000	31,920	87
Stage 3 (Both reservoirs)	300	47,150,000	7,860,000	45,600,000		15,760,000	15,260,000	131,630,000	438,800	6,037,000	1,475,000	7,512,000	25,040	69	14,000,000	145,630,000	485,430	8,318,000	27,730	76
DG-4 (Flatbrook to Boonton Res.—Passaic)	300	47,150,000	3,400,000	82,500,000			18,960,000(3)	152,010,000	506,700	6,813,000	555,000	7,368,000	24,560	67	Not required—Gravity delivery from Boonton res.					67
DG-5 (Flatbrook to Wanaque Res.—Passaic)	300	47,150,000	3,400,000	77,500,000			18,960,000(3)	147,010,000	490,000	6,593,000	555,000	7,148,000	23,830	65	Not required—Gravity delivery from Wanaque res.					65
DP—Pumping Diversions to Bound Brook																				
DP-1 (Pipeline—Lambertville to Bound Brook)	300	47,150,000	15,110,000	50,000,000			15,260,000	127,520,000	425,100	6,364,000	1,975,000	8,339,000	27,800	76	14,000,000	141,520,000	471,730	9,145,000	30,480	84
DP-2 (Lambertville to Back Brook—Neshanic)																				
Stage 1 (Flatbrook only)	70	14,750,000	4,390,000	3,180,000		6,270,000	3,950,000	32,540,000	464,900	1,576,000	625,000	2,201,000	31,440	86	5,870,000	38,410,000	548,710	2,603,000	37,190	102
Stage 2 (Flatbrook only)	200	31,300,000	9,110,000	6,620,000		11,350,000	10,060,000	68,440,000	342,200	3,297,000	1,473,000	4,770,000	23,850	65	10,590,000	79,030,000	395,150	5,421,000	27,100	74
Stage 3 (Both reservoirs)	300	47,150,000	12,410,000	9,990,000		15,760,000	15,260,000	100,570,000	335,200	4,843,000	2,051,000	6,894,000	22,980	63	14,000,000	114,570,000	381,900	7,686,000	25,620	70
DP-3 (Wash. Cross. to Stony Brook)	300	47,150,000	12,510,000	8,600,000		15,760,000	15,260,000	99,280,000	330,900	4,728,000	2,083,000	6,811,000	22,700	62	14,000,000	113,280,000	377,600	7,603,000	25,340	69
USING STORAGE IN ROUND VALLEY																				
DRV-1 (Frenchtown Pumping Diversion)(4)																				
Alt. 1 (With Wallpack Bend)	200(4)	15,850,000	10,760,000	54,835,000	$24,210,000(5)		10,060,000	115,715,000	578,600	5,620,000	1,082,000	6,702,000	33,510	92	Not required—Gravity delivery from Round Valley					92
Alt. 2 (With Flatbrook)	200(4)	10,000,000	10,760,000	54,835,000	24,210,000(5)		10,060,000	109,865,000	549,300	5,360,000	1,082,000	6,442,000	32,210	88	Not required—Gravity delivery from Round Valley					88
DRV-2 (With Wallpack Bend)	300	15,850,000	4,900,000	62,490,000	24,000,000(6)	15,760,000	15,260,000	138,260,000	460,900	6,994,000	1,810,000	8,804,000	29,350	80	14,000,000	152,260,000	507,530	9,610,000	32,030	88
SUPPLEMENTARY SUPPLIES WITH FLATBROOK																				
DG-6 (DG-3 route)	100	18,400,000	2,800,000	36,300,000		4,700,000	5,200,000	67,400,000	674,000	3,041,000	749,000	3,790,000	37,900	104	Not required—Gravity delivery from Chimney Rock					104
DP-4 (DP-2 route)	100	18,400,000	5,550,000	3,600,000		4,700,000	5,200,000	37,450,000	374,500	1,786,000	1,094,000	2,880,000	28,800	79	Not required—Gravity delivery from Chimney Rock					79

(1) Cost data in this table include only those facilities required for development and treatment of a dependable supply and do not include costs of transmission facilities beyond common point near Bound Brook, or beyond Boonton or Wanaque Reservoirs (Plans DG-4 and DG-5). Engineering, legal and administrative costs and interest during construction are included in capital costs.

(2) For plans depending on Wallpack Bend reservoir to supply compensation water for out-of-basin diversions, it has been determined that 75 percent of the New Jersey share of the project cost (30% of total) or $15,850,000 should be charged to water supply. This determination is based on the estimated cost of providing compensation storage for a 300 mgd diversion at other sites in the Delaware basin.

(3) Includes costs of treatment and booster pump facilities at Boonton and Wanaque reservoirs.

(4) North Jersey District Water Supply Commission plan, Stage 2—70 mgd yield from South Branch Raritan River and 130 mgd yield from Delaware River—pipeline delivery to Bound Brook from Round Valley reservoir. Costs include allowance for Spruce Run reservoir for regulation of minimum flows of Raritan River to 130 mgd below diversion at Bound Brook.

(5) Includes costs of developing Round Valley reservoir (Flow line elev. 380) and Spruce Run reservoir.

(6) Cost of developing Round Valley reservoir only (Flow line elev. 415).

In the operation of the plan, whenever the permissible diversion from the Delaware was greater than the water supply requirement, sufficient water to meet the demand would be permitted to flow by natural stream channels to Bound Brook and the excess would be pumped into storage at Round Valley. When the permissible diversions from the Delaware were less than the water supply demand sufficient water from Round Valley would be let down to Bound Brook via the South Branch of the Raritan River to make up the deficiency.

The pumping plant on the South Branch of the Raritan River at Hamden to pump excess Delaware water into Round Valley would have a rated capacity of 450 mgd and an installed capacity of 565 mgd. These capacities are the basic ones required for water supply use and only the cost for this installation is included in Table II-9. The site, however, is one at which a pumped storage generation plant (see description under Plan RV-4 and in Appendix F) may be operated with water let down from Round Valley to the South Branch. The pumping capacities and general economies of such an installation would depend on negotiations with the local electric utility company for the sale of power for peak load assistance.

At Bound Brook the water would be repumped and treated in the same manner as described for Plans DG-1 to DG-3. Storage in a Dock Watch Hollow Reservoir of an emergency supply which will permit at least a seven-day delivery by gravity would be an essential feature of this plan if the danger of service interruption due to power or mechanical failure is to be removed.

Plan DRV-2 illustrates one method and the estimated cost of obtaining a 300 million gallons per day supply from the Delaware River using the Round Valley Reservoir site for water supply storage and the Wallpack Bend Reservoir for compensation. This study would assume importance if the Round Valley Reservoir site were purchased for a water supply development and the decision was made to reserve Raritan Basin water resources for industrial and potable use within the Raritan Valley.

This basic plan may also be developed as a gravity supply from Round Valley by the addition of transmission mains to Bound Brook as in DRV-1. Also the Flatbrook Reservoir could be used to provide compensation but would require pumping from the Delaware River to obtain sufficient storage for this purpose for a 300 mgd diversion. Numerous other combinations using other diversion routes were investigated, but the presentations given here were found to be the most advantageous.

Because a large portion of the cost of Plan DRV-2 is in the Belvidere-Spruce Run Tunnel, which should be constructed to full size, this plan is not as amenable to economical stage development as other plans studied. The proportionate costs for developing Plan DRV-2 in stages of 70 mgd, 200 mgd and 300 mgd would be in approximately the same ratio as costs given for the three stages of Plan DG-3.

Delaware Diversion Plans Using Flatbrook Reservoir Only.

If the major portion of the additional water supplies needed for the Northeastern Region are to be obtained from the Raritan Basin, and the Delaware Basin is to be used only to supplement these supplies with the additional 100 mgd for the estimated requirement at the end of the century, this amount can be provided from the Flatbrook Reservoir alone. Two plans for the diversion of 100 mgd supplementary supplies were studied in detail. These use the most favorable gravity diversion route (Belvidere to Spruce Run—Plan DG-3) and the most favorable pumping route (Lambertville to Back Brook—Plan DP-2).

In both of these plans prior development of the Raritan Basin has been assumed to have been completed with the use of the Chimney Rock Reservoir (Plan CR-2) or with a combination of the East Branch and Dock Watch Hollow Reservoirs (Plan CR-4). The diverted water in both cases would travel by natural stream channels to Bound Brook and would be pumped into either Chimney Rock or East Branch Reservoirs. Additional pumping capacity at Bound Brook and additional treatment facilities at the reservoir head works for the 100 mgd Delaware diversion would be provided and are included in the plan costs on Table II-9.

Diversions would be at a relatively uniform rate of 100 mgd since releases will be regulated from Flatbrook storage and short term peaks will be balanced from Chimney Rock storage. Additional storage capacity for this diversion will, therefore, not be needed in the Chimney Rock Reservoir. The Flatbrook Reservoir would be developed to a flow line elevation of 470 which will provide sufficient storage to regulate the 100 mgd diversion and for necessary compensation releases. A pumping plant and force main will be needed to pump 100 mgd from the Delaware River into Flatbrook Reservoir.

Plan DG-6—100 Million Gallons Per Day Gravity Diversion to the Raritan Basin. In addition to the features and conditions described above this plan requires a diversion tunnel 81,000 feet (15.3 miles) long constructed on the Belvidere-Spruce Run route of Plan DG-3. The tunnel would be concrete-lined and 102 inches in diameter.

This plan would deliver a high quality water from a diversion above the Lehigh River, but the capital cost is nearly double that of the pumping diversion described below.

Plan DP-4—100 Million Gallons Per Day Pumping Diversion to the Raritan Basin. Under this plan the diversion regulated by Flatbrook Reservoir would be pumped from the Delaware River above Lambertville and discharged into the Raritan Basin south of Ringoes. This is the route described under Plan DP-2. An 84-inch force main 26,200 feet (5.0 miles) long will be required. The pumping plant would have a capacity of 125 million gallons per day.

Plan DP-4 is the most economical means studied for providing the additional estimated quantity of water that will be needed before the year 2000 in the Northeastern Region as a supplement to the full economic development of the Raritan Basin. The capital cost of this project and the cost of water at Bound Brook after treatment and delivery to the transmission system via Chimney Rock Reservoir is reasonably comparable to the lower cost projects studied for both the Raritan and Delaware Basins (see Tables II-8 and II-9). Since it is assumed that this plan will be used in conjunction with Chimney Rock or East Branch Reservoir, it is not necessary to add the cost of a seven-day high level emergency reserve as in the case with most of the stream channel delivery plans.

The Round Valley Reservoir cannot be substituted for the Flatbrook Reservoir in this plan since it is not in the Delaware Basin and therefore cannot be used for the compensation requirements of an out-of-basin Delaware diversion. To use the Round Valley Reservoir for the supplementary 100 mgd supply would necessitate a second reservoir in the Delaware Basin. This could be at Wallpack Bend, Flatbrook, Beaver Brook or other feasible locations.

Advantages of the Flatbrook site over the Round Valley site for regulation of flood flow diversions from the Delaware River include the following:

1. Runoff from the 65 square miles of drainage area directly tributary to the site can be utilized without pumping. Round Valley has no appreciable direct inflow.
2. Flood flows diverted from the Delaware River would have to be pumped only about 170 feet to the Flatbrook Reservoir (only 100 feet if used in conjunction with Wallpack Bend Reservoir), whereas such diversions must be pumped at least 220 feet to storage in Round Valley.
3. Flatbrook Reservoir can be used to store flood flows diverted by pumping from the Delaware River and the stored water can be released down the Delaware River to be picked up by other diversion facilities at any downstream point.
4. With regulations in Flatbrook Reservoir, the size of tunnels or pumping plants and discharge lines can be limited to those necessary for conveyance of only the average annual supply obtained plus 25 percent allowance for seasonal variations; whereas diversion facilities from the Delaware River to Round Valley, if used without upstream regulation, would have to be of sufficient size to convey about double the average annual

supply desired. This is of vital importance, in view of the lengths of the diversion routes involved.

5. It is probable that a pumped-storage plant could be utilized between the Delaware River and Flatbrook Reservoir and could produce sufficient revenue to reduce the overall annual costs. Such a possibility would have much greater economic importance if the Wallpack Bend Reservoir was to be available to serve as a large lower reservoir. While pumped-storage generation could be arranged at Round Valley, it would not be as attractive economically because of the necessity for provision of a lower pool, specifically for pumped-storage operation and because of the greater length of pipelines required to connect the two pools.

Other Delaware Basin Diversions Investigated.

There are a very large number of additional plans possible for the diversion of water from the Delaware Basin into the Raritan Basin. The following plans were investigated in addition to those presented above:

Direct gravity diversion from Wallpack Bend or Flatbrook to Round Valley.

Direct gravity diversion from Wallpack Bend or Flatbrook to Chimney Rock. A variation of Plan DRV-2 in which water for a 300 mgd supply is pumped from Frenchtown to Round Valley instead of using the Belvidere-Spruce Run Tunnel.

Diversions from the Musconetcong and Pequest Rivers and various combinations of these diversions with water from the Delaware River and Raritan Basin.

Summary of Plans for Diversion of Delaware Basin Water.

Table II-9, which follows and which has been referred to frequently in the text on the Delaware diversion plans, gives a synopsis of the costs that have been developed in detail for each of the plans presented. The table provides a convenient comparison of the capital and annual costs for all of the plans studied.

The plans selected for detailed study were those considered to have the greatest merit from all standpoints and to be illustrative of the range of diversion possibilities.

Table II-9 reflects only the costs of developing the supply to a common delivery point at or near Bound Brook. Costs include treatment and either delivery to Round Valley, Boonton, Wanaque or Chimney Rock Reservoirs or delivery at a pressure head equivalent to the flow line elevation of the Chimney Rock Reservoir (290 feet). In order to provide a relatively equitable basis for the comparison of all plans, those which make direct pumping delivery to the transmission system have had added to the basic costs a seven-day high level storage in the Dock Watch Hollow site together with pumping and force main facilities, and the piping necessary to make emergency deliveries by gravity.

The costs for the development of the transmission system beyond Bound Brook are given in Chapter V. Complete project costs including both resource development and transmission are presented in Chapter VI.

MULLICA—WADING RIVER BASIN

The basin of the Mullica River system—including that of its principal tributary, the Wading River—is the largest watershed in the southern part of New Jersey and ranks third in size among the river systems of the State (see Frontispiece). Practically all of the basin is situated in the portion of New Jersey known as the "Pine Barrens" and is underlain by water-bearing sands and gravels which form vast ground-water reservoirs. Surface soils in the area are highly permeable, with the result that storm runoff is at a minimum and streamflows are composed principally of overflow from the ground-water reservoirs. This situation results in a relatively uniform streamflow pattern, in comparison with the pattern for many other rivers of the State. This characteristic of streamflow in the Mullica River basin is illustrated by data presented on Plate 1-10 for the Batsto River, a major tributary of the Mullica River.

Development of potable water supplies from streamflows in the Mullica and Wading Rivers was discussed in the "Report on Water Resources of the State and Their Development" prepared in 1922 by Hazen, Whipple and Fuller. That report presented a plan which included two reservoirs—one on the Mullica River near Batsto and one on the Wading River near Harrisville—each with a flow line elevation of 40. The two reservoirs were to be joined by a canal and together would command a drainage area of 412 square miles. An aqueduct about 84 miles long would deliver water to Newark from the reservoir on the Wading River. A pumping station would lift the water about 200 feet to a filter plant from where it would flow in a concrete gravity section for the major portion of the aqueduct. The combined reservoir would have a water surface area of 54 square miles, an average depth of 12 feet, and a total capacity of 140 billion gallons, of which 106 billion gallons would be available in the upper 15 feet. A yield of 316 mgd of potable water was claimed for this development.

More recent consideration of this project resulted in the conclusion that the damsite on the Mullica River should be at Batsto about 4 miles upstream from the site originally considered, and that the flow line of that reservoir should be at elevation 30 instead of 40 to reduce the area flooded. The locations of the reservoir sites, which are largely within the boundaries of the State owned Wharton Tract, together with area-capacity curves are shown on Plate II-14.

Although a potable water supply on the order of 300 mgd dependable yield can be supplied by flows of the Mullica and Wading Rivers, (see the storage-yield curve on Appendix Plate A-1) such an amount of water could be utilized in New Jersey only in the Northeastern Region. It is obvious that potable water supplies needed by that region can be developed from the Raritan or Delaware River sources much more economically than from the Mullica and Wading Rivers because of the lesser cost of transmission. The extremely shallow storage and large surface areas of the Mullica and Wading reservoirs would result in high evaporation losses and the water quality and temperature would be inferior to that obtainable from projects having the advantage of deep storage.

In addition, surface reservoirs at these sites would cause an appreciable rise in the nearby ground water table, due to the porosity and transmissibility of the underlying Cohansey sands. "Bank storage"—water stored in the reservoir banks above the original water table—in the case of such reservoirs would be enormous and would delay accomplishment of the initial filling of the reservoirs. After the reservoirs are filled this "bank storage" will function essentially as additional reservoir capacity. However, due to the transmissibility of the Cohansey sand, it is probable that the raised water table surrounding the reservoirs will result in a considerable ground water flow around the dam sites. The cost of the extensive grouting necessary to avoid such losses would probably be prohibitive.

Potable water supplies of the size needed for the Camden or Atlantic City areas could be developed from surface flows of the Mullica and Wading Rivers by smaller reservoirs than those considered in the 1922 report. Supplies adequate to the year 2000 for the Camden and Atlantic City areas, however, can be obtained more reasonably by ground water developments, as discussed in Chapter III, than by surface reservoirs. A series of wells located adjacent to the rivers near the two suggested dam sites would cost much less than the dams and reservoirs, even though the sites are largely state owned. Water obtained from such wells should be of superior quality because of the filtering action of the sand between the river channel and the wells. Another major consideration is the fact that well supplies are more adaptable to economical stage development than are surface reservoir supplies. Futhermore, if the water supplies from the Wharton Tract or other areas of the Pine Barrens are developed by well fields of the type herein recommended, those areas will continue to have unrestricted availability for recreational use. For these reasons and because the water supplies at Camden and Atlantic City appear to be adequate for the next few years, it is considered advisable to hold surface developments on the Mullica and Wading Rivers in abeyance until additional ground water investigations have proved or dis-

proved the assumption that well developments are more practicable.

RANCOCAS CREEK BASIN

Rancocas Creek, with a watershed area of 335 square miles (see Frontispiece) is the largest tributary of the Delaware River in New Jersey and drains the western slope of the northern Pine Barrens, emptying into the Delaware River near Riverside about 10 miles upstream from Camden. The entire basin is within the Atlantic Coastal Plain ground-water province, described in Chapter III. The upper 80 percent of the basin is located in the Interior Plain sub-province and is characterized by underlying water-bearing sands and gravels, which form vast ground-water reservoirs containing water of relatively good quality. The lower 20 percent of the basin is in the lower Delaware River Valley and contains highly permeable sands and gravels at shallow depths. Because of the high permeability of the surface soils, practically all of the precipitation on the Rancocas basin—except during very intense storm periods—enters the soil. Streamflows in the area are almost entirely overflow from ground-water reservoirs. The effect of this temporary storage in permeable underground strata is a "damping" of extremes of streamflow. This characteristic of streamflows from the Pine Barrens area is illustrated by the monthly hydrographs for the Batsto River at Batsto on Plate 1-10. In comparison, flows of the Raritan and Pequannock Rivers, which do not benefit from extensive ground water outflow, are much more "flashy" with greater variations between minimum and maximum values.

Because of the comparatively uniform streamflow of Rancocas Creek, it is possible to obtain larger dependable yields from that source by direct diversion without reservoir storage than could be obtained from a drainage area of equal size in the northern part of the State. Rancocas Creek could provide an adequate water supply for Camden in the event that deterioration in the potable quality of water in the lower Delaware River forced abandonment of the present well system which depends partially on induced river water infiltration. In this case the logical location for diversion of a surface water supply from Rancocas Creek would be above tidal influence from the Delaware River at the junction of the two branches of the creek near Centreton, immediately upstream from the crossing of the New Jersey Turnpike. The drainage area above that point is about 290 square miles and the minimum monthly flow, on the basis of available streamflow records, averages about 142 million gallons per day.

As explained in Chapter V, it is possible under certain conditions that a new supply adequate to provide a dependable yield of 100 million gallons per day may be required for the Camden area by the year 2000. Although more detailed investigations will be required to select the most desirable source for such a supply, in the event the need occurs, it appears that such a yield could be obtained from Rancocas Creek without reservoir regulation. The demand of 100 mgd is the maximum estimated seasonal water usage for the year 2000. The coincidence of a maximum diversion requirement with a minimum monthly stream flow would still leave an average of 42 million gallons per day in the Creek below Centreton. Because of the infrequent occurrence of this minimum condition, it is believed that adequate flows will remain in the creek to preserve satisfactory stream conditions below the diversion.

The important features of a plan to develop a surface supply for the Camden area from Rancocas Creek are shown on Plate III-5. A diversion dam, intake, pumping station and treatment facilities will be required. The estimated costs for these works (exclusive of transmission mains to Camden) for a maximum diversion of 100 million gallons per day are as follows:

Diversion dam	$ 200,000
Intake and treatment works	5,200,000
Pumping plant	800,000
Capital cost of supply only	$6,200,000

Stage development or these facilities is economically feasible and would undoubtedly be desirable in order to keep capital outlay commensurate with the growth in water demand.

Rancocas Creek undoubtedly receives some pollution from Mount Holly and other municipalities located upstream from Centreton. The use of Rancocas Creek for a potable water supply may require the construction of improvements to the sewage treatment works of upstream municipalities. The responsibility for carrying out these improvements would undoubtedly be a subject for negotiation between the municipalities and the water developing entity. The cost of such a stream improvement program may have to be added, at least in part, to the basic cost of the resource development given above.

The description and estimated cost of the transmission main necessary to deliver water from Rancocas Creek to the existing distribution system of Camden is given in Chapter V. Complete project costs are summarized in Chapter VI.

WALLKILL RIVER BASIN

The Wallkill River and its New Jersey tributaries drain the upper part of the Appalachian Valley into New York State to the Hudson River. It has a drainage area in New Jersey of approximately 135 square miles. A storage site is available which would impound water from approximately 110 to 120 square miles of the New Jersey watershed area and would develop a dependable yield of between 90 and 100 million gallons per day.

At a flow line elevation of 440, 46 billion gallons of water would be stored with a flooded area of over 5000 acres. Water would be conducted from the reservoir by a tunnel probably using Wanaque Reservoir as its eastern terminus. A Wallkill-Wanaque tunnel would be approximately 16 miles in length.

In addition to the acquisition of a large amount of valuable farm property the development of a Wallkill Reservoir would involve the relocation of approximately 14 miles of railroad line and many miles of roads requiring a number of access causeways across the reservoir. The water of the Wallkill basin is excessively hard and frequently very turbid. Extensive treatment would be necessary to convert it to suitable quality for a potable supply.

In recent years two engineering reports have dealt with the possible use of the Wallkill Basin as the source of additional water supply for Northeastern New Jersey. These reports, both dated 1950 and made for the Passaic Valley Water Commission and the Interstate Commission for the Delaware Basin, rejected the Wallkill River as an undesirable source of water supply on the grounds of its high construction cost and inferior quality of water.

Independent examination of all of the facts covering Wallkill Basin water fully confirms the findings of the above reports. To the previous objections to this water resource should be added the possible complications that may arise as a result of the interstate character of the Wallkill River and local objections to the diversion of water out of a recreational area. For the above reasons the Wallkill Basin has not been considered as a favorable potential source of water supply for the Northeastern Region.

OTHER SURFACE WATER RESOURCES

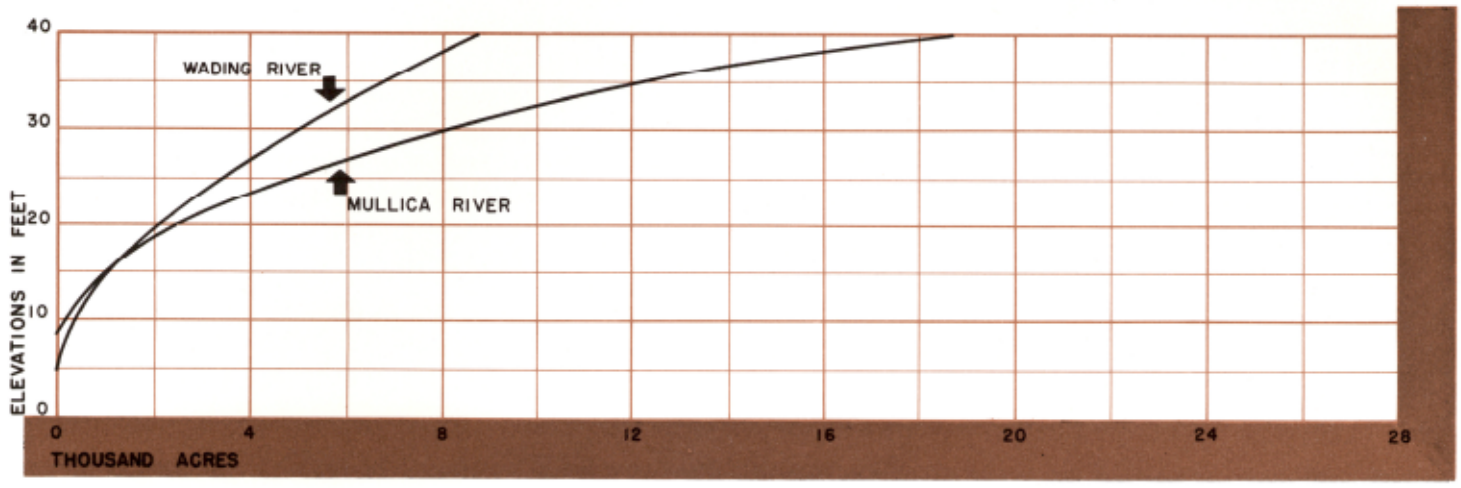
In addition to the river basins mentioned above which constitute the major surface water resources of the State, there are a number of streams with small-to-medium water supply potential. These streams are mostly those located on the eastern slope of the Coastal Plain draining into the Atlantic Ocean. Aside from the Mullica-Wading Basin and the Rancocas Creek Basin, the Coast Plain streams are in the order of their importance:

Great Egg Harbor River
Maurice River
Shrewsbury-Nevesink Basin
Metideconk River
Toms River
Manasquam River

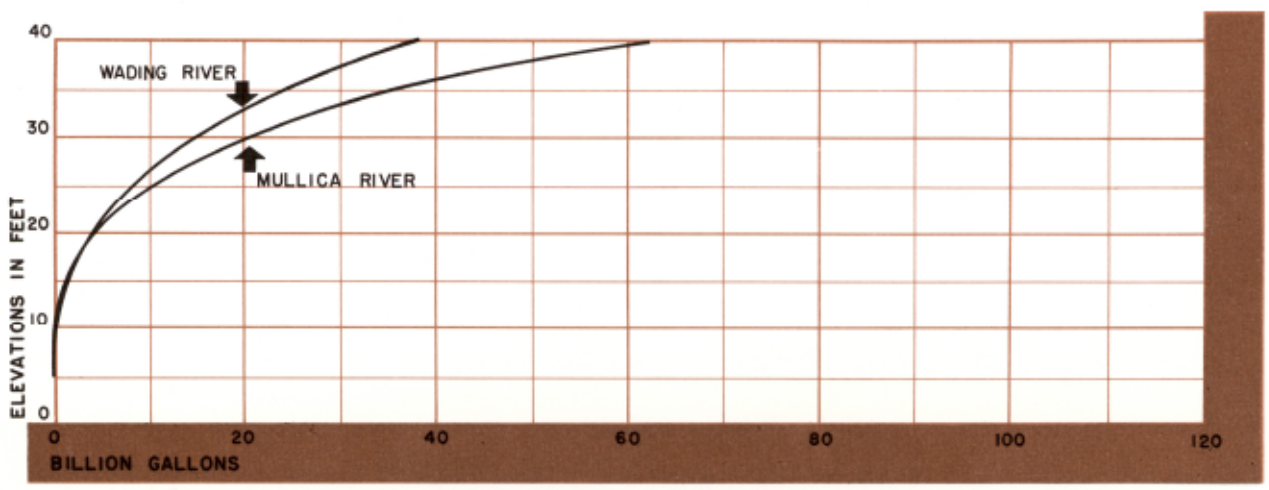
Appendix Plate A-1 contains mass hydrographs and storage-yield curves of the Great Egg Harbor and Maurice Rivers which gives an indication of their potential.

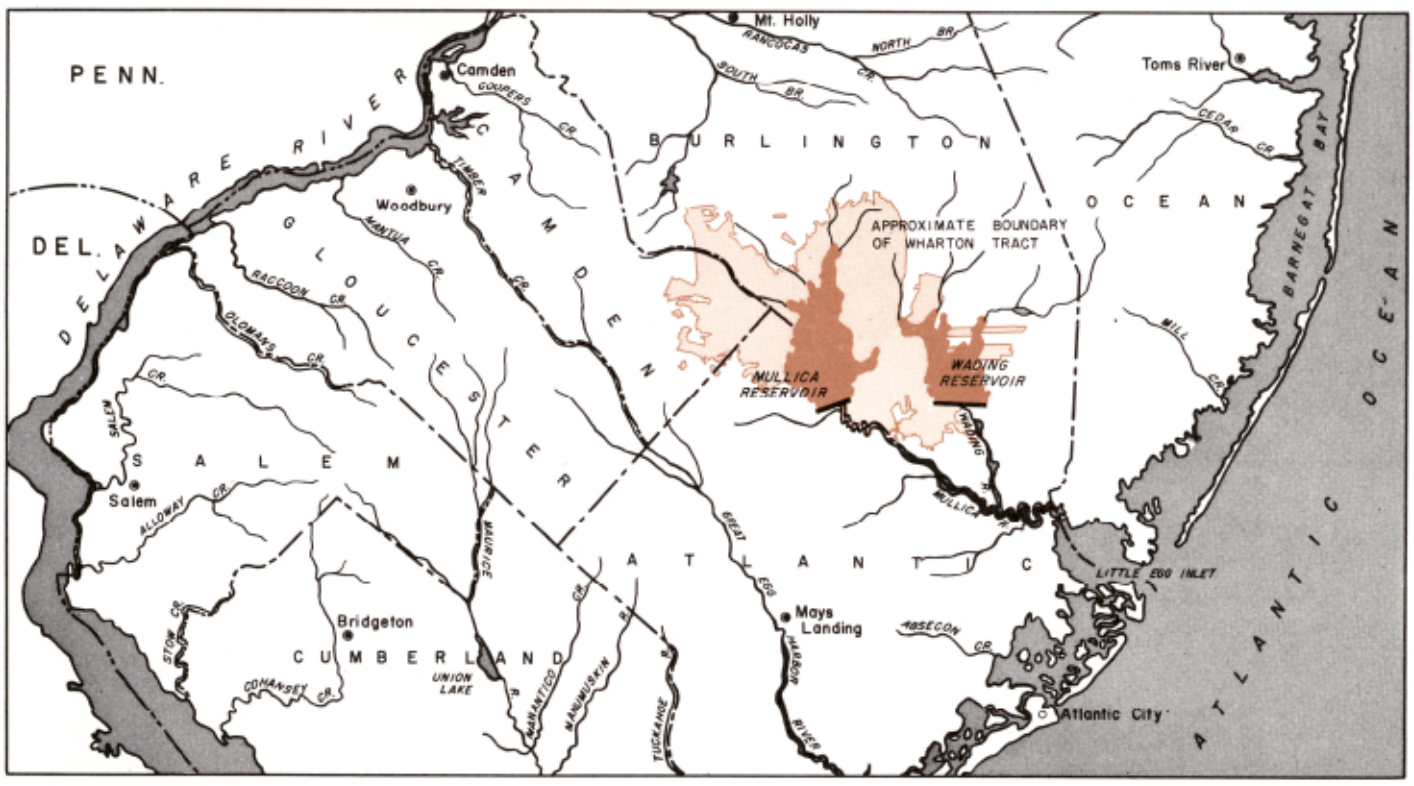
These rivers are located, with the exception of the Shrewsbury Nevesink, in an area of high ground water yield. The area is also topographically poor for the impounding of surface water. It is likely, therefore, that if diversions for water supply are made from these streams in the future it will be by means of filter galleries or wells with induced infiltration as described for the Mullica and Wading Rivers in Chapter III.

RESERVOIR SURFACE AREA



RESERVOIR STORAGE CAPACITY





SCALE 10 0 20 MILES 30

PLATE II-14
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY

TIPPETTS - ABBETT - McCARTH[illegible] TRATTON
ENGINEERS [illegible] NEW YORK

II-45

NEW JERSEY WATER RESOURCES DEVELOPMENT

AREA AND CAPACITY CURVES — LOCATION MAP
MULLICA RIVER BASIN RESERVOIR SITES

CHAPTER III

CHAPTER III

GROUND WATER

OCCURRENCE OF GROUND WATER IN NEW JERSEY

Beneath the land surface of New Jersey there is a great quantity of water contained in crevices and pore spaces in the rock formations.* This volume of water is vastly greater than all the water contained at any particular instant in the rivers, lakes and storage reservoirs on the land surface. Water is slowly moving through these natural underground reservoirs from areas where infiltration from rainfall is occurring, to natural outlets such as springs and seeps in the beds of surface streams, to the ocean from unconfined aquifers on the continental shelf and to points of artificial diversion at wells and filter galleries. The quantity in underground storage varies from season to season, decreasing, even with normal precipitation, during the summer and fall when the use of water by plants is large, and increasing during the winter and early spring when vegetal growth is at a minimum.

Essentially all ground water in New Jersey has its source in precipitation that falls within the State. Except locally, little or no ground water moves into the State from other regions and in these local exceptions, the distance of travel underground is confined to a few miles. Wells in some stream valleys, such as the Delaware River Valley, may obtain a considerable part of their production by infiltration from the adjacent stream. Some of this water coming from the stream is probably derived from distant sources.

There is a pronounced difference between geologic formations as to the amount of water they contain and the rate at which this water can move through these formations and into wells. The quantity of ground water at any one place is determined primarily by the size and number of saturated openings in the rock formations. These openings may be in the nature of interstices or voids between the grains of unconsolidated rocks such as sands and gravels or in the pores, joint planes and fissures in consolidated rocks of both crystalline and sedimentary types. The size of rock openings is important, since water held in minute pores is difficult to remove because of strong capillary attraction between the rock particles and the water, even though the percentage of voids may be relatively high. Thus, the character of the rocks, even more than the distribution of rainfall, controls the location of large ground-water supplies.

Materials such as coarser sands, gravel and some sandstones contain a considerable volume of relatively large voids, frequently as much as 30 to 35 percent of the entire rock mass. On the other hand crystalline rocks such as diabase and basalt (trap rock), schist, gneiss and granite have as a rule only extremely small pores between the rock crystals. The useable ground water in crystalline rocks occurs, therefore, in open fractures and fissures which usually constitute only a small percentage of the rock mass. It follows that there is likely to be a large volume of ground water stored where the underlying rocks are coarse sands and gravels and only relatively small quantities where the subsurface consists of dense crystalline rocks with few open joints and fissures.

An intermediate group of rocks with respect to ground water storage and yield would consist of finer sands, partially cemented sandstones and a variety of other sedimentary formations (including shales and limestones). Limestone formations containing fractures and large solution cavities may yield large quantities of ground water even though the rock itself may have a very dense character.

Although New Jersey contains a great variety of rock types, broad areas of the State are of sufficient similarity in kind of rock and land topography to be characterized as geologic provinces. There are four such regional geologic provinces in the State. These are the Highlands, the Appalachian Valley, the Piedmont Plain and the Atlantic Coastal Plain. The Highlands and the Appalachian Valley are somewhat alike with respect to the occurrence of ground water, and for the purpose of this report they are considered to form a single ground-water province. Therefore, New Jersey's underground water resources can be classified into three major ground-water provinces, the Highlands-Appalachian Valley Province, the Piedmont Plain Province and the Atlantic Coastal Plain Province (see Plate III-1).

* The term "rock formation" is used throughout the text of Chapter III in its geological sense and includes in addition to conventional rock all deposits such as sands, gravels, clays and other unconsolidated materials not normally referred to as rock.

THE HIGHLANDS AND APPALACHIAN VALLEY PROVINCES

The Highlands and Appalachian Valley form a broad belt of mountains and valleys lying between the northwestern border of the State and a line that passes in general a short distance west of Pompton Lakes, Boonton, Morristown and Frenchtown. This line coincides with the Ramapo Mountains in northern New Jersey. In the Appalachian Valley farthest to the northwest, the rocks are composed of limestone, shale and sandstone or quartzite, while in the Highlands, crystalline metamorphic and igneous rocks predominate. These rocks are generally not favorable for the production of large supplies of ground water, although wells in the Kittatinny limestone may yield 100 or more gallons per minute in areas where water-bearing openings have been enlarged by solution.

Glacial deposits form a discontinuous mantle over all of the Highlands and Appalachian Valley Provinces. Where the glacial debris covers the upland areas, the material is largely clayey and is generally not productive of large ground-water supplies. However, in some of the principal stream valleys there are stratified deposits of sand and gravel that may yield supplies of significant importance for local use. Such deposits have not been carefully mapped and the extent of their occurrence is only generally known at present.

THE PIEDMONT PLAIN PROVINCE

The Piedmont Plain Province is bounded on the northwest by the Ramapo and other mountains and on the southwest by the Fall Line, a line—or rather, a zone of varying width, of geologic contact between the hard massive rocks of the gently rolling Piedmont Plain and the unconsolidated sands, gravels and clays of the flat-lying Coastal Plain. It is called the Fall Line because of the occurrence of small falls and rapids where streams leave the hard bedrock areas in the interior and enter the area of softer deposits in the lower and flatter plain along the Atlantic Coast. This line extends across New Jersey from Trenton through New Brunswick to Perth Amboy.

Within the Piedmont Plain Province are parts of Hunterdon, Mercer, Middlesex, Morris and Passaic Counties and most or all of Somerset, Union, Essex, Hudson and Bergen Counties. The surface of the Piedmont Plain is underlain by sandstones, shales and trap rock. Unconsolidated glacial or related deposits mantle most of the province.

The sandstones and shales generally yield small to moderate supplies to wells. In the eastern part of Somerset County and the western part of Union County, through the central part of the province, moderate to large yields have been obtained from these formations. The trap rock, of which there are many outcrops in the Piedmont Plain Province, is one of the poorest of all rocks for obtaining water supplies. The glacial deposits are favorable for ground-water development only in areas where they consist of stratified sands and gravels. Such occurrences are spotty and poorly defined. In general, much of the area of the glacial deposits is composed of clayey drift which is unfavorable for ground water supply.

THE ATLANTIC COASTAL PLAIN PROVINCE

The Atlantic Coastal Plain Province lies south and east of the Fall Line (from Trenton to Perth Amboy), and comprises all of South Jersey. For the purpose of this report the Coastal Plain has been divided into three ground-water subprovinces. The eastern portion, designated as the Coastal Area, forms a band in south-north direction along the ocean from Cape May to the mouth of the Raritan River. The sub-

province designated as the Lower Delaware Valley Area forms a narrow belt along the Delaware River below Trenton. The broad area between these two sub-provinces has been designated the Interior Plain. (Plate III-1).

All of the Atlantic Coastal Plain Province is underlain by layers of sands, gravels, and clays which dip gently to the southeast. The geologic sequence of these deposits is given in Table III-1—Generalized Stratigraphy of the Atlantic Coastal Plain Province, and on Plate III-2—Generalized Cross-Section—Camden to Atlantic City, Showing Principal Water Bearing Strata. The coarser beds in these deposits are very favorable for the storage and movement of ground water. A large percentage of the regional precipitation enters the soil in this province and a considerable part of it is transmitted through the permeable sedimentary formations to the banks and beds of nearby streams. Not only is there a very large amount of water moving through the formations, but the total quantity stored in the sediments of the Coastal Plain is vast, aggregating many hundreds of billions of gallons.

Although the geologic relationships along the Lower Delaware Valley and along the Coastal Area of southern New Jersey are much the same as in the interior of the plain, ground water in sedimentary deposits forming the borders of most of the Coastal Plain is particularly susceptible to salt water contamination. The seriousness of this problem is increased by the fact that there are concentrations of municipalities and resort populations in these border areas, which use large quantities of ground water. Separate consideration is, therefore, required for these portions of the Atlantic Coastal Plain.

The Lower Delaware River Valley Area of the Atlantic Coastal Plain Province is a narrow belt one to three miles wide bordering the Delaware River between Trenton and the Delaware Bay. For the most part, it rises not more than 50 feet or so above the level of the river. For the purpose of this report, it is considered to extend from Trenton to Cape May, although the ground-water relationships in Salem, Cumberland and Cape May Counties are essentially the same as along the Coastal Area facing the Atlantic Ocean.

Some of the sand and gravel deposits adjacent to the Delaware River are Pleistocene and Recent in age, while others are of the older Raritan-Magothy formations. (See Table III-1 Generalized Stratigraphy.) Irrespective of their geologic age, all are generally similar in composition and exhibit similar water-bearing properties. Throughout most of the Lower Delaware Valley Area, these deposits are in direct hydraulic contact with water in the Delaware River. Under the natural conditions that existed before any development of ground-water supplies, the water table was higher than the river and ground water augmented the flow of the river. Under conditions of present-day well operation, the ground-water gradient has been reversed in a number of places by the drawdown due to pumping, so that an induced river water infiltration now augments the ground-water supply in these areas.

The relation of the Delaware River to the sand and gravel deposits along the stream adds two important factors to the conditions that normally apply to Coastal Plain aquifers. These are, (1) a very large source of recharge to those wells ending in formations that are hydraulically connected to the river, and (2) chemical characteristics of the well water represent a blend of river water and ground water. Both factors vary in degree among wells, depending upon the distance of the wells from the river, the permeability of bottom sediments in the river and in the formation between the river and wells, and the slope of the ground-water gradient from the river towards the wells. The overall result is that much larger quantities of water can be relied upon from a given area near the Delaware River than from similar deposits at greater distances from the river. However, if the stream should contain chemically undesirable water, this characteristic of the river water may ultimately result in an unsatisfactory quality of the well supply.

The Coastal Area (see Plate No. III-1) of the Atlantic Coastal Plain bears the same hydrologic relation to the Atlantic Ocean that the Lower Delaware Valley Area bears to the Delaware River. Prior to the withdrawal of ground water from wells along the coast, the level of fresh water in the underground reservoirs was higher than mean sea level, so that the ground-water gradient was toward the ocean and bays. As resort areas and permanent communities developed, groups of wells in many areas caused cones of depression to extend below sea level in places where sea water or brackish water in bays and inlets could replace the fresh water withdrawn. Such conditions have occurred chiefly in the shallow sand and gravel deposits that are not overlain by impermeable material.

The deeper water-bearing formations, however, are also susceptible to salt-water contamination. The seaward extensions of the deeper water-bearing beds contain salty water that may be either the water of original deposition, some of which was sea water, or salt water which invaded these formations at times during the glacial period when sea water covered more of the coastal areas than at present. In any event, the salty water present in the lower parts of these seaward-dipping formations moves toward wells when the artesian pressures in these formations are reduced. The position of the contact zone or interface between fresh water and salt water in artesian aquifers is governed largely by the fresh water head that builds up above sea level in the up-dip portions of the formations. The natural balance is disturbed by the withdrawal of fresh water, which causes

TABLE III-1

GENERALIZED STRATIGRAPHY OF THE ATLANTIC COASTAL PLAIN PROVINCE

Era	Age	Approximate Thickness	Formation	Ground Water Importance
	Recent	Variable	Alluvium	Minor Importance
	Pleistocene	0-460′	Glacial and non-glacial sand, clay and gravel deposits	Locally good Aquifers
Cenozoic	Tertiary	100-250′	Cohansey Sand	Very Good Aquifer
		100′	Kirkwood Sand	Good Aquifer
		11′	Shark River Marl	None
		25′	Manasquan Marl	None
		25-100′	Vincentown Sand	Good Aquifer
		30′	Hornerstown Sand	Minor Importance
		0-130′	Red Bank Sand	Minor Importance
Mesozoic	Cretaceous	40-80′	Mt. Laurel and Wenonah Sands	Moderate Importance
		30-40′	Marshalltown Formation	None
		20-140′	Englishtown Sand	Good Aquifer
		50′	Woodbury Clay	None
		50-60′	Merchantville Clay	None
		150-500+′	Raritan-Magothy Formation	Very Good Aquifer

LEGEND

LARGE TO VERY LARGE QUANTITIES OF FRESH WATER OF GENERALLY GOOD QUALITY ARE AVAILABLE AT MOST LOCATIONS, ALTHOUGH DEPTHS TO THE MORE PRODUCTIVE AQUIFERS WILL VARY FROM PLACE TO PLACE.

LARGE SUPPLIES AVAILABLE NEARLY EVERYWHERE AT SHALLOW DEPTHS NEAR THE DELAWARE RIVER. WELLS IN THE DOWNSTREAM SEGMENT BELOW CAMDEN ARE SUBJECT TO INFILTRATION OF SALT WATER FROM THE RIVER. THE UPSTREAM SEGMENT RECEIVES FRESH WATER FROM THE DELAWARE RIVER BUT IS SUBJECT TO POLLUTION FROM INDUSTRIAL WASTES CARRIED BY THE RIVER.

LARGE QUANTITIES OF WATER AVAILABLE AT SEVERAL DEPTHS BUT AQUIFERS ARE SUBJECT TO CONTAMINATION FROM SALT WATER. AMOUNT OF FRESH WATER OBTAINABLE MAY BE LARGE BUT WITHDRAWAL MUST BE SPREAD OVER BROAD AREAS TO MINIMIZE SALT WATER CONTAMINATION.

SMALL TO MODERATE SUPPLIES AVAILABLE FROM BEDROCK IN MOST PLACES. LARGE SUPPLIES CAN BE OBTAINED FROM SAND AND GRAVEL IN SEVERAL OF THE MAJOR STREAM VALLEYS.

ONLY SMALL SUPPLIES AVAILABLE FROM BEDROCK FORMATIONS. MODERATE TO LARGE SUPPLIES MAY BE OBTAINED FROM SCATTERED OCCURRENCES OF STRATIFIED SAND AND GRAVEL IN STREAM VALLEYS.

PENNSYLVANIA

HIGHLANDS AND APPALACHIAN VALLEY PROVINCES

SUSSEX · BERGEN · WARREN · MORRIS · PASSAIC · ESSEX · HUNTERDON · SOMERSET · UNION

PIEDMONT PLAINS PROVINCE

MIDDLESEX · MERCER · MONMOUTH · OCEAN

COASTAL PLAIN PROVINCE

BURLINGTON · CAMDEN · GLOUCESTER · ATLANTIC · CAPE MAY · SALEM · CUMBERLAND

Newton · Belvidere · Phillipsburg · Clinton · Hamden · Frenchtown · Flemington · Lambertville · Morristown · Paterson · Hackensack · Newark · Jersey City · Elizabeth · Martinsville · Raritan · Somerville · Bound Brook · New Brunswick · Freehold · TRENTON · Asbury Park · Toms River · Mt. Holly · Palmyra · Camden · Paulsboro · Woodbury · Deepwater Point · Salem · Bridgeton · Mays Landing · Atlantic City · Cape May

DELAWARE RIVER · HUDSON RIVER · LONG ISLAND SOUND · UPPER BAY · LOWER BAY · RARITAN BAY · SANDY HOOK BAY · BARNEGAT BAY · DELAWARE BAY · ATLANTIC OCEAN

CONN. · N. Y.

40° · 39° · 75° · 74°

SCALE 10 0 20 30 MILES

PLATE III-1

12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

GENERALIZED GROUND-WATER YIELD CHARACTERISTICS
OF THE MAJOR GEOLOGIC PROVINCES OF NEW JERSEY

a reduction in the fresh water head. Thus, all along the coast in southern New Jersey, large-scale lowering of artesian pressures in the deeper aquifers and even small-scale lowering of water levels in the shallow deposits may result in salt-water contamination. Within this sub-division of the Atlantic Coastal Plain, the limitations of ground-water supplies are related more to salt-water contamination than to inadequate yields of wells. There is a limit to the supply of fresh water. Use of water in excess of this limit will result in an admixture of saline water with fresh water and would ultimately destroy the potability of the supply.

The Interior Plain Area, that portion of the Atlantic Coastal Plain lying between the narrow belts along the Delaware River and the Atlantic Coast, is underlain by several extensive aquifers containing large quantities of fresh water. Water entering the underground reservoirs is derived from infiltration of local precipitation. The relatively uniform chronologic and geographic distribution of precipitation (see Chapter I) provides a more or less continuous addition to ground-water storage causing the sub-surface reservoirs of the Interior Plain to remain filled to levels above the surface streams. These streams continuously receive the overflow of the ground-water reservoir as though they were fed by slow changes in the level of the spillway crest of a great surface reservoir. Hydrographs, or diagrams of daily flow of streams in the Interior Plain, show a remarkably uniform rate of flow as compared to streams draining the Northern part of the State. In the Interior Plain, the storage capacity of the aquifers is very large, the percentage of rainfall that reaches the water table is high and the quality of the ground water is generally good.

GENERALIZED GROUND-WATER YIELD

It is possible to make only broad generalizations concerning the average yield that may be expected from large-diameter modern-type wells drilled into the different aquifers in New Jersey. Precise figures for the maximum quantity that each formation will yield to a new well cannot be given. This is not only because very little is known about some of the aquifers but because of the great number of variable factors that can affect the yield of a well. Among the geologic factors are the permeability, thickness, hydraulic gradient and distance to recharge, all of which can change locally from site to site. The method of drilling, size of well and well development procedures all can greatly affect the final productivity of a new well. Moreover, the spacing and alignment of the several wells in a well field can affect the yield of individual wells in the group.

With these limitations in mind, the available information on the yield characteristics of each major aquifer has been studied and the range in yield tabulated. These yield classifications are presented on Plate III-3 and represent the areas in which aquifers having a common range in yield crop out at the surface or occur just underneath the glacial cover. However, the structural pattern of some of the aquifers, particularly those in the Atlantic Coastal Plain, makes it possible to utilize these aquifers over broader areas than is represented by their zones of outcrop. For example, the Raritan-Magothy aquifer crops out along a relatively narrow belt extending from Deep Water Point to north of Perth Amboy. Plate III-3 indicates that within this outcrop area, wells yielding in excess of 500 gpm may be expected. However, the aquifer does not terminate at the southeasterly border of the outcrop area, but extends coastward beneath younger geologic deposits. Thus, use of the highly productive Raritan-Magothy aquifer is not limited to the zone shown on Plate III-3 but can be encountered at increasingly greater depths below the land surface in a down-dip direction (southeast) from the outcrop area.

The areas of utility of all the southeasterly dipping aquifers beneath the Atlantic Coastal Plain are greater than the outcrop areas as shown on Plate III-2. The effective area of each is limited by the depths to which drilling is practicable and by the quality of water found in the aquifer of the greater depths. On the other hand, along the northwest, or up-dip edge of the outcrop of each aquifer, the water-bearing materials are thin and the yield of wells will be less than where the full thickness occurs.

WITHDRAWAL OF GROUND WATER IN NEW JERSEY

The United States Geological Survey has estimated that the total withdrawal of ground water in New Jersey in 1950 was about 500 million gallons per day. It was further estimated that of the total, approximately one-third was pumped for public supply, about one-half by industry and about one-sixth for rural and irrigation uses combined.

At present, the State does not require all industrial or agricultural users of ground water to report the quantity of water withdrawn, as is required of the public water systems. Therefore, the present withdrawal of ground water by industry, believed to be about half of the total pumpage of ground water, must be approximated, based on knowledge of such withdrawal in localized areas and information obtained from the questionnaire on industrial water use reported on in Chapter IV. A considerable percentage of the water withdrawn for public supply is actually used for industrial purposes in the different communities. Table IV-7 shows that over one-half of the consumption of all public water supplies in 1954 was by industrial users. About 45 per cent of all public supplies are obtained from ground water sources.

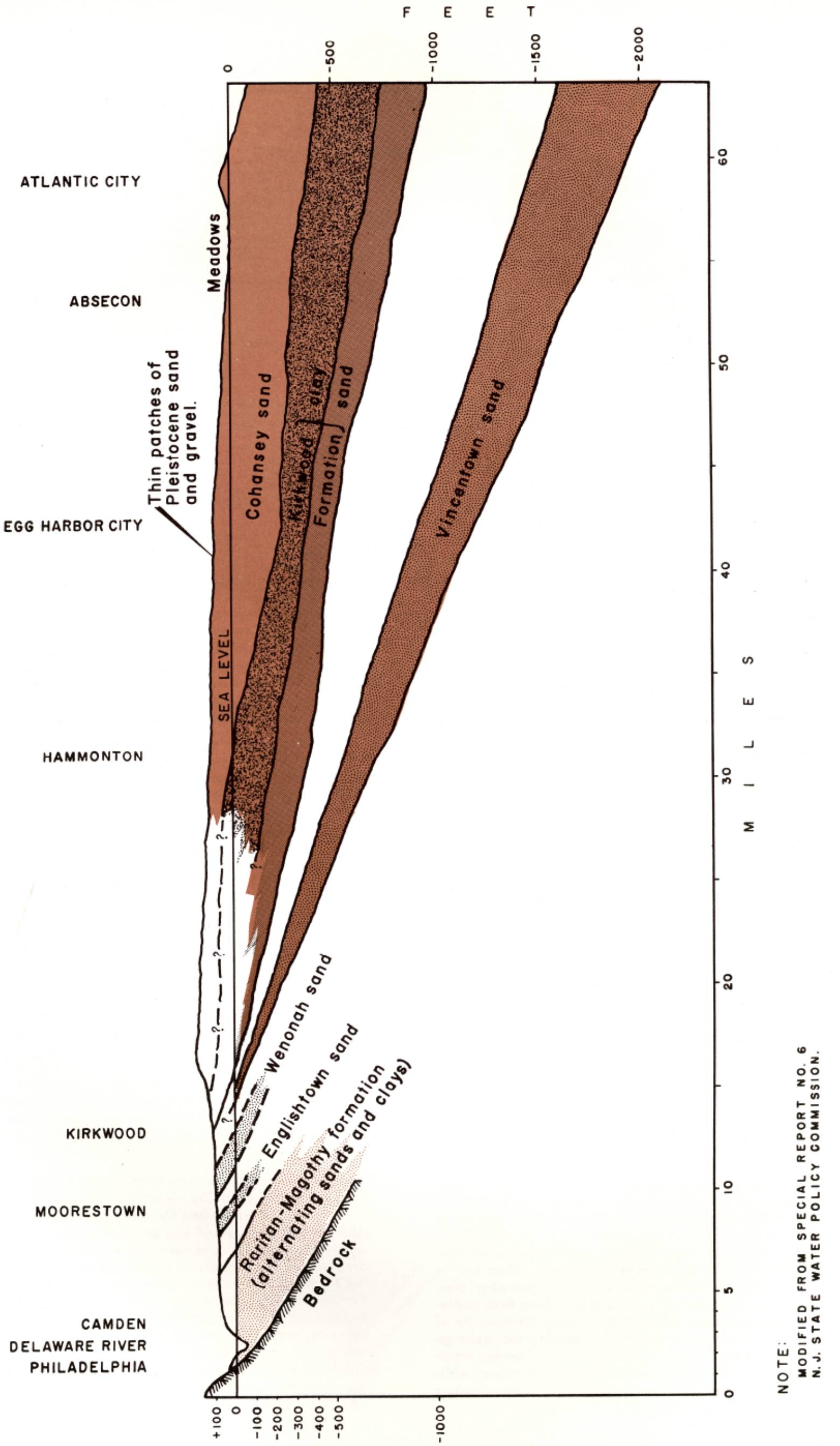
The Division of Water Policy and Supply of the State Department of Conservation and Economic Development receives quarterly reports from water companies and agencies indicating the quantity of water withdrawn from wells for public supply purposes. These records, covering all of New Jersey, as furnished by the Division, and in part by the U. S. Geological Survey, have been compiled for the six year period 1949-1954 and are given in Appendix B. In addition, the reported withdrawal of all public water supply systems during the past six years, 1949-1954, have been totaled annually and listed in the Table on Page B-1, Appendix B.

Only in recent years have farmers realized the full potential of supplemental irrigation in humid regions. The 1955 Yearbook of Agriculture, Water, reported a 75 per cent rise from 1939 to 1949 in the number of irrigated farms comprising the 28 Eastern States of the humid region, in comparison with a National gain of only 5 per cent. A survey in Virginia in 1953 indicated that irrigated farmland increased 700 per cent in 4 years. Irrigated acreage in New Jersey was estimated at 69,835 acres in 1954 and 28,117 acres in 1950—an increase of about 150 per cent. These data are summarized in Table IV-14.

Forty per cent of irrigation water requirements were estimated as obtained by ground-water withdrawal in 1954—according to a compilation of data obtained from all County Agricultural Agents especially for this report. Use of ground water for supplemental irrigation in New Jersey may be expected to rise proportionately to the anticipated increase in irrigated acreage. Leveling off of these requirements is forecast in the decade beginning in 1980.

Industrial development, as discussed in Chapter IV, is steadily expanding, and ground water is expected to figure at least as significantly in the year 2000 as at present. Advantages to industry of ground-water supply, such as nearly constant temperature, quantity and quality, may assume even greater importance in the future.

Ground water withdrawn for all purposes in 1950 and 1954 in New Jersey and withdrawals for the year 2000 are estimated in Table III-2.



NOTE:
MODIFIED FROM SPECIAL REPORT NO. 6
N.J. STATE WATER POLICY COMMISSION.

PLATE
III-2
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
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NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

GENERALIZED CROSS SECTION — CAMDEN TO ATLANTIC CITY, SHOWING PRINCIPAL WATER-BEARING STRATA

TABLE III-2

ESTIMATED GROUND WATER WITHDRAWAL

	1950 (average mgd)	1954 (average mgd)	2000 (average mgd)
Public Supply (Industrial and domestic)	164	186	333
Private industrial (Potable and non-potable)	260	296	466
*Irrigation	9	23	48
Rural (Farm and residential)	65	75	75
TOTAL	498	580	922

*Although irrigation requirements are seasonal, amounts shown are average daily rates to allow comparisons of total ground water use. See Chapter IV for more detailed discussion of irrigation water use.

Sources: "Estimated Use of Water in the United States—1950" U. S. Geological Survey Circular 115, 1951; Division of Water Policy and Supply, New Jersey Department of Conservation and Economic Development; Tippetts-Abbett-McCarthy-Stratton.

GROUND-WATER PROBLEMS

When an aquifer is penetrated by a well and water is withdrawn, a decline in water level in the form of a depression cone occurs around the well. If it were not for this gradient in the water table or in the artesian pressure surface, water would not continue to flow into the well. If the quantity of water withdrawn from the well does not exceed the quantity of recharge available to the well, the decline in water levels caused by the initial operation of the well will soon taper off and reach a level of stabilization. When stabilization is attained, the water level will fluctuate with changes in seasonal recharge and other natural causes but the effect of pumping will be fairly constant as long as the rate of withdrawal stays the same.

However, the operation of each additional well that is drilled into an aquifer results in some additional lowering of the regional composite water levels. The quantity of recharge that is available and can be transmitted by the aquifer may exceed the total quantity pumped, so that after each new well is placed in operation, a new but lower level of stabilization is attained. However, if more wells are operated than can be supplied by the aquifer, the initial drawdown of the wells will not reach equilibrium but will continue to decline. If the overdraft is small and the storage of water in the aquifer is large, the decline in water levels may be so slow that it will not be apparent except over long periods of time. Some aquifers, however, have small storage capacity, and overdraft from these formations may result in the failure of ground-water supplies with very little warning.

There are as yet only a few known areas in New Jersey in which the decline of ground-water levels may represent overdraft of the supply. In the Lower Delaware Valley, there may be one such area within the city of Camden where large diameter wells are used both by industry and for public water supply. A long term record of water level in an observation well within the city of Camden shows a progressive decline in water levels. A considerable part of this decline is believed to be the result of a gradual increase in total withdrawal, and the lower levels noted may reflect only a temporary condition during adjustment to new pumping rates. However, if the decline is a reflection of a long term depletion of water available from the formation, the quantity of water being withdrawn is probably exceeding the recharge and the area affected will eventually have a serious water problem. In the Perth Amboy area, the present rate of withdrawal is such that little or no additional ground-water development should be undertaken.

In the Triassic shales and sandstones of the Piedmont Plain the water-bearing sediments characteristically have low storage capacities. Commonly, in localities where numerous wells are operated, withdrawals exceed the natural replenishment and because of the small storage capacity of the aquifer, water levels decline rapidly. In an area southeast of Princeton water levels are now so low as to make any sizeable new development inadvisable. There are similar localized areas of large use where ground-water levels have declined seriously, such as at Newark. Doubtless there are additional localities where similar problems exist in the Piedmont Plain, but data for evaluating these problems are lacking.

Where salt-water encroachment occurs, it is generally related to declines in water level. In the Parlin-Old Bridge area, ground-water pumpage was found some years ago to be resulting in the encroachment of brackish water. In order to avoid the threatened contamination of the supply, water users in the area instituted a ground-water recharge program involving diversion of surface water into a large pond in a favorable intake area. By this addition to the natural recharge the decline of water levels has been stopped, and in turn, contamination of the supply has been prevented.

Along the Lower Delaware River Valley from Paulsboro south, the water-bearing sands and gravels in the valley alluvium are in hydraulic connection with river water that increases in salt content during periods of low flow. In this area, water levels in wells up to a mile or more distant from the river are at elevations only a few feet above river level. When the wells are pumped, water levels are generally drawn down below river level. Commonly, the cone of depression that is below river level extends to the channel area. As a result, river water, which at times is brackish, can enter the producing aquifers. There is some salt-water contamination now apparent in this area and more contamination will doubtless result if the shallow aquifers bordering the Delaware River are drawn on more heavily in the future.

Similar salt-water contamination exists to some degree in the coastal area from Cape May Point to Newark and in the lower valleys of the streams that discharge into the bays and Atlantic Ocean. As would be expected, contamination is now or likely to become most severe in the parts of the coastal area where water levels have had the greatest decline. In the Atlantic City area more ground water is being withdrawn than in other localities along the New Jersey coast and salt-water contamination constitutes an ever-present threat to the water supply. The salinity in portions of the shallow aquifers is high and chemical analyses show that in the deeper Kirkwood formation, from which the largest percentage of ground water is obtained, there has been a consistent though small increase in salinity in wells along the ocean front.

The Metropolitan Area of Northeastern New Jersey is one of the most highly concentrated and diversified industrial centers in the United States. The operations of some of these

RANGES OF WATER YIELDING CAPACITIES OF NEW JERSEY AQUIFERS

- OVER 500 GPM
- 100 TO 500 GPM
- 50 TO 100 GPM
- 10 TO 50 GPM
- 0 TO 10 GPM

NOTE:
IN THE COASTAL PLAIN PORTION OF THE STATE WHERE THE FORMATIONS DIP GENTLY TO THE SOUTHEAST, ONE OR MORE PRODUCTIVE AQUIFERS GENERALLY OCCUR AT GREATER DEPTHS BELOW THE AQUIFER OUTCROP AREAS AS SHOWN.

PLATE
III - 3
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
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NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

ESTIMATED CAPACITIES OF LARGE DIAMETER MODERN TYPE WELLS DRILLED INTO THE AQUIFER OUTCROP AREAS

industries result in pollution of water supplies by the disposal of acids, petroleum products, and many other types of industrial wastes. This is particularly true where the industries themselves are using wells and have caused the local water levels to decline, thereby facilitating to some degree the entrance of polluted surface water into local aquifers.

A serious instance of aquifer pollution by industrial wastes is the area from Secaucus south to Perth Amboy. Within this region pollution is perhaps the most severe in localized areas of petroleum refining, such as at Bayonne and Elizabeth.

Industrial pollution of a less severe nature, but no less widespread in occurrence, is taking place along the Delaware River in the Philadelphia-Camden region. In the past, the Delaware River has received large quantities of industrial wastes from industries along its borders. These wastes become a part of the water that is a source of infiltration to well fields bordering the river, and tend to contaminate wells in much the same way that salt water contaminates wells in that part of the valley below Paulsboro.

There is still another source of pollution in the Philadelphia-Camden area. This is the recharge believed to be taking place in dump areas where chemical and other industrial wastes are being disposed of. After infiltrating into the aquifer, these polluted waters move toward wells, including those in Camden and other areas. The wells showing evidence of such pollution are those obtaining water from the Raritan-Magothy aquifer. In recent years these wells have shown a significant increase in dissolved chemical concentrations. A similar but smaller area of industrial pollution has developed in northern Gloucester County. Thus, depending upon the location, some well owners may be affected by as many as three different sources of undesirable water, (1) salt-water contamination from the lower bay, (2) waste from dump areas and (3) wastes carried by the Delaware River from industries upstream.

POTENTIAL GROUND-WATER RESOURCES

THE HIGHLANDS AND APPALACHIAN VALLEY PROVINCES

The ground-water province formed by the Highlands and Appalachian Valley contains consolidated rocks that are generally unfavorable for the production of large supplies of ground water, with the possible exception of the Kittatinny limestone. The occurrences of large supplies of ground water within this formation are generally erratic because only where fractures and fissures have been locally enlarged by ground-water circulation is there appreciable storage and movement of water. Thus, while the formation may yield as much as several hundred gallons per minute at some sites, at other places there may have been little enlargement of the openings in the rock and yields of wells may be much smaller.

All of the Highlands and Appalachian Valley provinces were covered by one or more ice sheets during the geologically recent Ice Age. Locally, water issuing from the melting ice sheets deposited large quantities of glacial debris in the valleys of enlarged Ice Age rivers. In some cases these deposits underlie the courses of our present rivers. Elsewhere, the former channels have been abandoned and there may be little surface evidence of their position.

The glacial outwash sediments offer the greatest potential for large yields of any of the formations in the region. However, the location and extent of such favorable water-bearing materials is not well known. Furthermore, their identification and development for local water supplies may be quite difficult, requiring extensive test drilling, geophysical surveys and pumping tests to determine their hydrologic properties.

The ground-water potential of the Highlands and Appalachian Valley provinces is, therefore, limited to scattered localities within the outcrop area of the Kittatinny limestone and to the coarse sands and gravels deposited by glacial streams. Neither of these potential ground-water sources has been carefully investigated for the purpose of determining the actual availability of additional water. At present there is no reliable basis for even estimating the maximum utilization that might be made.

THE PIEDMONT PLAIN PROVINCE

The Piedmont Plain province is underlain chiefly by sandstones and shales and to a minor extent by trap rock. In the northern portion of the province, glacial deposits mantle the surface. Glacial outwash sediments occur in at least parts of the valleys of the major streams.

The sandstones and shales are moderately productive of ground water. Many of the smaller communities have obtained satisfactory quantities of water by drilling a number of wells in the Stockton and Brunswick formations. In general, the yield of individual wells in the Stockton is somewhat greater than the yield of comparable wells drilled in the Brunswick formation. However, the quantity of water in storage in either formation is small as compared to unconsolidated sediments, with the result that water-level fluctuations may be large. During extended dry periods the yield of wells may decline greatly.

The withdrawal of water in many localities within the Piedmont Plain is now about the maximum that can be pumped without causing water levels to decline below pump settings and perhaps below the bottom of the wells. Therefore, in some areas within this province where municipalities and industries have operating well fields, it is questionable whether or not additional large supplies can be obtained nearby. In other areas not previously developed, there remains a moderate potential in the sandstone and shale aquifers.

As in the Highlands and Appalachian Valley, the deposits of glacial outwash in river valleys of the Piedmont Plain have not been carefully mapped, nor have their water-bearing properties been widely studied. In places, such as in the Passaic River Valley, the yields of individual wells may exceed 1,000 gallons per minute. It is probable that by geophysical surveys, test drilling and additional geological studies, the courses of the streams that deposited the highly permeable sands and gravels can be ascertained and additional well fields developed. It is estimate that an increase in withrawal of perhaps 25 to 50 million gallons per day may be possible from new wells drilled in the outwash gravels where river infiltration from nearby surface streams can be utilized. Such withdrawals may locally decrease surface supplies by an equal amount, but the return drainage would normally reenter the stream at a lower elevation and be available for reuse.

THE ATLANTIC COASTAL PLAIN PROVINCE

The Lower Delaware River Valley Area is a part of the Atlantic Coastal Plain. Some of the water-bearing sands and gravels along the river are of glacial age, but most of the area is underlain by Raritan-Magothy deposits. The sediments, irrespective of age are similar in water-bearing properties. In general, the glacial materials directly underlie the river and form the immediate flood plain. The Raritan-Magothy sands and gravels characteristically underlie the glacial materials and extend perhaps two to three miles back from the river itself.

Numerous pumping tests made in connection with hydrologic studies in the valley area conclusively show that in well fields along the river, a considerable part of the water pumped is derived from river infiltration. So long as the river water is of satisfactory quality, it constitutes a factor that is beneficial to nearby wells in several respects. As compared to areas in the same aquifer farther from the river, wells adjacent to the river generally yield more, have less pumping lift, can be spaced closer together and are less subject to the competition for a limited supply that characterizes other heavily concentrated industrial and municipal areas.

Plate III-4 is a map of the Lower Delaware Valley subdivision of the Atlantic Coastal Plain. Between Trenton and Palmyra, just north of Camden, conditions are generally favorable for inducing infiltration from the Delaware River by pumping from wells located a few feet to as much as a mile from the river. Some localities adjacent to the river may not contain sands and gravels that are hydraulically connected to the river but tests indicate that such connections generally exist. Not all of this part of the Delaware Valley is available for the construction of new wells because the

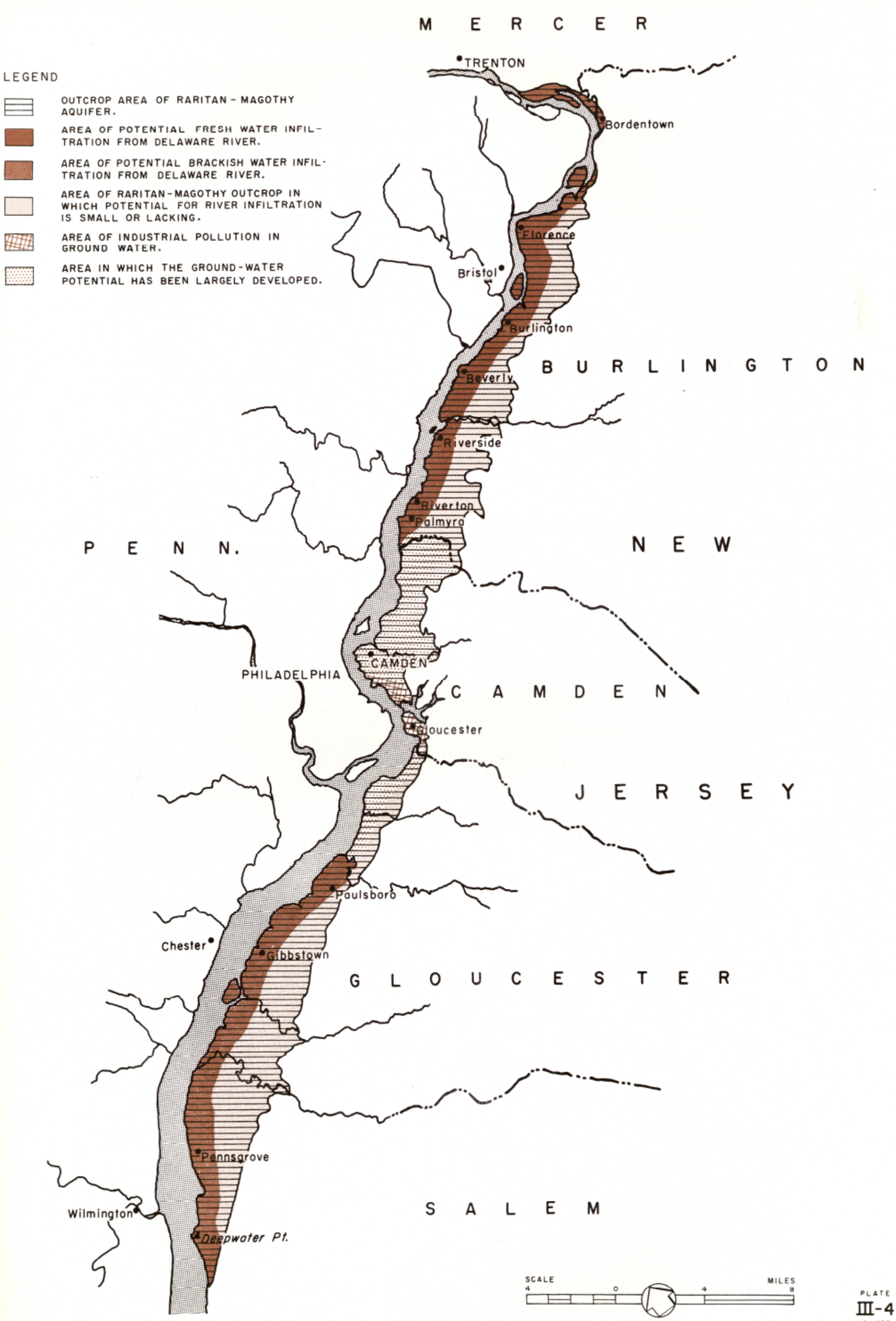


PLATE
III-4
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS
NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

GROUND WATER RESOURCES OF THE LOWER DELAWARE VALLEY AREA

ground-water potential at a few localities has already been largely developed.

Assuming that no more than one-half of the distance from Trenton to Palmyra may be geologically and physically suited for ground-water developments constructed so as to depend in considerable part on infiltration from the Delaware River, it is probable that more than 100 mgd of additional ground water might be developed from the strip of aquifer within a mile of the river. In small localities within this strip, wells or horizontal water-collector systems constructed at the river's edge might produce up to 50 mgd for a mile of river frontage. Such great productivity, however, requires direct communication between highly permeable sands and gravels and the river and a relatively short distance of travel for the induced infiltration. This favorable combination of conditions cannot be expected everywhere along this portion of the Delaware River.

Although river infiltration can take place anywhere in the Lower Delaware Valley where shallow sands and gravels are connected with the river, the development of additional supplies of fresh water will have to be restricted very largely to the area extending northeast from Palmyra. Present development and prior use of river frontage for docks and buildings will probably prevent further major development along a segment of several miles in the Camden area. Below Paulsboro the water in the Delaware River is brackish during periods of low flow. Thus, the potential from river infiltration in the valley south of the Camden area is counteracted by the presence of salt water in the river at times.

The channel of the Delaware River from Camden to Trenton may be widened and deepened by dredging to improve navigation to industries and municipalities. If carried out, such dredging will facilitate the infiltration of river water into the adjacent aquifers and will increase somewhat the influence that quality characteristics of the river water will have on quality of the water pumped. It is not known how effective anti-pollution measures will be in controlling industrial and municipal pollution in the fresh water portion of the Lower Delaware River, nor is there general agreement as to the effect dredging will have on salinity conditions in the river. Nevertheless, there can be little doubt but that water quality in wells along the river will be influenced more by the river after the channel is dredged, because of the improved opportunities for river infiltration.

Excluding the strip near the river where river infiltration can take place, there remains a band only a mile or so wide in which the Raritan-Magothy formations crop out at the surface and in which precipitation is the principal source of recharge. This narrow band constitutes the chief natural intake area for the aquifer. Some additional recharge may be provided by vertical leakage from overlying beds in down-dip areas of the aquifer, and to some extent by infiltration from streams crossing the narrow outcrop area.

Plate III-4 shows the outcrop pattern of the Raritan-Magothy formations and that portion of the outcrop area in which the Delaware River is relatively unimportant as a source of recharge. A part of this outcrop area near Camden already has numerous ground-water developments and additional new wells in this area may be considerably less productive than new wells drilled in undeveloped areas. Plate III-4 indicates those portions of the outcrop area that are generally favorable for additional ground-water development. Assuming on the basis of other studies in New Jersey, that recharge from precipitation averages about one million gallons per day per square mile, there is an approximate total of 40 to 50 million gallons per day that can be withdrawn continuously from that part of the outcrop area lying a mile or more back from the river. One quarter to one third of this quantity is probably being withdrawn by existing wells. The remainder, perhaps 25 to 35 million gallons per day, is available for additional development.

It should be recognized that if essentially maximum development is made in both the mile-wide strip along the Delaware River and in the remaining outcrop area of the Raritan-Magothy aquifer, utilization of this aquifer in its down-dip, artesian portion will be very greatly limited. Water intake for the aquifer occurs chiefly in the narrow belt of outcrop. Maximum development of ground-water supplies in the outcrop area will largely prevent the movement of water into the deeper, or down-dip portions of the aquifer. Under such conditions, most of the recharge to the aquifer southeast of the outcrop area will have to come from vertical leakage through the relatively impermeable clays that overlie the aquifer. However, such leakage may be sufficient to yield significant supplies if the area involved is large.

The chemical quality of water in the Raritan-Magothy aquifer in areas away from the river is generally good. However, high concentrations of iron and low pH values may make treatment desirable.

The Coastal Area subdivision of the Atlantic Coastal Plain does not differ geologically from the rest of the Atlantic Coastal Plain. It is discussed separately in this report because of the relatively large use of ground water in resort areas along the ocean front and because of the existing or threatening salt-water contamination that is locally related to such large uses.

Wells in the southern part of the Coastal Area obtain water from relatively shallow depths in the Cohansey formation or from sands of the Kirkwood formation at depths of several hundred feet. In the area from Asbury Park to Perth Amboy, ground water is obtained from the Mt. Laurel-Wenona, Englishtown and Raritan formations.

Major centers of withdrawal along the ocean are Cape May, Wildwood, Ocean City, Margate, Ventnor, Atlantic City and a closely-spaced series of resorts extending from Point Pleasant to Long Branch, of which Asbury Park is the largest. Additional centers of withdrawal are the municipalities on Raritan and Barnegat Bays.

The shallow Cohansey aquifer along the coast of southern New Jersey is quite susceptible to salt-water contamination. In general, the aquifer is highly permeable and though clay members may occur locally in the upper portion, as at Pleasantville, the development of an extensive cone of depression anywhere in this formation in the Coastal Area is likely to result in the infiltration of salty water. Salt water is known to have infiltrated into the Cohansey aquifer at Cape May Point, Cape May, Atlantic City, and Pleasantville, and probably is occurring at other places. Additional development of this aquifer near the coast can be undertaken on a limited scale but withdrawals should be widely spaced and as far from bodies of saline water as possible. Generally, the quantity of water withdrawn should not exceed about 1 mgd for each square mile of area in which recharge by precipitation can occur.

For the most part, the deeper aquifers form artesian systems with upper confining layers of clay that effectively retard or prevent the direct downward infiltration of sea water into the producing sands. The creation of large cones of depression in these artesian systems beneath bodies of salt water will not ordinarily produce any changes in quality due to infiltration from local surface water. However, highly mineralized water, which occurs in the down-dip portions of most of the Coastal Plain aquifers, may be near enough to centers of withdrawal along the coast to invade the well fields. The hydrostatic head (the elevation of water level in wells) in the water-bearing formations along the coast does not exceed a few feet or at most a few tens of feet above sea level. The ratio between the densities of sea water and fresh water is such that the relatively low artesian head in the different aquifers is insufficient to restrict the salt water to great depths. As a consequence, the aquifers that occur below depths of perhaps a thousand feet are likely to contain salty water. Therefore, many of the deeper aquifers that underlie the Coastal Area are useless as sources of water supply. In Atlantic City the 800-foot sands of the Kirkwood formation is fresh throughout most of the area but there is evidence that the salt water interface has moved landward toward the edge of the city. In the Asbury Park area, salt-water contamination of the artesian aquifers has not yet occurred.

In most areas of present withdrawal from the deeper aquifers along the coast, very little additional development can be made without ultimately causing salt water to move into or close to the well fields. However, moderate new developments can probably be made in aquifers not more than several hundred feet deep, if the wells are located at some distance from existing developments. As in the shallower aquifers, new wells should be spaced over a broad area and as far from the shore as practicable.

The Interior Plain Area of the Atlantic Coastal Plain, New Jersey's largest and best ground-water region, lies essentially undeveloped and unchanged from its original natural condition. Much of the region is covered by an oak-pine forest (the New Jersey Pine Barrens). It comprises an area of roughly 2,000 square miles. Nearly all of the Interior Plain is underlain by sand, principally the Cohansey and Kirkwood formations. The sandy nature of the soil, the flat topography and relatively uniform precipitation, combine to form an area of very high infiltration. Even in times of heavy precipitation, most of the water that falls enters the soil and a substantial part of this reaches the water table.

The Cohansey sand underlies more than 2,000 square miles of the Atlantic Coastal Plain and has a thickness of as much as 250 feet. It is almost everywhere composed of well-sorted quartz sand. Water contained in the formation is generally unconfined, as the few clay lenses that occur are local in extent. Therefore, essentially all of the more than 2,000 square miles of outcrop of this one formation alone is an area of very high infiltration capacity. For the magnitude of water in storage, the availability and directness of recharge and for the ease and economy with which large quantities of water may be withdrawn, this formation has no equal in northeastern United States. Properly constructed large diameter wells, perhaps 100 to 200 feet deep, may be expected to have yields averaging 500 to 1,000 gallons per minute.

Within a zone a few miles wide paralleling the northwestern border of the outcrop area, the Cohansey sand is too thin to furnish large yields to wells, but throughout nearly all of the balance of the outcrop area, the opportunities for obtaining large yields are believed to be very good. If completely utilized, the Cohansey aquifer would probably sustain a development of perhaps 2 billion gallons per day—the equivalent of a million gallons of infiltration per day for each square mile of outcrop. Doubtless, no such complete development of the potential would be economically feasible, because it would require a large number of wells dispersed over the entire area to prevent any lateral discharge from taking place around the borders. Nevertheless, a considerable part of the annual ground-water recharge can be developed by wells in a practical manner without the necessity of a widespread network of individual wells, as is described in a subsequent portion of this chapter.

The chief deficiency in properly planning for the immediate development of large quantities of ground water from the Interior Plain is that essentially no investigations have been made to determine the most favorable sites for development. Studies are needed to determine the hydraulic properties of potential areas, the proper spacing, depth, diameter and construction of wells, the probable yield per well that may be expected, and the chemical quality of water. The importance of such prerequisite studies may not be realized because of the overall excellence of the ground-water potential. However, it should be recognized, for example, that an area supporting wells each yielding 1,000 gpm rather than 500 gpm will require only half the number of wells and perhaps half the capital investment for a given quantity of water. Moreover, a well field involving a system of wells spaced one to each square mile would be much less practicable from an economic standpoint than a pattern of wells aligned at perhaps 500 foot spacings along a stream which by infiltration could sustain the perennial yield of the wells.

Depending upon the distance to which the water developed in the Pine Barrens may have to be transported to ultimate consumers, and land use practices that may affect the availability of water, it is estimated that perhaps one-fourth to one-third of the total annual recharge to the formation may be considered as a feasible ground-water potential. This is a quantity averaging from one-half to two-thirds of a billion gallons per day.

The chemical quality of ground water in the shallow aquifers of the Interior Plain is generally good, although moderately high concentrations of dissolved iron and somewhat low pH values may be expected. The water is soft, with a total hardness of less than 50 parts per million in most places. The leaching of organic material from the soil zone has resulted in moderate to high nitrate values in places. Ground-water developments in some localities may yield water of moderate color. Properly constructed wells should yield water with little or no turbidity or color.

All of the Coastal Plain aquifers that crop out west of the Pine Barrens (Plate III-2) underlie the Cohansey sand in the Interior Plain. The Kirkwood occurs just beneath the Cohansey and in places may be economically important for water supply even where the Cohansey would receive first choice in development. Generally, none of the aquifers that underlie the Cohansey sand in the Interior Plain will receive much development as long as the more favorable potential of the Cohansey remains available. The water-bearing characteristics of the deeper aquifers are not well known, although there is evidence that they thicken to the Southeast in the down-dip direction. The permeability of some of these aquifers may improve somewhat with depth.

The quality of water of the aquifers underlying the Cohansey is likely to be less desirable as the depth of the aquifers increases. The Raritan-Magothy aquifer, the deepest water-bearing bed underlying the Interior Plain, begins to be salty in southern New Jersey a considerable distance inland from the coast. The U. S. Geological Survey has indicated that the fresh water-salt water interface within the Raritan-Magothy aquifer extends diagonally across southern New Jersey along a line passing through Salem and Toms River. This interface probably passes beneath the Wharton Tract in the Pine Barrens. Any significant development in the Raritan-Magothy aquifer within the Wharton tract would likely produce water containing increasing salt concentrations as pumping continued.

PROCEDURES FOR EFFECTIVELY DEVELOPING THE GROUND-WATER POTENTIAL

The orderly development of the ground-water resources of an area must be based on knowledge of the amount and quality of water in the area and information about the formations constituting the underground reservoir. A ground-water resource is continually in the process of being depleted at the same time it is being recharged. In the natural state of the resource the volume of water in storage continually fluctuates. Although changes in quality are generally slow as compared to surface water, significant changes may take place.

Studies of the natural occurrence of ground water in New Jersey should include a program of systematically measuring water levels in wells which penetrate the principal aquifers in the State. To be effective, such measurements should be made regularly and continued over a long period of time in order to permit evaluations of the variations in natural discharge and recharge. The general information thus provided on natural changes in ground-water storage would constitute an important part of any detailed or localized studies leading to the development of a ground-water supply.

At present, New Jersey, through its cooperative program with the U. S. Geological Survey maintains approximately 275 observation wells in which periodic measurements of water levels are made. Of these, about 85 observation wells are equipped with water-level recorders. In a few of these a continuous record of more than 30 years is available. However, large areas of the State underlain by geologic formations known to be potentially important as aquifers have no existing observation wells. Future ground-water developments in these areas will be handicapped by reason of this lack of background data.

Just as in the past, most future ground-water developments of large capacity will be located in the Coastal Plain province of New Jersey. Consequently, the emphasis on additional observation wells should be placed on South Jersey areas. In areas where new ground-water developments are contemplated, such as in the Wharton Tract and other parts of the Pine Barrens, observation wells should constitute the first step in the investigations. These wells should be located away from the effects of present pumping so that the natural hydrologic conditions of the area can be determined.

In many respects, information on the chemical character of available ground-water supplies is just as important as information on quantity characteristics. The quality of ground water may vary from place to place even more intricately than the variations in geology. Broad assumptions concerning ground-water quality can generally be made if the character of the water-bearing materials is known. For example,

sand formations in the Coastal Plain of New Jersey commonly yield soft water, whereas water from limestones in northern New Jersey is characteristically hard. However, the water in many of the principal aquifers of the State exhibits differences in chemical characteristics from place to place within the same aquifer. In most instances, moderate changes in water quality will be of little concern to ground-water users. A problem of considerable importance, however, is the present occurrence of salt water in areas of the State where supplies of fresh water are being obtained. Moreover, in some areas conditions exist which will permit the encroachment of salt water in the future.

As in the observation well program, periodic sampling of water from selected wells for a considerable period of time will be required in order to determine any changes in water quality which may be taking place. Because of the characteristic slowness of changes in ground-water quality, the frequency of sampling can be much less than that of water-level measurements, and still provide effective information.

Because the largest new ground-water developments will undoubtedly be made in Coastal Plain Province, most of the wells to be sampled for water quality should be in the principal sand formations of South Jersey, particularly along the sea coast and adjacent to tidal bays and rivers, where salt water or other contamination is most likely to occur.

A third requirement for an adequate understanding of the overall ground-water supply conditions in New Jersey is an effective accounting of all important quantities of water being withdrawn from the ground. This information, together with observation wells serving as regional indicators of ground-water reservoir conditions and with a network of wells for determining water quality and warning of any encroachment of polluted and contaminated water, will enable new developments to be undertaken with proper safeguards. On no other basis can remedial measures be effectively designed and placed in operation at the proper time, nor can additional large-scale developments be made without risk of exceeding the available supply.

These factors for orderly future ground-water development have been recognized and studied as a part of the Federal-State ground-water program in New Jersey. In general, however, the number of wells for water-level observations and for quality of water sampling has been far short of the number necessary to protect adequately against costly mistakes in location and design of some new ground-water development. Furthermore, under the present ground-water program, it has not been possible to collect and maintain complete and adequate records of the use of ground water by industry and for irrigation, similar to those now available for public water supply.

The construction and use of wells should be based on specific knowledge of the ground-water hydrology of an area. For the actual location and construction of wells the hydrology of an area should be known in considerably more detail than the generalizations possible from the water-level characteristics and quality of water data obtained through broad state-wide programs. After a generalized program has shown that an area is favorable, the physical characteristics of the local aquifers should be determined, and studies made of the quantity of water obtainable from individual wells.

THE HIGHLANDS AND APPALACHIAN VALLEY PROVINCES

In Northwestern New Jersey the terrain is moderately rugged, sparsely populated and contains numerous surface streams providing water of better-than-average quality. At the present time the need for detailed ground-water studies in the Highlands and Appalachian Valley ground-water province is considerably less pressing than in the more populated portions of New Jersey. Furthermore, the well-developed pattern of surface drainage provides most localities with a nearby source of surface water. However, some of the major valleys may contain alluvial aquifers having a considerable potential supply, especially where such sediments are in hydraulic communication with surface streams. Knowledge of these ground-water potentials will be a definite asset as an aid in the location of industry or in the expansion of the existing facilities in the region.

THE PIEDMONT PLAIN PROVINCE

Although the yield characteristics of the bedrock aquifers in the Piedmont Plain are better than those of the Highlands and Appalachian Valley, the chief need for additional hydrologic studies in the Piedmont Plain is in extending knowledge of the erratic but highly productive glacial outwash deposits that occur in parts of the major river valleys. Most of these deposits are probably hydraulically related to surface streams, even though such connections may be indirect in some localities. Therefore, the dependable yield may be very large, even in small areas. However, if a nearby stream does not contribute infiltration to local deposits of outwash material, the yields of wells, though large at first, may rapidly decrease to much smaller quantities.

Occurrences of highly permeable glacial outwash deposits in stream valleys appear to be sufficiently numerous to warrant fairly extensive studies of their distribution and water-bearing properties. Utilization of these local aquifers for new supplemental water supply can be considerably increased. They constitute the only important potential for new ground-water developments of significant size in the Piedmont Plain.

Nevertheless, the bedrock aquifers of the Piedmont Plain are quite important at the present time in supplying a large number of small industries and communities with adequate quantities of water. The convenience and economy of such supplies, as compared to the extensive and costly installations that would be necessary for surface water systems, justify giving greater attention to these aquifers than would otherwise be warranted. To obtain further benefit from the sandstone and shale aquifers of the Piedmont Plain, studies should be made to ascertain the most practicable depth and diameter of wells, to determine factors relating to interference and spacing of wells and the effects of seasonal variations in recharge.

THE ATLANTIC COASTAL PLAIN PROVINCE

The Lower Delaware Valley Area

The U. S. Geological Survey has estimated that nearly 100 million gallons per day of ground water is withdrawn in the Lower Delaware Valley Area from aquifers on the New Jersey side of the river. As previously discussed, the potential in that part of the area between Palmyra and Trenton is very favorable for inducing large quantities of fresh water infiltration from the river. Elsewhere in the valley area, however, salt-water contamination, industrial pollution, and existing developments may prevent further development of large fresh ground-water supplies.

Because of the large use and the difficulties just enumerated for parts of the area, sound future developments will require detailed knowledge of local hydrologic conditions. Of particular importance will be the maintenance of a close check on chemical characteristics.

There can be no guarantee that the quality of water in the Delaware River between Bordentown and Paulsboro will continue to be a satisfactory source of infiltration for wells drilled into the valley alluvium and the adjacent Raritan-Magothy aquifer. Industrial wastes from up-stream sources or brackish water from down stream could seriously affect the utility of many million gallons of ground water withdrawn daily for residents and industries in this segment of the valley. Moreover, deterioration of the quality of the river water could deny to the Lower Delaware Valley area future use of the large ground-water potential previously described in this chapter. The small number of wells serving as quality of water sampling stations should be increased by several fold, both in the fresh water segment and in the area of salt-water contamination as shown on Plate III-4. This enlargement of chemical quality sampling stations should be continued until a more or less evenly-spaced system of wells about one mile apart along the river is obtained for the entire valley area from Bordentown to Deep Water Point. The Lower Delaware River Valley is the most critical area in New Jersey with respect to present and future quality of water problems, notwithstanding the severity of salt-water contamination along the Atlantic Coast. For this reason, an adequate sampling program should be established to provide data on changes in water quality in the valley as indus-

trial development increases, as future droughts and periods of low stream flow occur and in the event that the channel above Philadelphia is deepened.

To a somewhat lesser degree, a second prerequisite to the proper future development of the ground-water potential in the Lower Delaware Valley will require an increase in the number of observation wells now being measured. Additional observation wells should be established near the principal centers of ground-water withdrawal. Their chief purpose will be to determine the maximum safe withdrawal that can be made without exceeding the rate of annual recharge to the aquifers.

Before any new developments are undertaken, detailed hydrologic studies, based principally on test drilling and pumping tests, should be made to determine the most favorable localities for river infiltration within the fresh water portion of the Lower Delaware Valley Area.

The Coastal Area

There are a number of aquifers underlying the Coastal Area of the Atlantic Coastal Plain, several of which are capable of yielding very large quantities of ground water. However, from the Atlantic City area south, all but the Cohansey and Kirkwood sands lie at considerable depth. The top of the Raritan formation beneath Atlantic City is estimated to be 3,000 feet below land surface. As a result of the depths at which the older geologic formations lie, they probably contain water with salinities too high to be of use for water supply.

The principal ground-water problems along the coastal border of the Atlantic Coastal Plain are those of water quality and not quantity. For this reason, studies leading to additional development should include the determination of the fresh water-salt water relationships, so as to provide adequate forewarning of any encroachment of unsatisfactory water. In each area of withdrawal, such safeguards require a carefully selected pattern of outpost wells situated between the production wells and the salt water source. Outpost wells should be an integral part of any new development and their construction should not be delayed until after the first indication of salt water has appeared in a well field. At least two outpost wells should be provided between a well field and the salt-water source. They should be located in a line down the dip of the formation in the deeper aquifers and in the direction of probable salt-water infiltration in areas of shallow aquifers. Samples of water from the outpost wells should be obtained periodically, as often as once each month in heavily pumped areas. The program of periodic sampling should be carried on as long as pumping continues.

The Interior Plain Area

The Wharton Tract. It is probable that all of the many square miles of the Wharton Tract owned by the State of New Jersey is an effective recharge area for the Cohansey aquifer. At least 20 inches of rainfall during an average year reaches the shallow water table and moves laterally to nearby streams. Stream flow from the Wharton Tract is derived largely from ground water that seeps into the stream channels through the permeable sides and bottoms of the stream beds. Study of the stream flow records for the Batsto River indicate that during dry years at least 80 percent or more of the total surface discharge is derived from ground-water seepage.

The streams draining the Wharton Tract function in much the same way as drainage canals in a swampy area. They collect the ground water that slowly overflows from the underground Cohansey reservoir. This vast ground-water reservoir is maintained by precipitation in a state of saturation at all times and feeds the streams of the area which are in effect the lines of overflow of this reservoir. Each major rainfall recharges the underground reservoir so that its storage level is rarely lowered for long periods of time.

The large quantity of ground water available in the Cohansey underground reservoir can be developed by pumping from numerous wells sufficiently dispersed over the area so that mutual interference between the wells will not be excessive. Heavy pumping for such a group of dispersed wells would lower ground-water levels and partially dewater the upper part of the Cohansey aquifer. The net effect of such pumping would be to decrease the quantity of ground-water seepage into stream channels by an amount approximating the pumpage.

Until pumping tests have been conducted in the Wharton Tract, the proper spacing between wells dispersed over the area will not be known. If a development of large capacity is contemplated for the Wharton Tract, the proper well spacing may be such that the system of connecting pipe lines between the dispersed wells will be costly. Fortunately, another method of ground-water development can be utilized which will require much shorter connecting pipe lines than that needed for a layout of dispersed wells.

As noted above, the streams draining the Wharton Tract and surrounding areas bring the ground-water runoff of the several watershed areas to the lower part of the Wharton Tract. There can be practical use made of this natural ground dewatering system without constructing costly impounding surface reservoirs or extensive well field systems. The two principal streams in the Wharton Tract are the Mullica River with its tributaries, the Batsto, Mechescatauxin and Neschochague; and the Wading River with its East and West Branches. Both flow to the southeast, with the Mullica system draining the western part of the Tract and Wading River draining the eastern part and adjacent areas.

At a point south of Batsto just below the mouth of the Batsto River, the Mullica River has a drainage area somewhat greater than 200 square miles. The stream is not gaged at this point, but based upon flow records from 1927 to date for the Batsto River just above its mouth, the average flow of the Mullica near Batsto is estimated to exceed 200 million gallons per day. The records indicate that during a dry month, the Mullica River may be expected to have an average flow of about 90 million gallons per day. Similarly, the average flow of the Wading River at a point a short distance below Harrisville is estimated to approximate 150 million gallons per day. The average flow of the Wading River at this point during a dry month is computed to be about 40 million gallons per day. Each stream picks up most of the ground water that is derived from yearly precipitation that infiltrates to the part of the Cohansey aquifer within its drainage area. Each stream brings its portion of this large yearly ground-water recharge to the lower parts of the Wharton Tract where it can readily furnish river infiltration to continuously supply nearby wells with large quantities of good water.

No tests have been made in the Wharton Tract to determine the water-bearing properties of the Cohansey aquifer. The transmissibility (water transmitting capacity) of the Cohansey aquifer has been found by tests made in other parts of the Atlantic Coastal Plain to be such that a one mgd well deriving water from a constant source of river infiltration from a stream approximately 100 feet distant, can be spaced within a few hundred feet of a similar well along the stream without serious interference between the wells. If actual field tests carried out at sites for ground-water developments in the Wharton Tract show a transmissibility similar to that of the Cohansey in other areas, a closely-spaced line of wells could produce up to the entire flow of the stream at low stages. Such moderate variations in flow as occur in the Wharton Tract streams will have only slight effect on the dependable yield of the well fields. This is because the Cohansey aquifer probably has a specific yield of more than 20 percent (a decline in water level of one foot would occur as a result of withdrawing one-fifth of a cubic foot of water from a cubic foot of sand). It has been estimated by the U. S. Geological Survey that for each foot the water level is lowered over an area of one square mile, the Cohansey aquifer would yield nearly 50 million gallons of water. This vast reserve storage would be available to be drawn upon during short periods of low flow in the stream. During the fall of the year, the maximum capacity of a well field utilizing stream infiltration should be considered approximately the mean monthly flow of the stream during the dryest month. As noted above, the dry weather flow of the Mullica River is computed from existing records to be about 90 mgd and that of the Wading River about 40 mgd.

There is little doubt but that Wharton Tract ground-water developments large enough to augment existing supplies in the Camden and Atlantic City region to meet any foreseeable

sufficiently far in advance by the acquisition and reservation of adequate sites for future ground-water supply.

At present there probably are many small tracts of land publicly owned or controlled by municipalities, townships, counties or the State which may be suitable for reserving as future sites for supplemental ground-water supply. Those of appropriate size and nearness to existing facilities can be readily evaluated as to their general ground-water potential. When the potential appears favorable, test wells should be drilled and pumping tests conducted. By this means, questions as to the minimum area required for a given development, the possible effect of such new wells on other water users, and the approximate costs of needed expansions can be answered with fair reliability.

Ground-water sites to be held in reserve for future needs can probably be found within land now in public ownership, so that the purchase of additional property may not be required. Furthermore, such costs as may be necessary in reserving numerous scattered parcels of public lands for future water supply will undoubtedly increase with time, or these lands may not remain available. Prior to any acquisition, however, hydrologic studies should be made in each area of anticipated need.

DEVELOPMENT OF A MAJOR NEW GROUND WATER SUPPLY FOR THE CAMDEN AREA

As explained in the discussion of water requirements for the Camden Area (Service Area IX) in Chapter V, expected increases in water consumption or the necessity for abandonment of some of the well supplies presently used may require a new source capable of supplying up to 100 mgd by the year 2000. The possibility of developing such a new supply from surface flows of Rancocas Creek has been presented in Chapter II.

As explained previously in this chapter, it is also possible to develop such a supply by means of a ground-water development in the Mullica River Basin. Ground-water supplies may be obtained more conveniently and economically by a series of wells situated adjacent to the river bank (where they would be supplied by river infiltration) rather than by a widely dispersed well field located in the watershed area. By means of such a river bank collection system of wells, it is possible to develop the minimum surface flow of the stream without use of the ground-water reserves, although such reserves may be drawn upon during periods of deficient streamflow. As previously stated, the minimum monthly flow of the Mullica River at the mouth of the Batsto River is about 90 mgd. Considering that the ground water reserve may be drawn upon during dry periods, it is believed that the estimated requirements for water for the Camden area could be supplied by a well system constructed at this location.

In the development of cost estimates for the collection system, the following assumptions were made:

1) Each well would be 100 feet deep and be equipped with a casing 14 inches in diameter. The lower portion of the casing would be perforated and the well constructed to draw water only from the lower levels, thereby obtaining water of the best quality.

2) The wells would be spaced 500 feet apart in a line paralleling the river and about 100 feet removed from the river bank.

3) Available information indicates that each well in such an installation may be expected to yield one million gallons per day.

Since stage development of this supply will undoubtedly be desirable to reduce the capital outlay to the minimum necessary to keep abreast of the increasing requirements, it has been assumed that the 120 wells (including 20 as reserve capacity) which will ultimately be required would be constructed in 4 sections of 30 each. Two sections of wells would extend upstream along the Mullica River from the mouth of the Batsto River, and the other two sections would extend upstream along the Batsto River from the same point, as shown on Plate III-5. An intercepting pipe line would deliver water from the four sections to a central point, resulting in a modified "H" pattern. A booster pumping station would deliver water from the intercepting main to the transmission aqueduct at the required transmission pressure. Since the intervening sand and gravel between the river channel and each of the wells in the collection system would serve as a natural sand filter, it is assumed that no water treatment other than chlorination would be required for this supply. This chlorination could be accomplished at the booster pumping station or at another point in the transmission system.

The capital costs of these facilities required to develop a supply of 100 mgd at the point of connection with the transmission aqueduct are as follows:

120 Wells complete with Pumps	$3,000,000
Intercepting Pipe Line	2,200,000
Booster Pumping Station	1,300,000
Total Capital Costs	$6,500,000

The cost estimates given above do not include costs of the transmission aqueduct required to deliver water to the existing Camden distribution system. Transmission costs are covered in Chapter V.

DEVELOPMENT OF A MAJOR NEW GROUND-WATER SUPPLY FOR THE ATLANTIC CITY AREA

Requirements for new potable water supplies for the Atlantic City area due to increases in water consumption or the necessity for abandonment of some of the well supplies presently used may require a source capable of supplying a seasonal peak delivery of up to 22 mgd by the year 2000. Such a requirement is explained in the discussion of Service Area X in Chapter V.

As explained previously in this chapter, the minimum monthly flow of the Wading River at the junction of the two branches near Harrisville is about 40 mgd. Accordingly, a collection system of wells at that location, drawing upon the stream flow of the two branches of the river, could supply the requirement for Atlantic City without dependence upon ground water reserve. The location of the collection system for such a development is shown on Plate III-5. Construction of the well system would follow the general plan discussed in connection with the Camden supply. One line of 14 wells would extend upstream along the West Branch of Wading River and a second line of 14 wells would be constructed along the East Branch upstream from the junction of the two branches. As in the case of the collection system for Camden, an intercepting pipe line would deliver water from the wells (under pressure from the pumps at the individual wells) to a central point where the booster pumping station would be located. The booster pumping station would deliver water from the intercepting main to the transmission aqueduct at the required transmission pressure.

The capital costs of the facilities required to develop a dependable supply of 22 mgd for Atlantic City at the point of connection with the transmission aqueduct are as follows:

28 Wells (including 6 as reserve) complete with pumps	$700,000
Intercepting Pipe Line	620,000
Booster Pumping Plant	620,000
Total Capital Costs	$1,940,000

The estimated costs listed above do not include the cost of the aqueduct required to deliver water to connections with the Atlantic City distribution system. Costs of the aqueduct are presented in Chapter V.



PLAT III-5
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS – ABBETT – McCARTHY – STRATTON
ENGINEERS
NEW YORK

NEW JERSEY WATER RESOURSES DEVELOPMENT

EXISTING AND PROPOSED AQUEDUCTS
SOUTHWESTERN AND COASTAL REGIONS

CHAPTER IV

CHAPTER IV

FUTURE CONSUMPTION OF WATER

POPULATION

New Jersey is located at the geographical center of the heaviest concentration of population in the country. This region extends along the Atlantic Seaboard from Boston to Washington, D. C. New Jersey is also halfway between the giant metropolitan areas of New York and Philadelphia, parts of which are contained within the State. In this strategic position, New Jersey enjoys a thriving and steadily expanding economy.

Future consumption of water in New Jersey will result largely from the expected growth in the State's population. Increases in the number of New Jersey residents will be reflected both in the household use of water and in industrial and commercial water consumption. Preliminary to estimating future water demand, therefore, population forecasts have been prepared for each of the twenty-one counties of the State. These county forecasts, as shown in the table on Plate IV-1, were computed at ten-year intervals through the year 2000, and were also combined into groups approximating the State's four geographic regions in a graph which is shown on the same plate. A brief discussion of each county's growth outlook is presented later in this chapter.

U. S. POPULATION FORECASTS

Recent forecasts of population in the United States for the year 2000 range from 210 million (the lowest projection by the Social Security Administration) to 273 million (by the Stanford Research Institute). The estimates which were prepared prior to the 1950 census may be disregarded since they lack sufficiently current data. The most reasonable projection for consideration in this study appears to be that of the Social Security Administration which predicts a population of 254 million in the year 2000. This prediction is based upon an assumed relatively high fertility, a low mortality and an annual immigration of 100,000 persons.

STATE SUMMARY

The population of New Jersey was estimated to be 5,370,000 in July 1955, a figure which represents a 185% increase over the 1.9 million people at the turn of the century. The population of the United States as a whole increased only 117% during the same period. In fact, New Jersey's share of the country's population grew from 2.5% in 1900 to 3.3% in 1930, where it now stands. It is unlikely that this percentage will increase in the future, since the western states will probably continue to expand in population more rapidly than New Jersey.

Composition of Population

The population of New Jersey is composed primarily of the following occupational groups and their families:

1. Employees of the large number of manufacturing industries in the State.
2. Employees in retail and wholesale trades; business, professions and service trades catering to the State's residents.
3. Commuters who live in the State but work outside its borders.
4. Workers in agriculture, fishing and mining.
5. Retired persons.

A high proportion of New Jersey's population lives in urban areas: 87% in 1950 according to the U. S. Census, as compared to 64% for the country as a whole. A large share of the labor force is locally employed in manufacturing work, although out-of-state commuters populate vast urbanized sections served by an extensive network of interstate transportation facilities. Agriculture, transportation and the resort trade also contribute to the basic economy of the State.

Birth and Death Rates

The birth rate in New Jersey has remained consistently below the national average. Both state and national rates fell from a World War I high to a low during the mid-1930 depression period. The birth rate following the depression has generally increased to its present high level. For the purpose of this study, it is reasonable to accept the U. S. Census forecast which assumes a constant birth rate until 1965, followed by a gradual decline until 1975. During the period 1975 to 2000, the Social Security Administration's projections utilizing the mean of the 1940 and 1948 birth rates appear to be most suitable. Based on these forecasts and on New Jersey's past relationship to U. S. birth rates, the State's rates are likely to decline gradually from 20.2 per 1,000 population in 1950 to 15.5 in the year 2000 (see Table IV-1).

Forecasts of U. S. death rates from the same sources were adapted to New Jersey's population in a similar manner. The State's death rates thus may be expected to decline from the present level of 10.1 per 1,000 population to 9.7 in the year 2000 (see Table IV-1).

As a result of the predicted births and deaths in New Jersey, the natural increase is expected to decline gradually from 10.1 per 1000 population in 1950 to 5.8 in the year 2000. If the growth of the State's population during the last half of the century were due simply to this natural increase of the existing population, a total increase of about 2.1 million people could be anticipated.

TABLE IV-1

BIRTH AND DEATH RATES IN NEW JERSEY AND UNITED STATES, 1900-2000

(Per 1,000 Population)

	BIRTH RATES		DEATH RATES	
Recorded:	New Jersey	United States	New Jersey	United State
1900	17.6	*	16.1	17.2
1910	21.3	*	15.6	14.7
1920	24.2	27.7	12.8	13.0
1930	16.9	21.3	10.7	11.3
1940	14.3	19.4	10.9	10.8
1950	20.2	24.1	10.1	9.6
Projected:				
1960	19.0	22.0	10.0	9.5
1970	17.5	20.5	10.2	9.7
1980	16.0	19.0	10.1	9.6
1990	15.5	18.0	9.9	9.4
2000	15.5	18.0	9.7	9.2

* Not Available.

Sources: 1900–1950: New Jersey Department of Health and U. S. Public Health Service.
1960–2000: Projections by Tippetts-Abbett-McCarthy-Stratton.

Interstate Migration

Net migration into the State of New Jersey has been increasing during the past quarter century. An estimated net total of approximately 310,000 migrants moved into the State from all parts of the country during the decade 1940-50 (see Table IV-2) to take advantage of attractive residential areas and abundant opportunities for industrial employment. The U. S. Census Bureau expects migration into New Jersey to continue at an annual rate of between 26,000 and 40,000 persons, at least until 1965. It is estimated that during the second half of this century a net migration into the State coupled with the subsequent natural increases of these migrants will account for a population increase of about 1.2 million.

Forecasts of State Population

Population forecasts have been made for various New Jersey counties by several agencies. However, only two have been published for the State as a whole since the 1950 census. They are the May 1952 forecast of the New Jersey Department of Conservation and Economic Development which predicts a population of 5,857,000 in 1960, and the February 1955 forecast of the United States Census Bureau which predicts between 5,653,000 and 5,797,000 people in 1960, and between 5,954,000 and 6,247,000 in 1965.

The sum of our forecasts for each county indicates a total New Jersey population in the year 2000 of about 8.1 million, which is approximately 3.2 percent of the predicted total in the United States during that year. This increase will result from both the net interstate migration and natural increase mentioned above, and will constitute a rise in the State's population of approximately 3.3 million between 1950 and 2000.

REGIONAL POPULATION CHARACTERISTICS

As described previously, the State of New Jersey may be divided into four distinct regions: Northeastern, Southwestern, Coastal and Northwestern. Each region is generally homogeneous, but has one or more characteristics which distinguish it from the others. For purposes of studying population, the regional boundaries have been altered slightly to follow county lines. The differences, nevertheless, are negligible. The population density of New Jersey both by region as well as by county and municipality, is shown on Plate IV-2 and in Table IV-3.

The **Northeastern Region** (frequently referred to as the Northern Metropolitan Area) includes, for the purposes of the population study, all of Bergen, Essex, Hudson, Middlesex, Morris, Passaic, Somerset, and Union Counties, and is both the most densely populated and the most highly industrialized section of the State. The earliest and most intensely industrialized areas are centered in Hudson, Essex, Passaic, and Union Counties, while newer manufacturing industries are located in the peripheral counties. This entire region, except for Middlesex, Morris and Somerset, is heavily urban and provides most of the homes for hundreds of thousands of commuters who travel daily to the industrialized counties of New Jersey and to New York City. As the trend toward decentralization of the New York Metropolitan Area continues, the fringe counties should experience substantial growth in population and industry.

The **Southwestern Region,** which includes Burlington, Camden, Gloucester, Mercer and Salem Counties, is an urban, agricultural and industrial area along the lower Delaware River. It is linked economically to the heavily developed region across the river including Wilmington, Chester, Phila-

TABLE IV-2

POPULATION INCREASES IN NEW JERSEY, 1940-1950

(Number of Persons)

Regions & Counties	Total Increase	Natural Increase*	Net Migration
NEW JERSEY TOTAL	675,164	364,547	310,617
NORTHEASTERN REGION	402,129	268,660	133,469
Bergen	129,493	43,576	85,917
Essex	68,609	67,464	1,145
Hudson	−4,603	49,636	−54,239
Middlesex	47,795	24,329	23,466
Morris	38,639	12,105	26,534
Passaic	27,740	24,699	3,041
Somerset	24,662	9,102	15,560
Union	69,794	37,749	32,045
SOUTHWESTERN REGION	143,118	62,003	81,115
Burlington	38,897	9,106	29,791
Camden	45,016	23,337	21,679
Gloucester	19,508	7,203	12,305
Mercer	32,463	16,867	15,596
Salem	7,234	5,490	1,744
COASTAL REGION	114,963	26,203	88,760
Atlantic	8,333	3,609	4,724
Cape May	8,212	426	7,786
Cumberland	15,413	6,459	8,954
Monmouth	64,089	13,107	50,982
Ocean	18,916	2,602	16,314
NORTHWESTERN REGION	14,954	7,681	7,273
Hunterdon	5,970	1,542	4,428
Sussex	4,791	3,004	1,787
Warren	4,193	3,135	1,058

* Births minus deaths.

Sources: U. S. Census Bureau and New Jersey State Department of Health.

THOUSANDS OF PERSONS

Regions & Counties	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000
NEW JERSEY TOTAL	1884	2537	3156	4041	4160	4835	5700	6500	7200	7700	8100
NORTHEASTERN REGION	1256	1772	2244	2884	2954	3355	3910	4410	4820	5120	5360
Bergen	79	138	211	365	410	539	715	880	990	1070	1140
Essex	359	513	652	834	837	906	1000	1060	1120	1140	1150
Hudson	386	537	629	691	652	647	645	640	630	630	620
Middlesex	80	114	162	212	217	265	350	440	510	570	620
Morris	65	75	83	110	126	164	220	270	310	340	370
Passaic	155	216	259	302	309	337	375	410	460	500	530
Somerset	33	39	48	65	75	99	135	170	200	220	240
Union	99	140	200	305	328	398	470	540	600	650	690
SOUTHWESTERN REGION	319	398	517	641	664	809	990	1180	1350	1460	1550
Burlington	58	66	82	94	97	136	185	240	280	310	340
Camden	108	142	190	252	256	301	350	400	450	480	510
Gloucester	32	37	48	71	72	92	120	150	190	210	220
Mercer	95	126	160	187	197	230	275	320	350	370	390
Salem	26	27	37	37	42	50	60	70	80	90	90
COASTAL REGION	212	263	292	404	425	540	650	750	860	940	1010
Atlantic	46	72	84	125	124	132	150	160	170	180	190
Cape May	13	20	20	29	29	37	45	50	60	70	70
Cumberland	51	55	61	70	73	89	105	120	130	140	150
Monmouth	82	95	105	147	161	225	270	320	370	400	430
Ocean	20	21	22	33	38	57	80	100	130	150	170
NORTHWESTERN REGION	97	104	103	112	117	131	150	160	170	180	180
Hunterdon	35	34	33	35	37	43	50	50	60	60	60
Sussex	24	27	25	28	30	34	40	40	40	50	50
Warren	38	43	45	49	50	54	60	70	70	70	70

SOURCES: 1900-1950: U.S. Census Bureau; 1960-2000: Projections by Tippetts-Abbett-McCarthy-Stratton

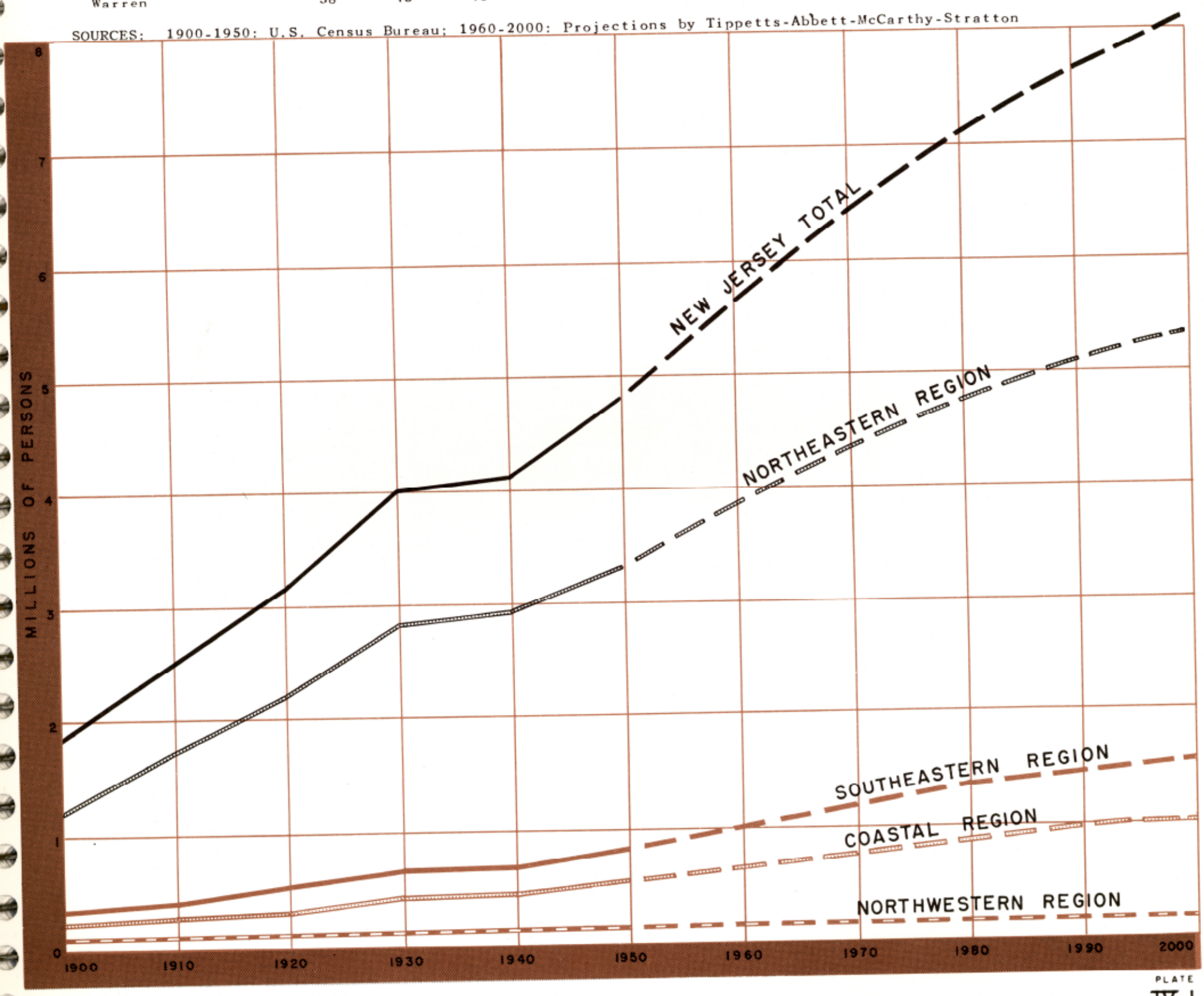


PLATE
IV-1
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS
NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT
POPULATION, 1900-2000

KEY FOR PLATE IV-2

POPULATION DENSITY OF NEW JERSEY MUNICIPALITIES, 1950

20,000 PERSONS PER SQUARE MILE AND OVER:

ESSEX COUNTY
1. Irvington

HUDSON COUNTY
2. East Newark
3. Guttenberg

HUDSON COUNTY (cont.)
4. Hoboken
5. Jersey City
6. Union City
7. Weehawken
8. West New York

10,000-19,999 PERSONS PER SQUARE MILE:

BERGEN COUNTY
9. Bogota
10. Cliffside Park
11. Garfield

CAMDEN COUNTY
12. Audubon Park
13. Camden
14. Woodlyne

ESSEX COUNTY
15. East Orange
16. Newark
17. Orange

HUDSON COUNTY
18. Bayonne
19. Harrison

MERCER COUNTY
20. Trenton

MONMOUTH COUNTY
21. Asbury Park

PASSAIC COUNTY
22. Passaic
23. Paterson
24. Prospect Park

UNION COUNTY
25. Winfield

5,000-9,999 PERSONS PER SQUARE MILE:

ATLANTIC COUNTY
26. Atlantic City

BERGEN COUNTY
27. Bergenfield
28. Dumont
29. East Paterson
30. Edgewater
31. Fairview
32. Hackensack
33. Hasbrouck Heights
34. Lodi
35. Maywood
36. North Arlington
37. Palisades Park
38. Ridgefield Park
39. Rutherford
40. Teaneck
41. Wallington
42. Wood-Ridge

BURLINGTON COUNTY
43. Beverly
44. Bordentown(City)

CAMDEN COUNTY
45. Audubon
46. Collingswood
47. Gloucester City
48. Merchantville
49. Oaklyn

CUMBERLAND COUNTY
50. Vineland

ESSEX COUNTY
51. Belleville
52. Bloomfield
53. Caldwell(Boro.)
54. Glen Ridge
55. Maplewood
56. Montclair
57. Nutley
58. South Orange

GLOUCESTER COUNTY
59. Woodbury

HUDSON COUNTY
60. North Bergen

MERCER COUNTY
61. Princeton(Boro.)

MIDDLESEX COUNTY
62. Dunellen
63. Highland Park
64. New Brunswick
65. Perth Amboy
66. South Amboy

MONMOUTH COUNTY
67. Belmar
68. Bradley Beach
69. Keansburg
70. Red Bank

MORRIS COUNTY
71. Morristown

PASSAIC COUNTY
72. Clifton

SALEM COUNTY
73. Penns Grove

SOMERSET COUNTY
74. Bound Brook
75. Somerville

UNION COUNTY
76. Elizabeth
77. Garwood
78. Hillside
79. Plainfield
80. Rahway
81. Roselle
82. Roselle Park

WARREN COUNTY
83. Phillipsburg

2,000-4,999 PERSONS PER SQUARE MILE:

ATLANTIC COUNTY
84. Margate City
85. Pleasantville
86. Ventnor City

BERGEN COUNTY
87. East Rutherford
88. Englewood
89. Fairlawn
90. Fort Lee
91. Glen Rock
92. Leonia
93. Little Ferry
94. Lyndhurst
95. Midland Park
96. New Milford
97. Ridgefield
98. Ridgewood
99. River Edge
100. Rochelle Park
101. Saddle River(Twp.)
102. South Hackensack
103. Tenafly
104. Westwood

BURLINGTON COUNTY
105. Burlington(City)
106. Mount Holly
107. Palmyra
108. Riverside
109. Riverton

CAMDEN COUNTY
110. Brooklawn
111. Haddon

CAMDEN COUNTY (cont.)
112. Haddonfield
113. Haddon Heights
114. Laurel Springs
115. Mount Ephraim
116. Pennsauken

CAPE MAY COUNTY
117. Wildwood

CUMBERLAND COUNTY
118. Bridgeton

ESSEX COUNTY
119. Verona
120. West Orange

GLOUCESTER COUNTY
121. National Park
122. Paulsboro
123. Pitman
124. Swedesboro
125. Westville

HUDSON COUNTY
126. Kearny

HUNTERDON COUNTY
127. Flemington
128. Lambertville

MERCER COUNTY
129. Hightstown
130. Hopewell (Boro.)

2,000-4,999 PERSONS PER SQUARE MILE (Cont.)

MIDDLESEX COUNTY
131. Carteret
132. Jamesburg
133. Metuchen
134. Milltown
135. South River

MONMOUTH COUNTY
136. Allenhurst
137. Atlantic Highlands
138. Avon-by-the-Sea
139. Fair Haven
140. Freehold(Boro.)
141. Highlands
142. Interlaken
143. Keyport
144. Long Branch
145. Neptune City
146. Oceanport
147. South Belmar
148. Union Beach

MORRIS COUNTY
149. Boonton(Town)
150. Butler
151. Chatham(Boro.)
152. Dover
153. Madison
154. Netcong
155. Rockaway

OCEAN COUNTY
156. Seaside Heights

PASSAIC COUNTY
157. Haledon
158. Hawthorne
159. Little Falls

SALEM COUNTY
160. Elmer
161. Salem

SOMERSET COUNTY
162. Manville
163. North Plainfield
164. Raritan
165. South Bound Brook

UNION COUNTY
166. Cranford
167. Fanwood
168. Kenilworth
169. Linden
170. Summit
171. Union
172. Westfield

WARREN COUNTY
173. Washington(Boro.)

1,000-1,999 PERSONS PER SQUARE MILE:

ATLANTIC COUNTY
174. Longport

BERGEN COUNTY
175. Carlstadt
176. Closter
177. Cresskill
178. Hillsdale
179. Hohokus
180. Moonachie
181. Northvale
182. Oradell
183. Park Ridge
184. Waldwick

BURLINGTON COUNTY
185. Delanco
186. Fieldsboro
187. Maple Shade
188. Pemberton
189. Wrightstown

CAMDEN COUNTY
190. Barrington
191. Bellmawr
192. Clementon
193. Hi-Nella
194. Lawnside
195. Magnolia
196. Runnemede

CAPE MAY COUNTY
197. Cape May(City)
198. North Wildwood
199. Ocean City
200. Wildwood Crest

ESSEX COUNTY
201. Cedar Grove
202. Essex Fells
203. Millburn

GLOUCESTER COUNTY
204. Wenonah
205. Woodbury Heights

HUDSON COUNTY
206. Secaucus

HUNTERDON COUNTY
207. Frenchtown

MERCER COUNTY
208. Ewing
209. Hamilton
210. Pennington

MIDDLESEX COUNTY
211. Middlesex
212. Spotswood
213. Woodbridge

MONMOUTH
214. Allentown
215. Englishtown
216. Farmindale
217. Manasquan
218. Matawan
219. Neptune(Twp.)
220. Sea Bright
221. Sea Girt
222. Spring Lake
223. Spring Lake Heights

MORRIS COUNTY
224. Morris Plains
225. Wharton

OCEAN COUNTY
226. Bay Head
227. Beach Haven
228. Island Heights
229. Lakehurst
230. Lavallette
231. Point Pleasant
232. Pt. Pleasant Beach
233. Seaside Park

PASSAIC COUNTY
234. North Haledon
235. Pompton Lakes
236. Totowa
237. West Paterson

SALEM COUNTY
238. Woodstown

SUSSEX COUNTY
239. Branchville
240. Hamburg
241. Newton
242. Sussex

UNION COUNTY
243. Springfield

WARREN COUNTY
244. Alpha
245. Belvidere
246. Hackettstown

500-999 PERSONS PER SQUARE MILE:

ATLANTIC COUNTY
247. Northfield
248. Somers Point

BERGEN COUNTY
249. Allendale
250. Demarest
251. Emerson
252. Englewood Cliffs
253. Harrington Park
254. Haworth
255. Norwood
256. Paramus
257. Ramsey
258. Wyckoff

BURLINGTON COUNTY
259. Florence
260. Moorestown
261. New Hanover

CAMDEN COUNTY
262. Berlin (Boro.)

CAMDEN COUNTY (cont.)
263. Berlin (Twp.)
264. Lindenwold
265. Pine Hill
266. Somerdale
267. Stratford

CAPE MAY COUNTY
268. Cape May Point
269. Stone Harbor
270. West Cape May
271. West Wildwood

ESSEX COUNTY
272. Livingston
273. North Caldwell
274. Roseland
275. West Caldwell

GLOUCESTER COUNTY
276. Glassboro
277. Newfield

500-999 PERSONS PER SQUARE MILE (Cont.):

HUNTERDON COUNTY
278. Bloomsbury
279. Califon
280. Clinton
281. Hampton
282. High Bridge
283. Lebanon
284. Milford
285. Stockton

MIDDLESEX COUNTY
286. Helmetta
287. North Brunswick
288. Piscataway
289. Edison (Raritan)
290. Sayreville
291. South Plainfield

MONMOUTH COUNTY
292. Brielle
293. Deal
294. Eatontown
295. Little Silver
296. Matawan
297. Monmouth Beach
298. Ocean
299. Rumson
300. Shrewsbury
301. West Long Branch

MORRIS COUNTY
302. Mine Hill
303. Mountain Lakes
304. Parsippany-Troy Hills
305. Pequannock
306. Riverdale

OCEAN COUNTY
307. Ocean Gate
308. Pine Beach
309. Ship Bottom

PASSAIC COUNTY
310. Wanaque

SOMERSET COUNTY
311. Rocky Hill

SUSSEX COUNTY
312. Franklin
313. Ogdensburg
314. Stanhope

UNION COUNTY
315. Clark
316. New Providence(Boro.)
317. Berkeley Heights (New Providence Twp.)
318. Scotch Plains

100-499 PERSONS PER SQUARE MILE:

ATLANTIC COUNTY
319. Absecon
320. Brigantine
321. Buena
322. Egg Harbor City
323. Hammonton
324. Linwood

BERGEN COUNTY
325. Alpine
326. Franklin Lakes
327. Mahwah
328. Montvale
329. Oakland
330. Old Tappan
331. Rivervale
332. Rockleigh
333. Saddle River(Boro.)
334. Upper Saddle River
335. Washington
336. Woodcliff Lake

BURLINGTON COUNTY
337. Bordentown(Twp.)
338. Burlington(Twp.)
339. Cinnaminson
340. Delran
341. Eastampton
342. Edgewater Park
343. Hainesport
344. Medford Lakes
345. Mount Laurel
346. Willingboro

CAMDEN COUNTY
347. Chesilhurst
348. Delaware
349. Gibbsboro
350. Gloucester(Twp.)
351. Voorhees

CAPE MAY COUNTY
352. Sea Isle City
353. Woodbine

CUMBERLAND COUNTY
354. Deerfield
355. Landis
356. Millville
357. Shiloh
358. Upper Deerfield

ESSEX COUNTY
359. Caldwell(Twp.)

GLOUCESTER COUNTY
360. Clayton
361. Deptford
362. East Greenwich
363. Elk
364. Greenwich
365. Harrison
366. Mantua
367. Monroe
368. Washington
369. West Deptford

HUNTERDON COUNTY
370. Glen Gardner

MERCER COUNTY
371. Lawrence
372. Princeton (Twp.)

MIDDLESEX COUNTY
373. Cranbury
374. East Brunswick

MIDDLESEX COUNTY (cont.)
375. Madison

MONMOUTH COUNTY
376. Howell
377. Marlboro
378. Middletown
379. Raritan
380. Roosevelt
381. Shrewsbury
382. Wall

MORRIS COUNTY
383. Boonton(Twp.)
384. Chatham(Twp.)
385. Chester (Boro.)
386. Denville
387. East Hanover
388. Florham Park
389. Hanover
390. Harding
391. Lincoln Park
392. Mendham(Boro.)
393. Montville
394. Morris
395. Mount Arlington
396. Passaic(Twp.)
397. Randolph
398. Roxbury

OCEAN COUNTY
399. Barnegat Light
400. Beachwood
401. Brick
402. Dover
403. Harvey Cedars
404. Lakewood
405. Long Beach
406. Mantoloking
407. South Toms River
408. Surf City
409. Tuckerton

PASSAIC COUNTY
410. Bloomingdale
411. Wayne

SALEM COUNTY
412. Lower Penns Neck
413. Upper Penns Neck

SOMERSET COUNTY
414. Bernards
415. Bernardsville
416. Bridgewater
417. Far Hills
418. Franklin
419. Green Brook
420. Millstone
421. Montgomery
422. Peapack-Gladstone
423. Warren
424. Watchung

SUSSEX COUNTY
425. Andover(Boro.)
426. Hopatcong

UNION COUNTY
427. Mountainside

WARREN COUNTY
428. Greenwich
429. Lopatcong
430. Oxford
431. Pohatcong
432. Washington(Twp.)

0-99 PERSONS PER SQUARE MILE:

(All municipalities with population densities less than 100 are shown by name on the map.)

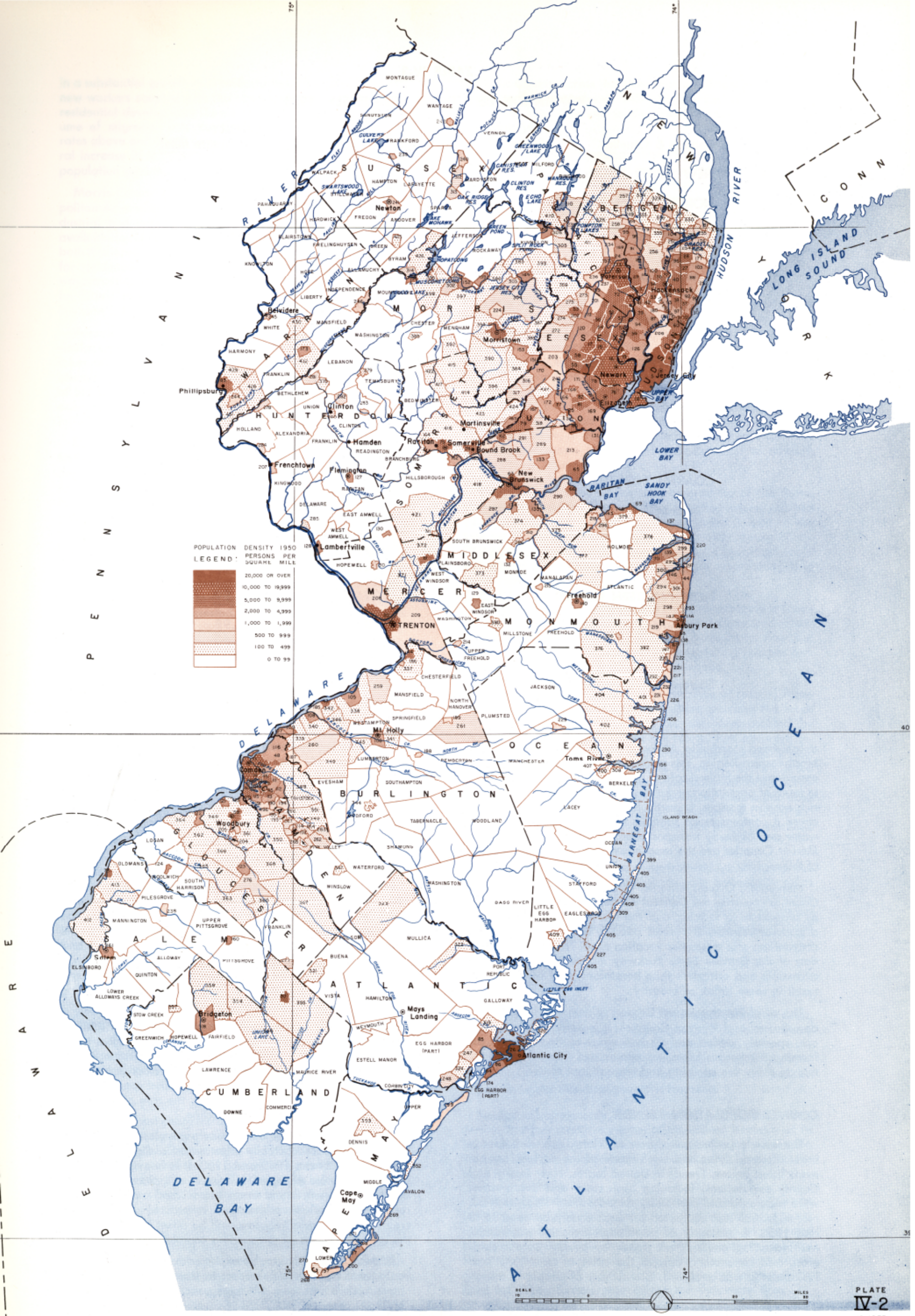

POPULATION DENSITY 1950
LEGEND: PERSONS PER SQUARE MILE
20,000 OR OVER
10,000 TO 19,999
5,000 TO 9,999
2,000 TO 4,999
1,000 TO 1,999
500 TO 999
100 TO 499
0 TO 99
PENNSYLVANIA
DELAWARE
NEW YORK
CONN.
SUSSEX
WARREN
MORRIS
PASSAIC
BERGEN
HUDSON
ESSEX
UNION
SOMERSET
HUNTERDON
MIDDLESEX
MERCER
MONMOUTH
OCEAN
BURLINGTON
CAMDEN
GLOUCESTER
ATLANTIC
SALEM
CUMBERLAND
CAPE MAY
Newton
Belvidere
Phillipsburg
Clinton
Hamden
Frenchtown
Flemington
Lambertville
TRENTON
Morristown
Paterson
Hackensack
Newark
Jersey City
Elizabeth
Martinsville
Raritan
Somerville
Bound Brook
New Brunswick
Freehold
Asbury Park
Toms River
Mt. Holly
Camden
Woodbury
Salem
Bridgeton
Millville
Mays Landing
Atlantic City
Cape May
HUDSON RIVER
LONG ISLAND SOUND
UPPER BAY
LOWER BAY
RARITAN BAY
SANDY HOOK BAY
DELAWARE BAY
ATLANTIC OCEAN
DELAWARE RIVER
RARITAN RIVER
PASSAIC RIVER
RAMAPO R.
PASSAIC R.
MUSCONETCONG R.
ROCKAWAY R.
WHIPPANY R.
ROCKAWAY CR.
GREENWOOD LAKE
CLINTON RES.
ECHO LAKE
OAK RIDGE RES.
CANISTEAR RES.
SPLIT ROCK POND
GREEN POND
LAKE MOHAWK
SWARTSWOOD LAKE
CULVERS LAKE
MOUNTAIN LAKE
JERSEY CITY RES.
COMPTON LAKES
SHADOW LAKE
MANASQUAN R.
METEDECONK R.
TOMS R.
OSWEGO R.
MULLICA R.
WEST BRANCH WADING R.
EAST BRANCH WADING R.
BASS R.
GREAT EGG HARBOR R.
TUCKAHOE R.
MAURICE R.
COHANSEY R.
SALEM R.
ALLOWAY CR.
OLDMANS CR.
RACCOON CR.
NEWTON CR.
CROSSWICKS CR.
ASSUNPINK CR.
STONY BRK.
MILLSTONE R.
LAMINGTON R.
ROCKY BRK.
LAWRENCE BRK.
MILLTOWN BRK.
SOUTH BRUNSWICK
PLAINSBORO
WEST WINDSOR
EAST WINDSOR
MONROE
MANALAPAN
HOLMDEL
ATLANTIC
MILLSTONE
FREEHOLD
UPPER FREEHOLD
JACKSON
NORTH HANOVER
PLUMSTED
SPRINGFIELD
WESTAMPTON
MANSFIELD
CHESTERFIELD
EVESHAM
SOUTHAMPTON
LUMBERTON
PEMBERTON
WINDSOR
TABERNACLE
WOODLAND
LACEY
BERKELEY
OCEAN
UNION
STAFFORD
LITTLE EGG HARBOR
EAGLESWOOD
BARNEGAT BAY
ISLAND BEACH
WATERFORD
WINSLOW
SHAMONG
WASHINGTON
BUENA
VISTA
HAMILTON
MULLICA
PORT REPUBLIC
GALLOWAY
EGG HARBOR (PART)
ESTELL MANOR
WEYMOUTH
LITTLE EGG INLET
DENNIS
MIDDLE
AVALON
UPPER
COMMERCIAL
DOWNE
LAWRENCE
FAIRFIELD
GREENWICH
HOPEWELL
STOW CREEK
LOWER ALLOWAYS CREEK
QUINTON
ELSINBORO
PITTSGROVE
UPPER PITTSGROVE
MANNINGTON
PILESGROVE
WOODBURY CREEK
SOUTH HARRISON
WOODBURY
GLOUCESTER
LOGAN
OLDMANS
WOOLWICH
FRANKLIN
MONROE
NORTHAMPTON
SPRINGFIELD
EVESHAM
MOORESTOWN
CHERRY HILL
HADDONFIELD
HADDON
PENNSAUKEN
CAMDEN
GLOUCESTER CITY
DELANCO
BURLINGTON
BORDENTOWN
FLORENCE
MOUNT HOLLY
LUMBERTON
PEMBERTON
WESTAMPTON
MANSFIELD
SPRINGFIELD
NORTH HANOVER
PLUMSTED
JACKSON
MANCHESTER
TOMS RIVER
BERKELEY
LAC

TABLE IV-3

POPULATION DENSITY OF NEW JERSEY, 1950

Regions & Counties	POPULATION (Number of Persons)	AREA (Square Miles)	DENSITY (Persons per Square Mile)
NEW JERSEY TOTAL:	4,835,329	7,522	643
NORTHEASTERN REGION	3,356,051	1,790	1,875
Bergen	539,139	233	2,314
Essex	905,949	128	7,078
Hudson	647,437	45	14,388
Middlesex	264,872	312	849
Morris	164,371	468	351
Passaic	337,093	194	1,738
Somerset	99,052	307	323
Union	398,138	103	3,865
SOUTHWESTERN REGION	807,669	1,947	415
Burlington	135,910	819	166
Camden	300,743	221	1,361
Gloucester	91,727	329	279
Mercer	229,781	228	1,008
Salem	49,508	350	142
COASTAL REGION	540,076	2,461	219
Atlantic	132,399	575	230
Cape May	37,131	267	139
Cumberland	88,597	503	176
Monmouth	225,327	477	472
Ocean	56,622	639	89
NORTHWESTERN REGION	131,533	1,324	99
Hunterdon	42,736	435	98
Sussex	34,423	528	65
Warren	54,374	361	151

Source: U. S. Census Bureau.

delphia and Morrisville. Although not as thickly settled as the Northeastern Region, this portion of the State is expected to experience the highest rate of growth of the four regions both in terms of population and industry. This region, which is near rich eastern markets, is particularly attractive to industry because it contains much suitable land that is served by rail, water and highway transportation. At present, Camden and Mercer Counties are the most heavily industrialized counties of this region.

Monmouth, Ocean, Atlantic, Cape May, and Cumberland Counties comprise the **Coastal Region** which derives most of its support from farming and the recreation "industry." It is a popular retreat for retired people, a center for business conventions and a summer vacation area. The recent completion of the Garden State Parkway makes this region more accessible and attractive than heretofore, and will probably result in some influx of industry.

The rural **Northwestern Region** is composed of Hunterdon, Sussex and Warren Counties. It is generally mountainous, sparsely settled and derives much of its support from farming. Numerous lakes, mountains and State Parks make this an attractive camping and recreational center.

COUNTY POPULATION TRENDS

The county projections shown on Plate IV-1 were formulated after analyses had been made of the various components listed below. Trends in United States, New Jersey and County populations, including birth rates and death rates, were tabulated and plotted by decades from 1900 to 1950. Net migration was computed for each county between 1940 and 1950. A summary of population densities was made. Manufacturing employment trends by county were considered, and commuter traffic to the cities of New York and Philadelphia was analyzed. The number of people from out-of-state who are attracted to the resort areas was considered, as was intra-state migration and decentralization. Various existing forecasts of population and birth and death rates for the United States, the State and for each county also were evaluated. The principal characteristics of each county are discussed below.

Northeastern Region

Bergen County has exhibited spectacular increases since 1940 in both population and industry, and holds promise of continued rapid growth for many years to come. Because many young families are establishing new homes in the County, the birth rate is higher than the State average and the death rate is correspondingly lower. The resulting natural increase, combined with the extensive migration which has been taking place, assures a rapid population expansion until much of the available land is utilized.

Essex has the greatest population (905,949 in 1950) of any of the counties in the State. Many commuters live in all parts of the County and almost half of its population is contained within the City of Newark. These factors account for the high population density. Since only limited space is available for new industry and population, the rate of growth of the County is expected soon to decline.

Hudson County is the most densely populated of all New Jersey counties and actually experienced a slight decline in population between 1940 and 1950. It is heavily industrialized and may be expected to receive still more industry as the remaining marshland areas are utilized and low grade residential areas are redeveloped. Its natural population increase, which is relatively low, will be offset by migration to the suburban areas of surrounding counties.

Middlesex County can be expected to profit from its advantageous location with respect to transportation, resulting

in a substantial growth in manufacturing. The need for many new workers coupled with the abundant areas available for residential development should cause the already large volume of migration into the County to increase. With birth rates above and death rates below the State averages, natural increase in Middlesex will contribute substantially to the population growth.

Morris County is located on the outer fringe of the Metropolitan Area where it will undoubtedly absorb much new industrial and population growth. Sufficient suitable land is available for light manufacturing in the eastern portion, while both that area and the hilly country to the west are attractive for residences. Proposed east-west and north-south expressways crossing the County should provide a strong stimulant for future development. The past steady rate of population increase is thus expected to persist.

Passaic County is geographically divided into two dissimilar sections: the rural northwest with many mountains and lakes, and the congested southeast with well-established manufacturing industries and a dense population. There is promise of but little growth in the largely unsettled northwest section due to its inaccessibility and rugged terrain. However, new industries in the central portion should attract some migrants.

Somerset County experienced rapid growth in manufacturing activity, even when others were suffering set-backs during the depression. Although still predominantly agricultural and residential, this county will certainly follow in the footsteps of neighboring Middlesex as a place for much new industry. It is well situated with respect to rail and highway transportation and offers numerous industrial sites. Its growing population will provide manpower for industry, both local and in the entire expanding area.

Union County has experienced a tremendous influx of new industry in recent years since Hudson and Essex Counties have become increasingly congested. Its desirable residential areas and remaining industrial sites, which are interlaced with many railroads and highways and served by adjacent waterways, make Union very attractive to manufacturers who wish to locate in the enormous New York market area. Population has increased steadily. As industry moves in, however, residential development will be pushed further into the suburbs. Even now average population density for the County is high.

Southwestern Region

Burlington County is expected to acquire new industry at a rapid pace along the Delaware River. The attractions are unusually strong because of the many suitable factory locations that are available and because of the excellent water, rail, and highway facilities. Reports of manufacturers' present plans in the area are most impressive. Two-thirds of Burlington, however, is occupied by the extensive pine forests which for the most part are uninhabited and undesirable for industrial sites. Only in the past decade did the County's population begin its fast rate of growth, which promises to continue with the enlarging requirements for industrial workers.

Camden, being directly across the Delaware River from Philadelphia, is the most populated of the Southwestern counties. It contains many residents who commute across the river as well as much industry of its own. Some in-migration of residents is expected, more to fill jobs in local industry than to commute to Philadelphia. A new vehicular bridge across the Delaware is now under construction in the vicinity of Gloucester City which will stimulate added growth in Camden County.

Gloucester County, which has the least manufacturing in the Region, is best characterized as agricultural. Over half of its area is under cultivation, although there is a fringe of industry along the Delaware River. The possibility of a new steel mill has stirred much speculation about the further displacement of farmland. It is likely that this industrial growth will take place slowly. Increases in population also will be caused by new commuters to Camden and Philadelphia.

Mercer County is dominated by the State Capital at Trenton and by surrounding long-established manufacturing industries. It is now relatively densely populated and industrialized, although its growth has not been rapid. The stimulation of Mercer which will come from the extensive development of Bucks County across the river should enliven its growth in the near future. Industry will also be encouraged if the Delaware Ship Channel is deepened as far upstream as Trenton.

Salem County is the least populated of the Southwestern counties. It lies at the southern end of the New Jersey Turnpike and is linked with Wilmington by the Delaware Memorial Bridge. More industry and migration will surely come as Camden, Burlington and Gloucester Counties become overburdened.

Coastal Region

Atlantic has long been a resort county with most of its activity centering on famous Atlantic City. A low percentage of its population is employed in manufacturing. Because of its dependency on resort activity, Atlantic's population actually declined during the 1930-40 decade. However, business conventions and other off-season activities are now being promoted in order to improve economic stability. As with other coastal counties, the Garden State Parkway improves the accessibility of this resort area. The County is attractive to retired people, a fact which accounts for the very low rate of natural increase. Manufacturing is expected to develop gradually in Atlantic County.

Cape May County, at the southernmost tip of the State, is a peaceful ocean resort of long standing which still has much undeveloped waterfront. Its population is next to the smallest in the State and is rising only slowly. Lying at the southern end of the Garden State Parkway, Cape May should experience gradual gains as a place for vacationing and retirement.

Cumberland, on Delaware Bay, is predominantly a farming county, supplemented by oystering and some well-established industries. Population increases have been slow but may be stimulated eventually as manufacturing reaches out. Much of lower Cumberland is tidewater land.

Monmouth County is an unusual mixture of resorts, farming, industry, and commuters. Agriculture provides the leading source of income. However, the seashore, assisted by improved highway access from the North, has attracted increasing numbers of persons. It is doubtful that many new industries will come to Monmouth. However, the expected spread of new plants in Middlesex eventually will make northern Monmouth a convenient and desirable residential area for commuters. The large immigration which the County experienced between 1940 and 1950 is not likely to continue at such a rapid rate.

Ocean, another resort and agricultural county, has the longest shore front in the State. Practically no industry exists here, although a sizeable new plant has been constructed recently. Large undeveloped areas are expected to attract many residents, and population already shows signs of rapid growth.

Northwestern Region

Hunterdon County is nearly 70% agricultural in area, most of which is devoted to dairy and poultry farms. Many of its new residents are gentlemen farmers who either commute to business or have retired. Its relatively elderly population results in a low rate of natural increase. A gradual rise in population of this rural county is foreseen.

Sussex, a dairy county, has the smallest population in New Jersey. It offers many recreational attractions because of its lakes and forests. A zinc mine constitutes the only industry. There is little prospect for rapid growth in the County in the near future.

Warren County is largely farmland and forests, with some industry centered in Phillipsburg. Vacationers may find many attractions here. Its population has increased slowly and evenly and shows little promise of changing pace as local industry gradually spreads. Some impetus to population growth may result from increases in industry in the Allentown-Bethlehem-Easton area across the Delaware River.

INDUSTRY

A large part of New Jersey's future demand for potable water will be created by a substantial increase in industrial consumption. As shown in Table IV-4, it is expected that industrial employment in the State will increase almost 60% between the years 1954 and 2000. The probable future distribution of employment among the four regions and among the various counties in the State is also indicated in this table.

TABLE IV-4

EMPLOYMENT IN MANUFACTURING INDUSTRIES OF NEW JERSEY, 1954 AND 2000

(Thousands of Covered Jobs)

Regions & Counties	1954	2000	Increase
NEW JERSEY TOTAL	795	1,250	455
NORTHEASTERN REGION	614	920	306
Bergen	80	127	47
Essex	142	188	46
Hudson	136	185	49
Middlesex	64	130	66
Morris	18	44	26
Passaic	77	95	18
Somerset	15	30	15
Union	82	121	39
SOUTHWESTERN REGION	123	247	124
Burlington	13	50	37
Camden	51	75	24
Gloucester	10	38	28
Mercer	38	70	32
Salem	11	14	3
COASTAL REGION	42	63	21
Atlantic	7	10	3
Cape May	1	2	1
Cumberland	19	26	7
Monmouth	14	23	9
Ocean	1	2	1
NORTHWESTERN REGION	16	20	4
Hunterdon	4	4	0
Sussex	2	2	0
Warren	10	14	4

Sources: 1954: New Jersey Department of Labor and Industry.
2000: Forecasts by Tippetts-Abbett-McCarthy-Stratton.

STATE SUMMARY

New Jersey is now one of the most heavily industrialized states in the country. Despite the fact that it ranks only 45th in area, it stands at seventh place in terms of value added by manufacture. New Jersey ranks first in the production of chemicals, and also plays a leading role in the manufacture of apparel, instruments, ceramic products, rubber goods, petroleum products, electrical machinery, other industrial machinery, foods, textiles and many other diversified items. The State's employment in all principal industries is shown by regions and counties in Table IV-5.

Advantages to Industry

The reasons for the growth of New Jersey's great complex of diverse manufacturing establishments are easy to discover. First is the nearness to the largest consumer market in the country. The three Middle Atlantic States of New Jersey, New York, and Pennsylvania alone contain a huge population having a combined personal income of 66 billion dollars in 1954. This figure represents one-fourth of the combined personal income of the entire nation. Within these particular states are located many fabricating industries which also consume the basic products of New Jersey's factories. In addition, numerous research laboratories are continuously developing new products for local manufacture.

The State's large labor supply and extensive transportation facilities are other attractions to industry. The tremendous seaports and airports of New York and Philadelphia are close to most New Jersey factories. In addition, numerous tidewater industrial sites in the State enable many industries to maintain private dockage for ocean going vessels. The "industrial corridor" between Camden and Bergen Counties is served by many trunkline railroads and highways, including the new Turnpike and Garden State Parkway.

Most counties within the State still offer large, dispersed sites for industrial development. Many of these tracts are located on tidewater, particularly in the Lower Delaware Valley. Due to the excellent transportation facilities available, transit time for both workers and goods can be held to a minimum at most of the available sites within the "industrial corridor."

Forecast of Industrial Development

The forecast shown in Table IV-4 indicates a probable employment of about 1,250,000 persons in all manufacturing plants in New Jersey by the year 2000. This would result in an increase of approximately 450,000 workers after 1954. The State's current ratio of 15 industrial workers to every 100 persons in the entire population is expected to remain fairly constant during the second half of the century.

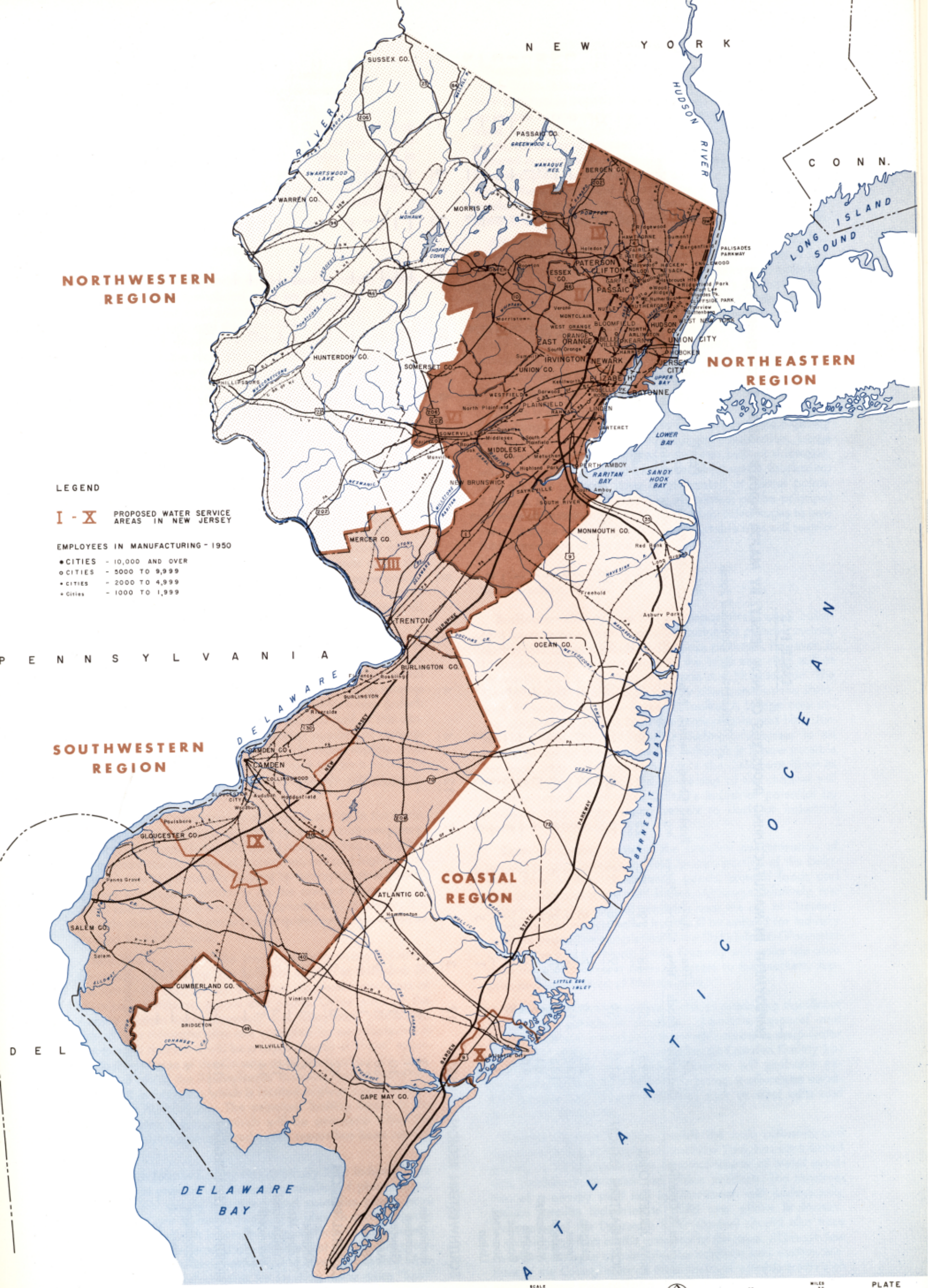
REGIONAL INDUSTRIAL CHARACTERISTICS

Over three-fourths of New Jersey's industrial employment is currently located within the Northeastern Region alone (see Plate IV-3). Most of the remaining workers are employed in the Southwestern Region. However, it is expected that the latter area will expand at twice the rate of the former during the second half of this century.

The **Northeastern Region,** as indicated above, currently provides by far the largest share of the jobs in manufacturing plants in the State. Various types of industry are concentrated in different parts of this region. "Heavy" industry is surrounded by "light" industry and is centered primarily at tidewater in Hudson, Essex, Union and Middlesex Counties. "Light" industry is also located in Bergen, Passaic, Morris and Somerset Counties, as is a rapidly growing number of industrial research laboratories. It is expected that the most intensive future manufacturing development will occur in the lightly-settled fringe areas of this region. However, it is possible that a significant portion of the marshlands in Hudson and Bergen Counties may be filled in for industrial use before the end of the century. This region has the dual advantages of nearness to tremendous markets in New York and of excellent land and sea transportation facilities.

The **Southwestern Region** contains important concentrations of industry in Mercer and Camden Counties. Smaller numbers of factories are located along the Delaware River in Burlington, Gloucester and Salem Counties. The latter, especially, have many large sites at tidewater suitable for "heavy" industries. Proximity to markets and supplies in Philadelphia, Chester, Wilmington and Morrisville make this an attractive area for new factories. Existing rail, highway and water facilities are extensive. The imminent completion of two new bridges across the Delaware River and the probable deepening of the channel from Camden to Trenton should enhance further the value of industrial sites along its banks.

The **Coastal Region** is of lesser importance in terms of industrial employment. However, Monmouth County contains sizable numbers of workers in apparel, textile and electrical machinery plants. Cumberland is also a leading center of glass production and apparel manufacture, and of the canning and freezing of food. Although Atlantic, Cape May and Ocean Counties have far fewer factories, it is likely that in the future they and the other parts of this region gradually will acquire moderate numbers of small plants. The recent



STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS
NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

INDUSTRIAL CITIES AND PROPOSED WATER SERVICE AREAS OF NEW JERSEY

TABLE IV-5

EMPLOYMENT IN MANUFACTURING INDUSTRIES OF NEW JERSEY, BY MAJOR INDUSTRY GROUPS, SEPTEMBER, 1954

(Thousands of Covered Jobs)

Regions & Counties	All Industries	Foods	Textiles	Apparel	Paper	Printing	Chemicals	Petroleum	Rubber	Leather	Stone, Clay & Glass	Primary Metals	Fabricated Metals	Machinery	Electrical Goods	Automobiles	Aircraft	Ships	Instruments	Miscellaneous
NEW JERSEY TOTAL	795	58	48	79	26	25	84	17	15	12	31	35	48	70	114	13	27	12	24	39
NORTHEASTERN REGION	614	39	39	58	22	21	68	12	10	10	13	27	37	59	88	13	27	3	23	35
Bergen	80	3	7	5	5	3	4	1	—	1	1	4	3	4	5	3	19	—	9	3
Essex	142	17	4	9	4	5	12	—	1	4	1	5	10	14	29	1	4	—	5	16
Hudson	136	11	7	19	6	5	13	4	—	2	1	4	10	15	25	—	—	2	1	8
Middlesex	64	1	1	7	2	2	15	1	—	1	3	7	2	3	8	2	—	1	5	1
Morris	18	1	1	1	1	—	2	—	2	1	1	1	1	3	2	—	1	—	—	1
Passaic	77	3	18	11	2	3	5	—	7	—	—	1	4	4	12	—	1	—	—	1
Somerset	15	—	—	1	—	—	4	1	—	—	5	—	—	—	3	—	—	—	2	2
Union	82	3	1	5	2	3	13	5	—	1	1	5	7	16	4	7	2	—	1	4
SOUTHWESTERN REGION	123	12	3	5	3	2	13	4	4	2	8	9	9	6	21	—	1	8	—	4
Burlington	13	—	1	1	—	—	—	—	—	—	—	5	1	1	1	—	—	—	—	1
Camden	51	9	—	2	2	1	3	—	—	1	1	1	1	1	16	—	—	8	—	1
Gloucester	10	1	—	1	—	—	2	4	—	—	—	—	1	—	—	—	—	—	—	—
Mercer	38	1	2	1	1	1	1	—	4	1	5	3	6	4	4	—	1	—	—	2
Salem	11	1	—	—	—	—	7	—	—	—	2	—	—	—	—	—	—	—	—	—
COASTAL REGION	42	6	2	12	—	1	—	—	—	—	9	—	1	1	3	—	—	—	—	—
Atlantic	7	1	—	4	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Cape May	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cumberland	19	4	1	4	—	—	—	—	—	—	7	—	—	—	—	—	—	—	—	—
Monmouth	14	1	1	4	—	1	—	—	—	—	1	—	1	1	3	—	—	—	—	—
Ocean	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
NORTHWESTERN REGION	16	—	1	1	2	—	1	—	—	—	—	1	1	4	1	—	—	—	—	—
Hunterdon	4	—	—	—	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Sussex	2	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Warren	10	—	1	—	1	—	1	—	—	—	—	—	1	4	1	—	—	—	—	—

Source: New Jersey Department of Labor and Industry.

completion of the Garden State Parkway and a rapidly growing labor supply will act as attractions for new industry.

The **Northwestern Region** has practically no industry except for the city of Phillipsburg in Warren County where large heavy machinery and chemical plants are located. Paper products, textiles and electrical goods are also produced in Warren and Hunterdon Counties. Proximity to the Allentown-Bethlehem-Easton industrial area in Pennsylvania is likely to induce a modest growth of industry in Warren County.

COUNTY INDUSTRIAL TRENDS

The projections of industrial employment by county shown in Table IV-4 were formulated after an intensive study had been made of past employment trends, the relative advantages of each county, and the availability of suitable factory sites. The future effects of continuing decentralization of manufacturing in the New York and Philadelphia metropolitan areas were likewise considered, as were possible improvements in local transportation facilities. Industrial development trends in each of the counties of the Northeastern and Southwestern regions are discussed below.

Northeastern Region

Bergen County now specializes in the manufacture of aircraft, instruments, textiles, apparel, machinery and a great number of other fabricated products. It is expected that the growth of this type of industry will continue, particularly along the northern border and southwestern portions of the County. It is probable that some of the marshlands along the Hackensack River will be drained and filled before the end of the century. This area, primarily because of its nearness to adjacent industrialized counties and to New York City, will afford advantageous sites for all types of factories.

Essex County is the largest in New Jersey both in terms of population and industry. Its principal factories produce electrical goods, foods, machinery, chemicals, fabricated metal products, precious metals and apparel. Due to a relative shortage of large industrial tracts, the County's future growth will not be as large as it was during the first half of this century. Small plants serving the increasing number of consumers in the region are likely to develop more rapidly than "heavy" industries. It is possible that there will be a moderate expansion of "light" industry in the sparsely settled northwestern part of the County.

Hudson is the most densely developed county in the State. Its primary industries are electrical and industrial machinery, apparel, chemicals, foods and metal products. This county has the greatest concentration of waterfront, rail and highway facilities in the Northeastern Region. Its future industrial development will depend primarily on the amount of marshland which can be drained and filled economically. However, it is possible that some deteriorating residential areas may be cleared for factory sites.

Middlesex is one of the most rapidly growing industrial counties in New Jersey. The factories located at tidewater on the Arthur Kill and Raritan River are significant producers of chemicals, fertilizers, metals and paints. Other parts of the County contain many assembly and fabricating plants. Although few tidewater sites are available for new factories, it is expected that there will be a rapid growth of "light" industry in the interior of the County, particularly along the Turnpike and along the Pennsylvania Railroad. Large tracts are available in this area, which is located midway between New York and Philadelphia. The principal limiting factor is the current water shortage, which will be overcome when the construction program outlined in this report has been carried out.

Although **Morris** County has relatively little industrial employment at present, an increasing number of pharmaceutical, electrical goods, machinery and cosmetics plants have been built there in recent years. It is also an advantageous location for research laboratories and offices of some important industrial concerns. It is probable that the rapidly growing population and the construction of several proposed highways will act as inducements for locating many more "light" industries within the County.

Passaic is one of the oldest developed industrial counties of the State. Although its textile mills and apparel factories have declined in importance since 1930, they are still by far the largest employers in the County. Nevertheless, there is a trend toward diversification, with the result that electrical goods, rubber products and many other items are now manufactured in considerable volume. New firms for the most part have occupied vacant factories. However, there is still some land in the southern and central parts of the County which is available for the construction of new plants. For this reason, a moderate expansion in industrial employment is predicted.

Although **Somerset** County now has the smallest number of manufacturing workers in the Northeastern Region, it has been expanding rapidly in recent years. Chemicals, electrical goods and building materials are the leading products. Somerset affords good sites for many types of industries and for research laboratories. Due to a current stringency in water supply, which will be eliminated when the new facilities indicated in this report have been constructed, and to relative remoteness from the large cities to the northeast, Somerset is likely to develop at a slower rate than other "fringe" counties of the region.

Union is now one of the primary industrial counties in the State. Large tracts of land near its extensive rail and highway arteries have been utilized for factory construction. Large chemical and petroleum plants have been built at tidewater, whereas machinery, automobile assembly, metal fabricating and apparel factories have been located at inland points. Although the County, because of its location on the principal arteries of transportation, still offers many advantages to new industries, the increasing shortage of suitable sites will restrict future growth to moderate levels.

Southwestern Region

Burlington County now has a comparatively small industrial labor force which is occupied mainly in primary metals, textiles and apparel plants. Its long-run potential, however, is favorable because of proximity to the huge new steel mill at Morrisville and to the cities of Trenton and Philadelphia. The County contains many large factory sites between the Delaware River and the New Jersey Turnpike. A bridge now under construction will link both the Pennsylvania and New Jersey Turnpikes. This will improve Burlington's access to all points served by those highways. Although it is now possible for small ships or barges to navigate the Delaware River as far as Trenton, the proposed deepening of the channel will increase greatly Burlington County's industrial potential by enabling large ocean-going vessels to dock at industrial waterfront facilities.

Camden County contains the greatest concentration of population and industry in New Jersey's portion of the Delaware River Valley. Its electrical goods, canned foods and shipbuilding plants are well-known. Although relatively few large factory sites are still available near the city of Camden, it is likely that many smaller tracts will be utilized for industry in future years. The completion of the Philadelphia-Gloucester City Bridge and the North-South Freeway will make this area even more attractive in terms of access to the markets, supplies and labor force of Philadelphia.

Gloucester County now has factories producing significant amounts of petroleum products, chemicals, apparel and foods. It contains many large tracts with access to deep-water shipping, railroads and the Turnpike. As Camden County becomes increasingly congested, Gloucester will probably experience a rapid growth in manufacturing. It affords an excellent location for "heavy" industries such as steel mills and other basic producers.

Mercer County's location, astride the main railroads and highways linking Philadelphia and New York, has contributed greatly to its prominence as a manufacturer of metal products, machinery, ceramics and rubber products. The construction of a nearby steel mill in Morristown will undoubtedly induce satellite industries to build new plants in Mercer. Deepening of the Delaware River channel should also have a stimulating effect on the economy of the area. Although few riverfront sites are obtainable, the northern and eastern sections of the County offer an abundance of suitable tracts with excellent land transportation facilities.

Salem County, once the most isolated area in the Southwestern Region, is now connected with the Wilmington industrial complex by the recently constructed Delaware Memorial Bridge. Chemicals, glass and canned foods are now the principal products of Salem's factories. Access to the existing deep-water channel of the Delaware River and to the New Jersey Turnpike is likely to stimulate future industrial growth, but at a slower pace than in adjoining counties of the Region.

AGRICULTURE

Although New Jersey's farms purchase very little water from public water supplies, they do draw significant quantities either from the same streams or from the ground water sources which also supply the public systems in certain areas. Therefore, it is necessary to examine the State's agricultural potential prior to forecasting total water requirements. As shown in Table IV-6, agriculture is an important segment of the State's economy. Almost 40% of the total area is occupied by farms, and agriculture produces over 300 million dollars in gross cash income annually. A discussion of agricultural prospects in each of the State's four regions follows below.

The **Northeastern Region** contains by far the smallest farm acreage. This is due, of course, to the dense population and industrial development in most of its eight metropolitan counties. However, the income from their nurseries, truck farms, dairy cattle and stockyards is relatively high. As the growth of population and industry continues in this region, it is likely that most agricultural enterprises will have moved to outlying areas by the year 2000.

The **Southwestern Region** is now first in terms of farm acreage and second in terms of farm income. Principal crops are leaf vegetables, potatoes, berries, tree fruit, poultry and dairy products. The expected influx of factories and homes into the Lower Delaware Valley will displace some farms. This is true especially in Burlington, Gloucester and Mercer Counties. However, agriculture is likely to remain an important source of income throughout this region.

The **Coastal Region** leads the State in terms of farm income, principally due to the poultry ranches, truck gardens and orchards of Monmouth, Ocean and Cumberland Counties. Although many farms in Monmouth undoubtedly will be sold for housing developments, agriculture is likely to remain strong because poultry ranches may be moved easily to the more sparsely populated southern part of the County. Cumberland probably will remain one of the State's principal vegetable canning and freezing centers. Some expansion of poultry and fruit raising in Atlantic and Ocean Counties is also possible.

The **Northwestern Region** depends on dairy cattle, vegetables, orchards and poultry for its sizable farm income. Proximity to the great consumer markets of the New York and Philadelphia metropolitan areas is likely to induce even greater agricultural production in this area.

CONSUMPTION OF POTABLE WATER

Water is a vital and often a limiting factor in area development. The continued growth of New Jersey's population and industry will depend in great measure on the availability of sufficient supplies of potable water. In the following forecast of future water consumption by decades, it has been assumed that the State's economy will expand at a rate commensurate with its other natural advantages and that the development of new potable water supplies will keep pace with this expansion so that no water shortages will impede growth at any time.

TABLE IV-6

AGRICULTURAL ACREAGE AND INCOME IN NEW JERSEY

Regions & Counties	FARMLAND, 1950 (1000 Acres)	FARMLAND, 1950 (% of All Land)	GROSS CASH FARM INCOME, 1954 ($1000)
NEW JERSEY TOTAL	1,725	35.8	334,836
NORTHEASTERN REGION	276	24.1	75,624
Bergen	13	9.0	11,599
Essex	6	7.1	3,827
Hudson	1	3.6	9,714
Middlesex	67	33.6	16,581
Morris	77	25.8	11,384
Passaic	9	7.5	4,708
Somerset	98	49.6	16,460
Union	5	8.0	1,351
SOUTHWESTERN REGION	557	44.7	89,754
Burlington	212	40.4	27,543
Camden	33	23.6	6,390
Gloucester	109	51.6	22,216
Mercer	80	54.8	13,294
Salem	123	54.7	20,311
COASTAL REGION	394	25.0	110,406
Atlantic	42	11.4	14,032
Cape May	29	17.1	3,369
Cumberland	136	42.2	33,055
Monmouth	146	47.9	40,123
Ocean	41	10.1	19,827
NORTHWESTERN REGION	499	58.9	59,052
Hunterdon	192	68.9	24,868
Sussex	164	48.5	18,024
Warren	143	61.7	16,160

Sources: U. S. Census of Agriculture; Sales Management's "Survey of Buying Power, 1955."

The geographic regions of New Jersey for which consumption data have been compiled are basically the same as those used in preceding sections of this chapter. However, the regional boundaries used in this consumption analysis do not follow county lines in all instances (see Plate IV-3). The populous portions of Passaic, Morris and Somerset Counties have been included within the Northeastern Region, whereas the sparsely-settled western parts of those counties are contained within the Nortwestern Region. The northwestern section of Burlington County likewise is considered part of the Southwestern Region, whereas the thinly-settled remainder is included within the Coastal Region.

FORECAST OF PUBLIC POTABLE WATER CONSUMPTION

Amounts of potable water sold by both publicly and privately owned supply systems to all consumers in New Jersey from 1920 to 1950 are shown on Plate IV-4. Forecasts of consumption for succeeding decades up to the year 2000 were made and are also shown on this same plate. The latter figures were obtained by combining two forecasts: one for industrial demand by decades until the year 2000 and the other for domestic, commercial and all other requirements by decades until 2000. Methods used in deriving these data are explained in greater detail in following sections.

The anticipated total statewide consumption of public potable water is expected to surpass 1,000 million gallons per day by the year 2000. This figure represents an increase of over 100 per cent since 1950. It is estimated that almost half of the total projected consumption will be used by industry (see Table IV-7). The remainder will be consumed primarily in homes, commercial establishments, institutions, steam electric power plants and public buildings. Approximately two-thirds of the 540-million gallons per day increase in demand is expected to take place in the Northeastern Region, although consumption in the Southwestern and Coastal regions will likely rise at a faster rate. The anticipated 340-million gallons per day rise in demand in the Northeastern Region alone will require the construction of new and extensive facilities, as are proposed elsewhere in this report.

The total per capita consumption of public potable water has been estimated for the years 1950 and 2000, and is shown by regions in Table IV-8. These data are based on the estimated number of actual consumers in each region, rather than on total population. It is assumed that public systems will supply virtually all of the State's population by the year 2000.

TABLE IV-7

CONSUMPTION OF PUBLIC POTABLE WATER IN NEW JERSEY, BY MAJOR USES, 1954 AND 2000

(Millions of Gallons per Day)

	1954			2000		
Regions & Counties	Total	Industrial	Domestic & Other Non-Industrial*	Total	Industrial	Domestic & Other Non-Industrial*
NEW JERSEY TOTAL	588	306	282	1058	518	540
NORTHEASTERN REGION	435	240	195	726	369	357
Bergen	52	31	21	127	51	76
Essex	113	60	53	152	75	77
Hudson	100	44	56	115	74	41
Middlesex	39	16	23	87	46	41
Morris	14	8	6	47	22	25
Passaic	63	54	9	92	57	35
Somerset	7	3	4	24	8	16
Union	47	24	23	82	36	46
SOUTHWESTERN REGION	84	46	38	211	120	91
Burlington	11	2	9	40	20	20
Camden	34	25	9	76	45	31
Gloucester	6	2	4	28	15	13
Mercer	30	15	15	58	35	23
Salem	3	2	1	9	5	4
COASTAL REGION	59	13	46	107	21	86
Atlantic	15	2	13	19	3	16
Cape May	4	1	3	7	1	6
Cumberland	11	5	6	21	8	13
Monmouth	22	4	18	45	8	37
Ocean	7	1	6	15	1	14
NORTHWESTERN REGION	10	7	3	14	8	6
Hunterdon	2	1	1	3	1	2
Sussex	2	1	1	3	1	2
Warren	6	5	1	8	6	2

* Includes consumption in homes, stores, offices, steam-electric power plants, street-cleaning, fire-fighting, etc.

Sources: Division of Water Policy and Supply, New Jersey Department of Conservation and Economic Development; Tippetts-Abbett-McCarthy-Stratton.

TABLE IV-8

PER CAPITA CONSUMPTION OF PUBLIC POTABLE WATER IN NEW JERSEY, 1950 AND 2000

Regions	POPULATION SERVED (% of Permanent Residents)		PER CAPITA CONSUMPTION OF POPULATION SERVED (Gallons per Day)	
	1950	2000	1950	2000
Northeastern	96	100	111	135
Southwestern	82	100	114	136
Coastal	101*	100	103	106
Northwestern	57	64	127	122
NEW JERSEY TOTAL	93	99	111	132

* High percentage due to great influx of summer residents.

Sources: 1950: New Jersey Department of Conservation & Economic Development.
2000: Forecasts by Tippetts-Abbett-McCarthy-Stratton.

Industrial Consumption

Industry is by far the largest single consumer of water in New Jersey. However, most of the industrial demand is for non-potable water needed in cooling and in certain manufacturing processes. The present and future needs of industry for potable water are analyzed immediately below, whereas non-potable water requirements are discussed in the following section.

Many industries such as those engaged in food processing, brewing and the manufacture of pharmaceuticals and chemicals require large quantities of potable water. Potable supplies are also required in all plants for general service and sanitary purposes. Such supplies are obtained mostly from public water systems, although some industries operate private potable supplies largely from ground water sources. It is estimated that 300 million gallons per day of potable water were purchased from public utilities by all New Jersey factories in 1954. This figure represents about 50% of all of the public potable water consumed in the entire state. In addition, approximately 30 million gallons per day of potable water were supplied by private industry-owned water systems throughout the State. The 1954 estimates and the forecasts for the year 2000 are tabulated by counties in Table IV-7 and by regions in Table IV-9 below. These 1954 estimates were derived from a special survey conducted by Tippetts-Abbett-McCarthy-Stratton. This survey, which is described below, to the best of our knowledge is the first comprehensive industrial water requirements census taken for the State of New Jersey.

A detailed questionnaire was mailed to approximately one thousand of the largest industrial firms in New Jersey. The questions were worded in such a manner that uniform data on the source and consumption of potable and non-potable water could be obtained throughout the State. Responses were obtained from companies which employ almost 30% of the State's industrial labor force (See Table IV-10). Because of individual plant differences in record keeping, the replies were not always in a form that could be readily employed for purposes of comparison. The respondent industrial plants were separated into 19 major groupings, as shown on Table IV-11, and patterns of industrial potable water consumption were then discernible. Consumption estimates for the Northeastern and Southwestern regions are probably the most reliable, since a far greater number of replies came from those areas.

The forecasts of industrial consumption of public potable water for the year 2000 (see Table IV-7 and Table IV-9) were derived by the extrapolation of 1954 per-employee consumption data for each county, after careful consideration was given to the types of industry most likely to expand in these areas. In order to arrive at county consumption forecasts for the year 2000, the resulting per-employee consumption data were then multiplied by the expected industrial employment shown in Table IV-4. According to this forecast, over 500 million gallons per day of public potable water will be required by all the State's industries in the year 2000. Although 60% of the 200-million gallons per day increase will be consumed by the Northeastern Region, it is anticipated that the requirements of the Southwestern Region will rise 160% over present consumption. The latter region offers many sites along the Delaware River which are ideal for heavy consumers of

TABLE IV-9

INDUSTRIAL CONSUMPTION OF PUBLIC POTABLE WATER IN NEW JERSEY, BY REGIONS, 1954 & 2000

Regions	TOTAL CONSUMPTION (Millions of Gallons per Day)		CONSUMPTION PER EMPLOYEE (Gallons Per Day)	
	1954	2000	1954	2000
Northeastern	240	369	391	401
Southwestern	46	120	375	482
Coastal	13	21	305	333
Northwestern	7	8	419	370
NEW JERSEY TOTAL	306	518	385	414

Source: Estimates and forecasts by Tippetts-Abbett-McCarthy-Stratton, based on industrial water-use questionnaire.

TABLE 1V-10

COVERAGE BY INDUSTRIAL WATER-USE QUESTIONNAIRE

Regions	TOTAL INDUSTRIAL EMPLOYEES IN NEW JERSEY (Number)	EMPLOYEES OF RESPONDENTS (Number)	(% of Total)
Northeastern	614,000	161,000	26
Southwestern	123,000	40,000	33
Coastal	42,000	7,000	17
Northwestern	16,000	3,000	19
NEW JERSEY TOTAL	795,000	211,000	27

Sources: New Jersey Department of Labor and Industry, Tippetts-Abbett-McCarthy-Stratton.

MILLIONS OF GALLONS PER DAY

Regions & Counties	1920	1930	1940	1950	1960	1970	1980	1990	2000
NEW JERSEY TOTAL	340	421	389	520	651	760	879	973	1058
NORTHEASTERN REGION	253	312	285	383	476	541	613	673	726
Bergen	23	29	30	42	62	78	94	110	127
Essex	58	76	76	102	122	132	142	147	152
Hudson	63	80	78	93	103	100	109	114	115
Middlesex	26	24	22	34	44	59	69	79	87
Morris	5	6	8	12	18	26	33	40	47
Passaic	57	71	38	59	65	71	79	85	92
Somerset	3	4	4	6	12	15	19	23	24
Union	18	22	29	35	50	60	68	75	82
SOUTHWESTERN REGION	43*	55	57	78	100	131	164	189	211
Burlington	5*	5	5	9	14	20	27	33	40
Camden	17*	27	25	33	40	53	63	71	76
Gloucester	3*	3	5	5	8	12	19	24	28
Mercer	17*	19	20	28	35	41	48	53	58
Salem	1*	1	2	3	3	5	7	8	9
COASTAL REGION	37*	47	40	50	65	76	89	97	107
Atlantic	12*	16	13	14	16	17	18	18	19
Cap May	2*	3	3	3	4	5	6	7	7
Cumberland	6*	7	8	10	13	14	17	18	21
Monmouth	11*	14	12	18	24	30	36	41	45
Ocean	6*	7	4	5	8	10	12	13	15
NORTHWESTERN REGION	7	7	7	9	10	12	13	14	14
Hunterdon	1	1	1	2	2	3	3	3	3
Sussex	1	2	2	2	2	2	2	3	3
Warren	5	4	4	5	6	7	8	8	8

* - estimated

SOURCES: 1920-1950: Division of Water Policy and Supply, New Jersey Department of Conservation and Economic Development; 1960-2000: Projections by Tippetts-Abbett-McCarthy-Stratton

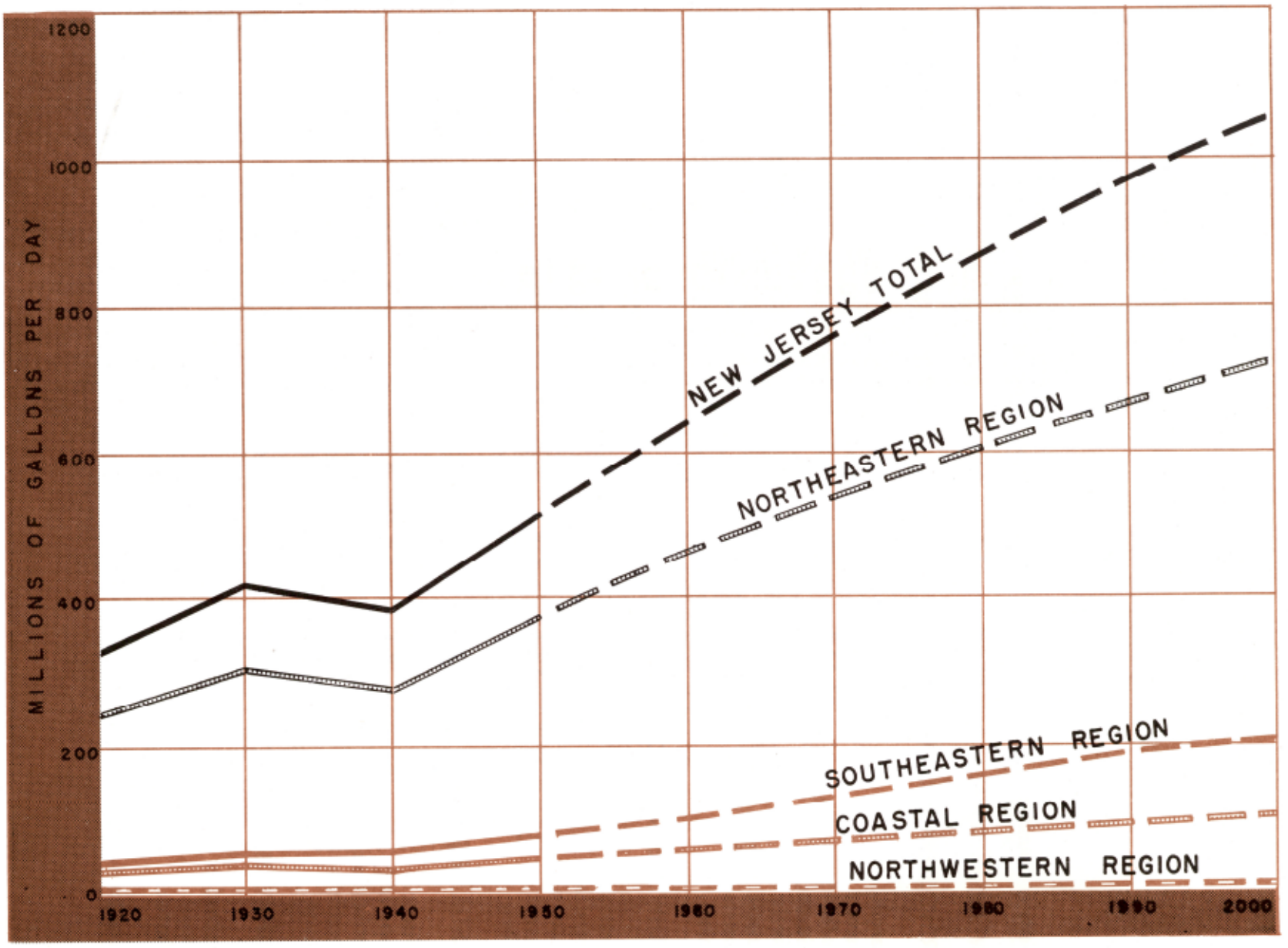


PLATE IV-4
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS
NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT
CONSUMPTION OF PUBLIC POTABLE WATER, 1920-2000

TABLE IV-11

INDUSTRIAL CONSUMPTION OF PUBLIC POTABLE WATER IN NEW JERSEY, BY MAJOR INDUSTRY GROUPS, 1954

(Millions of Gallons per Day)

Regions & Counties	All Industries	Foods	Textiles	Apparel	Paper	Printing	Chemicals	Petroleum	Rubber	Leather	Stone, Clay & Glass	Primary Metals	Fabricated Metals	Machinery	Electrical Goods	Automobiles	Aircraft	Ships	Instruments	Miscellaneous
NEW JERSEY TOTAL	305.7	41.9	41.4	9.5	15.7	5.2	69.1	10.3	5.3	4.0	11.9	13.1	13.0	11.8	27.1	4.1	4.1	3.2	4.9	10.0
NORTHEASTERN REGION	240.1	30.3	34.4	7.3	12.9	3.6	53.0	9.9	4.0	3.3	4.9	12.0	8.5	9.4	24.0	4.1	3.9	1.2	4.8	8.3
Bergen	31.0	4.3	0.7	0.6	4.8	0.6	4.4	0.8	0.2	0.3	0.8	1.7	1.3	0.2	3.7	1.1	2.2	—	2.3	0.7
Essex	59.7	17.7	4.0	2.3	0.3	1.2	13.2	0.4	0.3	1.3	0.7	1.9	2.3	3.7	2.9	0.2	1.3	—	1.0	4.3
Hudson	44.4	1.7	6.3	1.9	2.3	0.7	12.1	4.2	0.1	0.7	0.4	1.8	0.3	3.6	4.5	0.1	—	1.0	0.1	1.6
Middlesex	16.5	0.3	1.3	0.7	1.3	0.2	2.4	1.3	0.2	0.4	0.9	3.5	0.1	0.6	1.4	1.3	0.1	0.2	1.0	0.2
Morris	8.2	1.5	0.8	0.1	1.2	0.1	1.9	—	0.6	0.2	0.4	0.3	0.3	0.1	0.1	—	0.1	—	—	0.4
Passaic	53.8	2.5	20.9	1.1	1.7	0.2	10.8	—	2.5	0.3	0.9	0.6	3.7	0.2	9.9	—	—	—	0.3	0.2
Somerset	2.8	0.1	0.4	0.1	—	—	0.3	0.4	—	—	0.2	0.1	0.1	—	0.8	—	—	—	—	—
Union	23.8	2.2	—	0.5	1.3	0.6	7.9	2.8	0.1	0.1	0.6	2.1	0.4	1.0	0.7	1.4	0.2	—	0.1	0.9
SOUTHWESTERN REGION	46.1	7.5	2.2	0.6	1.2	0.5	14.7	0.4	1.2	0.6	5.8	0.7	3.6	1.3	2.2	—	0.2	1.7	0.1	1.6
Burlington	2.5	—	0.3	0.1	—	—	—	—	0.1	0.1	0.1	0.4	0.4	0.2	—	—	—	—	0.1	0.5
Camden	24.9	4.4	0.7	0.2	0.4	0.3	13.5	0.1	—	0.3	0.1	0.1	0.6	0.3	1.4	—	—	1.7	—	0.5
Gloucester	2.3	0.4	0.2	0.1	—	—	0.8	0.3	—	—	0.1	—	0.4	—	—	—	—	—	—	—
Mercer	14.6	2.4	0.6	0.2	0.8	0.2	0.4	—	1.1	0.2	4.4	0.2	2.2	0.8	0.8	—	0.2	—	—	0.6
Salem	1.9	0.3	0.4	—	—	—	—	—	—	—	1.1	—	—	—	—	—	—	—	—	—
COASTAL REGION	12.8	3.8	2.9	1.5	0.1	1.1	0.9	—	—	—	1.0	0.1	0.3	0.2	0.7	—	—	0.3	—	0.1
Atlantic	1.9	0.7	0.1	0.4	—	0.9	0.1	—	—	—	0.2	—	—	—	—	—	—	—	—	—
Cape May	0.6	0.3	0.1	0.1	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—
Cumberland	5.0	2.0	1.2	0.4	0.1	0.1	0.2	—	—	—	0.6	0.1	—	0.1	—	—	—	0.1	—	—
Monmouth	4.8	0.7	1.5	0.6	—	0.1	0.4	—	—	—	0.1	—	0.3	0.1	0.7	—	—	0.1	—	0.1
Ocean	0.5	0.1	—	—	—	—	0.2	—	—	—	—	—	—	—	—	—	—	0.1	—	—
NORTHWESTERN REGION	6.7	0.3	1.9	0.1	1.5	—	0.5	—	0.1	0.1	0.2	0.3	0.6	0.9	0.2	—	—	—	—	—
Hunterdon	0.9	0.1	0.1	0.1	0.4	—	—	—	0.1	—	0.1	0.2	0.1	—	0.1	—	—	—	—	—
Sussex	0.8	0.1	0.4	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—
Warren	4.9	0.1	1.4	—	1.1	—	0.5	—	—	0.1	—	0.1	0.5	0.9	0.1	—	—	—	—	—

Source: Estimates by Tippetts-Abbett-McCarthy-Stratton, based on industrial water-use questionnaire.

water, such as chemical plants, petroleum refineries and steel mills. Forecasts for intervening decades were formulated by a modified process of interpolation of data for each county.

The use of private industrial potable water supplies is expected to decline relative to total industrial potable water consumption by the end of the century because of the following reasons: Existing sources are being contaminated proportionately to the increase in population and industrial waste discharges; State law restricts withdrawal of large quantities of ground water for some private purposes; and costs of developing private supplies are not always competitive with water purchased from public water utilities.

Domestic and Other Non-Industrial Consumption

Estimates of current consumption of potable water purchased from public supply systems for use in homes, stores and offices, schools, hospitals and other institutions, utility companies and for municipal purposes (e.g. street-cleaning and fire-fighting) were obtained by subtracting estimated industrial consumption from total quantities supplied by all public systems. The 1954 estimates and the forecasts for the year 2000 are tabulated by counties in Table IV-7.

Per capita consumption of water for domestic and other non-industrial purposes is now especially high in the Coastal Region, where there is a high concentration of hotels and other accommodations for summer tourists, and a predominance of single family dwellings with garden plots. It is believed that per capita rates in most regions of New Jersey will increase about fifteen per cent by the end of the century, because of the increasing use of automatic home laundries, dishwashers, garbage disposal units and other water-using devices which may be developed (see Table IV-12). As indicated in Table IV-8, it is assumed that almost the entire population of the State will be served by public water systems at that time.

The forecasts of domestic and other non-industrial water consumption shown in Table IV-7 were derived by multiplying expected per capita rates by the anticipated population of each county (see Plate IV-1) in the year 2000. It is believed that about 540 million gallons per day will be required for all non-industrial uses throughout the State by that year. The Northeastern Region will require the greatest absolute increment (about 160 million gallons per day), although the Southwestern Region's requirements will rise most rapidly (approximately 140%). Consumption figures for intervening decades were computed by multiplying interpolated per capita rates by the appropriate population projections.

CONSUMPTION OF NON-POTABLE WATER

Consumption of non-potable water is far greater than that of potable water within the State of New Jersey. Replies from electric and gas utilities and from factories employing almost 30% of the State's industrial labor force indicate that these plants alone use nearly 3 billion gallons of non-potable water per day (see Table IV-13). The responses were obtained from a substantial proportion of the plants using 55 thousand gallons of water per day and over. (The U. S. Department of Commerce estimated that factories reporting water intake of 55 thousand gallons per day and over—both potable and non-potable—in 1953 accounted for 90 to 95 percent of the water used.)

TABLE IV-13

REPORTED CONSUMPTION OF NON-POTABLE WATER IN NEW JERSEY, 1954

(Millions of Gallons per Day)

Regions	Total	Industries	Electric & Gas Utilities
Northeastern	1,971	327	1,644
Southwestern	870	219	651
Coastal	95	3	92
Northwestern	0	0	0
TOTAL	2,936	549	2,387

Source: Tippetts-Abbett-McCarthy-Stratton industrial water-use questionnaire. (These data do not represent statewide totals. They are based solely on actual replies from major water-using plants.)

The greater part of the industrial demand is for non-potable water required for cooling and "wet industry" processing. In these uses, water serves as a heat-exchange medium, diluent, or for other flow-through processes in which very little water is removed before being returned to the non-potable source. Almost any source of water, including seawater and polluted river water, can be used for cooling purposes. Most New Jersey industries requiring large amounts of cooling water have established plants on tidewater sites to take advantage of the inexhaustible supplies available. In New Jersey there are also a few users of large quantities of water located on streams. Such industries are dependent on a fluctuating stream flow wherever rivers have not been regulated by storage of flood water.

Most of the replies to the industrial water-use questionnaire came from plants located on the Hudson River, Passaic River, Arthur Kill, Raritan River, and lower Delaware River. The principal factories requiring large amounts of non-potable water are those producing petroleum products, chemicals, building materials, aluminum, copper, steel, pasteurized milk, vegetable oil products, and electrical goods. Electric and gas utilities also use vast quantities of non-potable water.

USE OF WATER FOR SUPPLEMENTAL IRRIGATION

Recent developments in portable sprinkler equipment coupled with comparatively high prices for agricultural products have resulted in an appreciable increase in the practice of crop irrigation in eastern United States. Crop failures or reduced yields caused by lack of rainfall at criti-

TABLE IV-12

PER CAPITA CONSUMPTION OF PUBLIC POTABLE WATER IN NEW JERSEY, BY MAJOR USES, 1954 AND 2000*

(Gallons per Day)

Regions	Total		Industrial		Domestic & Other Non-Industrial	
	1954	2000	1954	2000	1954	2000
Northeastern	125	135	69	68	56	67
Southwestern	116	136	64	76	52	60
Coastal	93	106	20	21	73	85
Northwestern	116	122	82	72	34	50
NEW JERSEY TOTAL	119	132	62	65	57	67

* See Table IV-8 for percentage of population served in each region.
Source: Estimates and forecasts by Tippetts-Abbett-McCarthy-Stratton.

cal times during the growing season may be eliminated economically by the utilization of portable sprinkler-type irrigation equipment. This equipment can be taken from storage and placed in service on any land suitable for farming in a matter of hours by a crew of two men. Previously, supplemental irrigation was not practicable in normally humid regions. Most of the land was not suited topographically for conventional field flooding or row irrigation from ditches; and the drought periods were too infrequent to justify the costs involved in extensive land leveling and in the maintenance of ditches and other specialized irrigation structures.

It has been demonstrated that supplemental irrigation (supplying the additional water needed to maintain optimum growth of crops) not only removes much of the risk due to precipitation failure but actually increases crop yields during average years since water is provided to the crops at critical periods. In the decade ending in 1954 the area under sprinkler irrigation in New Jersey increased from a nominal amount to an estimated 70,000 acres. Garden vegetables, potatoes and berries are the principal crops irrigated by sprinkler systems. In addition, about 3000 acres of cranberries are flooded during each winter to prevent frost damage. This latter use, however, is of small consequence in relation to the total supply since the water is taken from local streams and swamp areas at a time when it is usually plentiful.

Approximately 10 billion gallons of supplemental irrigation water would be required during a year of average precipitation to maintain optimum plant growth on an area of 70,000 acres. The relative importance of such an amount of water may be appreciated by considering that it is adequate for the needs of an average city of 250,000 people.

In order to determine the present and probable future water requirements for farm and nursery irrigation in New Jersey, inquiries were sent to all of the County Agricultural Agents in the State. The information that was obtained is presented in Table IV-14. From this information it appears likely that 145,000 acres of farm land will be irrigated by the year 2000 and will require 43.5 billion gallons of water during an exceptionally dry year similar to 1932. However, for a year of average rainfall only 20 billion gallons would probably be required for irrigation. This amounts to twice the present average requirements.

About 40 per cent of the water now used for sprinkler irrigation comes from wells or springs. Considering that adequate surface water flows are not available on most farms, and that ground water can be obtained from wells in the majority of farming areas of the State, it is probable that an increasing portion of irrigation water will be drawn from wells. However, experience with shallow wells for irrigation water has been unsatisfactory in many areas and the tendency will be to utilize deeper sources for the principal farm supplies.

COMPETITION WITH POTABLE WATER SYSTEMS

The portion of the Raritan River Basin located above Bound Brook and including the Millstone River was chosen for a detailed study of irrigation water requirements. This area was selected for study because of the possible effect of irrigation requirements on the several plans that have been considered for developing runoff from this basin as a public potable supply. Although the Southwest and the Coastal

TABLE IV-14

IRRIGATED ACREAGE AND MAXIMUM IRRIGATION WATER REQUIREMENTS, 1950-2000

Regions & Counties	IRRIGATED AGRICULTURAL AREAS (Acres)					MAXIMUM ANNUAL IRRIGATION REQUIREMENTS* (Millions of Gallons)				
	1950	1954	1960	1980	2000	1950	1954	1960	1980	2000
NEW JERSEY TOTAL	28,117	69,835	100,575	137,650	145,100	8,435	20,930	30,172	41,305	43,530
NORTHEASTERN REGION	4,128	11,595	13,775	15,600	15,600	1,238	3,479	4,159	4,690	4,680
Bergen	1,537	1,200	700	0	0	461	360	210	0	0
Essex	467	490	400	100	100	140	147	120	30	30
Hudson	145	145	100	100	100	43	44	30	30	30
Middlesex	488	6,000	9,000	12,000	12,000	146	1,800	2,700	3,600	3,600
Morris	616	2,300	2,300	2,300	2,300	185	690	690	690	690
Passaic	856	900	650	500	500	257	270	195	150	150
Somerset	5	135	200	200	200	2	41	60	60	60
Union	14	425	425	400	400	4	127	127	120	120
SOUTHWESTERN REGION	12,564	19,600	30,000	45,500	45,500	3,769	5,880	9,000	13,650	13,650
Burlington	8,387	10,000	11,000	12,500	12,500	2,516	3,000	3,300	3,750	3,750
Camden	862	2,200	3,000	3,000	3,000	259	660	900	900	900
Gloucester	1,690	1,900	7,000	15,000	15,000	507	570	2,100	4,500	4,500
Mercer	1,478	2,500	4,000	5,000	5,000	443	450	1,200	1,500	1,500
Salem	147	3,000	5,000	10,000	10,000	44	900	1,500	3,000	3,000
COASTAL REGION	10,559	38,440	52,800	70,550	70,800	3,168	11,592	15,840	21,165	23,400
Atlantic	2,987	15,000	20,000	20,000	20,000	896	4,500	6,000	6,000	6,000
Cape May	81	1,200	2,400	4,800	6,700	24	360	720	1,440	2,000
Cumberland	4,418	11,000	20,000	30,000	33,300	1,325	3,300	6,000	9,000	10,000
Monmouth	2,140	8,900	9,900	15,000	16,700	642	2,670	2,970	4,500	5,000
Ocean	933	340	500	750	1,300	280	102	150	225	400
NORTHWESTERN REGION	866	2,200	4,000	6,000	6,000	260	660	1,200	1,800	1,800
Hunterdon	203	500	500	500	500	61	150	150	150	150
Sussex	122	200	500	500	500	37	60	150	150	150
Warren	541	1,500	3,000	5,000	5,000	162	450	900	1,500	1,500

* Assuming dry year consumption of 11 inches or 0.3 million gallons per acre.

Sources: U. S. Census of Agriculture, 1950; forecasts by Tippetts-Abbett-McCarthy-Stratton, based on questionnaire to County Agricultural Agents.

Regions have greater irrigation water requirements, the water used for irrigation in these areas is not anticipated to be competitive with potable water systems. The latter regions have large, relatively untapped ground water storage which is ample for irrigation purposes.

The counties located in the Raritan Basin and their present and future estimated irrigated acreage and irrigation water requirements are listed in Table IV-15. These water requirements were based on estimates of irrigated acreage located within the drainage area. Although sections of Morris and Monmouth Counties are included within the Raritan Basin, practically none of their irrigated acreage is located within the Basin. Similarly, only portions of the irrigated farm land in Mercer and Middlesex are in the portion of the Basin tributary to Bound Brook.

From Table IV-15, it may be noted that the irrigated acreage in the Raritan Basin could have required an estimated 1.1 billion gallons of water in 1954, had it been a critically dry year. It is assumed that 11 inches of supplemental irrigation water would be needed in a dry year to maintain optimum plant growth. In an ordinary year this amount would be reduced by about one-half, assuming a minimum supplement of 5 inches of irrigation water. For the decade ending in 2000, it is probable that a maximum of 1.9 billion gallons of water would be required in a dry year to supply the irrigated acreage within the Basin.

The magnitude of irrigation requirements is relative to the runoff available from the drainage area. Runoff in the Raritan Basin was studied for a typical dry (1932) and a typical wet (1938) growing season. Two recent seasons (1950 and 1954) were also studied and compared with irrigation requirements in the former seasons. During 1932, an exceptionally dry year, runoff for the irrigation season (July, August and September) totalled 6.2 billion gallons, whereas in 1938, an exceptionally wet season, 149.5 billion gallons of runoff were recorded. Recently 25.5 billion gallons and 25.2 billion gallons were recorded respectively for 1950 and 1954 from July to September.

During the growing season, future irrigation requirements could hypothetically amount to nearly 30 per cent of the available runoff, assuming a repetition of conditions as of July-September 1932 and an irrigation requirement of 1.9 billion gallons. Requirements of this order represent an important use of Raritan Basin water and should be considered in any plan for development of the basin runoff as a major water supply.

Maximum reductions in river flow due to irrigation use, however, would occur during dry periods when the natural flow is inadequate to permit diversions for potable supplies. During low stream-flow periods, potable supplies would be drawn entirely from water held in storage reservoirs for this specific purpose. For this reason, irrigation would not be in direct competition with potable supplies, but would increase the storage needed for regulating releases to maintain a fixed minimum rate of river flow for the benefit of downstream interests.

WATER CONSERVATION MEASURES

Enormous quantities of water are wasted annually by industrial and domestic consumers. Future water requirements could be reduced if water conservation were practiced by everyone. Two effective water conservation measures are (1) re-use of industrial water and (2) metering of all consumer outlets.

It is estimated that industry presently obtains 300 million gallons of water per day from public water systems in New Jersey and this amount will nearly double by the year 2000. This usage might be substantially reduced through an effective program of industrial water re-use. It is doubtful, however, whether voluntary water re-use would be widely adopted by New Jersey industry. There are understandable reasons for this reluctance to be concerned with water re-use. In most industrial plants that were built when the supplies of water were abundant, the equipment has been designed to operate efficiently on large volume flows. It is very costly to revise water-using equipment in an existing plant, and it is frequently extremely difficult to show economies resulting from capital expenditures for conservation that are as great as the earnings that might be attained more immediately from the investment of the same capital in productive facilities. The available techniques for reducing industrial water requirements invariably add to the complexity of construction and operation of the industrial water system. These techniques require careful design and, for full effectiveness, they need skillful operation.

Possibly the public interest might be served by governmental policies offering financial incentives, such as local tax reductions, that would encourage water-saving measures. However, this type of plan is more applicable to arid regions, where the need is more urgent. A compulsory conservation program, similar in enforcement to municipal smoke-abatement programs, is feasible but not desirable from the standpoint of attracting new industry and keeping established industry. Another measure which has been used where conservation is a matter of greatest necessity is a scale of charges which increases as water usage increases.

There are many examples of industrial establishments that have instituted remarkable water-saving jobs. These plants are of two kinds: (1) Those that were faced with closure because of growing water shortages and (2) those built where there was little water to begin with. A number of industrial plants built within recent years have made maximal use of water conservation methods through more generous design of heat-exchanging devices, through automatic control equipment on water flows, through recycling, through use of the water successively in numerous processes, and through substitution of water of inferior quality for less available high

TABLE IV-15

AGRICULTURAL IRRIGATION IN RARITAN RIVER BASIN, 1950-2000

Counties	IRRIGATED AREAS* (Acres)					MAXIMUM ANNUAL IRRIGATION REQUIREMENTS** (Millions of Gallons)				
	1950	1954	1960	1980	2000	1950	1954	1960	1980	2000
Hunterdon	203	500	500	500	500	60	150	150	150	150
Somerset	5	135	200	200	200	2	40	60	60	60
Mercer	1,000	1,700	2,700	3,300	3,300	300	510	810	990	990
Middlesex	100	1,200	1,800	2,400	2,400	30	360	540	720	720
TOTAL	1,308	3,535	5,200	6,400	6,400	392	1,060	1,560	1,920	1,920

* Irrigated acreage shown is for the Raritan River Basin above the Bound Brook gaging station. Complete irrigated acreage is shown in Table IV-14.

** Estimated requirement is based on 11 inches annual (100 days) supplementary water (0.3 million gallons per acre).

Sources: U. S. Census of Agriculture, 1950; estimates and forecasts by Tippetts-Abbett-McCarthy-Stratton.

quality water. Several good examples of increased production with little or no increase of water consumption were noted on the returns to the New Jersey Industrial Questionnaire used for this survey. One example was an electric generating station which increased its power output 1,200,000 megawatt hours, or 80% from 1949 to 1954. In this same period, its requirement for public potable water decreased 100,000 gallons per day, about 20 percent.

The second principal method of encouraging water conservation is through a program of water meterage. Meterage encourages thrift and normalizes demand. The practice of water meterage is widespread in New Jersey, and no appreciable increase in water savings can be realized by additional use of meters. It is advisable, however, to continue to expand the meterage program to provide full coverage throughout the State.

The best water conservation program will not eliminate the requirement to expand water supply and distribution systems. However, an effective conservation program highlighting industrial water re-use and meterage could minimize local water shortages and also reduce long-range requirements.

CHAPTER V

CHAPTER V

STUDY OF WATER DEMAND BY SERVICE AREAS AND TRANSMISSION REQUIREMENTS

The water resources of New Jersey, as stated previously, are adequate, with proper development, to meet all estimated demands that may arise in the future. In Chapter IV data were presented regarding the past and projected potable water requirements of the State by counties for the period 1920 to 2000. Numerous plans for development of potable water supplies for various regions of the State have been described in Chapters II and III. The purpose of this chapter is to present information regarding the need for water in those portions of the State which will require additional major supplies prior to the year 2000 and to describe the transmission systems necessary to deliver water from the new resources to the affected areas. In many localities there are shortages of water due to the inadequacy of distribution systems that have failed to keep pace with growth in demand. Review of the adequacy of the local distribution systems is not within the scope of this report. Any local improvements or additions to these systems, required for proper water service, can most effectively be carried out by the distributing agencies.

NORTHEASTERN REGION

The Northeastern Region contains the greatest concentration of population and water use in the State. Plate V-1 shows the boundaries of the region and the general areas presently served by major water distribution systems. The boundaries of the seven service areas which comprise the region are indicated also. Records of potable water consumption and information regarding the dependable yields of the several water systems of the region were assembled. Plate V-2 summarizes these data and shows among other things the projected demand for potable water to the year 2000. Table V-1 lists the projected potable water requirements of the Northeastern Region by decades to the year 2000.

TABLE V-1

POTABLE WATER REQUIREMENTS

NORTHEASTERN REGION

Date	Estimated Annual Average million gallons per day
1955	440
1960	475
1970	542
1980	607
1990	667
2000	726

It will be noted that the safe yield of the combined systems has consistently, with the exception of the 1930-1945 period, been only slightly greater than the consumption. This situation is undesirable and could lead to serious water shortages if domestic and industrial expansion suddenly outpaced water development. It could certainly hinder industrial expansion and inhibit the use of affected areas for housing development.

By necessity, estimates of future water demands rely primarily on the trends indicated by records of past consumption. If, however, new dependable water supplies are made available to an area, past trends of industrial and residential growth rates are apt to be accelerated. In addition, as illustrated by the graphic record of past water consumption on Plate V-2, weather conditions, economic conditions, or national emergencies are reflected in very appreciable and often unpredictable changes in water consumption. For these reasons it would be unwise to provide water system capacity only adequate to supply the projected demand. Experience indicates that in planning future water supply additions it is desirable to provide for a demand 25 percent greater than that projected for normal growth conditions. For this reason a curve defining 125 percent of the projected demand has been superimposed on Plate V-2 to indicate the required safe supply for planning purposes.

The stepped dashed line on Plate V-2 indicates the magnitude and timing for completion of desirable stages of construction for additional potable water supplies for the Northeastern Region. The program is based on the assumption that the existing systems in the Region will, in the immediate future, be expanded together with improvements in transmission and interconnection facilities to develop the maximum economic potential from their respective sources. The existing systems and recommended expansions are discussed in Chapter II. Since each system is autonomous within its own distribution area, any measures taken for the expansion of existing systems should preferably be by the system ownerships. These agencies, however, may be unwilling to develop supplies not presently salable on their own systems, or they may be financially unable to supply the funds. The indicated target dates for development of new supplies would have to be reassessed and moved up if it appeared that expansion of existing supplies was not being fully carried out or planned for the early future.

It is estimated that the fully expanded existing systems would add a net of 122 million gallons of water per day to the supplies of the Northeastern Region (129 mgd less 7.0 lost to New York State by 1975). It is therefore advisable that means be established for the encouragement of these expansions including State guarantees on the sale of surplus water.

Using existing system expansion as a basic criteria of development, the completion of Stage 1 for a new supply of 70 mgd should be planned for no later than 1965. The four stages of construction proposed for new supplies in addition to the expanded systems would provide the total of 300 mgd of additional potable water which will be needed in the Northeastern region by the year 2000. The four stages mentioned in this chapter refer to the development of the transmission facilities and are reconcilable with the stages proposed for source development. Stage 2 for the transmission system would provide facilities for delivering 140 mgd. Such a supply may be obtained from the East Branch Reservoir (Plan CR-3) by the installation of part of the additional pumping capacity at Bound Brook and additional booster pumping and treatment capacity at the reservoir outlet needed for the CR-2 or CR-4 plans. A supply of 200 mgd, for which the Stage 3 transmission facilities would be required, would be furnished by Plans CR-2 or CR-4 (discussed in Chapter VI for the second stage of source development). The complete transmission system, including Stage 4 facilities, would be required for the third stage of source development for a dependable yield of 300 mgd.

PROJECTED REQUIREMENTS BY WATER SERVICE AREAS

To facilitate the analysis of water use and future requirements in the Northeastern Region, the Region was divided into seven service areas, as shown on Plate V-1. The water service areas are convenient geographical sections of similar economic type which lend themselves to detailed analysis of water requirements more readily than the larger and more complex regions. The service areas are used for study purposes only and it is not to be inferred that the existing water systems within the service areas will in any way lose their autonomy as a result of studying the areas as units. Plate V-3 presents a graphic comparison of projected potable water demand with existing and proposed dependable supplies of existing systems for each of the seven service areas of the Northeastern Region.

Water Service Area No. I includes the eastern portion of Somerset County, the northern part of Middlesex County and all of Union County with the exception of the City of Elizabeth. It is supplied by four of the five major privately owned water companies operating in the Northeastern Region. They are the Elizabethtown Water Company, Commonwealth Water Company, Plainfield Union Water Company, and Middlesex Water Company. The existing dependable supply is considered to be adequate until about 1974 if the individual water systems involved will interchange water freely. The Elizabethtown Water Company, because of its location on the Raritan River, is the only system in a position to carry out large scale development to increase its yield. However, if Raritan River water was utilized for this purpose it would conflict with programs designed to utilize the river for region-wide bene-

fits. The Delaware and Raritan canal may be utilized as an additional source of potable water for this area. The Commonwealth Water Company is presently expanding its system with storage on the upper Passaic River at Millburn to yield an additional 10.6 mgd, and it appears that this will have to be added to before 1970 in order to provide full service. The Plainfield Union Water Company and Middlesex Water Company depend primarily on wells for a source of supply and appreciable expansion of either system is not considered to be feasible.

Water Service Area No. II, including all of Essex County, the City of Elizabeth in Union County, and the southern portions of Bergen and Hudson Counties, is the most densely populated section in the Region and is responsible for approximately 50 percent of the present water consumption. This area's principal water supplies come from three major surface sources originating outside the service area. These are the Pequannock (Newark), Wanaque-Ramapo (North Jersey District) and Rockaway (Jersey City) systems whose combined safe capacity is only sufficient to meet the existing average demands of the area. Recommendations for additional development of these systems is discussed in Chapter II. Other important systems operating in this area are the Commonwealth Water Company and the municipal water departments of East Orange, Orange, South Orange and Essex Fells. The Commonwealth Water Company program was briefly discussed under Service Area No. I and it is not considered probable that any appreciable new supplies may be derived from expansion of the smaller municipal water departments. Some investigators in the past have concluded that many of the small sources of water supply would be abandoned as suburban or industrial developments encroached on the watersheds, or larger supplies became available for wholesale purchase. Present indications are that new supplies will be considerably more expensive than existing ones, hence it is probable that most of the small supplies will continue to be used and that enough of the supplies will be expanded to offset those that may be abandoned. Even with the preservation and expansion of existing supplies, water from a major new supply should be made available as soon as possible for Service Area No. II, since the present dependable capacity provides no margin of safety over current water consumption. In the event of a succession of dry years in the near future, restrictions on water use in this service area will be necessary to avoid shortages of water for the most vital industrial and domestic needs.

Water Service Area No. III, the eastern half of Bergen County and the northern part of Hudson County, is supplied almost wholly by the Hackensack Water Company. Some increase in yield is possible for this system and the salient features of the Hackensack Water Company's expansion plans are covered in Chapter II. Extensive residential and industrial development in Bergen County has increased water consumption to the point where continued development will begin to reduce the safe margin of reserve. New supplies should be brought into Service Area No. III within the next 5 years if the growth of the area is to continue at the present rate.

Water Service Area No. IV contains the more built-up sections of Passaic County and the more sparsely settled areas of Bergen County. The major water supply system in this area is operated by the Passaic Valley Water Commission. This system is described in Chapter II. Direct diversion of Passaic River water at Little Falls accounts for approximately 50 percent of the dependable supply, while the remainder is obtained from the Wanaque-Ramapo system. A large-scale increase in dependable supply is possible for this service area if construction of the Point View Reservoir discussed in Chapter II is carried out. At the present time the dependable capacity available to this area provides very little margin over water consumption and is frequently less than peak demands. This area would be particularly vulnerable to the adverse effects of a dry year with accompanying heavy usage, because no large-scale storage facilities are in existence. After expansion of the system yield by the proposed 55 mgd, it would be possible to meet all anticipated requirements of the service area to the year 2000. An expansion of the size of the Point View Reservoir Project would provide more additional yield than can be used for several years in Service Area No. IV. However, water could be conveniently wholesaled on a temporary basis to deficient systems in Service Areas Nos. II and III.

Water Service Area No. V is located entirely within Morris County and includes most of the more built-up sections. The actual dependable yield for this area is difficult to assess because water is supplied by several small systems and accurate information on their ultimate capacity is not available. However, Service Area No. V is located within the Passaic basin, hence any extensive development of the existing systems, whether by ground or surface supplies, would have a net result of reducing the anticipated safe yield of the other systems utilizing the Passaic River or its tributaries. The chart on Plate V-3 indicates that some supplemental supplies should be made available for Morris County in the next few years. Local expansion and individual well development (feasible for the less populated areas) will probably keep the problem from becoming critical for a number of years. If demand in Service Area No. V begins to exceed the ability of local systems to provide a safe supply, dependence will have to be placed on the new regional supplies to be developed. It is also possible that if a new major supply is developed with a broad basis of availability, arrangements can be made to interchange water with the large surface water systems which have developed supplies in this service area for delivery to Service Area No. II.

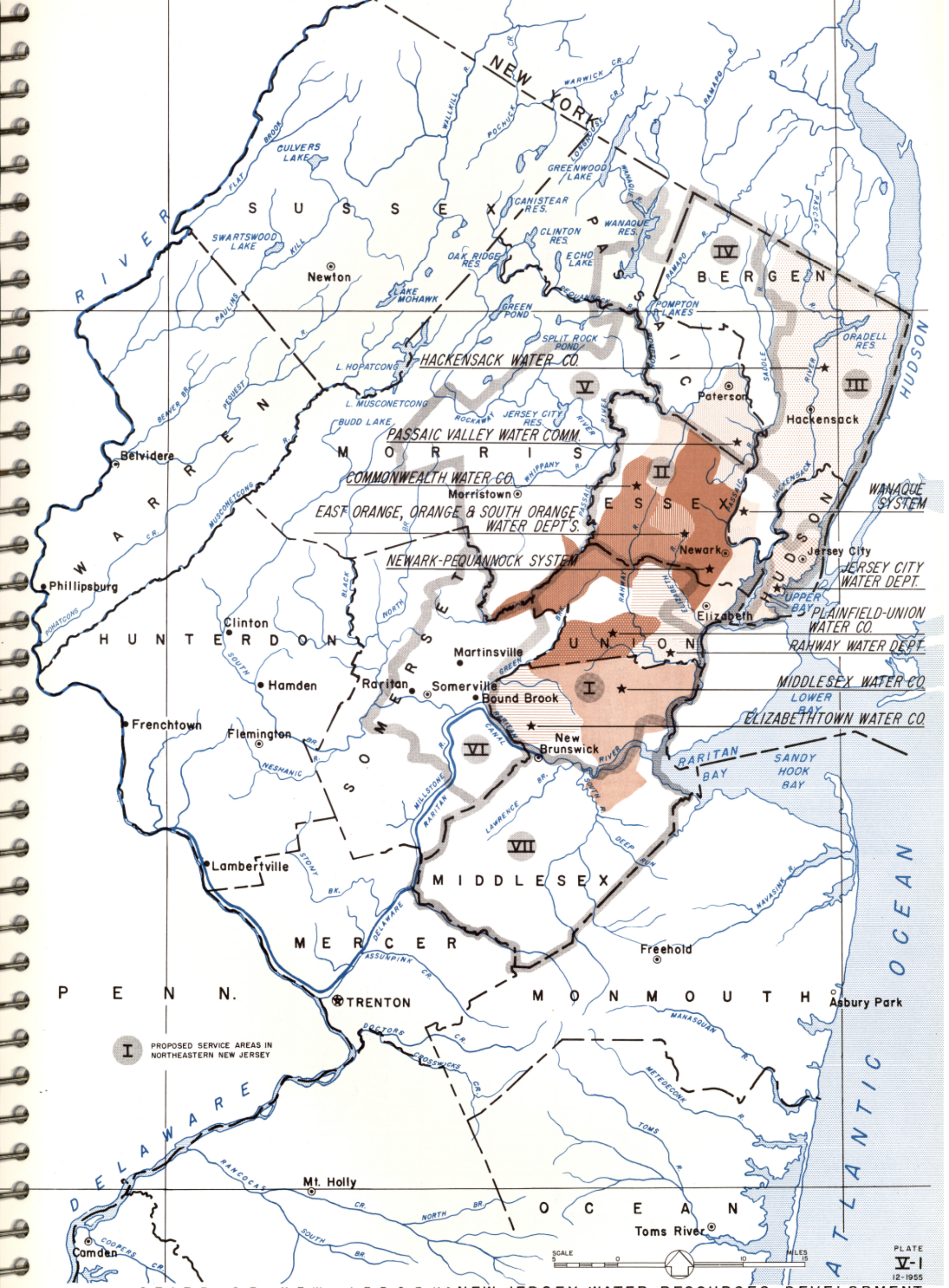
Water Service Area No. VI is located in Somerset County and though much of its area is presently farmland, considerable industrial potential does exist. Here as in Water Service Area No. V the value of the dependable yield is difficult to ascertain. A few small systems are now furnishing water from ground and surface sources. Service Area No. VI could obtain wholesale water from the facilities of any major project utilizing water from the Raritan River, or using the Raritan River channel as a means of conveyance for Delaware Basin water. Unless unusual growth occasioned by accelerated industrial activity (which could result from the availability of greater potable and industrial water supplies) should occur, the existing supplies augmented by additional well supplies should meet requirements in the service area until about 1970.

Water Service Area No. VII is located in the southern part of Middlesex County and includes the cities of New Brunswick, Perth Amboy and South Amboy. The major systems operating in this area are the New Brunswick Water Department, Perth Amboy Water Works and the Duhernal System jointly owned and operated by the DuPont, Hercules Powder and National Lead Companies. The Duhernal system is supplied primarily by ground water, with surface reservoirs used for ground water recharge and to prevent salt water intrusion where such a danger exists. Several smaller municipalities and industries maintain wells to supply their own needs. Most of the systems use ground water; however, the New Brunswick Water Department uses surface water from Lawrence Brook and 7.5 million gallons per day from the Delaware and Raritan Canal. The canal also supplies 2.33 million gallons per day to the Johnson & Johnson Company in New Brunswick.

The ground water aquifers are already being pumped at or above capacity along the lower Raritan River and some salt water intrusion has occurred in the Farrington sand formation. The dependable ground water supply along the Raritan River in this service area is probably somewhat less than the present rate of pumping, which is reported to be from 32 to 35 mgd. It is estimated that the safe withdrawal of ground water in this service area is 30 mgd if salt water contamination is to be avoided. Some increase in ground water recharge would be realized from the proposed Crab Island Reservoir project, discussed in Chapter II, but such increase cannot be reliably evaluated without extensive study. The present dependable supply for this area, as shown on Plate V-3, would be unable to meet a sustained high seasonal demand if it coincided with an extended dry period, without dangerous overpumping of ground water supplies.

DISTRIBUTION OF SUPPLY FROM PROPOSED EXPANSIONS OF EXISTING SYSTEMS

As indicated by Plates V-2 and V-3, it is of vital importance that the proposed expansions of the Pequannock system of the City of Newark, the Rockaway system of Jersey City and the Point View Project of the Passaic Water Commission be



STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

GENERAL AREAS PRESENTLY SERVED BY MAJOR WATER DISTRIBUTION SYSTEMS IN NORTHEASTERN REGION

STATE OF NEW JERSEY | NEW JERSEY WATER RESOURCES DEVELOPMENT

LEGISLATIVE COMMISSION ON WATER SUPPLY

PROJECTED POTABLE WATER DEMAND COMPARED WITH EXISTING AND PROPOSED SUPPLIES FOR NORTHEASTERN REGION

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V-4

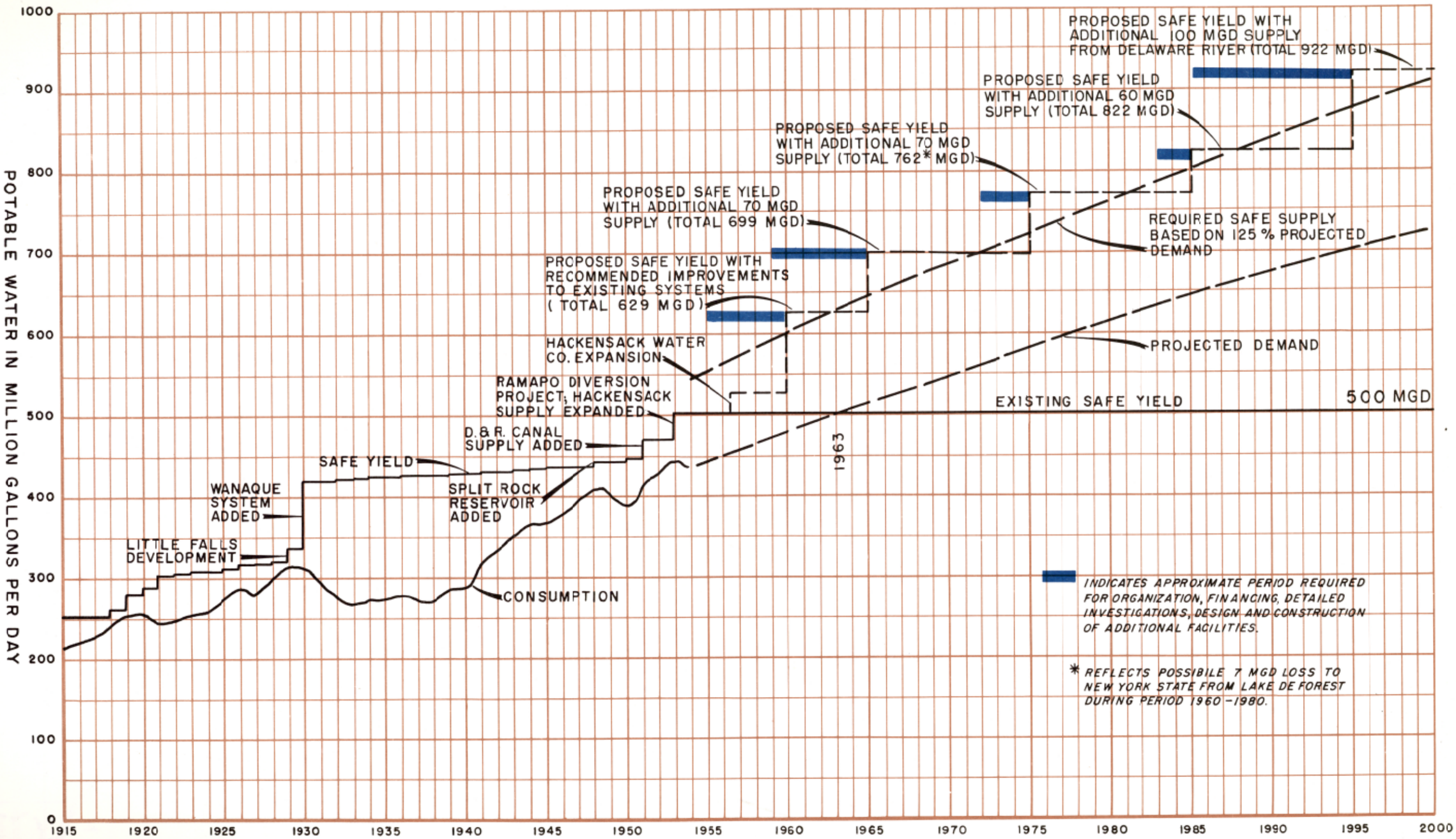

PLATE V-2
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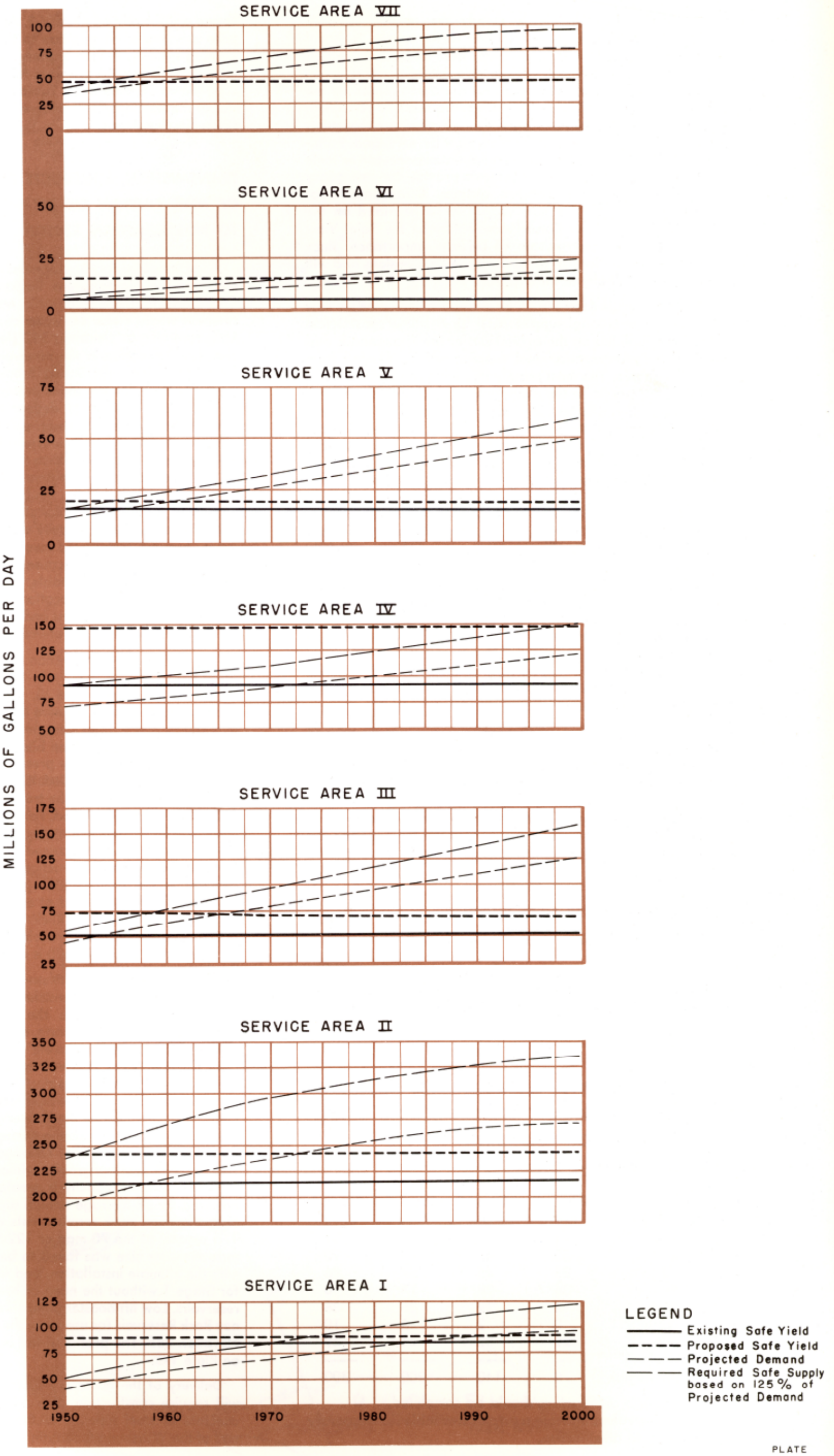

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PROJECTED POTABLE WATER DEMAND COMPARED WITH EXISTING AND PROPOSED SUPPLIES FOR WATER SERVICE AREAS - NORTHEASTERN REGION

implemented immediately to supply the reserve capacity necessary for an adequate and safe water supply. It should be emphasized, in this connection, that for such increased capacity to provide the region-wide benefits necessary—rather than an excess of reserve for the areas served by the three expanded systems with inadequate supplies remaining for neighborhood areas—legal and physical arrangements for distribution of the new supplies must be arranged. Fortunately, the major systems are already interconnected to some extent and contractual arrangements provide for emergency interchange of water between systems. Arrangements for delivery of part of the new supply to be provided on the Passaic Valley Water Commission system by the Point View Project to other systems are of primary importance, since that is by far the largest of the proposed expansions and will be required initially in other areas.

Water Service Area No. II, as previously indicated, is now in need of additional supplies and by the time construction can be completed on the expansions of the Pequannock and Rockaway systems additional supplies will be needed from another source. The most readily available water for Service Area No. II would be the expanded yield of the Passaic Valley Water Commission after completion of the Point View Project. Interconnections are available for delivery of water from the Passaic Valley System to either the Wanaque or Jersey City aqueducts. Delivery to the Jersey City aqueducts could be by gravity, but the water would require pumping to be delivered into the Wanaque aqueduct, which maintains a greater pressure. An emergency connection exists with the Pequannock system but the difference in pressure in the lines would require that the Passaic Valley supply be pumped. In addition there is a 51 inch force main from the Little Falls pump station to Harrison with connections to Clifton, Passaic and Nutley. Since the Passaic Valley Water Commission is a participant in the Wanaque-Ramapo system, an arrangement for the delivery of a part of its Wanaque-Ramapo supply to systems supplying Service Area No. II, in lieu of Point View Project water, should involve only contractual and financial negotiations and would eliminate the need for most of the pumping at the interconnections.

It appears then that sufficient interconnections do exist to distribute the excess water from Service Area No. IV to Service Area No. II. The aqueducts of the major systems are all capable of delivering more water than the present yield of their systems with the exception of the Jersey City aqueduct from the Brookdale Gate House to the Troy Street Gate House in Jersey City. However, if pumping facilities were added the capacity of this section of the aqueduct could be increased considerably.

REQUIREMENTS FOR NEW SUPPLIES BY SERVICE AREAS

A four stage program of construction to make the 300 mgd of dependable potable water supply, required for the Northeastern Region by the year 2000, available when needed is shown graphically on Plate V-2. As indicated, these new supplies are needed in addition to the proposed expansions of existing systems. If such expansions are not executed in the immediate future, the program for completion of a new major supply must be advanced. Table V-2 is presented to show by stages the new supplies which will be required in each of the seven Service Areas.

TABLE V-2

ADDITIONAL WATER SUPPLIES NEEDED IN SERVICE AREAS OF THE NORTHEASTERN REGION AFTER EXPANSION OF EXISTING SYSTEMS— MILLIONS OF GALLONS PER DAY

Service Area	Stage 1 1965*	Stage 2 1975*	Stage 3 1985*	Stage 4 1995*
I	–4**	5	15	27
II	53	65	73	90
III	23	45	57	86
IV	–36**	–28**	–17**	0
V	12	19	26	38
VI	0	2	5	10
VII	22	32	41	49
Total for Region	70	140	200	300

*Date stage construction should be completed.
**Negative values indicate a surplus available for temporary delivery to other areas.

TRANSMISSION AQUEDUCTS FOR DELIVERY OF NEW RARITAN OR DELAWARE SUPPLIES TO NORTHEASTERN REGION

All of the plans for development of new potable water supplies for the Northeastern Region, described in detail in Chapter II, that are adaptable economically to stage construction would make the water available either in Chimney Rock reservoir at elevation 290 (less an assumed 5 feet for ordinary fluctuation in the reservoir), or at a common point for transmission near Bound Brook at equivalent hydraulic pressure. Costs for the plans presented in Chapter II include all facilities required to deliver a dependable supply of treated water to the common point of transmission under a pumped or gravity pressure equivalent to a level of elevation 290 (less a 5 foot allowance for reservoir fluctuation and 12 feet head loss in the treatment plant). It was assumed that pressure filters, of a design similar to that shown on Appendix Plate A-11, would be used for all plans. Pressure filters, rather than the conventional gravity sand filters, were chosen primarily because they would involve somewhat smaller capital expenditures and also because they require less space and appear to be more adaptable to the topography and have greater flexibility as to location. Detailed studies, however, required for specific designs and construction plans may show the gravity filters to be preferable.

It is obvious from inspection of Table V-2 that the major portion of the new supply in Stage 1 will be required in Service Areas Nos. II and III. The primary aqueduct then, must be located so as to serve these areas. Numerous aqueduct routes with various sizes and types of pipe, and depending in varying degrees upon booster pumping for the maintenance of required delivery pressures at interconnections with existing systems were studied. On the basis of such an analysis, the general layout of the transmission system as indicated on Plate V-4 was developed. Pertinent features of the primary aqueduct and appurtenant facilities to serve Service Areas Nos. I through IV are discussed below for the four stages of transmission system construction, assuming that the point of delivery to the transmission system is at the outlet of the treatment facilities located at or near the south shore of the East Branch of Chimney Rock Reservoir as shown on Plate II-9. A separate aqueduct required to serve the lower Raritan valley (Service Area No. VII) is also discussed.

Stage 1–70 mgd. For this stage, which should be completed by 1965, an aqueduct consisting of 4,300 feet of 120 inch diameter tunnel (through the First Watchung Mountain) lined with reinforced concrete, and 103,000 feet of 108 inch diameter prestressed concrete or steel pipe would extend from Chimney Rock reservoir to a point of connection with the existing 60 inch diameter Wanaque main in Newark. Such an aqueduct, which would receive water from the treatment plant at Chimney Rock reservoir at a pressure level of about 273 feet (after passing through the filter plant), would be able to deliver a flow of 150 mgd to Newark at a pressure level of 235 feet by gravity without need for a balancing reservoir. Such a capacity is greater than would actually be required for an average annual supply of 70 mgd, assuming that maximum peak requirements would be on the order of 175 percent of the 70 mgd or 122.5 mgd. However, the 108 inch diameter size was found to be most economical for use with the ultimate installation, and would function adequately for Stage 1 without the need of booster pumps or balancing reservoirs. Low lift booster pumps would be required at Chimney Rock Reservoir for use when the reservoir level was below elevation 285. The profile of the aqueduct routes are shown on Plate V-5.

Delivery of the necessary supply to Service Area No. VII will require construction of a 54 inch diameter prestressed concrete or steel pipeline 50,000 feet long from the lower end of the Watchung Mountain tunnel to interconnection with



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EXISTING AND PROPOSED AQUEDUCTS IN NORTHEASTERN REGION

facilities of the Elizabethtown Water Company, Middlesex Water Company and the New Brunswick and Perth Amboy Water Departments. This aqueduct, the route of which is shown on Plate V-4, would function adequately by gravity for all requirements of the Service Area to the year 2000. Adequate service could be maintained for this area to the year 1975 by construction of a 42 inch diameter line with a considerable saving in initial capital cost. However, a second 42 inch diameter line would be required prior to the year 2000 in this case, so that the final cost would be much greater than for a single 54 inch diameter line.

Estimated capital and annual costs of the transmission lines recommended for Stage 1 are presented below. These costs include sectionalizing valves, surge valves and air inlet and release valves for efficient performance of the system, as well as manholes for inspection and maintenance. Capital costs include allowances for rights-of-way, engineering, legal and administrative costs and interest during construction. Annual costs cover interest and amortization, operation and maintenance.

Tunnel 4,300 feet long through First Watchung Mountain	$ 2,568,000
Aqueduct from Watchung Tunnel to Newark (103,000 feet—108" dia.)	17,846,000
Aqueduct from Watchung Tunnel to lower Raritan Valley (Area VII) (50,000 feet—54" dia.)	3,266,000
Capital Cost of Stage 1 Transmission Facilities:	$23,680,000
Annual Cost of Stage 1 Transmission, including interest and amortization, operation and maintenance	$ 1,023,000

Water delivered to the 60 inch diameter Wanaque main at Newark may be diverted two ways: south to Elizabeth and north to the Belleville Reservoir. Connections provided along the aqueduct from Chimney Rock reservoir, as shown on Plate V-4, would deliver water to the water systems of Service Area No. I. A large percentage of this area can be served by direct connections while delivery to the mains in the Cedar Grove Reservoir zone will require some pumping because of the higher pressure in the Pequannock System. As supplies are made available to this section of the area, the existing aqueducts may be relieved of supplying water to the southern extremities of their systems and may be tapped more heavily to meet demands in other parts of the area or may transfer water to the Jersey City aqueduct. Connection at Newark, therefore, permits convenient interconnection to both the Wanaque and Pequannock systems as well as providing supplementary supplies for Service Area No. II.

The most convenient means of serving Service Area No. III would be via the existing two 72" Jersey City Aqueducts from the vicinity of the Brookdale Gate House to Jersey City. At the present time flow in the two Jersey City Aqueducts from Brookdale Gate House is controlled by the elevation of an overflow chamber upstream. If this section of the aqueduct from Brookdale to Jersey City were placed under pump pressure, a slight increase in head would enable a great increase in flow through the conduits. It would then be possible to interconnect from this line to extensions of the Hackensack Water Company system in Rutherford, Secaucas, North Bergen and Weehawken, but the mains would require enlargement to handle the supplemental supplies to be needed in this area.

Stage 2—140 mgd of Additional Supply—This stage, which should be completed by 1975, will require additions to the transmission facilities. These will include a 108 inch diameter prestressed concrete or steel pipeline 91,000 feet in length, running from a point on the Stage 1 aqueduct in Mountainside Borough to Montclair (as shown on Plate V-4), two balancing reservoirs at Mountainside, booster pumping stations at Mountainside and Montclair and connections to the major existing systems at Montclair. The profile of the proposed aqueduct routes are shown on Plate V-5. Estimated capital and annual costs for the Stage 2 transmission system are as follows:

Mountainside to Montclair Aqueduct	$17,482,000
2 Balancing Reservoirs at Mountainside	1,552,000
Booster Pumping Station at Montclair	1,000,000
Booster Pumping Station at Mountainside	566,000
Connections to existing major systems	2,204,000
Capital Cost of Stage 2 additions	$22,804,000
Capital Cost of Stage 1 facilities	23,680,000
Total Capital Cost of Transmission System for Stages 1 and 2	$46,484,000
Annual Cost for Stage 2 Transmission, including interest and amortization, operation and maintenance	$ 2,117,000

Interconnections to be provided along the proposed aqueducts, as shown on Plate V-4, together with interchange arrangements for deliveries at the terminal points at Montclair and Newark, including a new 60 inch line 24,000 feet in length, for deliveries to water facilities of Service Area No. III, will accomplish delivery of the new supplies to Service Areas Nos. I, II, III and VI. High level supply to Service Area No. V and the western portions of Service Areas Nos. II and IV may be provided from the reservoirs of existing major systems with such deliveries being replaced by supplies from the new aqueducts at Montclair or Newark, through interchange agreements. The 54 inch diameter aqueduct to the lower Raritan valley included as a part of Stage 1 will be adequate to supply the additional quantities needed in Service Area No. VII.

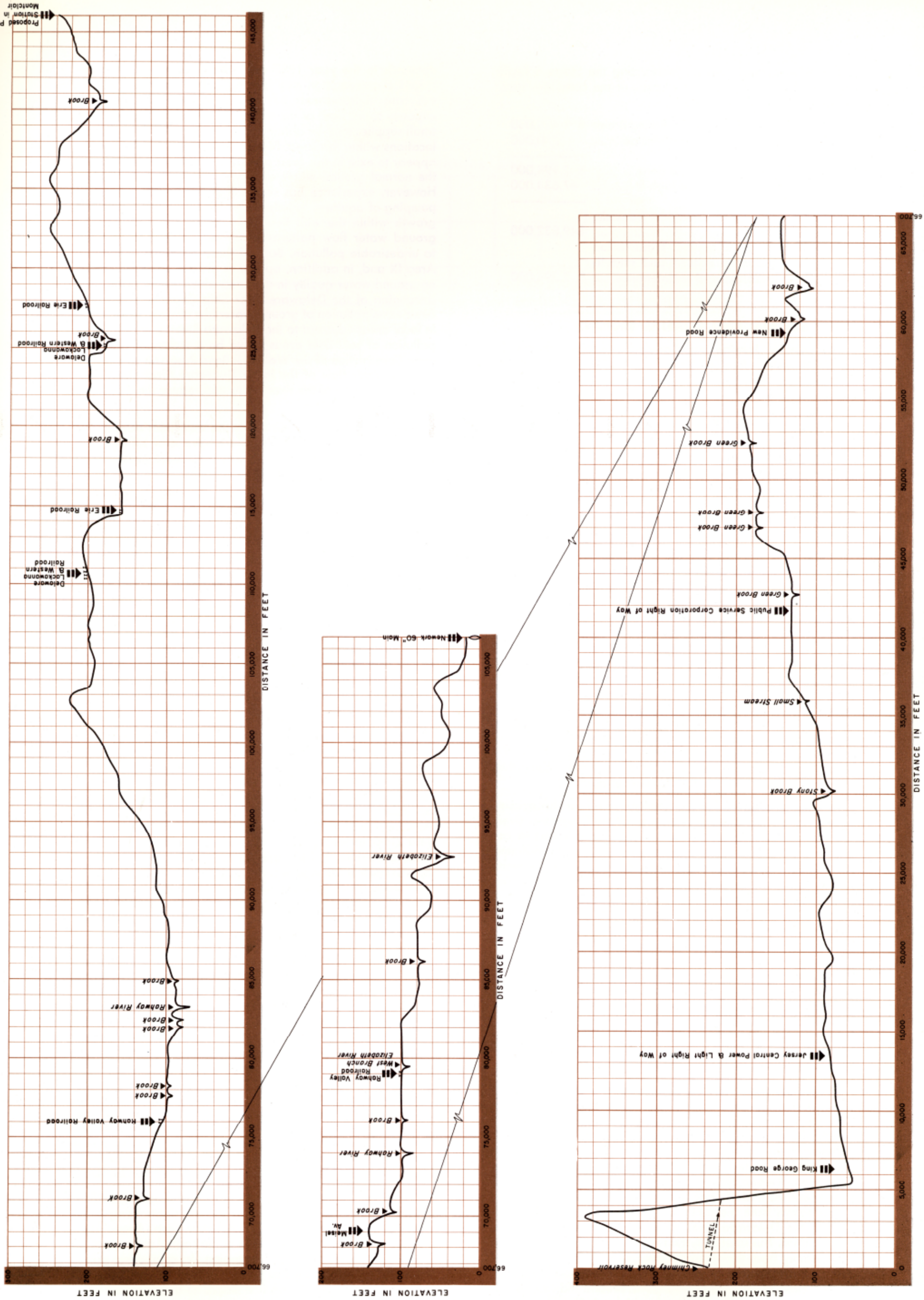
Data presented in Table V-2 indicates the estimated distribution among the seven Service Areas of the Region of new supplies provided by Stage 2 construction.

Stage 3—200 mgd of Additional Supply—This stage, which should be completed by 1985, will complete the facilities required for transmission of the 200 mgd supply which would be provided by the development of the Raritan River source. Additional facilities required for transmission include increased capacity in the booster pumping stations at Mountainside and Montclair. The capital costs of Stage 3 items and the capital and annual costs of the full transmission system after completion of Stage 3 are estimated as follows:

Additions to Booster Station at Mountainside	$ 150,000
Additions to Booster Station at Montclair	1,000,000
Capital Cost of Stage 3 Additions	$ 1,150,000
Capital Cost of Stages 1 and 2	46,484,000
Total Capital Cost of Transmission System including Stage 3	$47,634,000
Annual Cost of Stage 3 Transmission, including interest and amortization, operation and maintenance	$ 2,196,000

With the addition of these Stage 3 facilities, the 200 mgd supply can be delivered to the points of interconnection with existing systems as required for distribution to all of the Service Areas in the Region. It should be understood, however, that extensive review and detail study will be necessary prior to the design and construction of works to be needed so far in the future. At the time of design cognizance should be taken of the additional demand data and other information available as to water requirements for specific areas in order that the completion dates and service requirements may be coordinated as closely as possible with needs.

Stage 4—300 mgd of Additional Supply—This stage, which would in all probability be supplied by a diversion from the Delaware River, should be completed by 1995. Additional facilities required for transmission of the expanded supply will include a booster pumping station near Bound Brook and a third balancing reservoir at Mountainside. These facilities should adequately increase the aqueduct capacity to transmit the 300 mgd supply to points of delivery to existing systems for distribution. It is assumed that supplies needed by Service Area No. VI will be withdrawn at an interconnection near Bound Brook.



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PROFILES OF ROUTES FOR PROPOSED AQUEDUCTS - NORTHEASTERN REGION

Estimated capital costs of constructing the Stage 4 facilities and the capital and annual costs of the complete transmission system are as follows:

Booster Pumping Station near Bound Brook	$ 1,428,000
Balancing Reservoir at Mountainside.....	770,000
Capital Cost of Stage 4 Additions.....	$ 2,198,000
Capital Cost of Stages 1 through 3.....	47,634,000
Total Capital Cost of Complete Transmission System	$49,832,000
Annual Cost of Complete Transmission System, including interest and amortization, operation and maintenance.....	$ 2,394,000

SOUTHWESTERN AND COASTAL REGIONS

The cities of Trenton and Camden and their suburbs, in the Southwestern Region, have been designated as Water Service Areas Nos. VIII and IX respectively and Atlantic City and its environs in the Coastal Region has been designated as Service Area No. X. Unlike the Northeastern Region, the water supply systems of each area are not interconnected and hence they were studied individually for the needs of each specific area. Any improvements or additions made to supplies in these Regions would not necessarily provide region-wide benefits. Plate V-6 shows the supply and demand estimates for the designated service areas in the Southwestern and Coastal Regions, while Plate V-7 indicates the major systems and the areas they serve.

Water Service Area No. VIII is situated in Mercer County and includes the City of Trenton. Several small systems using well water operate in the outlying districts. The Trenton Water Department owns the only large facility in this area and, by utilizing Delaware River water, it supplies about 90 percent of the potable water consumed. Some increase may be obtained by development of new well supplies of the smaller systems but not on a large scale. The supply that may be developed from the Delaware River is more than ample to meet all estimated demands for this area to the year 2000. A new filtration plant of 25 million gallons per day capacity has recently been completed in Trenton and is already operating at over design loads for peak summer time demands. Estimates for this area indicate that an increased supply will be needed within the next 2 to 3 years if the anticipated growth of Mercer County is to be encouraged.

Additional supplies for the Trenton area can be accomplished by an increased diversion from the Delaware River. The new filtration plant at Trenton may be doubled in capacity to 50 million gallons per day by additional treatment facilities and minor alterations in the plant. Such an increase should provide a safe supply to meet requirements to the year 1975. Certain additions to the distribution system would be necessary to insure delivery to the more remote areas of Hamilton, Ewing and Lawrence Townships, where the industrial and residential growth is expected. As the needs for the smaller systems increase beyond their dependable yield, the possibilities for interconnecting with the Trenton system will require additional study. All present and future planning on additions to the network should consider these possibilities. Increases in dependable supply beyond the year 1975 may be accomplished with Delaware River water either from enlarged Trenton facilities or a new plant owned and operated by a combination of the smaller outlying systems.

Water Service Area No. IX includes the City of Camden and surrounding areas in Burlington, Camden and Gloucester Counties. There are over 15 separate water departments or companies operating in this area each with a capacity of 1 million gallons per day or more. The two largest systems are the Camden Water Department, which obtains its supply from ground water sources in the Raritan formation adjacent to the Delaware River, and the New Jersey Water Company, which pumps from the same formation at one location adjacent to the Delaware River, and from another area a few miles inland. The smaller systems also obtain their water supplies mainly from underground sources in the Raritan formation and are located at various points throughout the area, usually close to the facility they serve. Present indications are that the existing safe supply should be sufficient to meet demands to the year 1987 and with improvements the anticipated consumption may be supplied to the year 1993. In this case improvements will consist of increasing pumping capacity to the limit of the safe yield of the well fields. More small supplies may be obtained by opening well fields in new locations within this area. No sizeable water problem would appear to exist in this area providing nothing occurs to upset the normal ground water quality in the Raritan formation. However, experience has shown that large scale continued pumping of aquifers, together with industrial and residential growth within the well field area, often cause changes in ground water flow patterns which may subject the aquifer to undesirable pollution. Both of these conditions prevail in Area IX and, in addition, opinion is divided as to the effects on ground water quality in this area which would result from deepening of the Delaware River Ship Channel to Trenton. Since some pollution of ground water has already been noted in local areas adjacent to the Delaware River, any additional pollution of well field areas would be a matter of real concern. Construction of the Wallpack Bend Reservoir to increase the low water flow of the lower Delaware River should improve the quality of the river water and reduce the danger of ground water pollution.

Because a possibility exists that the well fields adjacent to the Delaware River may in the future have to be utilized to a lesser degree or abandoned, it was considered necessary to examine sources for supplemental supplies.

It is probable that saline intrusion or other pollution of ground water adjacent to the Delaware River, if it continues, will be gradual and any wells which have to be abandoned can be replaced as needed by new wells located in areas where the ground water supply originates from inland sources. It is conceivable, however, that a prolonged dry period with resultant low flows of the Delaware River and reduced ground water outflow to the River from the Pine Barrens area, could result in sufficient increase in the salt concentration of the river water in the Camden area that rapid contamination of ground water within three miles or so of the river would occur in a relatively short time. In such a case, a major new water supply for the Camden area would be urgently needed. This situation is discussed in greater detail in Chapter III.

The present safe yield of potable water supplies for the Camden metropolitan area is about 118 mgd. Of this amount, about 80 mgd are pumped from wells situated within 3 miles of the Delaware River. Expansion of local well fields beyond the zone of probable influence from the Delaware River may be accomplished to increase the safe yield to about 120 mgd. As shown on Plate V-6, the required suppy for the area in the year 2000, including a desirable allowance to account for unusual conditions, is 140 mgd. On this basis a new supply of approximately 20 mgd will be required for the area by the year 2000, as a minimum condition, and under adverse conditions (assuming pollution of ground water supplies within 3 miles of the Delaware River) a new supply of approximately 100 mgd will be required.

The sources for obtaining a supply of 100 mgd for the Camden area (Water Service Area No. IX) have been examined. These include a surface supply obtained by diversion from Rancocas Creek near Centerton, described in Chapter II, and a ground water supply obtained from a system of wells adjacent to the Mullica and Batsto Rivers in the Wharton Tract, described in Chapter III. Plate III-5 shows the location of these supply areas and the routes of aqueducts required to deliver the water to the existing Camden distribution system. The location of the Camden aqueduct from the Wharton Tract would facilitate interconnection to the smaller outlying systems east of the city whereas the location of the aqueduct from the Rancocas Creek development would enable easier connection to be made to the systems adjacent to the Delaware River and in the northerly portion of the Service Area.

Table V-3 shows the capital cost of the proposed aqueducts only for both plans. Capital costs include right-of-way engineering, legal, financing and construction costs. Annual costs include interest and amortization of the capital cost as well as cost of power required for pumping. In computing power costs, full development has been assumed. Power costs will be considerably less in the first stages of development when less than maximum flow is being pumped.

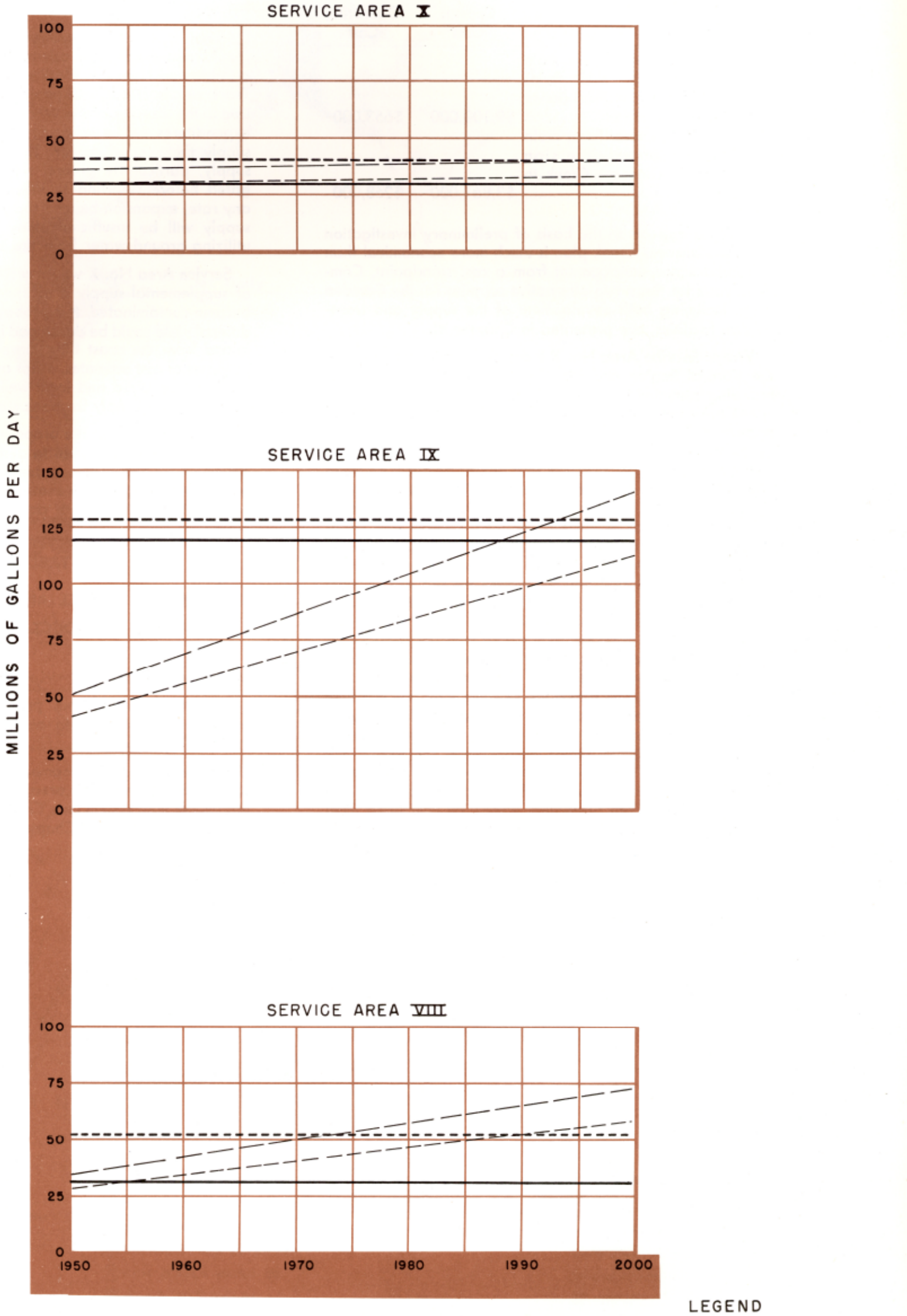

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TABLE V-3

ESTIMATED CAPITAL AND ANNUAL COSTS FOR PROPOSED AQUEDUCTS—CAMDEN AREA

Plan	Description of System	Capital Cost	Annual Operating Cost
1	1—60" diameter force main from proposed well fields located near Mullica-Batsto Rivers to Camden	$9,100,000	$653,000
2	1—60" diameter force main from proposed diversion point on Rancocas Creek to Camden	$3,861,000	$268,000

It would appear on the basis of preliminary investigation that the Rancocas Creek plan is much more economical than a ground-water development from a cost standpoint. Complete costs for these two alternative supplies for the Camden area, including both development of the supply and transmission facilities, are presented in Chapter VI.

Water Service Area No. X is the only designated area in the Coastal Region and includes Atlantic City and its surrounding communities. The seasonal fluctuations in demand in this area are considerably different from the conventional pattern as found in the other service areas studied. In most areas the highest summer demand is between 120 and 140 percent of the yearly average and winter demand between 70 and 90 percent of the yearly average. Service Area No. X, because of its fine beaches, hotels and recreational facilities, is host to thousands of vacationists each summer and a demand of 200 percent of the yearly average is not unusual. Water supply installations must be designed to meet the maximum demand that will be placed on the system even though it occurs only for a few months of the year. Therefore the projected demand curve as shown on Plate V-6 indicates a demand which is twice the anticipated average annual consumption. The safe supply required to meet fluctuations in this demand are indicated on the 125 percent projected demand curve. It appears that if the existing wells can continue to supply water at maximum rates observed during peak demand periods and the surface supply of Absecon Creek remains unchanged, no major expansion of the supply will be needed. In the discussion of ground water in Chapter III the various unfavorable factors influencing the water bearing strata in this area are presented. It may be concluded from the analysis presented in Chapter III that a reasonable doubt exists as to the actual permanence of the supply. No definite conclusions as to Atlantic City's future needs can be advanced until the program for ground water investigation and research recommended in Chapter VI have been carried out. However, means and costs for developing a new supply unaffected by salt water have been studied and are presented below.

If the quality deterioration of the Atlantic City supply should materialize, an adequate replacement supply may be obtained from the Wading River source in the Wharton Tract, as discussed in Chapter III and shown on Plate III-5. Due to the distance of the Wharton Tract from the area, large expenditures will be needed to finance the aqueducts and to supply the needed power. Therefore, all closer sources of supply, particularly ground water, should be fully investigated before resorting to Wharton Tract development. At any rate, expansion beyond the year 2000 when the present supply will be insufficient, may best be accomplished by utilizing ground water from the Wharton Tract source.

Service Area No. X would require approximately 22 mgd of supplemental supply if all the existing well fields should become contaminated. It is probable that a considerable additional yield could be developed in well fields located further inland from the coast than those now in use; however, for purposes of cost estimates, it was assumed that the full 22 mgd would be required and local well fields would only provide an emergency supply for peak summertime demands.

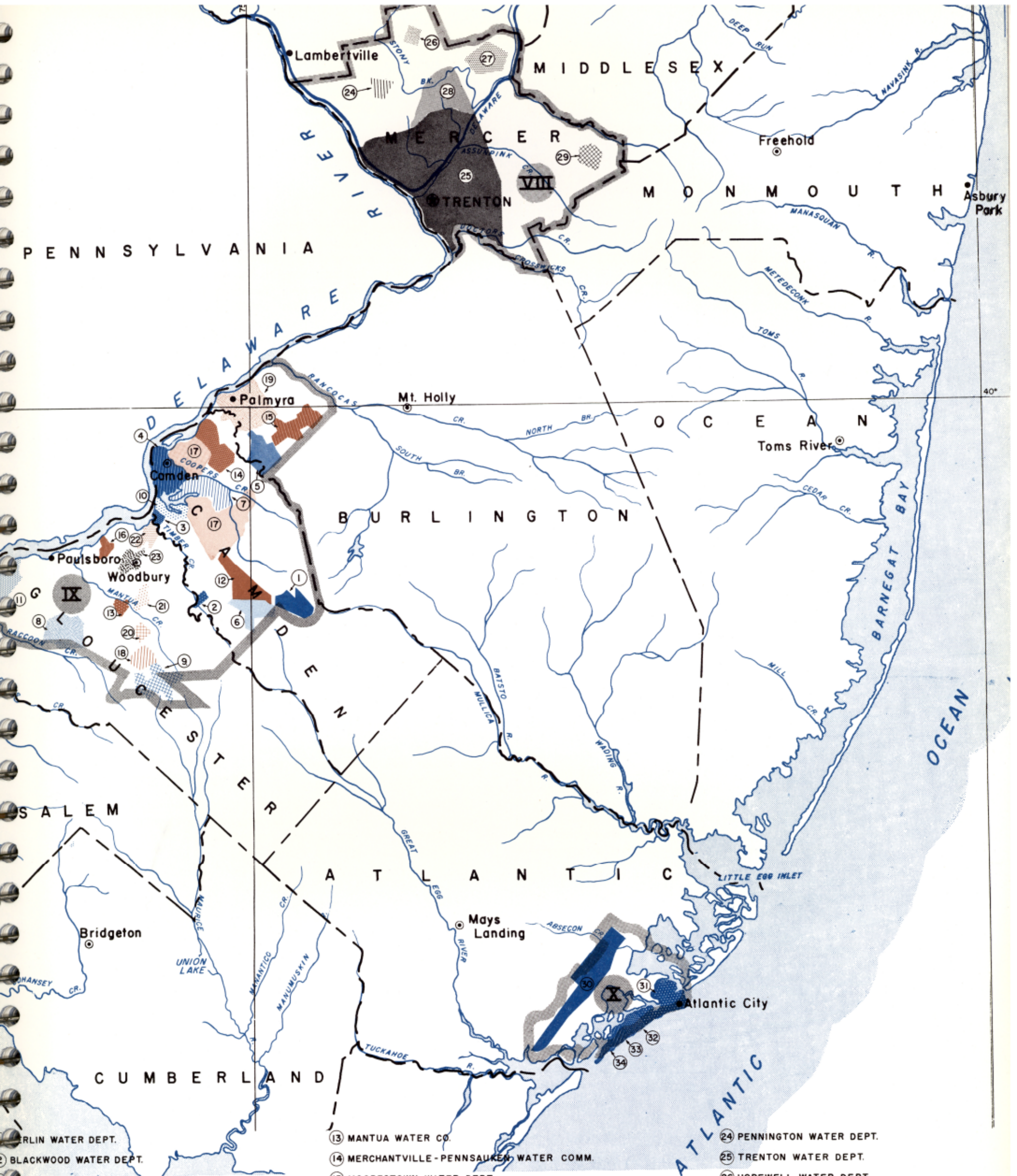
The capital cost for the proposed aqueduct from the Wading River collection system to a connection with the existing Atlantic City distribution system is shown in Table V-4. The annual operating cost as shown includes interest and amortization of the capital cost and cost of power required for pumping.

TABLE V-4

ESTIMATED CAPITAL AND ANNUAL COSTS FOR PROPOSED AQUEDUCT—ATLANTIC CITY AREA

Description of System	Capital Cost	Annual Operating Cost
1—36" force main from proposed well fields located near the Wading River	$4,1000,00	$232,000

Complete costs for development of such a Wading River supply for the Atlantic City area, including development of the infiltration well system (see Chapter III) and the transmission system are presented in Chapter VI.



(1) BERLIN WATER DEPT.
(2) BLACKWOOD WATER DEPT.
(3) BROOKLAWN WATER DEPT.
(4) CAMDEN WATER DEPT.
(5) CHESTER WATER DEPT.
(6) CLEMENTON WATER DEPT.
(7) COLLINGSWOOD WATER DEPT.
(8) EAST GREENWICH TWP. WATER DEPT.
(9) GLASSBORO WATER DEPT.
(10) GLOUCESTER WATER DEPT.
(11) GREENWICH TWP. WATER DEPT.
(12) LAUREL SPRINGS WATER CO.
(13) MANTUA WATER CO.
(14) MERCHANTVILLE-PENNSAUKEN WATER COMM.
(15) MOORESTOWN WATER DEPT.
(16) NATIONAL PARK WATER DEPT.
(17) NEW JERSEY WATER CO
(18) PITMAN WATER DEPT.
(19) RIVERTON-PALMYRA WATER CO.
(20) SEWELL WATER CO.
(21) WENONAH WATER DEPT.
(22) WESTVILLE WATER DEPT.
(23) WOODBURY WATER DEPT.
(24) PENNINGTON WATER DEPT.
(25) TRENTON WATER DEPT.
(26) HOPEWELL WATER DEPT.
(27) PRINCETON WATER CO.
(28) LAWRENCEVILLE WATER CO.
(29) HIGHTSTOWN WATER DEPT.
(30) ATLANTIC CO. WATER DEPT.
(31) ATLANTIC CITY WATER DEPT.
(32) VENTNOR WATER DEPT.
(33) MARGATE CITY WATER DEPT.
(34) LONGPORT WATER DEPT.

PLATE V-7
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GENERAL AREAS PRESENTLY SERVED BY MAJOR WATER DISTRIBUTION SYSTEMS IN SOUTHWESTERN AND COASTAL REGIONS

CHAPTER VI

CHAPTER VI

FINDINGS AND RECOMMENDATIONS

STATE-WIDE WATER SUPPLY POTENTIAL

The general hydrologic studies presented in Chapter I and the more specific studies of surface and ground water in Chapters II and III show that there are sufficient potential water resources available to the State of New Jersey to provide for predictable needs.

All of the State's water requirements to the year 2000 can be met entirely from resources within the boundaries of the State without interstate agreements or permissive judgments from the United States Supreme Court. There are, however, economic advantages in using water from the interstate Delaware River Basin to provide the necessary additional supplies which will be needed in the Northeastern Region after 1995. The development of Delaware Basin Storage will be essential for the purpose as well as for regulation of the river to provide a sustained minimum flow. The preservation of the potable quality of both surface and ground water resources in the lower Delaware Valley may depend on the regulatory works undertaken for the augmentation of low flows in the Delaware River.

The Northeastern Region is the only area of the State which cannot depend on its own water potential and must, of a certainty, reach out beyond its regional boundaries for additional water supplies. The Southwestern Region may also find it necessary eventually to go beyond its boundaries to the Wharton Tract for a new supply, should there be a deterioration in the present supply drawn from wells which induce infiltration from the Delaware River. Timely development of river regulation as mentioned above could in all probability avoid any necessity for the Southwestern Region to go beyond its boundaries for water supply. Both the Northwestern and the Coastal Regions have ample potential water resources within their boundaries for their own needs and to make up the deficiencies, in the present or foreseeable future, in the other two Regions.

WATER RESOURCES AVAILABLE TO THE NORTHEASTERN REGION

The Northeastern Region containing the largest part of the State's population and industry was found to be the only area facing a critical water shortage on a regional scale. Water supplies available to this region while still more than the average demand are considerable less than a safe supply based on 125 percent of average demand. Projections of water consumption indicate that by 1963 average demand will exceed existing safe yield if no additions are made to the supply. A total of 422 million gallons per day will have to be added to the water resources of this region by the year 2000 in order to maintain a satisfactory safe relationship between supply and demand. The increase should be added in increments corresponding as closely as possible to the projected average demand plus a 25 percent safe margin. (See Plate V-2.)

Water supply in the Northeastern Region is derived largely from surface sources and extensive utilization has already been made of the Passaic and Hackensack River flows for this purpose. Some additional water supply development, however, is still possible in these two river basins by expanding existing water supply systems to their ultimate limit of practicability. Table VI-1 lists the water supply systems using flows of the Passaic and Hackensack Rivers, their present safe yield and expanded yield.

As shown on Table VI-1 (including the note at the bottom of the table) 129.0 million gallons per day can be added to the supplies of the Northeastern Region by expanding existing systems. Of this amount 52.0 million gallons per day would be made available by additions to the supplies of private water companies or small municipal systems, but this total may later be reduced 7.0 mgd by water consumption in the New York State portion of the Hackensack Basin. The remaining 77 million gallons per day would be obtained from publicly owned systems; 7.4 mgd from the City of Newark Pequannock River System, 14.6 mgd from the Jersey City Rockaway River System and 55.0 mgd from the Passaic Valley Water Commission Passaic River System. This additional supply can be utilized through existing interconnections without expenditures for new transmission mains.

The estimated cost of expanding these three public supplies is $22,140,000 or an average cost per million gallons of system capacity of $287,500. This, by a wide margin, is the lowest priced major addition that can be made to the water supplies available to the Northeastern Region.

It is recommended that measures be taken to encourage the immediate development by the public owners of the Pequannock, Rockaway and Passaic Valley Water supply systems to expand their supplies to produce a total additional yield of 77 million gallons per day. The early completion of these additions to existing supplies is so strongly in the public interest, that it is further recommended that the public owners of the three systems be given a reasonable, but specifically limited time within which to make the additions and failing this the expansion should be undertaken by the State.

It is also recommended that the present restrictions on the diversion of water from the Ramapo River to Wanaque Reservoir be reviewed toward the possibility that changes in the restrictions may be made without injury to downstream riparian rights. Relaxation of the restrictions could increase the Wanaque-Ramapo yield with the existing pumping installation by as much as 16.0 million gallons per day.

TABLE VI-1

PRESENT AND EXPANDED YIELDS OF EXISTING SYSTEMS—PASSAIC AND HACKENSACK RIVER BASINS

System	River Basin	Present Dependable Yield—mgd	Dependable Yield with Proposed Expansion —mgd	Proposed Increase in Dependable Yield—mgd	Est. Total Cost	Capital Cost Per Million Gal. of Capacity
Pequannock (Newark)	Passaic	46.0	53.4	7.4	$8,640,000*	$1,167,600*
Rockaway (Jersey City)	Passaic	68.0	82.6	14.6	3,500,000	239,700
Wanaque-Ramapo	Passaic	106.0	106.0	—	—	—
Passaic Valley Water Com.	Passaic	35.0	90.0	55.0	10,000,000	181,800
Hackensack Water Co.	Hackensack	50.0	74.5	24.5		
Commonwealth Water Co.	Passaic	17.4	28.0	10.6		
Minor Systems	Hackensack & Passaic	51.7	60.0	8.3		
Totals				120.4**	$22,140,000	

*Includes costs of improvements to increase capacity and operating efficiency of transmission system.

**Total increase of 120.4 mgd is for existing systems in the Passaic and Hackensack Basins. 8.6 mgd may be added to minor systems in other parts of region making a total of 129 mgd.

Of the 52.0 million gallons per day that may be added to the yield of private water companies and small municipal systems approximately 7.0 mgd may revert to Rockland County usage in New York State by 1980 reducing the amount available to New Jersey to 45.0 mgd. Of this approximately 28 mgd is in various stages of development and it is reasonable to assume that in view of this increasing demand for water and the relatively low cost of the additions to existing supplies that all of them will be developed within the next few years.

It has been the opinion of some investigators in the past that many small supplies in the Northeastern Region would be abandoned because of pollution and increased land values. The abandonment of some minor surface supplies in the recent past gave support to this conclusion, but present evidence does not appear to bear out a continuation of this trend. In fact, as the realization spreads of the probable costs for new major supplies, there are likely to be increasing efforts made to protect, expand and perpetuate existing small supply systems.

Assuming that the three major public supplies will be expanded by 77 mgd and the others by 45 mgd or a total of 122 mgd, there remains 300 mgd of new water supplies which will be required by the Northeastern Region by the year 2000. The development of 122 mgd will provide the Northeastern Region with a safe supply based on 125 percent of projected demand until 1963 after which the total safe yield will again fall below the required safe supply (See Plate V-2). Considering the time required for the organization, financing, detailed field investigations, preparation of designs and specifications and the construction of a major water supply facility; it is essential that the steps necessary for the next addition to the Northeastern Region Water supply be taken without undue delay.

The additional 300 mgd of water required for the Northeastern Region by the end of the century may be obtained from the Raritan River Basin primarily with a supplementary supply from the Delaware Basin after full economic development of the Raritan, or it may be drawn entirely from the Delaware Basin. The following Tables VI-2 and VI-3 give the summarized results of cost studies for various Raritan and Delaware Basin water supply development plans.

After an exhaustive study of the possibilities for water supply development and transmission for the Northeastern Region using the waters of the Raritan and Delaware Basins as presented in Chapters II and V, the following engineering conclusions are reached:

1. That the estimated 300 million gallons of additional water which will be needed in the Northeastern Region after expansion of existing supplies can best be provided by developing 200 mgd in stages in the Raritan Basin and 100 mgd in the Delaware Basin.

2. That the water supply potential of the Raritan River at Bound Brook considered to be economically feasible of development is 400 million gallons per day. Of this, 150 mgd should be allocated to the maintenance of a minimum stream flow above the Elizabethtown Water Company diversion at Bound Brook. The necessary storage for maintenance of the minimum stream flow should be provided by an on-river reservoir. This provision should be made a part of every major water supply plan for the Raritan River Basin.

3. That the development of the Raritan Basin using the Chimney Rock site for a storage reservoir gives the best combination of economy, water quality and dependability of all of the Raritan plans studied. This confirms the findings of the Preliminary Report. The more detailed studies of the Final Report show, however, that certain variations in the use of the Chimney Rock site may be desirable and effect economies in the earlier stages of construction. These variations are:

   a) For the first or 70 mgd stage of development only the eastern half of the Chimney Rock site (East Branch Reservoir) may be used with a reduction in initial construction cost of nearly ten million dollars. (Plan CR-3 costing $56,650,000 as opposed to Plan CR-1 alternate 2, costing $66,410,000—See Table VI-2.)

   b) In the second or 200 mgd stage the balance of the Chimney Rock site could be developed at a total estimated cost of $108,434,000, or the Dock Watch Hollow site may be substituted for the west half of Chimney Rock. In the latter case the total estimated cost would be $107,674,000. (See Plans CR-2—Alternate 2, and CR-4 in Chapter II and Table VI-2.)

4. That the 100 million gallons per day supplementary supply required from the Delaware River may be economically and satisfactorily provided by a pumping diversion from the Delaware River above Lambertville delivering into the Raritan Basin at Back Brook near Pennington. Water would flow by natural channels to Bound Brook and would be pumped into Chimney Rock Reservoir. In conjunction with this diversion Flatbrook Reservoir would be developed near its junction with the Delaware to provide storage both for regulation of the diversion and for compensation releases as may be required by the Supreme Court of the United States. The total estimated cost of this stage including Flatbrook Reservoir is $39,648,000. (See Plan DP-4 in Chapter II and Table VI-3.)

5. That the combination of Plan CR-2 Alternate 2 (built in two stages) and Plan DP-4 is the most desirable method of meeting the long term needs of the Northeastern Region from the standpoint of a balanced consideration of water quality, dependability of supply and delivery, construction cost, cost of water and stage development flexibility. The costs for this long term development are as follows:

Plan	Potable Yield mgd	Total Capital Cost	Cost Per Million Gal. of Capacity	Annual cost per mgd	Cost Per Million gallons of Water
CR-2 (Alt. 2)	200	$108,434,000	$542,200	$31,700	$87
DP-4	100	39,648,000	396,480	30,780	84
Total	300	$148,082,000	$493,600	$31,380	$86

TABLE VI-2

COST SUMMARY—RARITAN RIVER BASIN POTABLE WATER SUPPLY PROJECTS*

Plan	Potable Yield mgd	CAPITAL COST: Development of Supply	CAPITAL COST: Transmission System	CAPITAL COST: Total	CAPITAL COST: Per Million Gallons of Capacity	ANNUAL COST**: Total	ANNUAL COST**: Per mgd	***Cost of Water per Million Gallons
OR–2—Using 2 on-river reservoirs								
OR–2A (North Branch + Spruce Run)	69	$26,730,000	$23,680,000	$50,410,000	$730,600	$2,895,000	$42,000	$115
OR–2A (North Branch + Spruce Run)	165	42,350,000	46,484,000	88,834,000	538,400	5,061,000	30,700	84
OR–2B (Spruce Run + Rocky Hill)	69	24,760,000	23,680,000	48,440,000	702,000	2,805,000	40,700	111
OR–2C (Rocky Hill + North Branch)	69	26,070,000	23,680,000	49,750,000	721,000	2,865,000	41,500	114
OR–2D (Stony Brook + Spruce Run)	69	25,400,000	23,680,000	49,080,000	711,300	2,835,000	41,100	113
OR–3—Using several on-river reservoirs								
OR–3A (4 reservoirs)	200	52,550,000	47,634,000	100,184,000	500,900	5,967,000	29,800	82
OR–3B (7 reservoirs)	250	71,825,000	48,634,000	120,459,000	481,800	7,241,000	29,000	79
RV—Using Round Valley reservoir								
RV–1 (Pipeline transmission from Round Valley)	70	46,450,000	23,680,000	70,130,000	1,001,900	3,773,000	53,900	148
RV–2 (Channel delivery Round Valley to Bound Brook)	150	Same as RV–3 after 7-day gravity reserve is added.						
RV–3 (RV–2 + 7-day reserve in Dock Watch Hollow)	150	54,770,000	46,484,000	101,254,000	675,000	5,857,000	39,000	107
RV–4 (RV–2 + full Dock Watch Hollow)	200	71,600,000	47,634,000	119,234,000	596,200	7,432,000	37,200	102
CR—Using Chimney Rock reservoir								
CR–1 (Alt. 1A—North Branch Supply)	70	46,530,000	23,680,000	70,210,000	1,003,000	3,613,000	51,600	141
CR–1 (Alt. 2—Bound Brook supply)	70	42,730,000	23,680,000	66,410,000	948,700	3,543,000	50,600	139
CR–2 (Alt. 1A–N. Br. + Bound Brook)	200	66,400,000	47,634,000	114,034,000	570,200	6,496,000	32,500	89
CR–2 (Alt. 2—Bound Brook only)	200	60,800,000	47,634,000	108,434,000	542,200	6,336,000	31,700	87
CR–3 (East Branch reservoir)	70	32,970,000	23,680,000	56,650,000	809,300	3,113,000	44,500	122
CR–4 (East Branch + Dock Watch Hollow)	200	60,040,000	47,634,000	107,674,000	538,400	6,396,000	32,000	88

*Including costs for development of supply and for transmission to interconnections with delivery systems together with facilities for regulation of minimum flows below diversions at Bound Brook to 130 mgd. Also included are costs for Dock Watch Hollow reservoir and appurtenant facilities for a 7-day emergency gravity supply for those plans without high level storage (OR–2, OR–3, and RV–2).

**Including interest and amortization, reserve for replacements, operation and maintenance.

***Assuming 100 percent utilization of supply.

TABLE VI-3

COST SUMMARY—DELAWARE RIVER POTABLE WATER SUPPLY PLANS(1)

Plan	Potable Water Yield mgd	CAPITAL COST				ANNUAL COSTS(2)		Cost of Water Per Million Gallons (3)
		Development of Supply	Transmission System	Total	Per mgd	Total	Per mgd	
USING WALLPACK BEND AND FLATBROOK								
DG—Gravity Tunnel Diversions								
DG–1 (Frenchtown to S. Br. Raritan)	300	$140,570,000	$49,832,000	$190,402,000	$ 634,670	$10,492,000	$34,970	$96
DG–2 (Stockton to Bedens Brook)	300	150,270,000	49,832,000	200,102,000	667,010	10,912,000	36,370	100
DG–3 (Belvidere to Spruce Run)								
Stage 1 (Flatbrook only)	70	78,380,000	23,680,000	102,060,000	1,458,000	5,126,000	73,230	201
Stage 2 (Flatbrook only)	200	114,360,000	47,634,000	161,994,000	809,970	8,579,000	42,900	118
Stage 3 (Both reservoirs)	300	145,630,000	49,832,000	195,462,000	651,540	10,712,000	35,710	98
DG–4 (Flatbrook to Boonton Res.—Passaic)	300	152,010,000	49,832,000(5)	201,842,000	672,810	9,762,000	32,540	89
DG–5 (Flatbrook to Wanaque Res.—Passaic)	300	147,010,000	49,832,000(5)	196,842,000	656,140	9,542,000	31,810	87
DP—Pumping Diversions to Bound Brook								
DP–1 (Pipeline–Lambertville to Bound Brook)	300	141,520,000	49,832,000	191,352,000	637,840	11,539,000	38,460	105
DP–2 (Lambertville to Back Brook–Neshanic)								
Stage 1 (Flatbrook only)	70	38,410,000	23,680,000	62,090,000	887,000	3,626,000	51,800	142
Stage 2 (Flatbrook only)	200	79,030,000	47,634,000	126,664,000	633,320	7,617,000	38,080	104
Stage 3 (Both reservoirs)	300	114,570,000	49,832,000	164,402,000	548,010	10,080,000	33,600	92
DP–3 (Wash. Cross. to Stony Brook)	300	113,280,000	49,832,000	163,112,000	543,710	9,997,000	33,320	91
USING STORAGE IN ROUND VALLEY								
DRV–1 (Frenchtown Pumping Diversion)								
Alt. 1 (With Wallpack Bend)	200	115,715,000	47,634,000	163,349,000	816,740	8,898,000	44,490	122
Alt. 2 (With Flatbrook)	200	109,865,000	47,634,000	157,499,000	787,500	8,638,000	43,190	118
DRV–2 (With Wallpack Bend)	300	152,260,000	49,832,000	202,092,000	673,640	12,004,000	40,010	110
SUPPLEMENTARY SUPPLIES WITH FLATBROOK								
DG–6 (DG–3 route)	100	67,400,000	2,198,000(4)	69,598,000	695,980	3,988,000(4)	39,880	109(4)
DP–4 (DP–2 route)	100	37,450,000	2,198,000(4)	39,648,000	396,480	3,078,000(4)	30,780	84(4)

(1) Including costs for development of supply and for transmission to interconnections with delivery systems. Costs of Spruce Run reservoir for regulation of minimum flow of Raritan River below diversions at Bound Brook have been included for both alternates of Plan DRV–1, which provide for 70 mgd of supply from the South Branch of Raritan River. Also included are costs for Dock Watch Hollow reservoir and appurtenant facilities for a 7-day emergency gravity supply for those plans without high level storage directly connected to the transmission system (DG–1, –2, –3, DP–1, –2, –3 and DRV–2).

(2) Including interest and amortization, reserve for replacements, operation and maintenance.

(3) Assuming 100 percent utilization of supply.

(4) Includes only those incremental transmission facilities required for expansion of the system necessary for use with a 200 mgd supply obtained from the Raritan River.

(5) Transmission costs for these plans considered the same as for DG–3 to provide a comparative basis. Detailed estimates for Plans DG–4 & 5 were not made but will not be less than for DG–3.

The cost per million gallons of water is based on 100 percent utilization of the supply.

As may be noted on Tables II-8 and II-9 in Chapter II and Tables VI-2 and VI-3 above, Raritan Basin supplies may be developed with on-river reservoirs (OR Plans) for a lower capital cost and a lower cost of water than other plans studied for both the Raritan and Delaware Basins. This difference is particularly marked in the first stage of development in which the on-river reservoirs would have a yield of 69 million gallons per day and the off-river reservoirs 70 million gallons per day. The lowest cost first stage on-river project is Plan OR-2B which uses a combination of Spruce Run and Rocky Hill reservoirs for supply and stream flow regulation. The next three projects in the order of their capital cost are Chimney Rock (Plan CR-3—East Branch Reservoir), Delaware Pumping Diversion with Flatbrook Reservoir (Plan DP-2 Stage 1) and Round Valley (Plan RV-1). The estimated costs of these four plans are summarized in Table VI-4 for easy comparison.

Plan DP-2 is based on Delaware water only and therefore does not include regulation of a minimum flow in the Raritan River. Compensation releases for the Delaware River are included in the plan.

For the second or 200 mgd stage of development the order with respect to cost remains the same as the first stage except that Round Valley Reservoir used with Dock Watch Hollow Reservoir and stream channel delivery to Bound Brook (Plan RV-4) is less costly than a Delaware Basin diversion. The proposal to develop the second stage of Round Valley with 70 mgd from the Raritan Basin and 130 from the Delaware (Plan DRV-1 Alt2) is costlier than taking the full stage from the Delaware using Flatbrook Reservoir. Table VI-5 shows the cost comparison for six of the Stage 2 plans.

TABLE VI-4

COST SUMMARY—PLANS FOR NEW 70 MGD SUPPLY

Plan	Potable Yield mgd	Capital Cost Including Transmission	Cost Per Million Gal. of Capacity	Total Annual Cost	Cost of Water Per Million Gal.
OR-2B Spruce Run & Rocky Hill Res.	69	$48,440,000	$702,000	$2,805,000	$111
CR-3 East Branch Reservoir	70	56,650,000	809,300	3,113,000	122
DP-2 (Stage 1) Delaware Diversion w/Flatbrook	70	62,090,000	887,000	3,626,000	142
RV-1 Round Valley-Stage 1	70	70,130,000	1,001,900	3,773,000	148

TABLE VI-5

COST SUMMARY—PLANS FOR NEW 200 MGD SUPPLY

Plan	Potable Yield mgd	Capital Cost Including Transmission	Cost Per Million Gal. of Capacity	Total Annual Cost	Cost of Water Per Million Gal.
OR-3A 4 On-River Reservoirs	200	$100,184,000	$500,900	$5,967,000	$82
CR-4 East Branch & Dock Watch Hollow	200	107,674,000	538,400	6,396,000	88
CR-2 (Alt. 2) Chimney Rock-Full Reservoir	200	108,434,000	542,200	6,336,000	87
RV-4 Round Valley & Dock Watch Hollow	200	119,234,000	596,200	7,432,000	102
DP-2 (Stage 2) Delaware Diversion w/Flatbrook	200	126,664,000	633,320	7,617,000	104
DRV-1 (Alt. 2) Round Valley—Stage 2	200	157,499,000	787,500	8,638,000	118

The above plans except for DP-2 provide for a minimum flow of 130 mgd in the Raritan below diversions at Bound Brook. Plan DRV-1 (Alt. 2) also provides compensation for the out-of-basin Delaware diversion. Plan DP-2 uses no Raritan water and therefore only provides compensation for the Delaware diversion.

In the third stage of development for 300 mgd, the on-river (OR), Round Valley (RV) and Chimney Rock (CR) plans all use a combination of Raritan and Delaware Basin waters. The Delaware gravity diversion (DG) and pumping diversion (DP) plans depend on Delaware Basin water only. Table VI-6 gives the comparison between 13 plans studied for the 300 mgd stage of development. Plans are presented in the order of their total estimated construction cost:

It is obvious from the above tabulation that the order of construction costs does not follow the order of the cost of water per million gallons. The disparity is brought about by differences in operating costs between gravity diversions and pumping diversions. Thus Plans DG-4 and DG-5, which convey water entirely by gravity, have high capital costs together with costs of water comparable to the projects with the lowest capital costs. Unfortunately, these two plans as well as the other gravity diversions cannot be economically constructed in stages. The costs of water given in the table is based on an assumed full utilization of the supply. Since demand will not equal the 300 mgd supply until late in the century, any plan which cannot be constructed in stages will have a long period of deficit operation and will not be economically feasible.

In addition to the important economic questions of capital cost, the cost of water and possibility of stage construction, there are considerations of delivery which must enter into any decision on a choice of project. On the basis of the criteria of quality and dependability, first place must be given to Plans DG-4 and DG-5 which take water by gravity from Flatbrook Reservoir to Boonton or Wanaque Reservoirs. Upper Delaware water delivered from deep storage in Flatbrook Reservoir would be of superior quality and would have a very large reserve of water which could be delivered without dependence on pumping operations. In view of these favorable conditions and the reasonable unit cost of water, either Plan DG-4 or DG-5 would be a highly desirable source of supply for the Northeastern Region if a ready market could be found for 300 million gallons per day of water. Unfortunately there does not appear to be any possibility of disposing of large surpluses of water until the demand in the Region would reach the yield of these projects.

The plans next in order of preference on the basis of quality and dependability are those that make direct gravity delivery from Round Valley, Chimney Rock or Dock Watch Hollow. For the first stage of 70 mgd there are Plans RV-1, CR-1 and CR-3; for the 200 mgd stage Plans RV-4, DRV-1, CR-2 and CR-4, and for the 300 mgd stage Plans DRV-2, RV-4 plus DP-4, CR-2 plus DP-4 and CR-4 plus DP-4. The water sources used by these plans would all be relatively equal in quality, all would receive quality improvement through deep storage, all would have dependable yield and could make delivery by gravity most of the time. In view of this condition, it would appear that a choice between these sites should be made on the basis of economic and other factors not involving quality and dependability.

The least preferable plans from the standpoint of quality and dependability of delivery are the on-river (OR) plan and others using stream channel conveyance of water to Bound Brook not followed by deep high level storage. Although a seven day reserve storage in Dock Watch Hollow for emergency delivery of water by gravity has been included with these plans, it is not the equivalent of full delivery from deep storage as provided in the Chimney Rock and Round Valley Plans. All of the on-river plans would make

TABLE VI-6

COST SUMMARY—PLANS FOR NEW 300 MGD SUPPLY

Plan	Potable Yield mgd	Capital Cost including Transmission	Cost Per Million Gal. of Capacity	Total Annual Cost	Cost of Water Per Million Gal.
OR-3A plus DP-4 4 on-river Res. & Del. Pump Diversion	300	$139,832,000	$466,110	$9,045,000	$83
CR-4 plus DP-4 E. Branch, Dock Watch & Del. Pump Diversion	300	147,322,000	491,070	9,474,000	87
CR-2 (Alt. 2) plus DP-4 Chimney Rock Del. Pump Diversion	300	148,082,000	493,600	9,414,000	86
CR-2 (Alt. 1) plus DP-4 Chimney Rock Del. Pump Diversion	300	153,682,000	512,270	9,574,000	87
RV-4 plus DP-4 Round Valley, Dock Watch & Del. Pump Diversion	300	158,882,000	529,610	10,510,000	96
DP-3 Del. Pump Diversion from Washington Crossing	300	163,112,000	543,710	9,997,000	91
DP-2 Del. Pump Diversion from Lambertville	300	164,402,000	548,010	10,080,000	92
DG-1 Gravity Diversion from Frenchtown	*300	190,402,000	634,670	10,492,000	96
DG-3 Gravity Diversion from Belvidere	*300	195,462,000	651,540	10,712,000	98
DG-5 Gravity Diversion to Wanaque	*300	196,842,000	656,140	9,542,000	87
DG-2 Gravity Diversion from Stockton	*300	200,102,000	667,010	10,912,000	100
DG-4 Gravity Diversion to Boonton	*300	201,842,000	672,810	9,762,000	89
DRV-2 Pumping Diversion to Round Valley	300	202,092,000	673,640	12,004,000	110

*Not amenable to stage construction.

direct delivery of water from stream channel to treatment plant to transmission mains without any intervening storage. The on-river reservoirs would be shallow and have many thousands of acres of water surface which would be conducive to the production of taste and color, high summer temperatures and high evaporation losses. Except for the seven day emergency storage, the on-river plans depend entirely on power for the maintenance of service.

On Table II-8 in Chapter II costs are given for an on-river development (Plan OR-3B) to yield 250 million gallons per day. This would require three additional reservoirs and make the total flooded area for on-river projects exceed 17,000 acres. This plan has been omitted from comparative consideration in this chapter since it is recommended that all feasible development of the Raritan River beyond 350 mgd (200 mgd new supply, 20 mgd Elizabethtown Water Company diversion and 130 mgd stream regulation) be reserved for further augmentation of the sustained minimum flow.

As shown on the above tables the on-river plans are the lowest in capital cost and water cost. However, the difference between the lowest on-river plan and the least costly off-river plan tends to diminish as development increases. In the 70 mgd stage of development, on-river water would cost $111 per million gallons against $122 for the East Branch of Chimney Rock and $148 for Round Valley. In the 200 mgd stage, on-river water would cost $82 against $87 for Chimney Rock and $118 for Round Valley (Stage 2 of North Jersey District Plan). In the final 300 mgd stage, on-river water would increase in cost slightly to $83 per million gallons, Chimney Rock water would be $86 and Round Valley water would be $110. None of these differences would warrant the development in the Raritan Basin of an on-river supply of inferior quality and dependability compared with the water of off-river plans. The somewhat lower cost of on-river water will not constitute sufficient recompense to the average consumer for the use of an inferior water supply.

On the other hand, the difference between the quality and dependability of Raritan Basin water combined with Delaware water as developed with off-river reservoirs, and the highly desirable upper Delaware gravity supplies of Plans DG-4 and DG-5 is not sufficient to warrant the many years of very high cost water that would result from the deficit operation of these plans if either of them were built. The choice of a new major water supply for the Northeastern Region of New Jersey, if consideration of quality and dependability are to be tempered with those of cost, must be between the various off-river reservoir plans that use Raritan Basin Water supplemented by diversions from the Delaware River. The cost figures developed for these plans show a very substantial difference in favor of those using all or part of the Chimney Rock Reservoir Site for water storage.

In consideration of all of the findings in the preceding chapters and summarized in this chapter, the following recommendations are made for a major new water supply for the Northeastern Region of New Jersey:

1. That a reservoir for storage of water pumped from the Raritan River at Bound Brook be developed in the East Branch of the Chimney Rock Reservoir Site together with pumping station, force main, treatment plant, booster pumps and all other appurtenances. The reservoir is to have a flow line elevation of 290 and will be operated for an initial yield of 70 million gallons per day.

   Estimated cost $28,200,000

2. That a reservoir for the impounding of water for stream flow regulation be built on Spruce Run a tributary of the South Branch of the Raritan River. This reservoir should have a flow line elevation of 276.7 and will regulate a minimum sustained flow at Bound Brook after diversions of 130 million gallons per day.

   Estimated cost $4,770,000

3. That a transmission system as described in Chapter V and shown on Plate V-4 designed to convey water from the East Branch Reservoir to the anticipated areas of demand be constructed as a part of the first stage of the major water development.

   Estimated cost $23,680,000

4. That additional land acquisitions adequate for the development of the second and final stages of the water supply be made as a part of the first stage. This recommendation may be carried out by acquiring

   a) The West Branch of the Chimney Rock site, which is the preferred project, or,

   b) The Dock Watch Hollow site.

The first site is slightly more expensive to purchase and develop, but is given preference because of its greater simplicity and somewhat lower indicated cost of water due to lower operating costs. The Dock Watch Hollow site also has its advantages; it would displace less people than the west branch of Chimney Rock, it would avoid taking quarry property and the main reservoir of the Bound Brook Water Company, it would be a favorable site for a pumped storage generation plant which could lower costs of operation and it would be able to provide gravity delivery to future high level service areas.

Land in either of these sites may be reserved for future water supply development by

a) Outright purchase of all of the property with arrangements for occupancy under lease until needed for water development.

b) Purchase of undeveloped property only at the present time to prevent further development and purchase of balance when needed for expansion of the reservoir. This method will also require adequate and equitable provisions for owners who may wish to sell their property before it is needed for reservoir expansion.

If the first course of action—full purchase—is adopted one of the following sums will be needed:

To purchase West Branch of Chimney Rock $5,260,000

To purchase Dock Watch Hollow . . . 3,420,000

If the second method—purchase of undeveloped land only—is used one of the following sums will be required:

To purchase vacant land in Chimney Rock $1,500,000

To purchase vacant land in Dock Watch Hollow 1,200,000

The total appropriation needed to execute the recommended first stage 70 mgd water supply project for the Northeastern Region including land and rights-of-way acquisition, construction of reservoir, pumping station, force main, booster station, treatment plant and transmission mains, engineering, legal and administrative costs and interest during construction is . . . $56,650,000

To this should be added the cost of acquiring land for the second or 200 mgd stage of development either in the West Branch of Chimney Rock or in Dock Watch Hollow. This acquisition may be made in accordance with suggested methods above.

THE EXPANDED USE OF GROUND WATER

New Jersey's ground-water resources may be grouped according to three major geographic regions. In the sparsely settled northwestern portion of the State the rocks are relatively unproductive of ground water. In the Piedmont Plain area of north central New Jersey the rock formations yield moderate supplies and, locally, valley-fill deposits of sand and gravel support wells of high yield. In all of the Atlantic Coastal Plain area of southern New Jersey large supplies are available either from wells drilled into sands and gravels that are exposed at the surface, or by drilling through clay layers of moderate thickness to tap artesian aquifers that dip oceanward beneath the clays.

New Jersey uses about 500 million gallons of ground water each day. Of this, about one-third is withdrawn for public supplies, one-half by industry and about one-sixth for rural and irrigation uses combined. A compilation of the withdrawal of ground water by public water systems in 1954 was made from data supplied by the State. A review of ground-water withdrawal by public water-supply systems in the 5-year period 1950-1954, indicates that requirements have increased nearly 3 percent a year or an average of 4.6 mgd for each year. It is estimated that the annual increase in industrial ground-water pumpage since 1950 has been about 9 mgd, and for the same period the increase for supplemental irrigation may be about 4 mgd.

Most ground-water problems in New Jersey result from the local demand exceeding the capacity of the local water-supply installations, or because of pollution or contamination of the supply, rather than because of any widespread basic inadequacy of the ground-water resource itself. However, over-development has occurred in a few places where the quantity of ground water available is less than the requirements of the locality. For the most part, areas in which the demand has exceeded the supply are underlain by rocks of the Piedmont Plain or the Highlands and Appalachian Valley ground-water provinces in which the storage and movement of ground water are generally unfavorable.

In New Jersey, except perhaps in the Piedmont Plain. changes in the chemical quality of ground-water supplies appear to be a more serious problem at present than use in excess of the dependable yield. The withdrawal of ground water is always accompanied by a lowering of water levels. If water of undesirable quality is present near wells, the gradient that is established toward the wells as soon as withdrawal begins may cause the undesirable water to enter the wells. As a result, many wells near the coast or adjacent to areas of brackish water, such as inland bays and tidal streams, no longer produce fresh water. Occurrences of contamination by salt water are numerous along the Atlantic Coast from Cape May to Newark and along Delaware Bay below the Camden area.

Wells polluted by industrial wastes are more spotty in their occurrence but as would be expected, they are more likely to present problems in the manufacturing areas of the northeastern metropolitan region, and along the Delaware River in the Camden area. In some cases, industrial pollution is so limited as to affect only the wells of the industry responsible for the pollution, but in other cases, a single source of pollution may be evident throughout a neighborhood of considerable size. Where water infiltrating from streams or rivers furnishes an appreciable part of the water obtained from wells, pollution of the surface sources may seriously detract from the usability of the ground water. In the Philadelphia-Camden area, where well supplies are maintained in considerable part by recharge from the Delaware River, the industrial pollution in the river water is of increasing concern.

Additional supplies of ground water are potentially available throughout all of New Jersey, although the magnitude of these potentials varies greatly from place to place. In the northwest, it is probable that future large supplies can be developed only from scattered occurrences of glacial outwash in major stream valleys. Such deposits have not as yet been mapped. Indeed, in some valleys it is only surmised that such deposits exist.

In the Piedmont Plain, Triassic sandstones and shales will support moderate new ground-water developments in areas away from existing wells. Larger quantities, perhaps from 25 to 50 mgd, could be developed by full utililization of the scattered occurrences of outwash gravels in the major stream valleys.

It is in the Atlantic Coastal Plain, however, that New Jersey's great undeveloped ground-water resources occur. In this area there are billions of gallons of water in storage in the sandy formations that dip at low angles beneath the Interior Plain and extend beneath the Continental Shelf off the New Jersey coast. The rate of infiltration of rainfall into these sand aquifers probably exceeds an average of 2 billion gallons per day.

It will be feasible to develop large additional supplies of ground water in part of the Lower Delaware River Valley and in numerous localities in the interior of the Atlantic Coastal Plain. In the Lower Delaware Valley, as much as 100 to 200 mgd may be developed on the New Jersey side of the river between Trenton and Palmyra by wells favorably located for inducing river infiltration. Perhaps 25 to 35 mgd of additional water may be obtained from the Raritan-Magothy outcrop area beyond the zone of river infiltration. Elsewhere in the valley, the unsatisfactory quality of the water or existing withdrawals largely preclude further extensive developments.

In the interior of the Atlantic Coastal Plain, at least several hundred million gallons of ground water per day could be developed without exceeding the average rate of recharge. Ground-water storage beneath the surface is so vast and so readily available to relatively shallow wells that seasonal variations in precipitation or even drought years will have little effect on the ability of wells to maintain yields. The hydrology of the Pine Barrens is such that, as in the Wharton Tract, streams may be considered to function dominantly as ground-water canals. As such, they conveniently transport ground water from larger intake areas to localities where groups of wells can be continuously supplied by infiltration from the stream. It is estimated that at least 130 mgd can be developed in the lower portion of the Wharton Tract for distribution as supplemental supply to the Lower Delaware Valley and to the southern Atlantic Coast of New Jersey. About 30 mgd are believed to be available from one or more areas in the northern Pine Barrens, for possible use in the southern portion of the Northeastern Region. An indefinite number of smaller supplies can be developed as needed for scattered communities and industrial centers in South Jersey if groundwater sites are selected, preferably from publically-owned lands, on the basis of hydrologic studies and tests.

Although a large amount of information has been gathered in numerous local areas, knowledge of New Jersey's ground-water resources on a state-wide scale is seriously deficient. Consequently, any present plan for developing additional supplies on a regional or state-wide basis must necessarily be general in nature. Actual developments, if soundly planned, must be based on detailed studies. In only a few small areas of the State are ground-water conditions sufficiently known to permit adequate planning without considerable additional test drilling and study.

It should be recognized that the present deficiencies of basic data partially prevent the resolving of ground-water problems or the fullest development of extensive ground-water potentials that are known to exist in southern New Jersey. The following recommendations are made so that the State can improve its position with respect to hydrologic knowledge and thus more effectively utilize its ground-water resources.

The first and major requirement in achieving the desired development of the State's ground-water resources is to provide for a comprehensive and continuing hydrologic study of all important ground-water provinces and their individual aquifers. The nature of the studies is such that the important factors involved require observations over a period of years, rather than concentrated activity over a short period. This phase of the work probably can be done most effectively by expanding the investigational programs being cooperatively conducted by the Division of Water Policy and Supply of the State Department of Conservation and Economic Development and the U.S. Geological Survey. These cooperative programs have related mostly to areas of present or impending water problems, such as at Atlantic City, Camden, Newark, etc. Such programs are valuable and necessary activities but

provide little opportunity for studying areas of favorable potential or for enlarging the knowledge of local areas to the regional bases from which statewide planning can proceed.

As a means to the ends desired, there is need for additional observation wells which reflect the natural hydrology of formations in areas away from centers of large withdrawals. Exclusive of observation wells in special research projects, the number of observation wells reflecting natural storage and recharge conditions, now numbering about 50, should be increased to about 200. The increase in the number of observation wells should be timed so as to provide the full number at the end of five years. Most of the new wells should be located in the unconsolidated aquifers of the Atlantic Coastal Plain and in undeveloped outcrop areas of the Triassic sandstones and shales of the Piedmont Plain. Wherever possible, such new observation wells should be drilled on publicly-owned property, as this improves the chances of obtaining records of long duration.

During the next five years, the number of observation wells located to show the effects of pumping from areas of large withdrawal should be increased from the present number of about 200 to about 400. If data provided by such wells are not available for areas like the Lower Delaware Valley, the expected large-scale expansion in ground-water use will result in needless confusion as to spacing of wells, interference by others, etc.

Along the Lower Delaware Valley from Deep Water Point to Bordentown, shallow wells spaced approximately 1 mile apart should be provided during the next 10 years to permit a continuing detailed study of quality of water relations between the river and valley sediments.

Outpost wells for obtaining quality of water samples should be provided for every center of large withdrawal along the Coastal Area of southern New Jersey. Where not already established, at least two outpost wells should be provided between a well field and the shore, in a line down the dip of the formation in the deeper aquifers, and in the direction of probable salt-water infiltration in areas of shallow aquifers. Such outpost wells should be established as soon as possible. Wells suitable for obtaining water-level measurement should be used in conjunction with the water quality observations.

The detailed ground-water studies now in progress in a few problem areas should be increased, particularly with respect to quantitative studies and those factors relating to salt-water contamination and industrial pollution. Additional studies of this type should be undertaken in the Lower Delaware Valley and Coastal subdivisions of the Atlantic Coastal Plain, and the Piedmont Plain. Hydrologic studies based principally on test drilling and pumping tests will be required to determine the most favorable localities for river infiltration within the strip along the Delaware River between Trenton and Palmyra.

Test drilling and pumping tests should be undertaken in the Wharton Tract near the community of Batsto within one or more areas bordering the Batsto River and within one or more areas bordering the Mullica River. Such tests should be designed to determine the effectiveness of the infiltration of river water into the underlying aquifer when a cone of depression is formed by pumping, the most effective spacing of wells drilled along the streams, the color and chemical quality of ground-water derived from stream infiltration, and related factors. Similar tests should be made along the Wading River just south of Harrisville.

When the results of the hydrologic studies are available, it will then be possible to plan in detail the construction of one or perhaps two well fields in the lower reaches of the Mullica River as a supplemental supply for the New Jersey portion of the Lower Delaware Valley and a similar well field along the Wading River for supplemental supply in the southern New Jersey coastal areas. These two systems will probably provide dependable long-term supplies of at least 90 and 40 mgd, respectively.

The feasibility of such large-scale ground-water developments is enhanced by several factors. Chief among these are:

1. The very large quantity of ground water in subsurface storage in areas such as the Wharton Tract affords a means of minimizing the effects of droughts which endanger many surface water supplies. This vast underground storage can be drawn upon during long periods of deficient rainfall, thus serving the same purpose as surface reservoirs but without entailing costly construction of dams.
2. The utilization of the water resources beneath the land surface can be accomplished without loss of the land area itself, except that zoning compatible with good watershed management should be maintained.
3. Use of the natural underground reservoir rather than an open body of water on the land surface will result in much lower evaporation and transpiration losses.
4. After the major pipe lines to areas of consumption have been installed, the actual production of the water supply can be enlarged as needed, well by well, without the necessity of initial costly reservoir construction based on design requirements of some period far in the future.
5. Problems of color and turbidity control will generally be absent in ground-water supplies from these areas, although iron removal may be required. If water from surface reservoirs is used, water treatment to overcome color and turbidity will be needed.

In order to implement the above program of ground water investigation and study it is recommended that an appropriation of State funds of $100,000 be made yearly for the next five years.

WATER RESOURCES AVAILABLE TO THE SOUTHWESTERN AND COASTAL REGIONS

The Southwestern Region has available to it the waters of the Delaware River, the streams draining the Western slope of the Pine Barrens and the ground water of the Interior Plain. The Coastal Region has available to it the streams draining the eastern slope of the Pine Barrens and the ground water of the Interior Plain and Coastal Area.

As indicated in Chapter III the development of water supplies in these Regions has been and will doubtless continue to be by wells which pump either ground water or a combination of ground water and induced infiltration from streams. Exceptions to this rule are the cities along the Delaware River such as Trenton and Lambertville, which take surface supplies directly from the river or its tributaries.

There is no question of a shortage of supply in these Regions. However, there are two areas of potential difficulty —Camden and Atlantic City—in which the existing supplies are threatened by a deterioration in the potable quality of the water. In Camden this is due to pollution and salt water intrusion in the Delaware River which affects wells that have a physical connection with river water through the highly permeable sands and gravels between the wells and the river. In Atlantic City wells have been overpumped until ground water levels are dangerously lower than sea level. Shallow wells have already become contaminated by salt water and wells in the deeper aquifers, while still delivering fresh water, are unpredictable as to their future performance.

The augmentation of the low flows in the Delaware River given by compensation releases of the New York City water system will improve the quality of water in the lower Delaware and should have a beneficial effect on the water supply of the Camden area. The additional regulating effect that would be obtained with the construction of the proposed Wallpack Bend Reservoir may result in permanently improving river water to a degree that will make it unnecessary for Camden to look for a replacement of its supply obtained from wells with infiltration of river water.

In Atlantic City the situation calls for careful control of pumping and observation. In this connection the observation and outpost wells recommended in this chapter would be of greatest use in determining whether the situation at Atlantic City can be stabilized and at what rate, if any, the movement of salt water landwards is taking place in the deep aquifers.

The eventuality, which may be remote, that the water supplies of both Camden and Atlantic City may have to be

replaced by resources not influenced by the tidal portion of the Delaware Basin or the Atlantic Ocean, was considered. Fortunately, the water resources of the State-owned Wharton Tract can be developed to serve both areas. The type of development recommended calls for the use of high yield, relatively shallow infiltration wells placed in well fields parallel and adjacent to the principal streams of the Wharton Tract. It is anticipated that such wells will each yield upwards of one million gallons per day. They will normally draw most of their water by infiltration from the streams, but can also use the large ground water storage as a reserve in the event of an unusually protracted dry period. In this development it is proposed to use the Mullica River and its tributary, the Batsto River, for the Camden area. The two branches of the Wading River would be the most economical for serving the Atlantic City area. (See Plate III-5.)

For the Camden area a surface supply from Rancocas Creek was also found to be feasible as a future supply in the event of the need to replace existing wells. Water would be diverted directly from the stream above tidal influence from the Delaware. (See Plate III-5.)

Table VI-7 gives the cost of developing water supplies from the Wharton Tract to Camden and Atlantic City and from Rancocas Creek to Camden.

The interests of the Southwest and Coastal Regions, with respect to the development and preservation of its water resources, may best be served by the recommendations given above together with the recommendations given below for the Wallpack Bend Reservoir.

A special case in the Coastal Region exists in the northern part of the Region in Monmouth County. The geological formations in the area drained by the Shrewsbury and Navesink Rivers are not conducive to the production of large quantities of ground water. Sites for large storage of surface water are not available because of the relatively low relief of the topography. The area is now supplied by a combination of surface and ground water resources and the situation with respect to supply is not critical. This area, which is within commuting distance of Metropolitan centers, has experienced considerable recent growth which will probably continue. It may eventually be necessary to use supplies from the northern Pine Barrens for this area, and the long-range program recommended for ground water research should be arranged with this in mind.

FINDINGS AND RECOMMENDATIONS ON THE WALLPACK BEND RESERVOIR

The Wallpack Bend Reservoir development as proposed in the September 1955 report of Albright & Friel will provide the following benefits to the State of New Jersey.

1. It would assure a minimum flow in the Delaware River at Trenton of 3400 cubic feet per second during a period equal to the worst drought of record.
2. It would provide the compensation storage (on the basis of present requirements) for a diversion outside of the Delaware Basin of at least 300 million gallons per day for use in the Northeastern Region of New Jersey. Storage to regulate the water supply cannot be provided in Wallpack Bend without sacrificing river regulation. Such storage should be provided separately at a site such as Flatbrook Reservoir.
3. Wallpack Bend Reservoir would provide a certain increase of flood control under conditions assuming that capacity will be available in the reservoir at a time of flood or that sufficient advance warning of a flood is given to permit release of water in the reservoir in order to provide space for the retention of flood water. It should be understood that this is incidental flood control and not positive flood control. It is nevertheless an important benefit, since the pattern of flood occurrences in the east is such that there would normally be some capacity in the reservoir at the time to retain flood waters. In order to obtain a positive increase of flood control with the Wallpack Bend Reservoir it would be necessary to sacrifice part of the river regulation benefit.
4. The increase in the minimum flow of the river would improve pollution conditions and retard the tidal movement of salt water in the lower Delaware River. This would safeguard many of the water supplies dependent on the lower river and perhaps make their replacement unnecessary.
5. The greater volume of fresh water moving down the river during dry periods will help to protect the oyster industry in Delaware bay and to maintain optimum conditions for shellfish development.
6. The maintenance of navigation in the river below Trenton will be aided by the increased river flows.
7. Opportunities for the development of recreational facilities will be created along the shores of the Wallpack Bend Reservoir.

In consideration of the above benefits it is recommended that the State of New Jersey cooperate with the Commonwealth of Pennsylvania in the construction of a reservoir at Wallpack Bend to the extent of 30 percent of the total cost less the cost of recreational facilities on the Pennsylvania side.

Unless there is an intention to divert more than 300 million gallons of water per day out of the Delaware Basin it is not recommended that the participation by the State of New Jersey should exceed thirty percent of the total cost less the cost of recreational facilities on the Pennsylvania side. Thirty percent represents a fair proportionate share for the State of New Jersey, based on the area of Delaware watershed in each state. It should be recognized that aside from rights to claim compensation storage for a greater out-of-basin diversion, the same downstream benefits will accrue to the State of New Jersey irrespective of the percentage of participation in the reservoir project.

TABLE VI-7

COST SUMMARY—SUPPLEMENTAL SUPPLIES FOR ATLANTIC CITY AND CAMDEN

Source & Area Served	Potable Yield* mgd	CAPITAL COST Development of Supply	Transmission System	Total	Per mgd	ANNUAL COST Total	Per mgd	Cost of Water per Million Gallons
SURFACE SUPPLY								
Rancocas Cr.—Camden	80	$6,200,000	$3,861,000	$10,061,000	$132,620	$792,000	$9,900	$27
GROUND WATER SUPPLY								
Mullica—Camden	80	6,500,000	9,100,000	15,600,000	195,000	1,396,000	17,450	48
Wading—Atlantic City	8	1,940,000	4,100,000	6,040,000	755,000	515,000	64,275	176

*Average annual value—In the case of Atlantic City the new supply must be capable of supplying a seasonal delivery of 22 mgd.

CHAPTER VII

CHAPTER VII

LEGISLATIVE ACTION, FINANCIAL REQUIREMENTS AND ADMINISTRATIVE ORGANIZATION

The engineering objectives and recommendations outlined in the preceding chapters will require a legislative program to provide for their legal, administrative and financial requirements. In general this includes legislation:

1. To authorize the development, design and construction of a major water supply or supplies to solve the long-range water needs of the State, and also to permit service and operating responsibility to remain in the various public and private water supply and distribution systems within their respective service areas.
2. To provide immediate relief of current water shortages by facilitating the increase of water supply from existing systems through additional development and improved distribution of the total available supply.
3. To strengthen the police powers of the Division of Water Policy and Supply, so as to assure the most efficient use of existing supplies in light of local needs and safe yields.

STATE WATER AGENCY

The nature of these legislative purposes, as well as the financial requirements to be developed, practically dictate the need for a state water agency to administer the construction program and arrange for its financing. This does not mean, however, that the state must go into the business of selling water at retail. From an engineering standpoint a clear choice of methods is open:

1. The state agency may be authorized to acquire, construct, finance, operate and maintain new water supply systems.
2. The state agency may be authorized to acquire, construct, and finance new water supplies, but to turn them over for operation to an appropriate district, regional or municipal operating system, as determined by the legislature.

The choice between these two alternatives is a matter of legislative policy. In the selection of that policy, however, it should be pointed out that the State's water problem can be resolved most effectively and economically only if it is viewed in comprehensive terms, including the over-all water supply, and existing and future needs, together with considerations of sewage disposal and stream pollution control, recreational possibilities and industrial development.

In this perspective, the water problem is not peculiar to Northeastern New Jersey, as compared with the south or central regions of the State. While attention has been focused on the North Jersey problem as the most urgent at the moment, there is already plainly apparent a need for an early program of study and action to safeguard the water supplies of Atlantic City and Camden. There are also important potentialities for recreational and industrial development in South Jersey if the Wharton tract and other sources are developed into usable water supplies.

ARGUMENTS FOR A STATE WATER AGENCY

An evaluation of alternative administrative devices indicates the need for a State administered water agency, if, as a matter of legislative policy, a long range solution of the water problem is desired. In particular, the following considerations are persuasive:

1. A statewide agency would obviously be best suited to make an integrated approach to the statewide water needs. It is a basic premise of any major water supply program that the water resources which happen to be found in any particular part of the State do not belong to the people of that part of the State, or to their political subdivisions, any more than to the State as a whole, although it may be more convenient and economical to develop certain resources to fulfill the needs of certain parts of the State. In the selection of reservoir and dam sites, and ground-water fields, and in the design of water supply facilities to serve any given region of the State, however, it is most efficient and economical to decide upon these policies in light of the overall needs and plans for the State as a whole.

   If a major new supply were to be developed by any existing municipal or privately owned water utility, or any new organization of less than statewide jurisdiction and responsibility, the water development would be owned by, and subject to the control of, a limited proprietorship, while the rest of the State would be left to rely on such surplus as the owners might be willing to offer. While it is theoretically possible for the State to mandate an apportionment of the available supply as between the owners and non-owners who might require additional water supply, it is neither desirable nor reasonable to expect any water agency of limited ownership and responsibility to afford any more than incidental consideration to the needs of "outsiders" in the basic planning and designing of a new water supply system. The history of the development of the water supply systems of the City of Newark, Jersey City, Passaic Valley Water Commission, and the North Jersey District Water Supply Commission, has shown the great benefits that can accrue from far-sighted water development planning by municipally owned water supply systems. Similarly, the growth in investment and extension of service and supply by privately owned public water systems, particularly the Elizabethtown Water Company and Hackensack Water Company, have demonstrated the capacity of these private enterprise systems to develop the water resources available to them within the limits of development justified by present consumer demand. It is neither appropriate nor reasonable, however, that the municipally or privately owned systems should be expected to invest in major water supply facilities which appear to be for the benefit solely of non-owners, in the case of the municipally owned systems, or for future development of the region or the State on an uneconomic basis, in the case of the privately owned systems.
2. Public capital supplied by the State is alone justified in assuming the burden of long range water supply financing. The preceding chapters of this report have reflected three factors which have gradually produced the necessity for a changing concept of the water supply problems of the metropolitan areas of New Jersey. These three factors, a marked increase in the per capita consumption of water, a need to go further and further from the centers of consumption to find adequate sources of supply, and a greatly increased cost of acquisition of land, structures, and equipment, have contributed to create a new dimension to the financial problems of water supply. Over the past fifty years, as more water has been needed not only to supply an expanding population and industry but also to furnish more water per capita to satisfy the needs of a changing way of life, nearby sources of supply have more and more been exploited to their maximum safe yield, and it has become necessary to turn to more distant and more costly sources. The need to avoid an excessive cost to the consumer of water still remains, however, if we are to avoid serious deterrents to economic growth and a rising standard of living. This combination of factors which produces unavoidably high cost for new water supplies, together with the desirability of maintaining a moderate price to consumers, creates a need for tax support on the broader base, geographical and financial, available only to the State government.

   The importance of anticipating future water needs, at least to assure a safe margin over anticipated future demand, is also an important obstacle to the use of private capital. If the economic deterrent of limited water supply, and the perennial water shortages of recent years are to be eliminated, major new supplies should be built to anticipate future needs rather than to satisfy existing demand alone. This is especially true of a major supply which may require five or more years to construct. Of necessity the investment of private capital must proceed step by step not too far ahead of a development of actual demand, if uneconomic risks are to be avoided. There is an important place for such development of local resources in the present water supply outlook in New Jersey, but the development of one or more major new supplies must

be planned and designed in light of the same broad public good which is the justification for other state and municipal services of government which cannot appropriately be rendered by private capital. The use of a state-wide agency would seem to be a corollary to the use of State credit and financial capacity.

3. The administrative organization should be equal to the scope of the problem. A real solution of the State water problem, as this report demonstrates, must be adequate to meet the needs of municipal and privately owned water distribution systems in any part of the State. It must be able to plan in terms of the interrelated problems of the several regions of the State, for the best use of water resources wherever they may be found, and for the interrelated potable and industrial water supply needs which are characteristic of a growing industrial State. To this end, the administrative agency should be selected with reference to the broad overall needs of the entire State for water for domestic and industrial uses, as well as for recreational purposes.

4. The alternative of a municipal partnership such as the North Jersey District Water Supply Commission would require supplementary State financing and controls. While this District Commission could claim the advantage of a going concern, it would also be obliged to overcome the disadvantages which have been considered in points 1, 2 and 3 above. Spokesmen for the District have recommended that State support be considered if the District were to be used as a vehicle to provide a major supply for North Jersey. (See Public Hearing on Senate Number 372 and Assembly Number 595, before Senate and Assembly Committees on Revision and Amendment of Laws, August 22, 1955, afternoon session transcript, page 27). Their suggested legislation for an $85 million bond issue is included in Senate Number 214, introduced March 28, 1955.

A municipal cooperative arrangement, such as the North Jersey District Water Supply Commission, operates upon the credit of the member municipalities. Under Chapter 5 of Title 58 of the Revised Statutes, the contracting municipalities are obligated to contribute, upon the call of the Commission, toward the capital cost of the water supply project in proportion to the quantity of water they each contract to take. The municipalities in turn are authorized to issue their own bonds to acquire the necessary capital funds. (R.S. 58: 5-28). Under this arrangement the operating expense of the water supply system is also apportioned to the member municipalities in proportion to the amount of water each contracts to take (R.S. 58: 5-23). In effect, therefore, the capital and operating expense of the Commission is backed by the property taxing power of each member municipality. If the water revenues of the municipality are at any time insufficient to cover its commitments under its contract it would be able to fall back upon its property taxing power to make up the deficit. The municipalities commit themselves to take a certain amount of water, and they pay for the capital and operating cost in that proportion whether they use the water or not.

The burden of this type of arrangement upon municipal taxpayers will depend upon the size of the present water supply project in relation to their present needs, and also on the extent to which they have available water revenues which might be applied to the cost of the annual debt service and operating expense of a new supply. For example, if the economical size of a new project was 70 million gallons a day with a total capital cost of 60 million dollars, the member municipalities would be required to carry the entire debt service and operating expense of the 70 million gallons system even though they used only a small part of its capacity, until such time as they are able to sell the surplus water to non-member municipalities or their own demand increases sufficiently to absorb the surplus.

The financial impact of the burden of carrying such a water supply system, especially in the early years of operation, would depend upon the extent to which the member municipalities already have revenues from an established water supply system built in past years when costs were much lower. Since new water supplies are certain to be much more expensive than old water supplies, a municipality which is in a position to average the new cost with its old cost, would be better able to participate in a new supply without undue financial strain and without the need to pass on to its new consumers the full cost of the new water. For example, among the eight municipalities which have joined in the Round Valley application, Newark, Kearney and Bloomfield are present participants in the North Jersey District, while Bayonne, Elizabeth, Hillside, Orange and Cedar Grove would be new members. It is doubtful whether the taxpayers, especially those in the latter group, should be expected to underwrite the capital cost of a water supply system designed to meet the future demand in other municipalities and counties.

If the Legislature desires to retain a proper measure of local responsibility, this can be preserved by using the state agency for the purpose of acquisition, construction and financing, and turning over distribution responsibilities to appropriate district, municipal or private supply and distribution systems.

SELECTION OF A STATE WATER AGENCY

The proposed program could be undertaken either by the Division of Water Policy and Supply or by a newly constituted State authority or corporation within the Department of Conservation and Economic Development. The latter would be similar to the State Highway Authority within the State Highway Department. There are advantages and disadvantages to each arrangement but the matter is principally one of legislative policy rather than of engineering necessity.

A brief summary of the arguments pro and con may be convenient as a matter of public information. Normally an existing state agency would be the first choice. In the present case this would be the Division of Water Policy and Supply, which is headed by a Director responsible to the Commissioner of Conservation and Economic Development. This has the obvious advantage of turning the work over to a division which has long been associated with the State's water problems and which is already integrated with the State's administrative structure.

A newly constituted water agency, also established within the same department, would permit the legislature to create a board or commission as its head. This would offer the opportunity, if desired, of giving representation to the various counties, municipalities and water supply systems most directly interested. As a new administrative unit, such a water agency might have greater flexibility of organization, staffing and policy.

From the viewpoint of administration, either choice would require an essentially new administrative unit with respect to personnel, office space, legal, engineering and other technical services. In either case, the actual design, construction and supervision of the work would undoubtedly be accomplished through the usual contractual arrangements. In brief, the choice is principally in the type of top policy-making body which would be most satisfactory from the viewpoint of the Governor and the Legislature.

POWERS OF A STATE WATER AGENCY

The principal powers of whatever state water agency is selected will necessarily include power:

1. To design, construct and operate one or more new major water supplies as may be authorized by law, but not to operate any local distribution system.

   This would require legal authority not only to construct and finance the new supply system but also to select and acquire sites in North, South and Central Jersey for conservation and development of watersheds, for dams, reservoirs and pumping stations, and rights of way for transmission lines and for the acquisition of additional ground water preserves. Legislative policy with respect to the choice among these expenditures could, if desired, be carried out through the annual control of appropriations.

2. To fix the sales price or rates for sale of water from the state-developed supplies. This is an essential financial power.

3. To construct, or to advance capital to existing public systems to construct, approved extensions and additions to existing systems and to arrange by contract, the control and disposition of the additional water made available by such construction, for use wherever needed.

   This would facilitate complete development of existing water systems similar to the recommendations made in this report for augmenting the existing Northeastern Region supplies. This power, together with Item No. 4 below, appears well adapted to eliminate the reasons why existing public system have not yet built the reservoirs which could with comparative speed augment the dependable supply available to the Northeastern Region. The reason for past delay may possibly be classified as follows: (a) The system itself does not require the additional supply. (b) The system itself requires the additional supply only if it continues to sell water to non-members, with the appearance that the system in fact is expanding its resources for the benefit of others. (c) The system does not need an additional supply except to meet shortages in times of extreme drought, and it is uneconomical to make a major investment for such limited use. (d) The system in fact has a sufficient supply, but has a poor distribution system to meet peak loads, the correction of which requires such a great capital outlay that it would not produce a commensurate return to the private operator. (e) The interchange of water between surplus and deficit systems is limited either by lack of inter-connections or by cost differentials between the two systems.

4. To integrate the total water supply resource of the State for its total needs through the construction and operation of interconnections, reservoirs and booster stations and the making of contracts with existing systems for transmission of water and for the exchange of water between existing and new supply systems.

   This will provide increased efficiency in the operation of both existing and proposed new supplies.

5. To enter into agreements with public and private water systems for the joint construction or operation of interconnecting facilities by such public and private systems, and to transfer water between operating systems at established rates, with the approval of the State Water Policy Council.

   This would permit the equalization, for purposes of inter-change of water, of water rates within a supply district and would have the effect of eliminating an economic deterrent to the exchange of water between systems due to difference in cost.

6. To acquire for public use, upon payment of just compensation, the unused watershed rights of a municipal or privately owned system, when needed to prevent regional shortages.

   This would permit the recapture of unused watershed rights, as a last resort, where the owner of such rights declines to use or permit the use of them for the benefit of the general area served. This would prevent the hoarding of water rights which places an unfair burden on the area as a whole by making it necessary to bring water from greater distances and at much higher costs.

7. To acquire additional ground water reserves, and to construct and maintain water conservation facilities, as it may find necessary and desirable.

   This would permit the acquisition of preserves similar to the Wharton Tract for the purpose of serving other areas of the State.

8. To enter into contracts, and to pledge its revenues and property as further security therefor.

9. To acquire real and personal property for its authorized purposes by gift, purchase, lease or condemnation, so far as may be necessary to execute any project authorized by the Legislature.

FINANCIAL REQUIREMENTS

The recommended program of short-range improvements and long-range development will require immediate capital funds, which may be provided in whole or in part through bond issues, and continuing current income which may be derived in whole or in part from water charges. It is the purpose here to review alternative methods for meeting these requirements.

METHODS OF FINANCING

The choice of the method of financing largely depends upon whether the program that is activated is statewide or not, and what is deemed to be a fair allocation of total cost.

General Credit and General Revenues

In most of the past proposals it has been assumed that the development of new supplies will require the use of the general credit of the State, supported by general tax revenues as long as the new supplies operate at a deficit. Since the only efficient way to build new supplies is to anticipate the needs of future years, it should be expected that any new supply may operate initially at a deficit, and certainly will be unable to meet all debt service charges out of revenues for a number of years if an excessively high initial rate for the new water is to be avoided. It is, of course, feasible to finance all of the requirements of the new program in this way, provided existing or foreseeable State tax revenues are available for this purpose. This method would be especially appropriate if the expenditure program were to be for statewide purposes. Future net operating profits could be returned to the State Treasury to make up for past operating deficits if that were the legislative policy.

General State Credit Supported By Special Revenue Sources

In view of the fact that any major supply will be of special benefit to the area for which it is developed, and in consideration of the advantages of avoiding a new burden on the State's treasury, alternative ways of financing the program, based upon an equitable allocation of its cost may be considered.

An equitable system of financing may be based upon a recognition of the benefits received from an adequate water supply, beyond those realized by water users. These benefits may be realized by persons and property as follows:

1. The community being better served, each individual property owner within the area of the improvement is indirectly benefited because of the availability of water for potential use, which enhances the value of his property.
2. Each person realizes benefits from improved fire protection, health, industrial prosperity, and civic improvement, all of which require adequate water supply.

In view of these non-user benefits, a method of financing the capital cost of the water supply which places the entire capital cost upon users may well be questionable. In the present state of development of the New Jersey water supply program, a method of financing which places the burden of operating deficits and unearned fixed charges on general State revenues may also be undesirable. If the Legislature desires to recognize these questions of equity, it may apportion the various elements of cost according to a statement of policy which has been adopted by a professional study group consisting of water engineers, investment bankers, lawyers, governmental administrators, and public utilities commissioners[1] as follows:

> "The needed total annual revenue of a water works shall be contributed by users and non-users (or by users and properties) for whose use, need and benefit the facilities of the works are provided approximately in proportion to the cost of providing the use of the benefits of the works."

In other states, there are good examples of the application of such a policy: the Washington Suburban Sanitary Dis-

[1] Fundamental Considerations in Rates and Rate Structures for Water and Sewage Works. A Joint Report of Committees of the American Society of Civil Engineers and of the Section of Municipal Law of the American Bar Association and Representatives of the American Water Works Association and various other associations.

trict (Maryland), the Buffalo Sewer Authority (New York), the Ohio Conservancy Districts (Ohio), and the East Bay Municipal Utility District (California). In New Jersey, the North Jersey District Water Supply Commission (Chapter 5 of Title 58 of Revised Statutes) has the possibility of non-user support through taxes levied by member municipalities to pay their respective shares of debt service operation and maintenance cost if their water rates are insufficient for these purposes.

A policy of allocating some costs to non-users should be applied with the recognition of the natural division of the costs of a water supply system into the following three types of expenditures:

1. Acquisition and construction of major structures, dams, reservoirs, main pumping station and transmission mains —these benefit non-users as well as users.
2. Local distribution including booster pumps, lateral mains, distributing reservoirs and standpipes—these are of local benefit only.
3. Current operation and maintenance including pumping and treatment—these benefit consumers only.

SOURCES OF REVENUE

It has been assumed that the most favorable method of financing would be upon the **general credit** of the State—but this does not necessarily mean support by **general revenues** of the State. In fact, the types of cost and benefits to non-users might make it inequitable to use either all general revenues (which do not recognize special benefit to users) or all service charges (which do not recognize benefits to non-users).

Capital costs are especially suitable for some support from non-user revenues. If such support is not provided, those who use the facility will pay the capital costs and those who do not have immediate use but do have ultimate need (and therefore present benefit) would escape a fair part of the capital burden.

In the case of any particular improvement, the non-users will enjoy benefits which are different in kind and degree depending upon their location with respect to the improvement. It would be fair and equitable to recognize the difference in non-user benefits in establishing the method of financing and allocation of the cost. These considerations suggest the possibility of three sources of revenue to support the immediate and long-range programs.

Water Service Charge

This is the basic charge for the sale of water. In the past this charge has included all costs in connection with the supply of water except in cases where deficits were covered by general taxation. The service charge still remains the simplest and most direct, though not necessarily the most equitable means of collecting water revenues. Whatever means may be chosen to produce water system revenues, the service charge should at least include all costs of operation, maintenance, pumping, treatment and management, and could fairly include the annual interest charge for the use of capital.

Special State Assessment to be Levied in Benefited Area

In accordance with the principle that users and non-users alike, within the area served by a water supply, receive benefits from the water supply, a special State assessment based on property values or other equitable determination might be levied within an area of benefit to finance the capital costs of the water development.

Since the needs and benefits of non-users vary widely in different sections of the State, it may not be considered equitable to use general state revenues to provide the needed capital. Instead this need can be equitably treated by analogy to the special benefit assessment for local improvement. The differences are that in the present case the Legislature, rather than a local governing body, would authorize the assessment and define the benefited area for each improvement, and that the assessment would be to political subdivisions within the area of benefit rather than to individual property owners. The State water agency would then spread the assessment according to the legislative mandate.

It is likely that, for the sake of convenience of administration, the Legislature would desire to include entire counties within the area of assessment—and for legal reasons should preferably do so—and require each county to raise its apportioned share of the cost by a special water millage added to the general tax rate. If both interest and principal were to be financed by such an assessment, the annual cost of principal payments could be apportioned among the counties according to the full valuation taxable, and interest cost could be apportioned among the municipalities in proportion to new water use.

For example, a $60,000,000 water development amortized on a straight-line basis over 35 years would require $1.7 million to be raised annually from the benefited area. In the Northeastern Region this amount would be spread over ratables with an equalized valuation of about $14.9 billion. A person who now pays a tax of $500 per year would pay a water assessment of about two dollars. The following tabulations show the equalized valuations taxable of the Northeastern Region by Counties:

County	Equalized Valuation	Percent
Bergen	$3,330,687,000	22.3
Essex	3,335,350,000	22.4
Hudson	1,690,379,000	11.3
Middlesex	1,499,470,000	10.1
Morris	1,047,314,000	7.0
Passaic	1,409,372,000	9.4
Somerset	529,518,000	3.5
Union	2,083,374,000	14.0
TOTALS	$14,925,464,000	100.0%

Uniform Water Use and Diversion Fee

If the State Treasury requires an additional source of revenue to finance its water supply commitments, it would be appropriate to consider an extension of the existing tax on "excess" diversion of water (R.S. 58:2-1 et. seq.) to include all present users of water. Funds raised in this manner would support over-all planning, surveys and tests and help to finance any demand upon the Treasury to meet deficits. The present tax is on surface water diversion, but if it were used in this manner it should include ground water, exempting diversions of less than 100,000 gallons daily.

It is the present users of water who have the primary interest in protecting present supplies against shortage and drought. It is also the present industries which have the greater interest in stream flow regulation. The precise interest of any one consumer cannot be measured. If we follow the policy, however, that every user is protected in his use only because someone else is not permitted to divert surface waters or overpump ground water, under State regulatory law (e.g. R.S. 58: 4A-1 et. seq.), the common interest of all present users in protecting and increasing present supplies is plain. This could justify placing some cost on all water users, whether or not they are immediate users of any new supply. The present tax, imposed by R.S. 58: 2-1 et. seq. is levied at a rate of not less than $1 nor more than $10 per million gallons, as fixed by the Water Policy and Supply Council. In North Jersey alone, with the proposed amendments, it could yield approximately $800,000 for each $5.00 of rate charged per million gallons of water based on present consumption.

EXTENT OF PROBABLE NEED FOR STATE SUPPORT

The main factors, other than the ultimate capital cost of the project, which will determine the need for tax support in the early years of a new water supply system are:

1. The maturity schedule of the bond issue.
2. The demand for water in relation to the capacity of the new system.
3. The price fixed by the State agency for the sale of the new State-developed supply of water.

It is accepted practice that the interest which accrues on borrowed funds during the construction period be capital-

ized, and included in the amount of the bond issue. The result is that neither principal nor interest payments need to be made out of tax or non-tax revenues of the water supply system during the construction period, which might be estimated at five years. For purposes of State debt management or for legal reasons, however, the State might prefer to pay these interest charges as they accrue out of current State revenues. If so, and assuming a $60 million bond issue for the completed project, there would be an annual average interest charge during the first five years of from $750,000 to $900,000 depending upon the interest rate, estimated from 2½% to 3%, at which the bonds were sold.

The first maturity of principal payment would ordinarily be deferred until the first year of operation of the water supply system. If temporary financing is used during this initial period and the $60 million issue is retired in equal annual installments over thirty-five years (the maximum period of maturity under the State Constitution) the annual cost of debt service for principal payments would be $1.7 million. The interest cost would probably range from $1.5 million to $1.8 million for the first year, declining annually as the principal payments are made, to $43,000 to $51,000 for the last period of the bond issue. Under this type of maturity schedule the debt service for principal and interest in the first year of payment would thus amount to $3.2 million to $3.5 million on a $60 million issue, depending upon the rate of interest which has been estimated at from 2½ to 3%.

Since the critical years, financially speaking, would be the early years of operation of a new water supply system (until the consumer demand equalled at least half of its capacity) it might be desirable to postpone the first maturity of principal for ten years. This is an accepted practice in the financing of such a large scale public improvement as a major water supply. If this were done, it would require the amortization of principal to take place between the tenth and thirty-fifth years, requiring 2.4 million dollars annually in principal payments. Under this plan the water system and its financial provisions would be required to produce the annual interest cost of $1.5 million to $1.8 million during the first five years of operation, but would not be required to meet any annual maturities of principal. In the eleventh year, however, the combined total of interest and principal would be about 900 thousand dollars greater as an annual charge than it would have been in the sixth or corresponding year under the plan of equal annual installments over thirty-five years. The total cost of spreading the amortization over thirty-five years would be less than that of spreading it over twenty-five years, but payments out of the State Treasury would probably be greater under the thirty-five year plan while payments by consumers in the form of water charges would probably absorb the greater cost of the twenty-five year plan of amortization.

EFFECT ON FINANCING OF PARTIAL CONSUMPTION

Estimates made elsewhere in this report indicate that the projected demand for water in the Northeastern Region would provide a market for an additional 192 million gallons per day by 1994. This would utilize the entire yield of expansions to existing systems (including minor systems) plus the entire yield of a major new supply of 70 million gallons per day capacity. Such a period of absorption does not take into consideration possible acceleration of water consumption due to the availability of new dependable water supplies of large magnitude or other variations in water consumption.

These data confirm the necessity for some form of tax support regardless of the project selected or whether it is operated by the State or by the North Jersey District Water Supply Commission. Such support is necessary if the new water is to become available to consumers at a price comparable to the wholesale price of $100 per million gallons which is now on the high side among the prices charged for the exchange of water between municipalities. The question remains whether such tax support should come from a limited number of municipalities who contract to be members of the system, from the whole region which would be benefited by the availability of the new supply, or from the State as a whole. In view of the current conditions which cause high costs of new water however produced, it appears preferable to have the State Administration coupled with state-wide or region-wide financing.

PRICE CHARGED FOR WATER

It is essential that the water agency which is responsible for the development of the water supply be empowered to fix the price at which it shall be sold. The price as fixed will not only affect the demand for the new water until such time as no other lower priced water is available, but will also influence the amount of the deficit that must be made up from non-user revenues, such as general treasury funds of the State. The State already has this problem in that it now sells water from the Delaware and Raritan Canal at wholesale, and may engage in this business up to a volume of 100 million gallons daily under the decree of the United States Supreme Court which permits the State to withdraw that quantity of water from the Delaware River Basin without compensating releases. In the case of a new major water supply, however, the problem would be different in that cost of the new water would be substantially greater than the cost of old water.

From the viewpoint of water supply alone, the price should be fixed at such a level as will not unduly burden consumers of water from the newly developed supply as compared with those served by older water supplies. This policy would permit consumers to choose among the most convenient sources of water supply rather than to exhaust the lower priced sources before turning to the newly developed supplies. Such a policy would, however, present the possibility of a heavier burden upon the State Treasury to meet deficits in the early years than would a policy of maintaining an average price over the years sufficient, after the full demand rate is reached, to reimburse the State Treasury for previously incurred deficits.

In either event, it will be proper to permit the State to differentiate in the price of water on the basis of quantity to be supplied, distances between supply and points of distribution, inter-connection cost, and the like. While the State Water Agency would not be subject to public utility regulation, it would nevertheless be desirable to fix the price of the State-supplied water after public hearing upon reasonable notice to the public.

Water service charges which would meet all costs of operation, maintenance, and debt service, or all such costs exclusive of amortization of the State bonded debt incurred for the capital cost of the recommended Plan CR-3, for a new supply of 70 million gallons per day using the East Branch of Chimney Rock Reservoir, are shown below and on Figure VII-1. The cost data presented represent those for the first year of operation and reflect a repayment period of 35 years with interest at 2.5 percent as well as operation and maintenance costs consistent with the assumed delivery rates.

COST OF WATER PER MILLION GALLONS

Portion of New Supply Sold		Service Charge Bearing All Costs		Service Charge with special assessment for repayment of principal
		With equal annual payments for principal & interest combined	With equal annual principal payments	
Percent	mgd			
15	10.5	$749	$903	$480
25	17.5	454	546	292
35	24.5	327	393	212
50	35.0	232	278	152
75	52.5	159	189	105
100	70.0	122	145	81

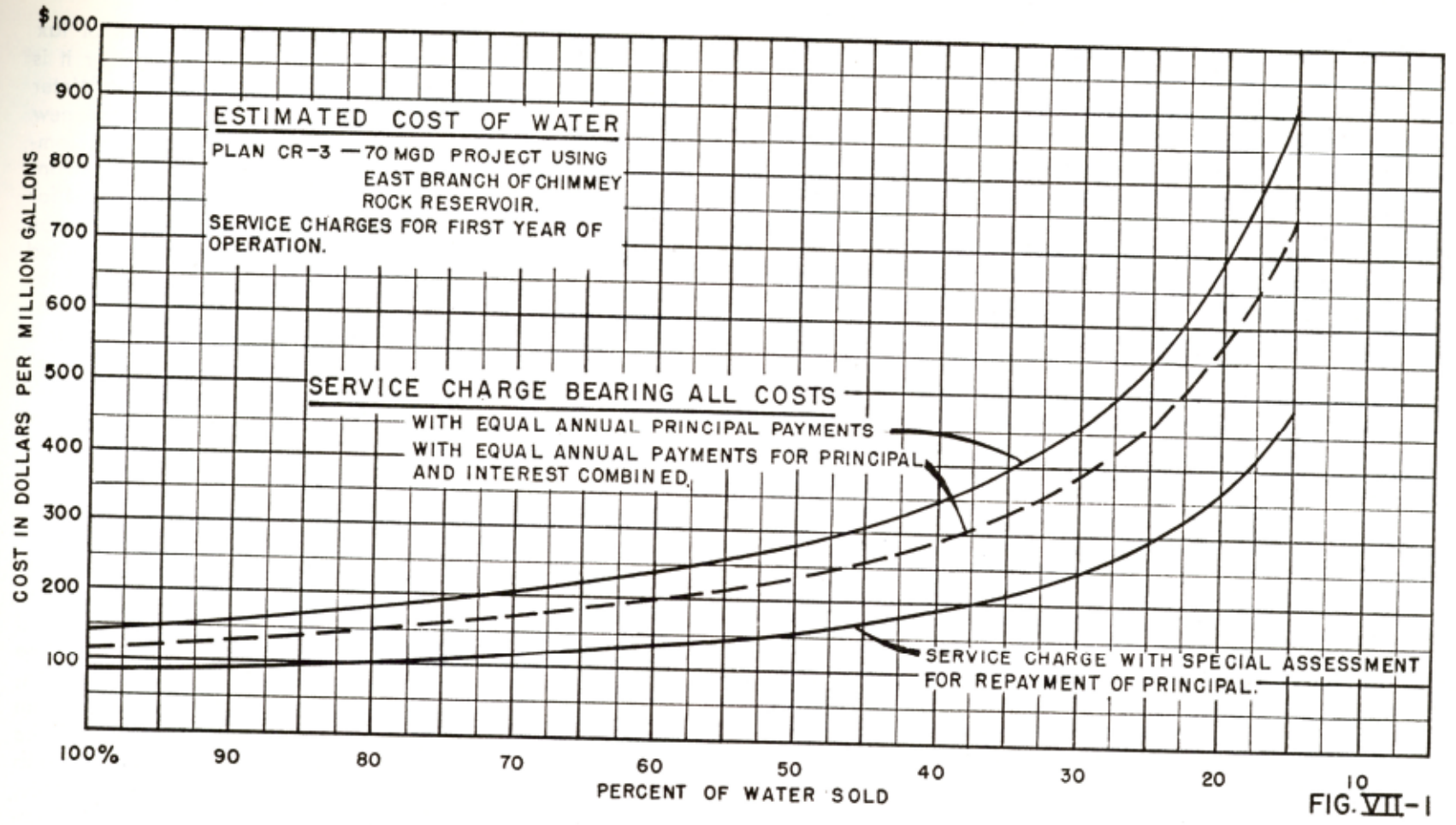


FIG. VII-1

It is apparent from the above data that a tax subsidy amounting to the annual amortization of principal only would enable water to be sold at a price of $150 per million gallons when such a project as Plan CR-3 was being used at about 55 percent of its capacity. Other possible combinations of price, demand and subsidy may be developed from the data presented.

WORKING CAPITAL

The State Water Agency should, if possible, have some working capital so that it may begin immediately the short-range improvement of existing systems through interconnections, dams, reservoirs, etc. with a minimum addition to the needed bond issue. To this end, the Legislature may wish to consider the transfer of balances from other State funds which may no longer be needed for their original purposes.

SUMMARY OF ALTERNATIVE FINANCING PLANS

Alternative financing for water supply projects would be feasible as follows:

1. General state credit and general revenues could properly underwrite the capital cost and operating deficits of the new supplies.

2. General state credit and a special revenue program could equitably apportion the capital costs and operating deficits among users and non-users roughly in proportion to their respective use, need, and benefit as follows: (a) wholesale supply charges which will be reflected in rates charged directly to users in recognition of their direct use and benefit, (b) a state assessment of capital costs to property within the area of special benefit of each project, and (c) a uniform water use and diversion fee (extending the present diversion tax) in recognition of the state-wide general need and benefit of the program.

3. Working capital provided from existing State funds in recognition of the general state interest in the problem.

ADDITIONAL LEGISLATION

To strengthen the powers of the Water Supply Council, it is recommended that legislation be adopted as follows:

1. To establish legislative formulae to compel compensating flows in streams which are to be used for water supply. This would give residents along affected streams a guarantee that their rights will be protected, and should allay the fears of injury from any proposed reservoir construction. It would require a formula which might be based on a percentage of average flow, on a fixed rate of flow per square mile of drainage area, or similar method. As a fixed legislative rule it would provide a firm assurance of minimum riparian flows which may not necessarily be offered under the present power of the State Water Policy and Supply Council to establish minimum releases in streams that are dammed for water supplies.

2. To assure that the franchises of water supply systems now operating are being used in accordance with their terms and particularly that local supply and distribution facilities are fully adequate to meet all requirements, including those in peak demand. This may, in part, be an economic problem where improvement in local distribution would require large capital expenditures without greatly increasing revenues. The legislation should provide assurance that the terms of existing franchises will be maintained and should include adequate penalties for failure to do so over any extended period of time, even to the extent of revocation for repeated and prolonged violation.

3. To assure that ground-water supplies contemplated and reserved for future public development, as well as existing supplies from sub-surface sources, will not be jeopardized or encroached upon by large users or sources of pollution. This will require a review of existing "protected area" legislation so as to expand and strengthen its effect.

4. To clarify the respective responsibilities of the Water Policy and Supply Council and the Public Utilities Commission in the field of water utility regulation.

APPENDIX A

DELAWARE BASIN STREAMS

CUMULATIVE RUNOFF IN BILLION GALLONS

YEARS BY MONTHS

RANCOCAS CREEK NEAR CENTRETON (DRAINAGE AREA 304 SQ.MI.)

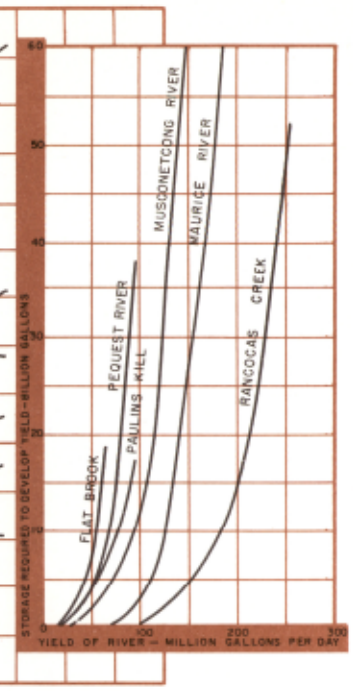
MAURICE RIVER AT MILLVILLE (DRAINAGE AREA 217 SQ.MI.)

MUSCONETCONG RIVER NEAR BLOOMSBURY (DRAINAGE AREA 143 SQ.MI.)

PAULINS KILL NEAR BLAIRSTOWN (DRAINAGE AREA 128 SQ.MI.)

PEQUEST RIVER AT PEQUEST (DRAINAGE AREA 108 SQ.MI.)

FLAT BROOK NEAR FLATBROOKVILLE (DRAINAGE AREA 65 SQ.MI.)



ATLANTIC BASIN STREAMS

PASSAIC RIVER AT PATERSON (DRAINAGE AREA 785 SQ.MI.)

RARITAN RIVER AT BOUND BROOK (DRAINAGE AREA 779 SQ.MI.)

MULLICA AND WADING RIVERS (COMBINED) NEAR BATSTO AND HARRISVILLE (DRAINAGE AREA 409 SQ.MI.)

GREAT EGG HARBOR RIVER AT EMMELVILLE (DRAINAGE AREA 195 SQ.MI.)

HACKENSACK RIVER AT NEW MILFORD (DRAINAGE AREA 113 SQ.MI.)

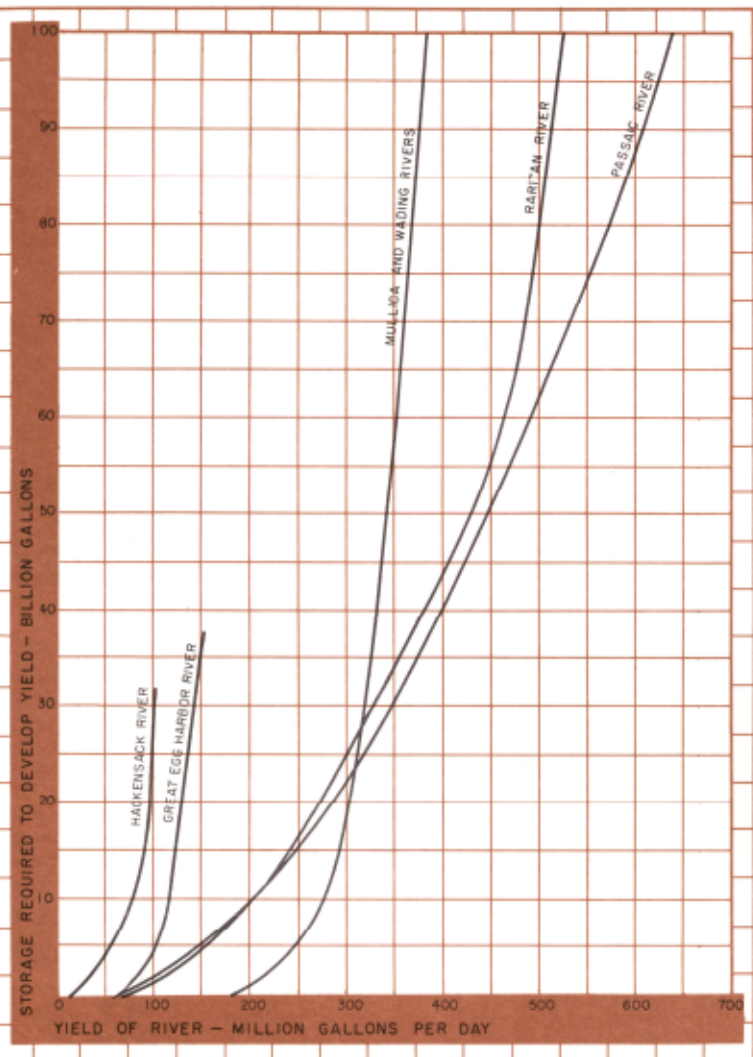


PLATE A-1
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY

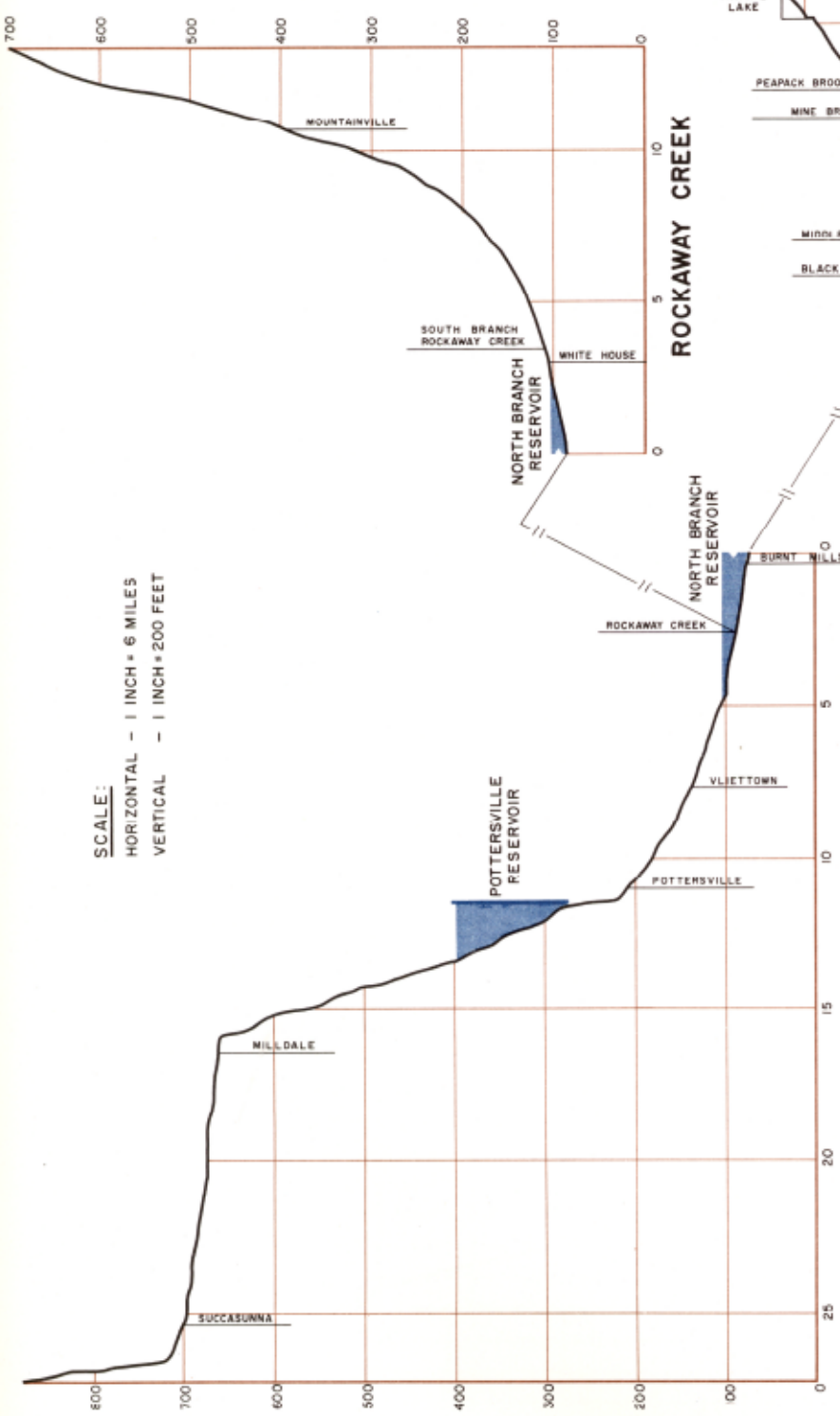
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS
NEW YORK

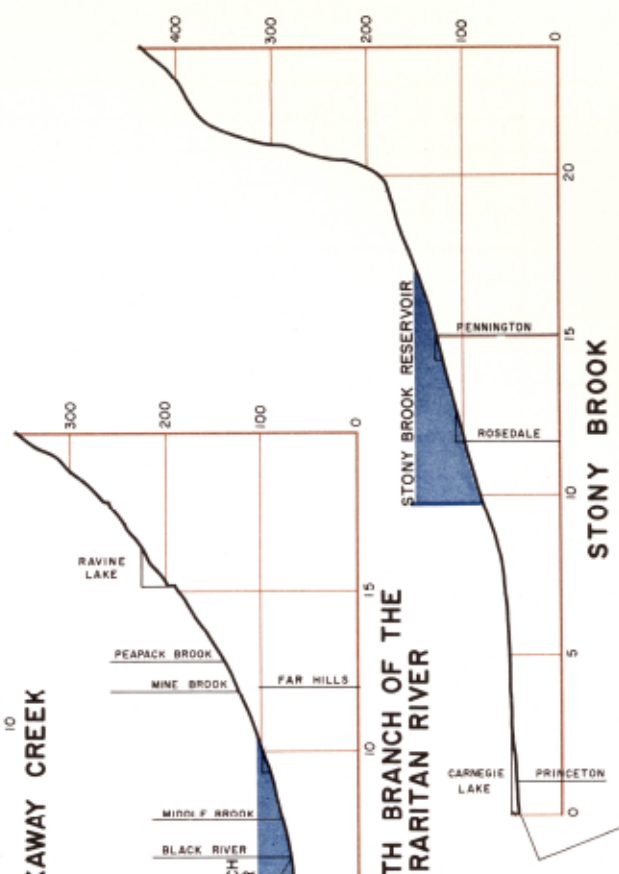
NEW JERSEY WATER RESOURCES DEVELOPMENT

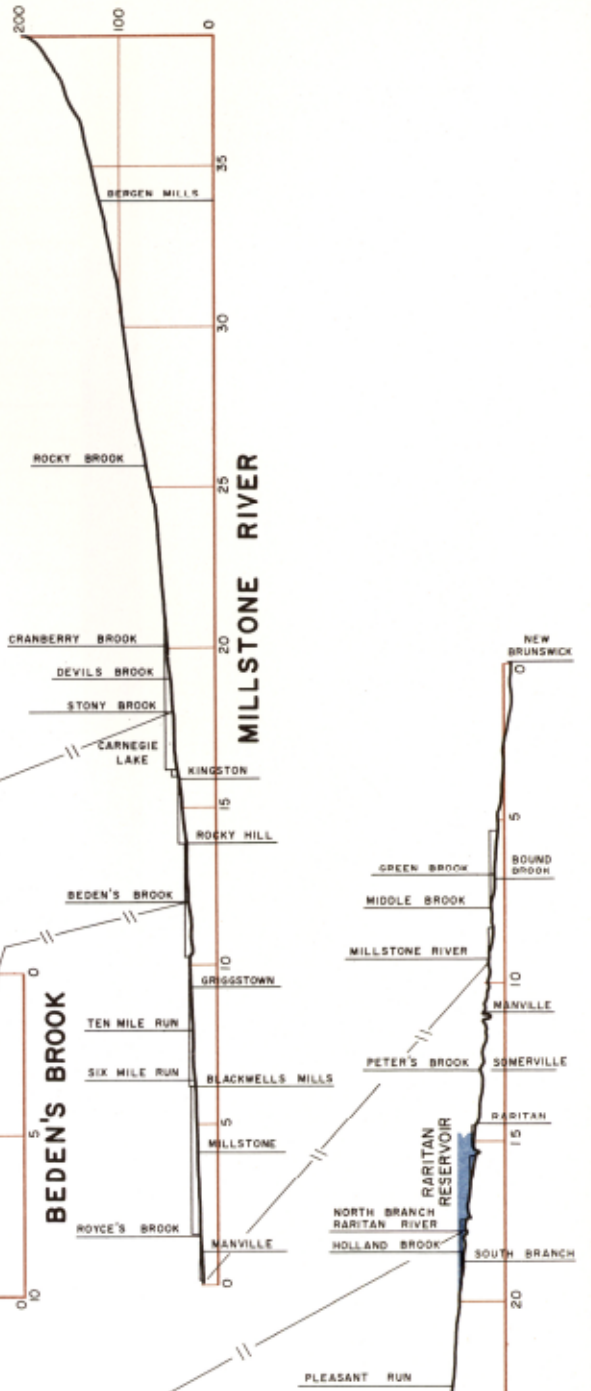
MASS HYDROGRAPHS AND STORAGE - YIELD CURVES

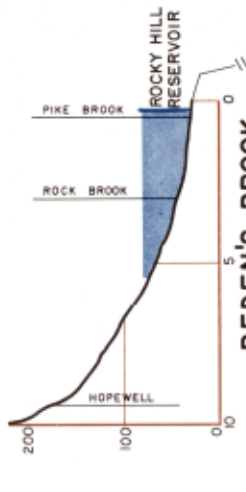
(BASED ON MONTHLY STREAM FLOW RECORDS)

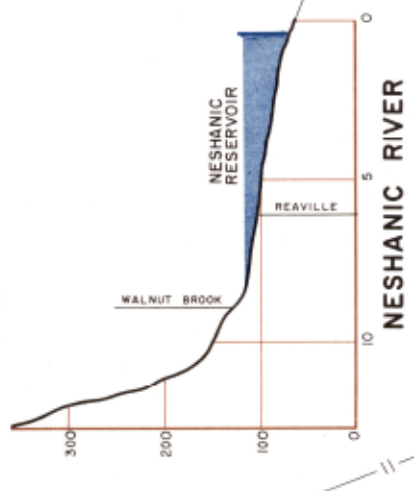
SCALE:
HORIZONTAL – 1 INCH = 6 MILES
VERTICAL – 1 INCH = 200 FEET

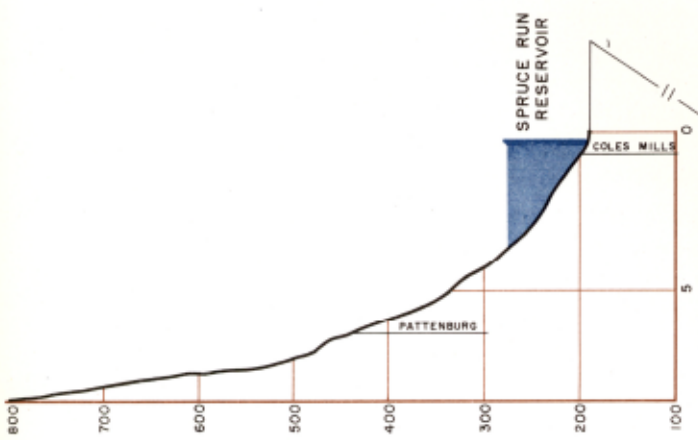


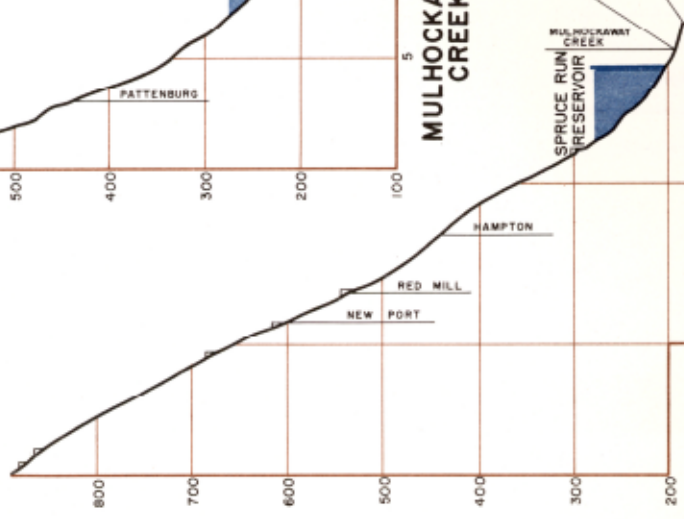










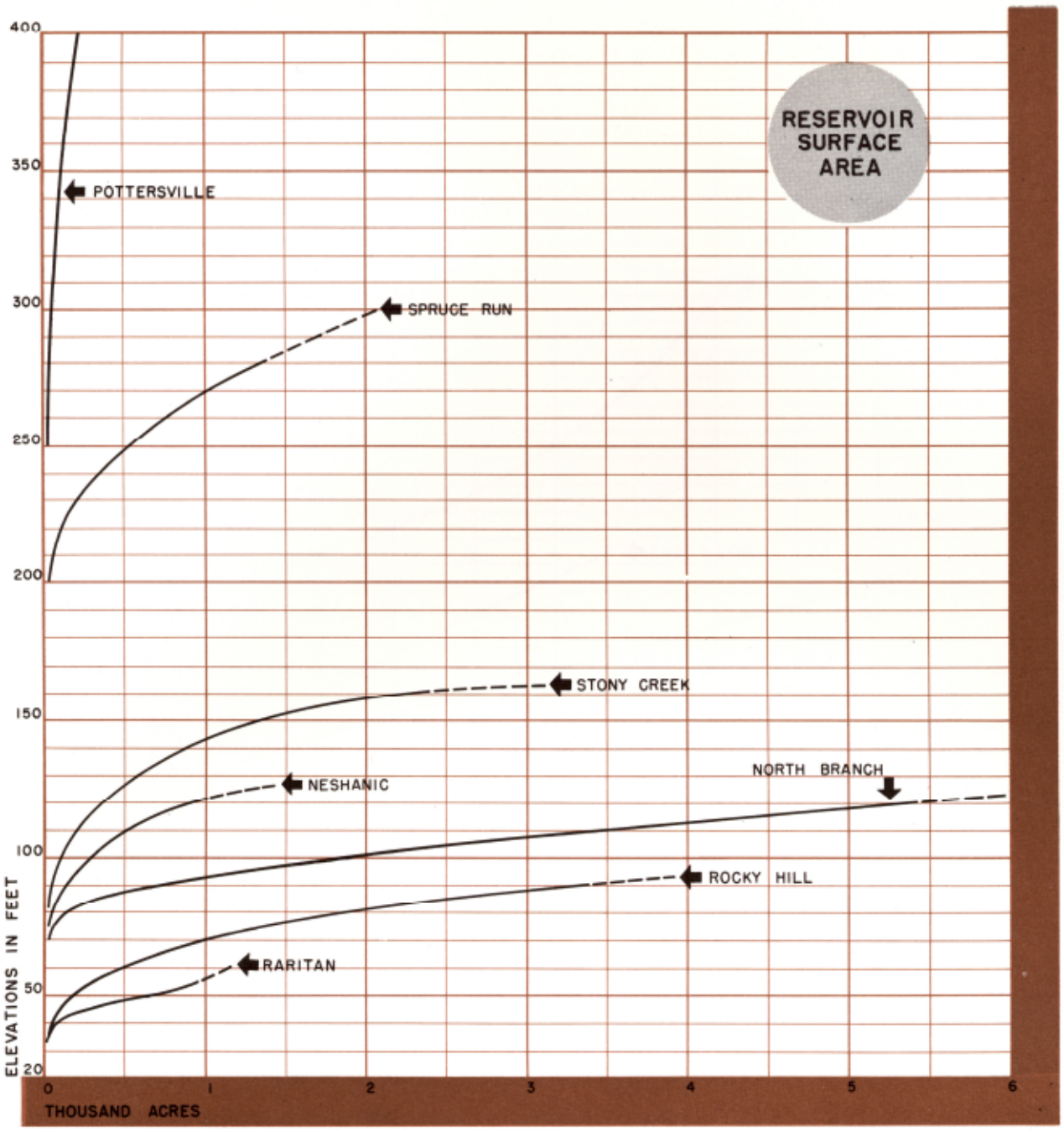


STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS – ABBETT – McCARTHY – STRATTON
ENGINEERS
NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

STREAM PROFILES – RARITAN RIVER BASIN

PLATE
A-2
12-1955



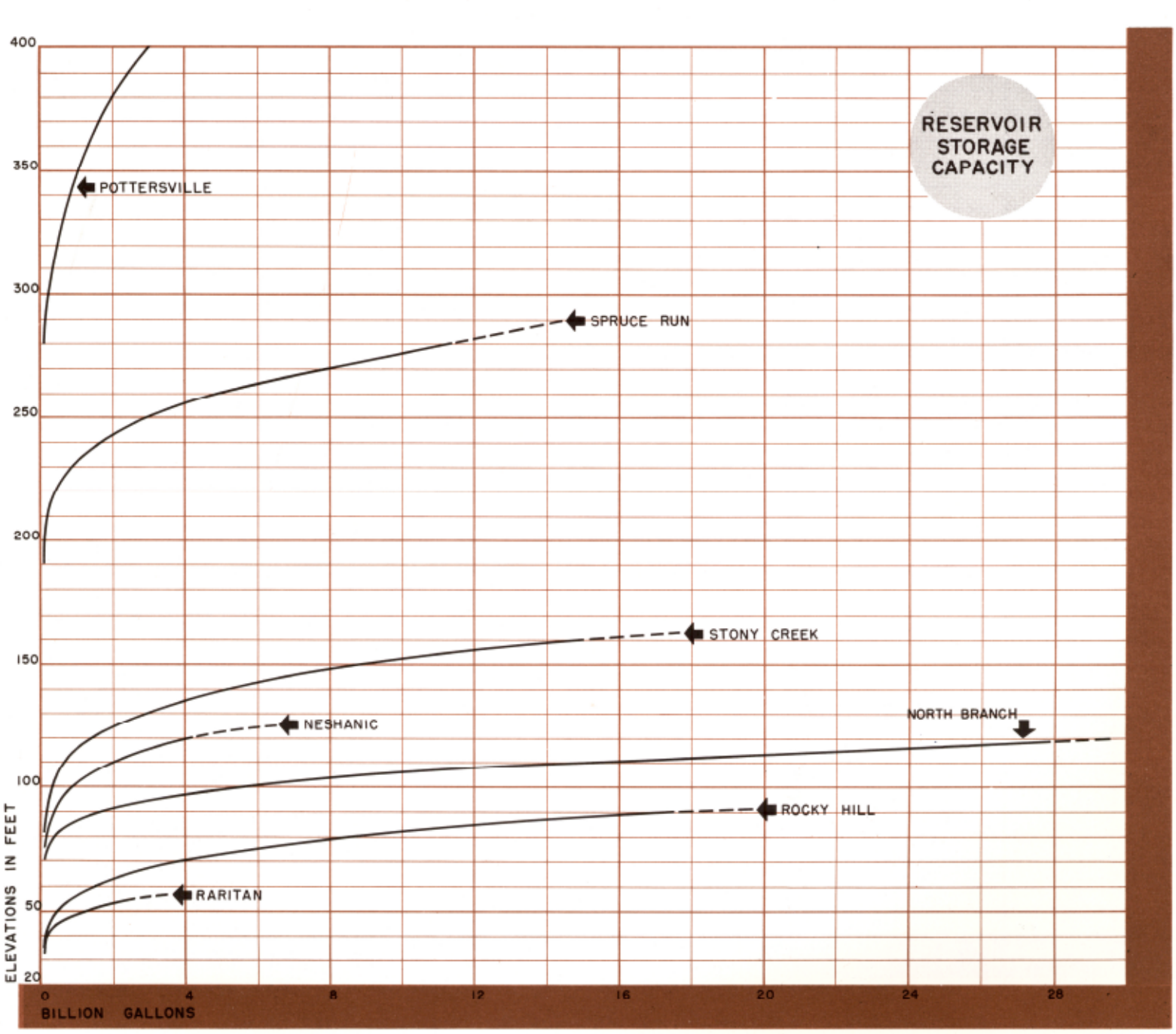


PLATE
A-3
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY

TIPPETTS - ABBETT - McCARTHY - STRATTON
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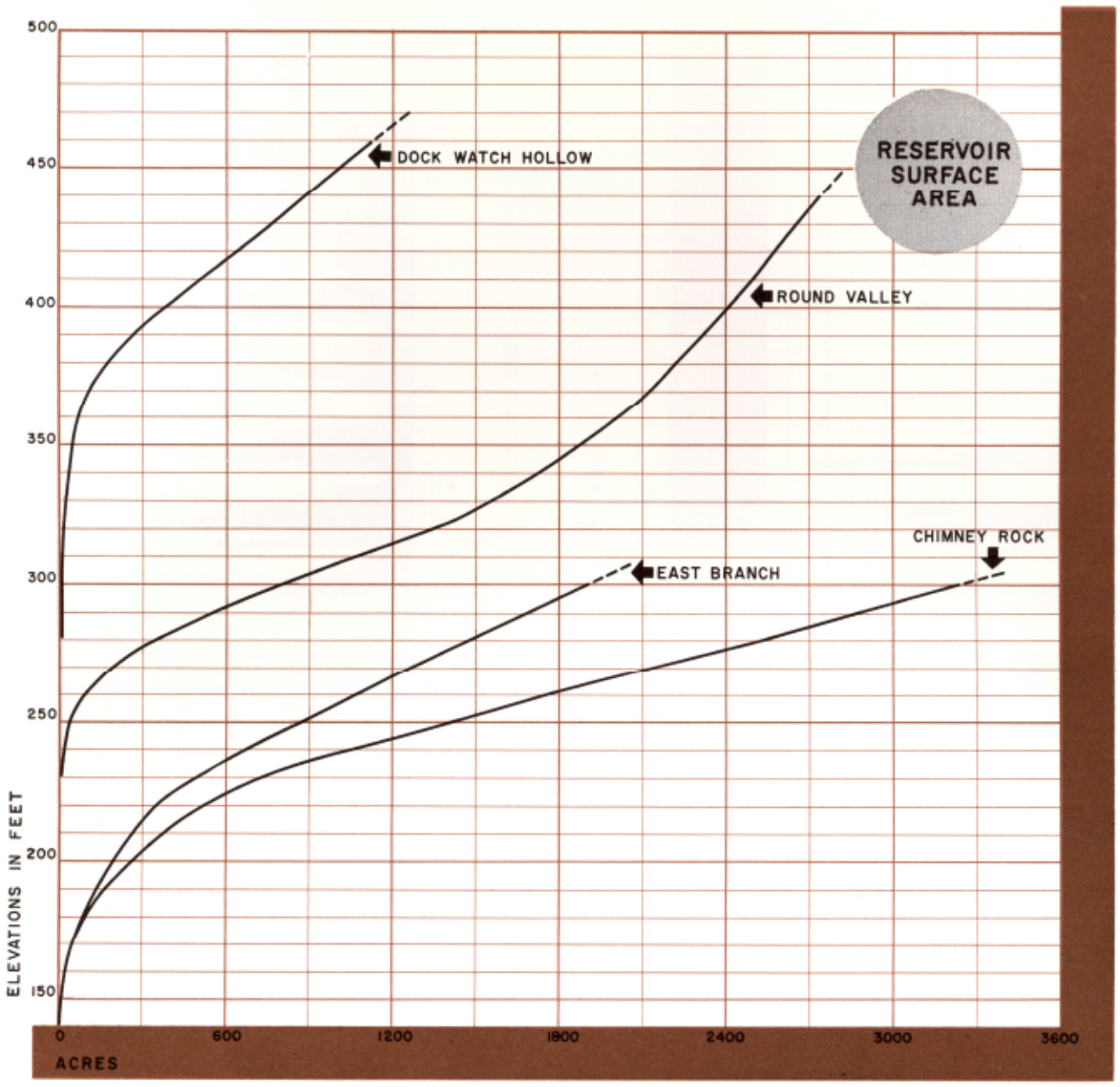
NEW JERSEY WATER RESOURCES DEVELOPMENT

AREA AND CAPACITY CURVES

RARITAN RIVER BASIN ON-RIVER RESERVOIR SITES



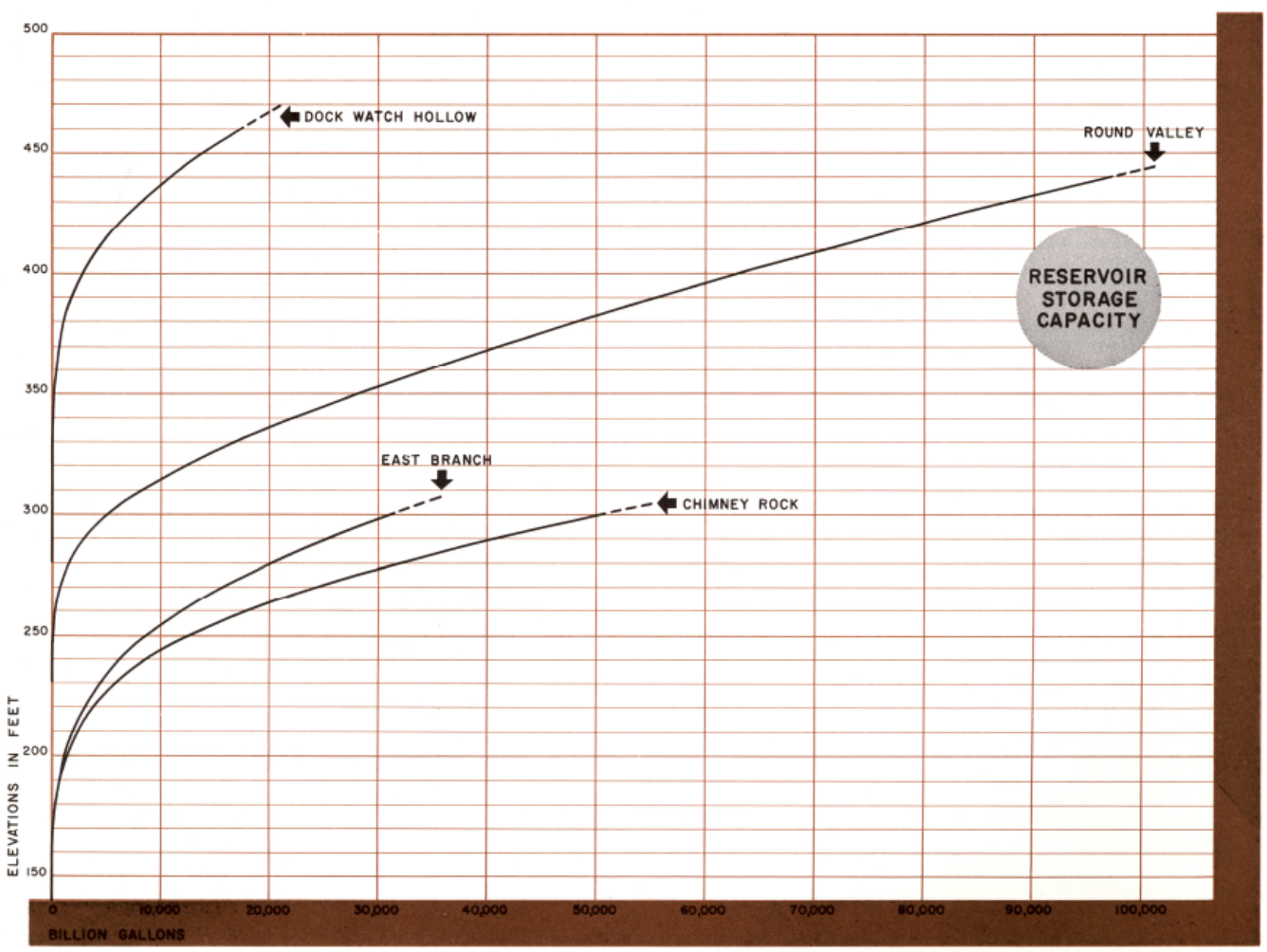


PLATE
A-4
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS
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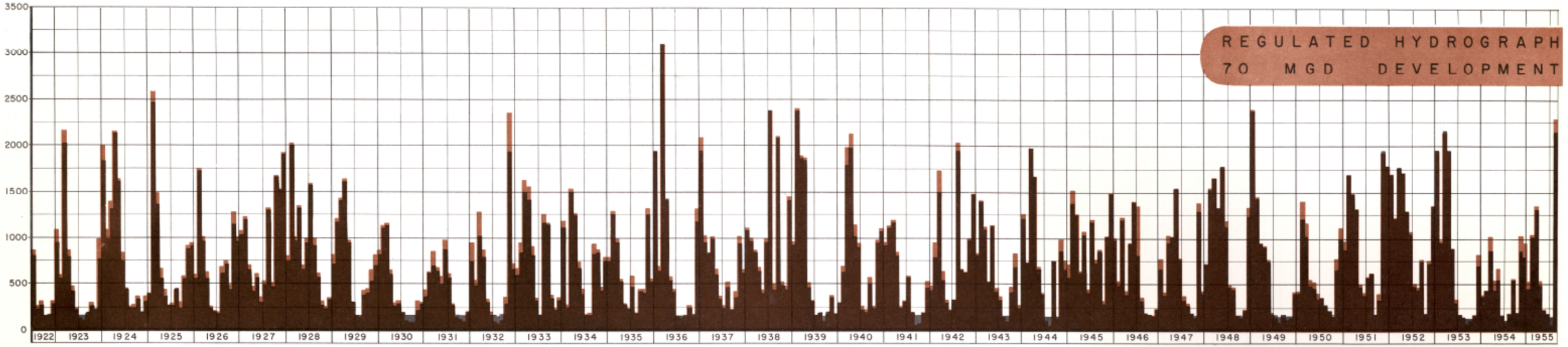
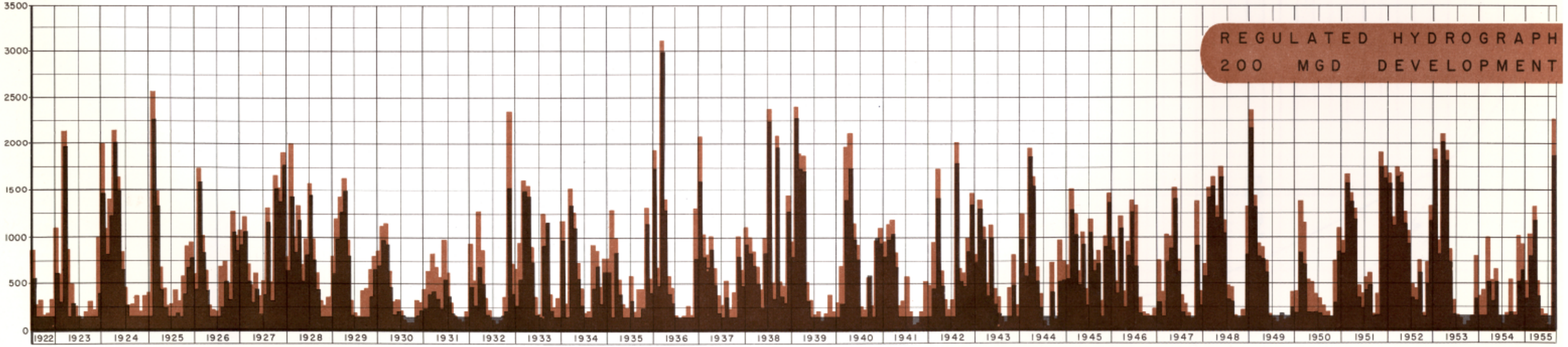
NEW JERSEY WATER RESOURCES DEVELOPMENT

AREA AND CAPACITY CURVES

RARITAN RIVER BASIN OFF-RIVER RESERVOIR SITES

MONTHLY AVERAGE FLOW IN MGD





YEARS (BY MONTH)

UNREGULATED FLOW

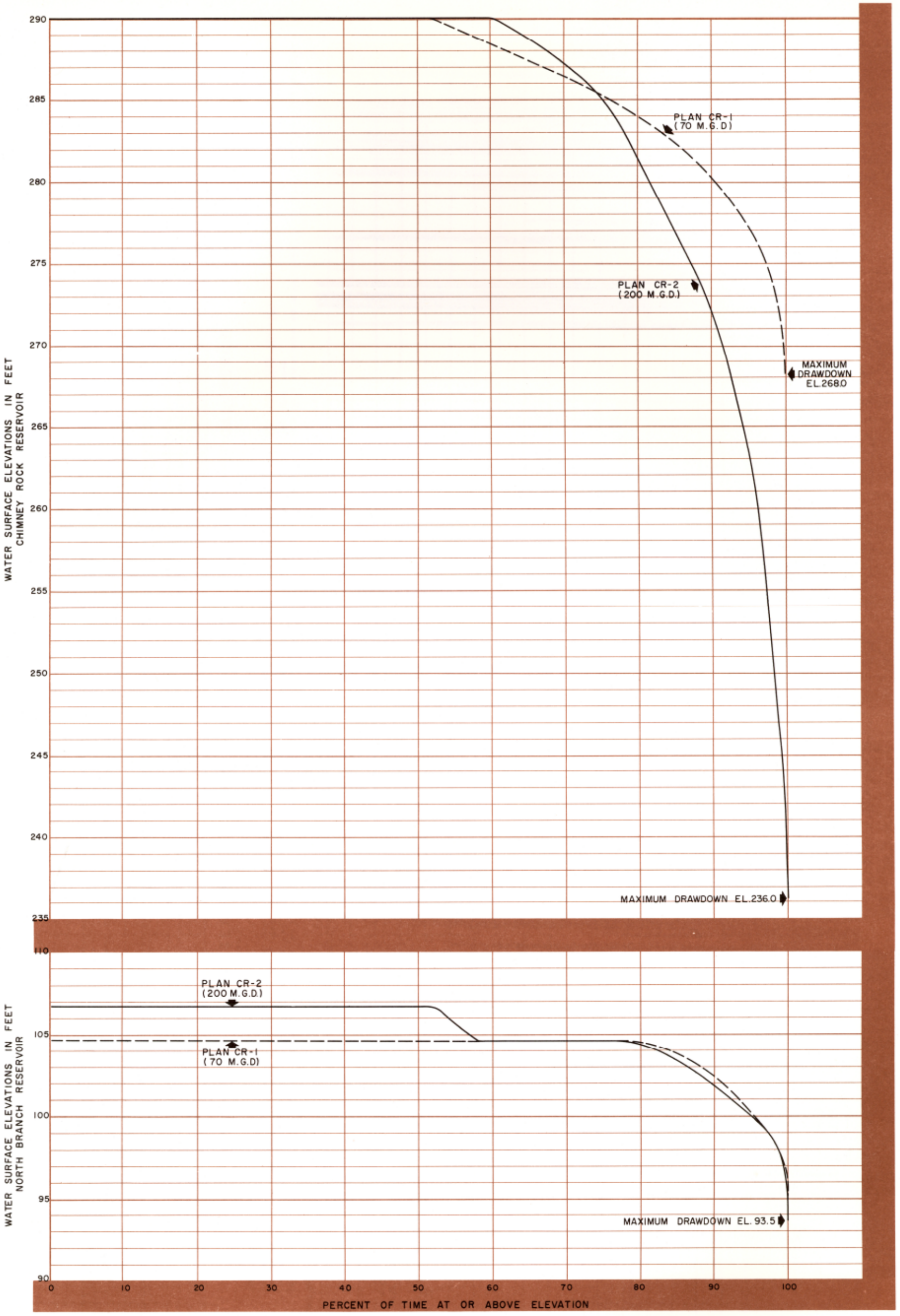
REGULATED FLOW

MONTHLY HYDROGRAPHS
RARITAN RIVER AT BOUND BROOK
1922-1955

TIPPETTS - ABBETT - McCARTHY - STRATTON

PLATE A-5

12-1955



NOTE:
VALUES BASED ON MONTHLY OPERATIONAL STUDIES FOR THE PERIOD FROM JULY 1922 TO JULY 1955

PLATE
A-6
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
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NEW JERSEY WATER RESOURCES DEVELOPMENT

RESERVOIR ELEVATION vs. FREQUENCY
FOR PLANS CR-1 AND CR-2

STATE OF NEW JERSEY | NEW JERSEY WATER RESOURCES DEVELOPMENT

LEGISLATIVE COMMISSION ON WATER SUPPLY

TIPPETTS - ABBETT - McCARTHY - STRATTON
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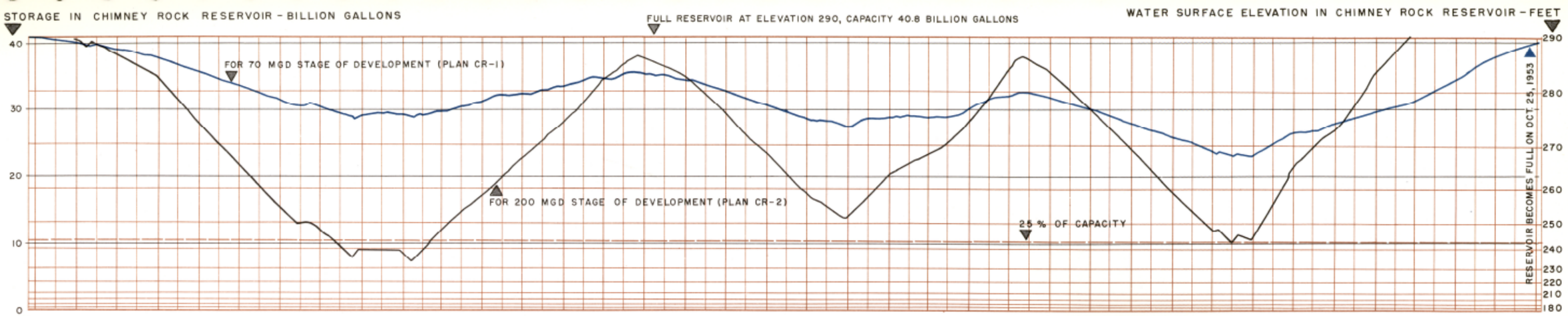
CHIMNEY ROCK - RARITAN RIVER OPERATION 1930 - 1933



CHIMNEY ROCK RESERVOIR - STORAGE FLUCTUATIONS - 1930-1933 CRITICAL PERIOD

FLOWS EXCEEDING 2300 MGD

| | | |

STATE OF NEW JERSEY

NEW JERSEY WATER RESOURCES DEVELOPMENT

LEGISLATIVE COMMISSION ON WATER SUPPLY

NORTH BRANCH RARITAN RIVER OPERATION 1930-1933

TIPPETTS - ABBETT - McCARTHY - STRATTON
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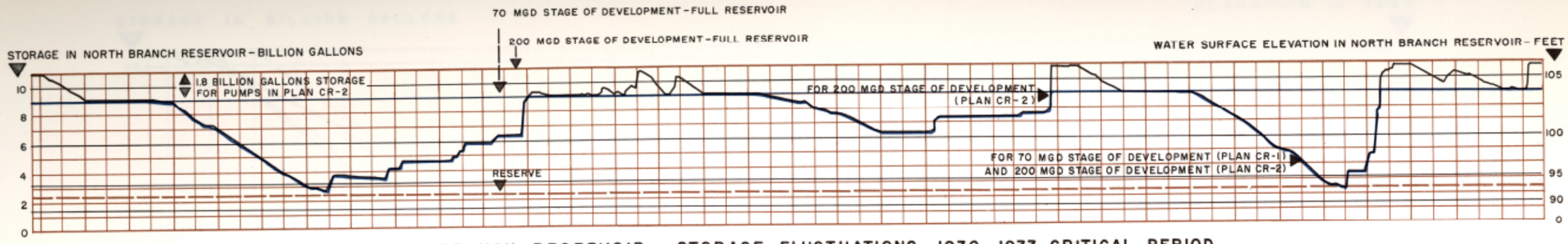
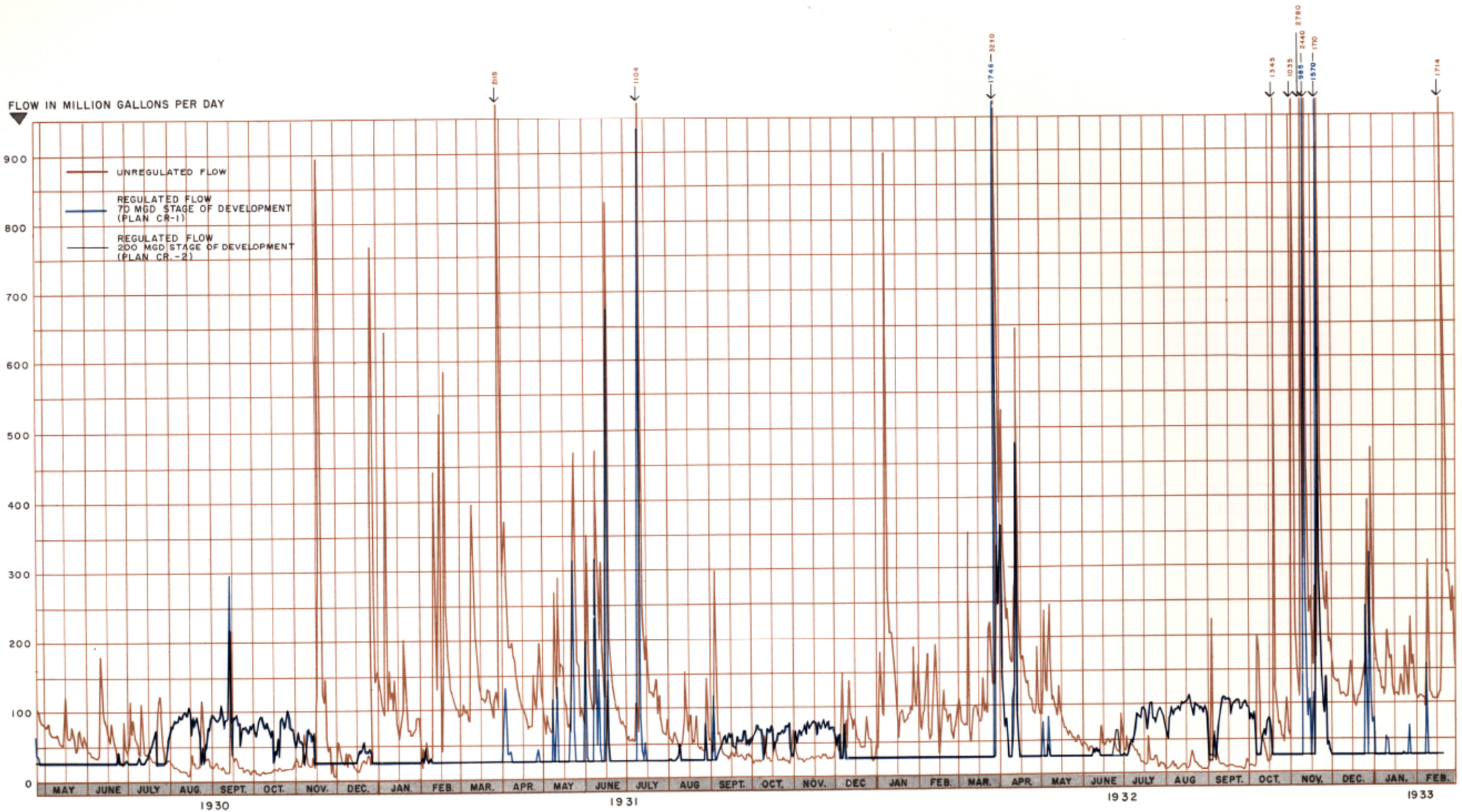
PLATE
A-8
12-1955



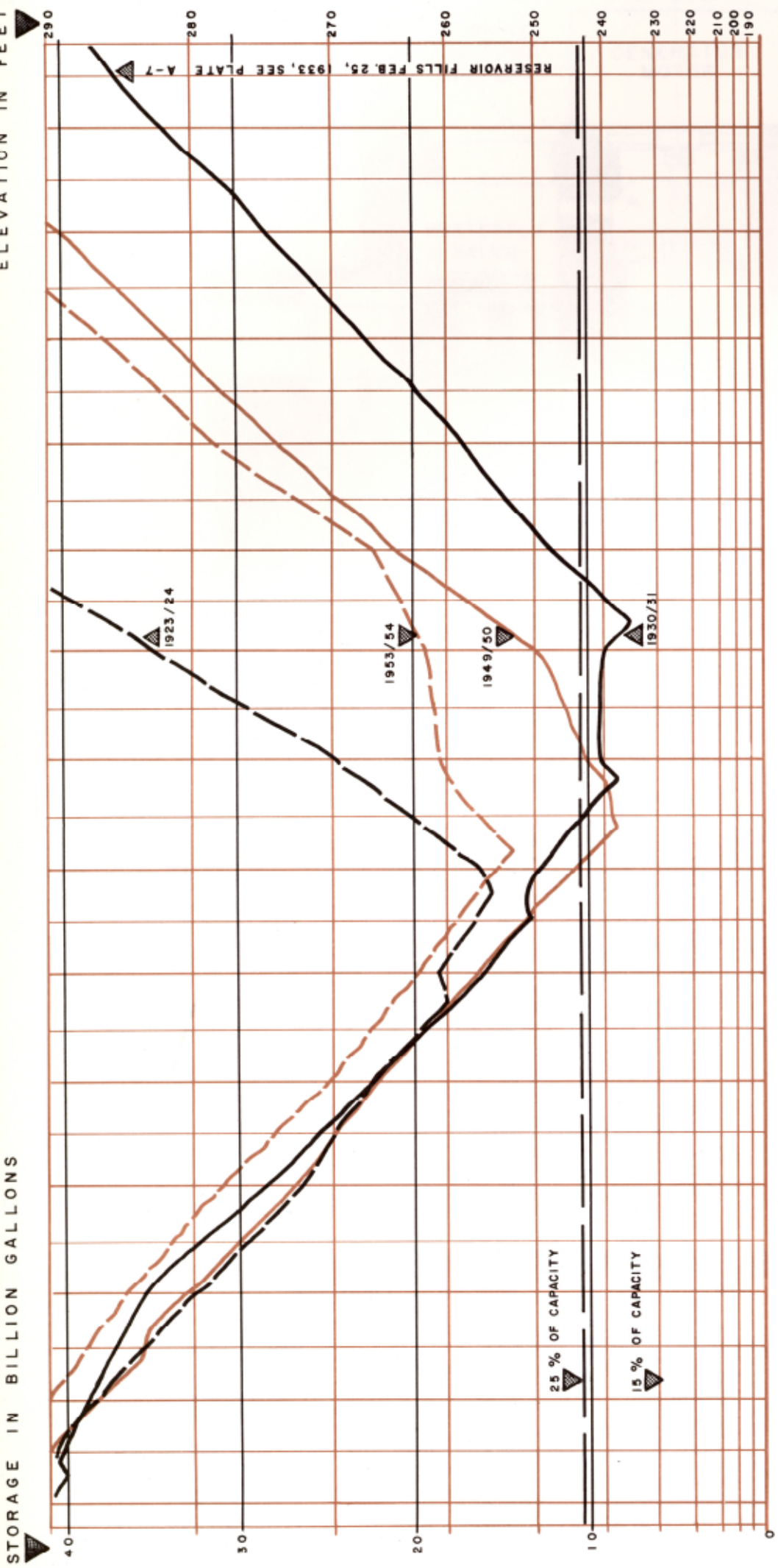
NORTH BRANCH RESERVOIR - STORAGE FLUCTUATIONS - 1930 - 1933 CRITICAL PERIOD



DAILY HYDROGRAPH - NORTH BRANCH OF RARITAN RIVER - 1930 - 1933 CRITICAL PERIOD

NOTE THESE GRAPHS DO NOT REFLECT THE ADDITIONAL WATER NECESSARY TO COMPENSATE FOR IRRIGATION USE. IF THIS IS PROVIDED FOR IN THE NORTH BRANCH RESERVOIR THE FLOW LINE ELEVATION WOULD BE INCREASED TO 105.3 FT. SEE CHAPTER II OF TEXT.

STORAGE FLUCTUATIONS – CHIMNEY ROCK RESERVOIR



STORAGE FLUCTUATIONS – NORTH BRANCH RESERVOIR

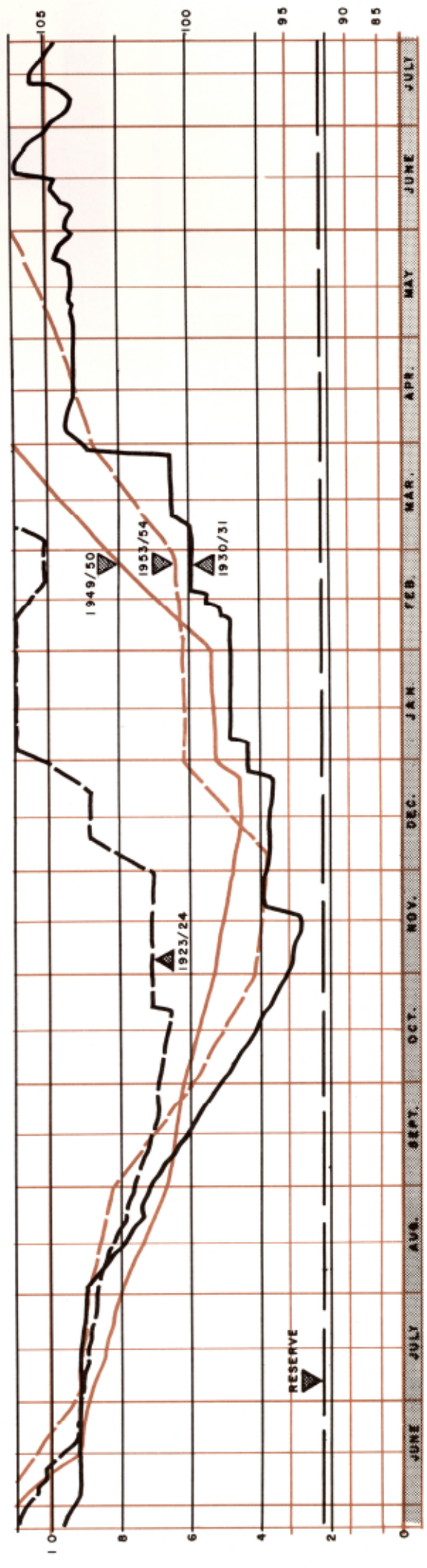


PLATE
A-9
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
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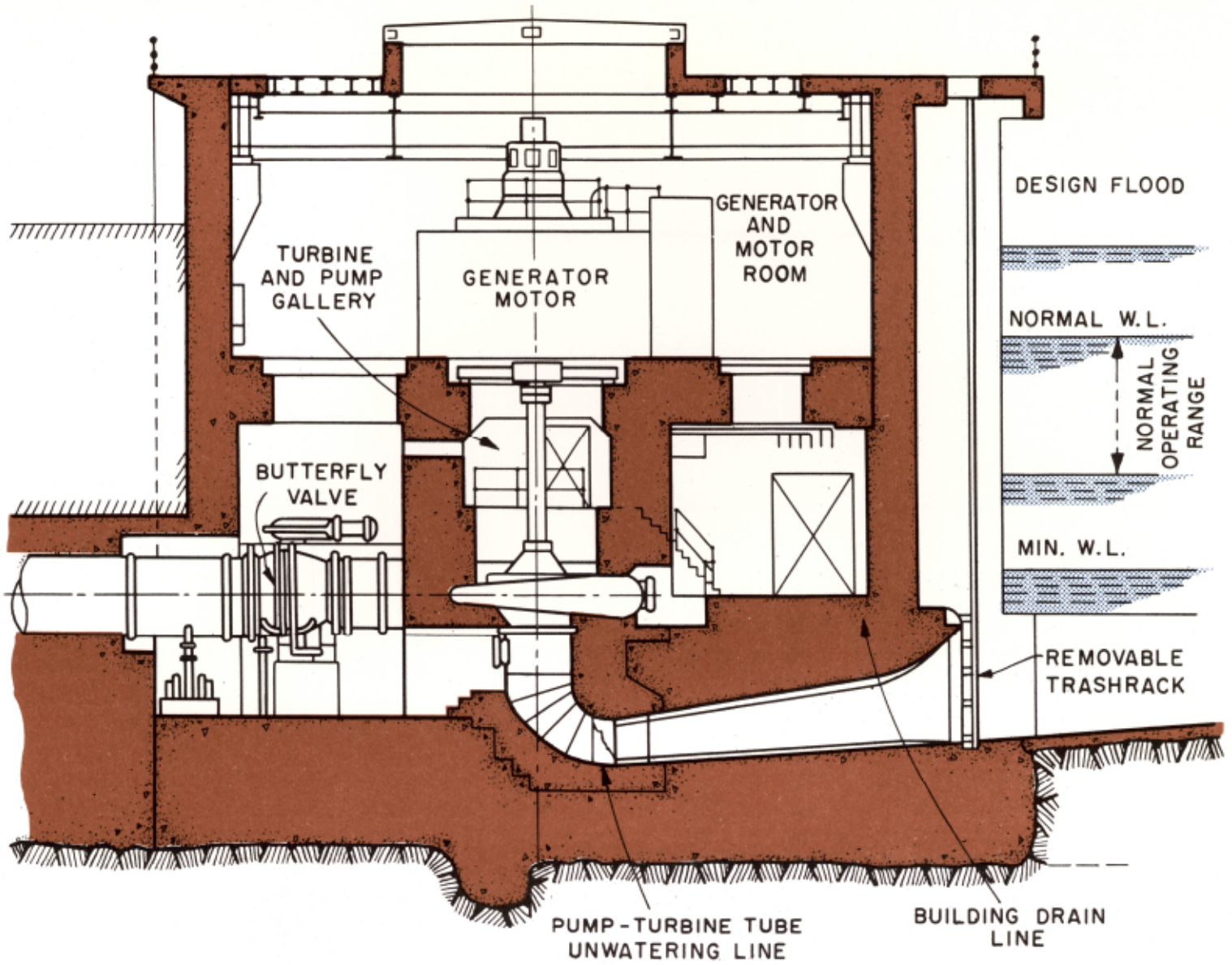
NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

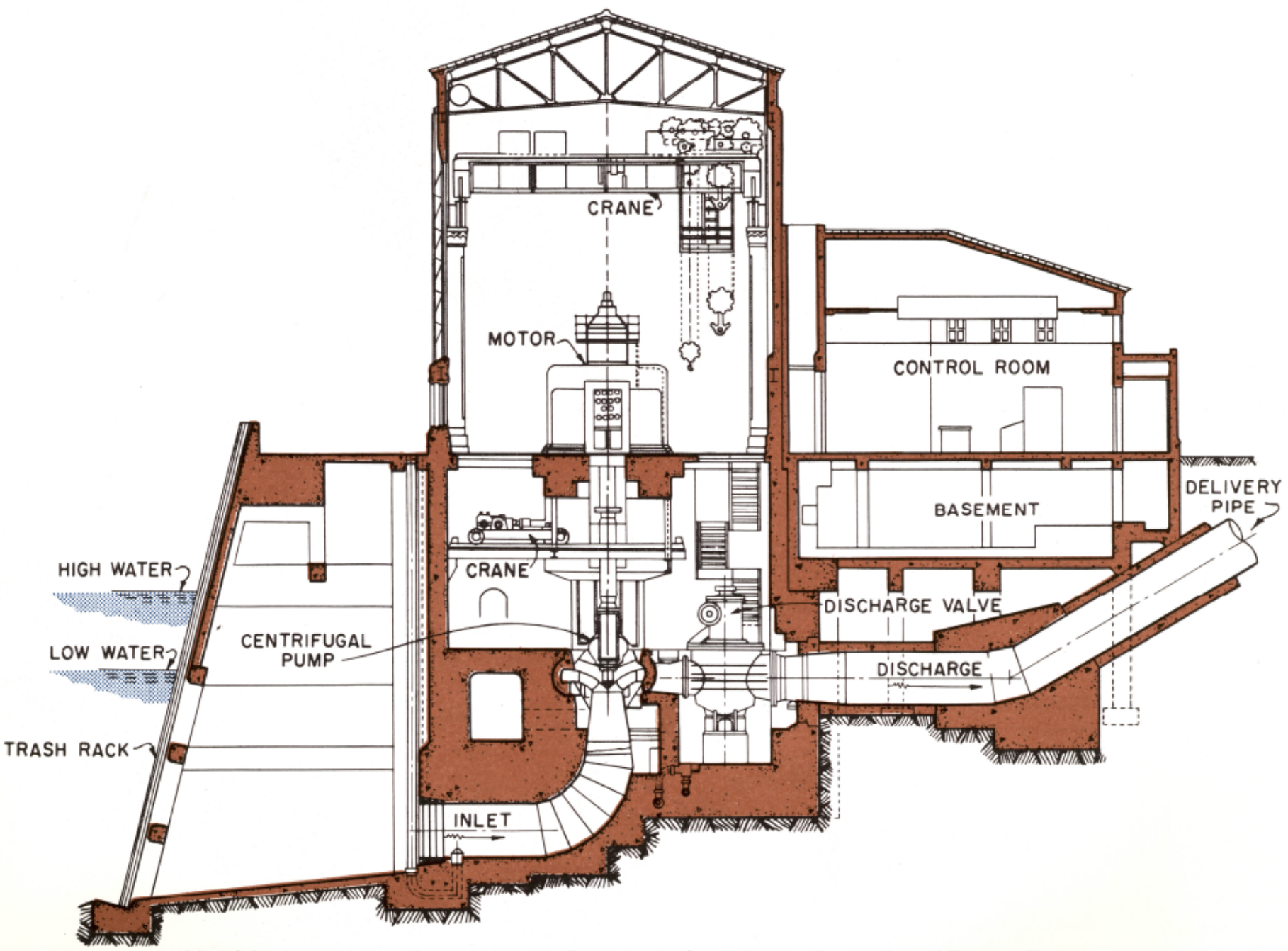
RESERVOIR OPERATION DURING CRITICAL DROUGHT PERIODS
PLAN CR-2 (200 MGD YIELD)



CROSS SECTION THROUGH A TYPICAL PUMP-TURBINE INSTALLATION

10 0 10 20 30

SCALE IN FEET



CROSS SECTION THROUGH A TYPICAL PUMPING PLANT INSTALLATION

10 0 10 20 30

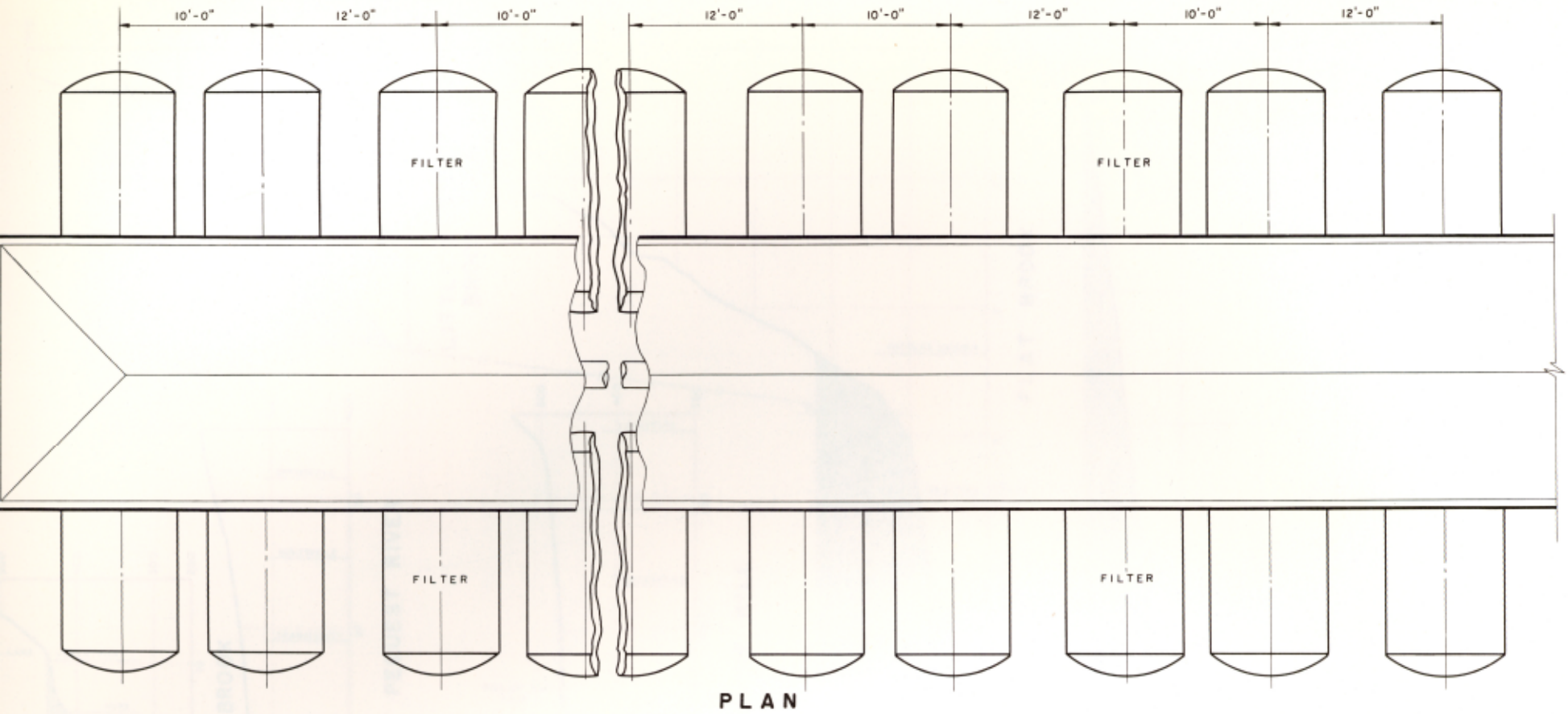
SCALE IN FEET

PLATE
A-10
12-1955

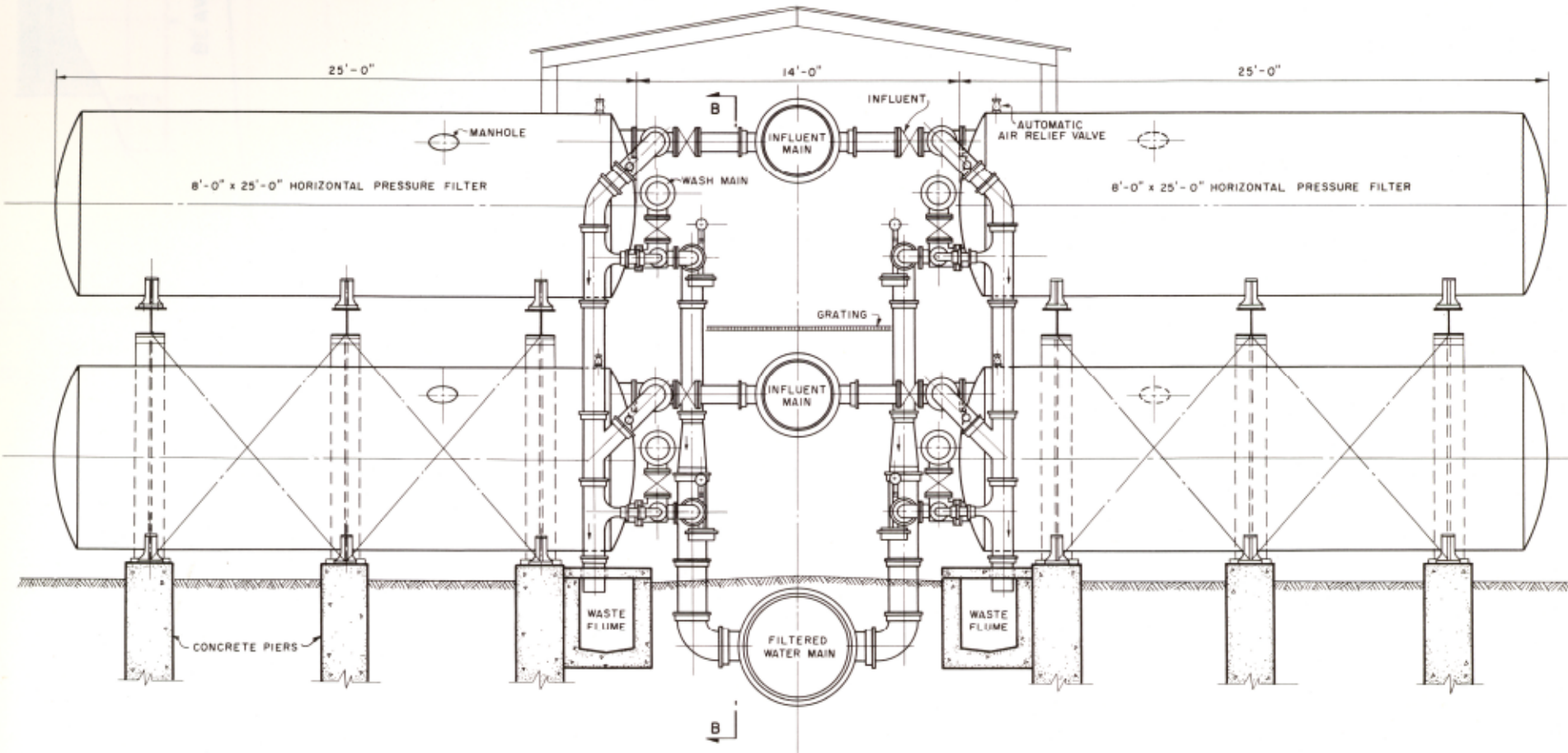
STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON

NEW JERSEY WATER RESOURCES DEVELOPMENT

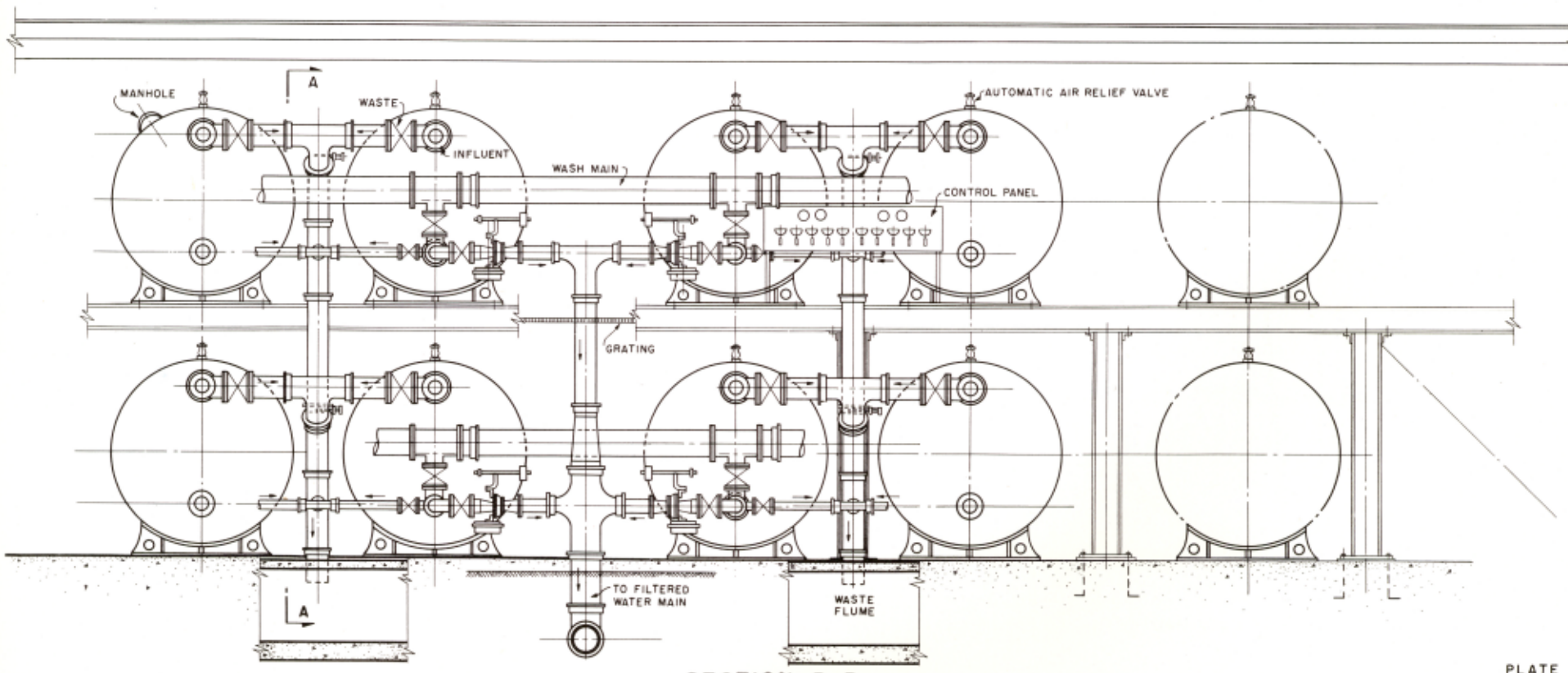
TYPICAL PUMP AND PUMP-TURBINE INSTALLATIONS



PLAN



SECTION A-A



SECTION B-B

PLATE
A-II
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
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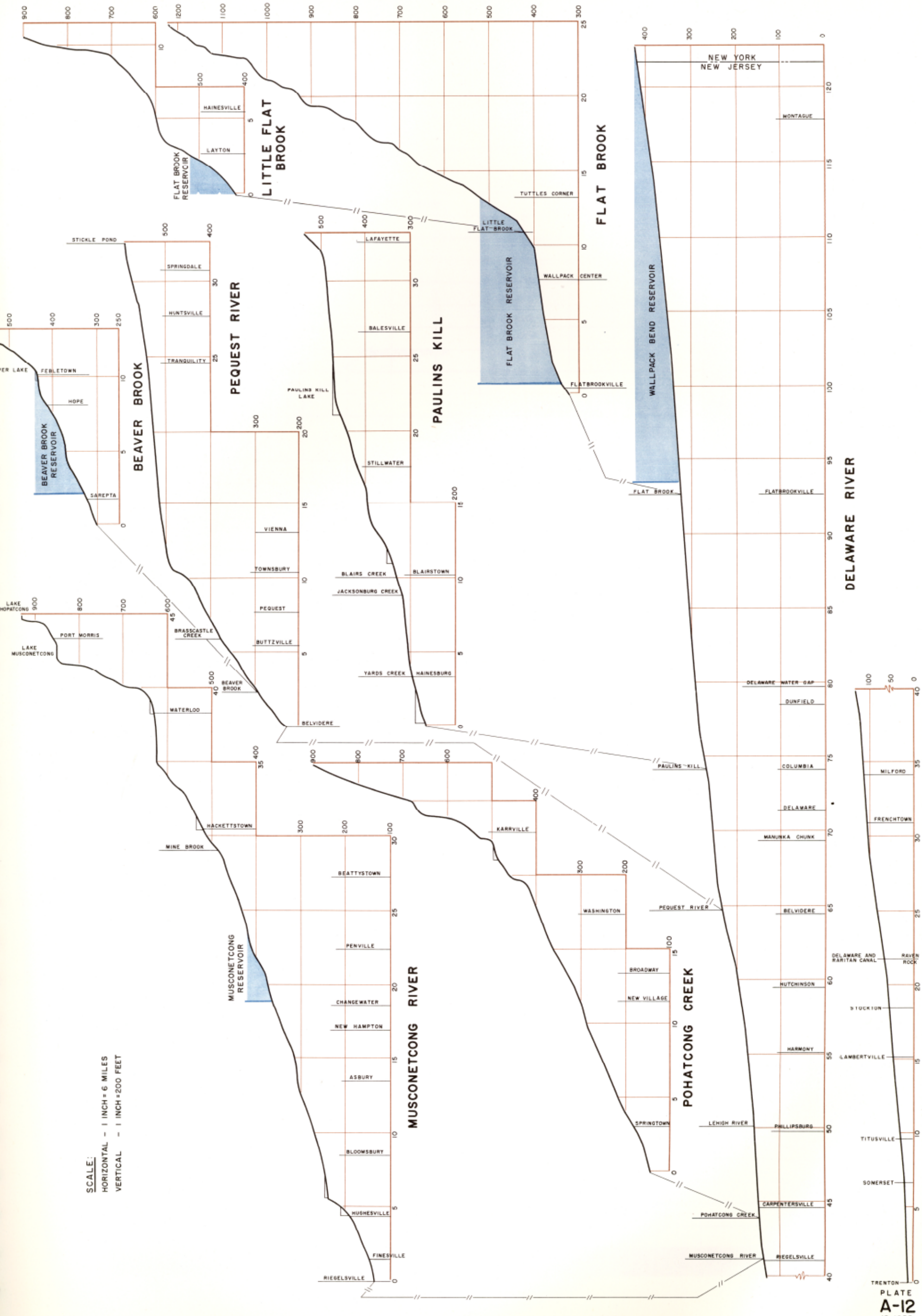
NEW JERSEY WATER RESOURCES DEVELOPMENT

TYPICAL WATER TREATMENT PLANT INSTALLATION



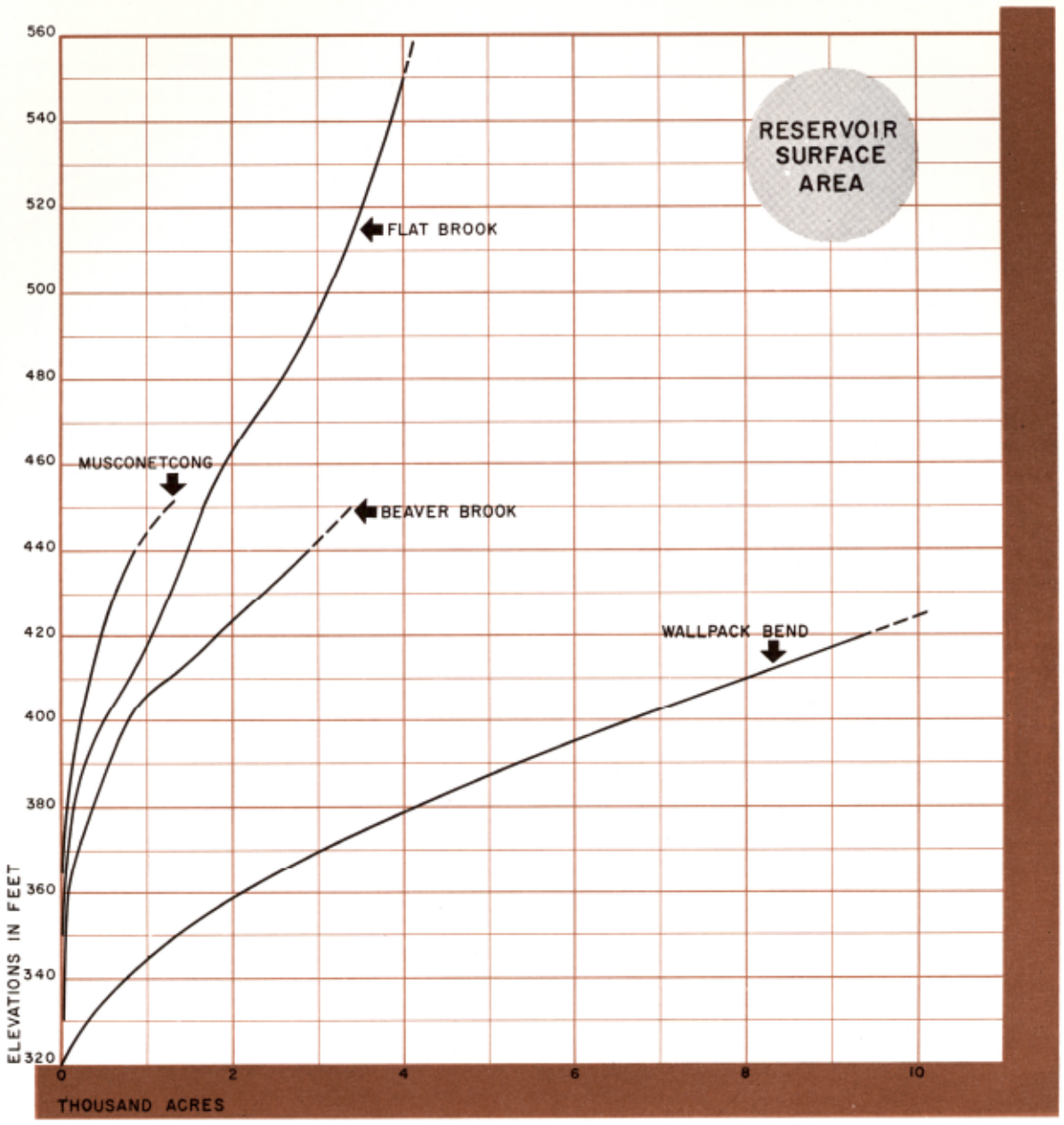
SCALE:
HORIZONTAL - 1 INCH = 6 MILES
VERTICAL - 1 INCH = 200 FEET

PLATE
A-12
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS
NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

STREAM PROFILES - DELAWARE RIVER BASIN



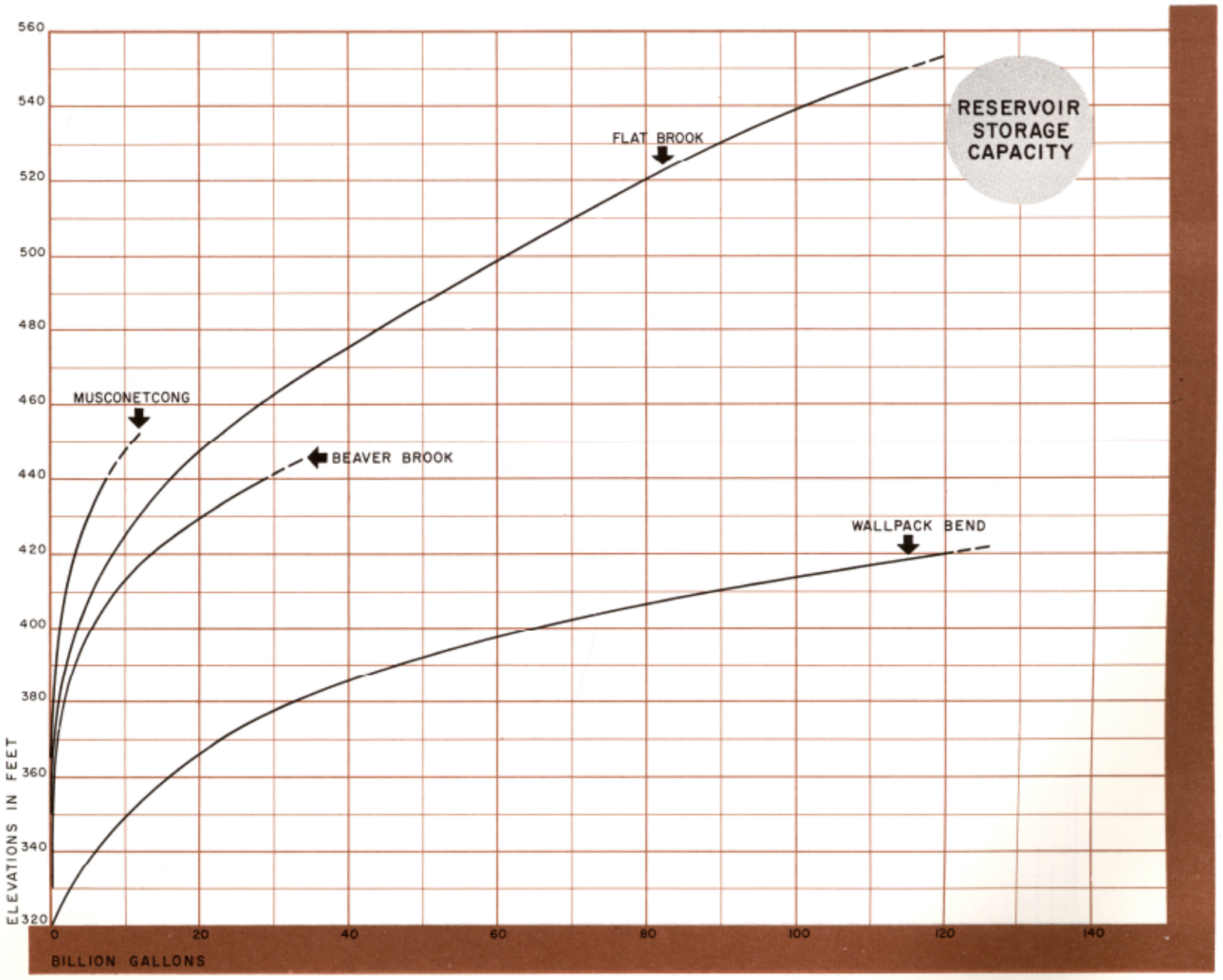


PLATE
A-13
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY

TIPPETTS - ABBETT - McCARTHY - STRATTON
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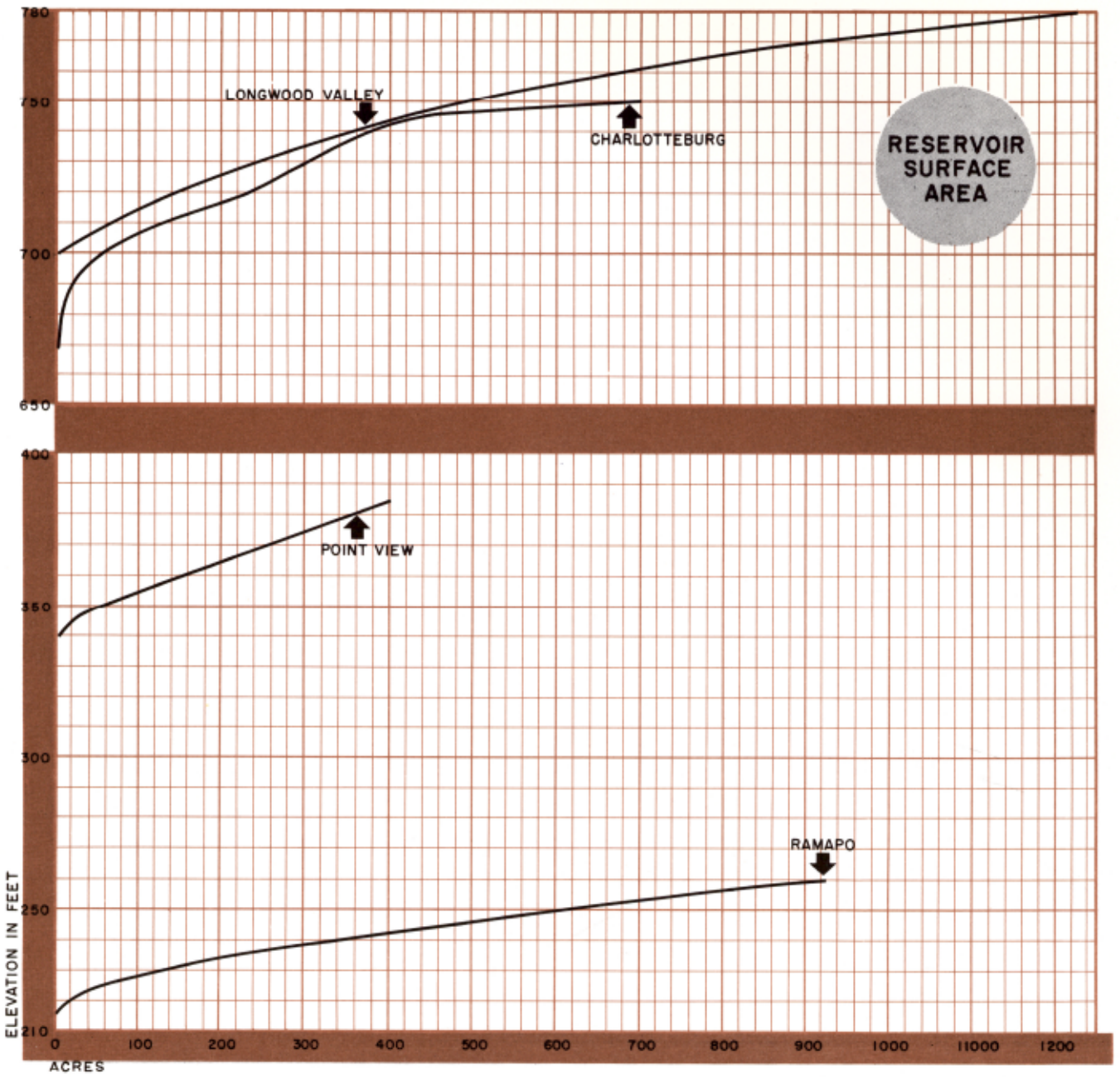
NEW JERSEY WATER RESOURCES DEVELOPMENT

AREA AND CAPACITY CURVES
DELAWARE RIVER BASIN RESERVOIR SITES



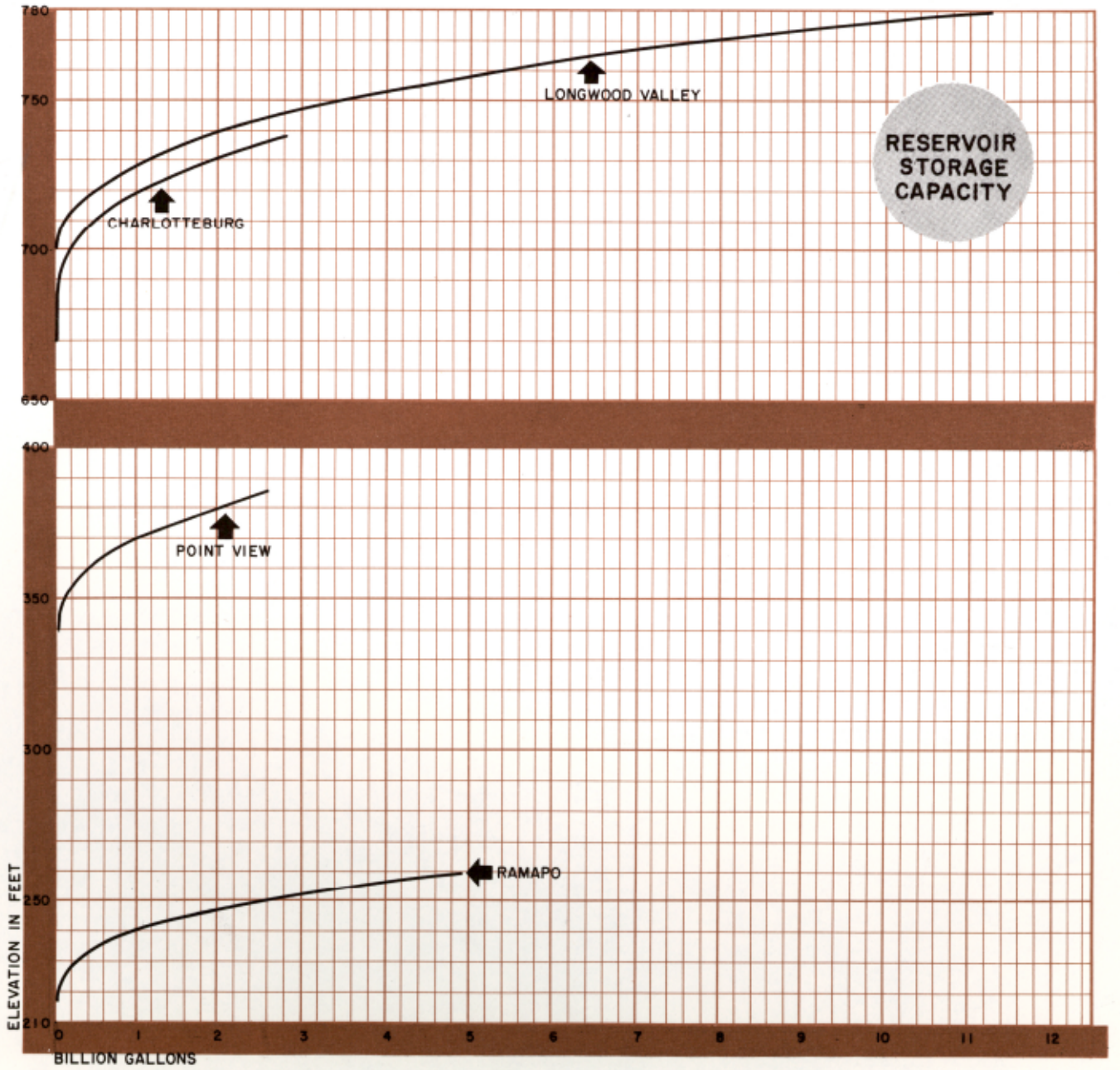


PLATE
A-14
12-1955

STATE OF NEW JERSEY
LEGISLATIVE COMMISSION ON WATER SUPPLY
TIPPETTS - ABBETT - McCARTHY - STRATTON
ENGINEERS
NEW YORK

NEW JERSEY WATER RESOURCES DEVELOPMENT

AREA AND CAPACITY CURVES
PASSAIC BASIN RESERVOIR SITES

APPENDIX B

APPENDIX B

GROUND-WATER INVENTORY

OF

PUBLIC WATER SUPPLIES

IN THE

STATE OF NEW JERSEY

SUMMARY OF GROUND-WATER DIVERSIONS

IN

MILLION GALLONS PER DAY

Year		Coastal Plain Province (Table B-1)	Piedmont Plain Province (Table B-2)	Highlands Province* (Table B-3)	Grand Total
1954	Annual	106.5	74.2	5.1	185.8
	Max. Month	160.7	92.3	7.1	260.1
1953	Annual	108.2	74.5	3.5	186.2
	Max. Month	160.1	88.0	4.8	252.9
1952	Annual	106.8	69.3	3.3	179.4
	Max. Month	154.4	80.8	4.3	239.5
1951	Annual	103.5	64.7	3.2	171.4
	Max. Month	142.5	71.2	4.0	217.7
1950	Annual	98.7	62.6	3.0	164.3
	Max. Month	135.8	70.6	3.8	210.2
1949	Annual	98.1	65.2	2.8	166.1
	Max. Month	142.9	79.6	3.7	226.2

*No data are included from the Appalachian Valley Province as ground-water diversions are negligible.

COASTAL PLAIN GROUND-WATER INVENTORY

NO.	COMPANY LOCATION (County)	STATION	WELL DATA: WELL NO.	DIAM. (Inches)	DEPTH (Feet)	REPORTED WELL YIELD (gpm)	PUMP CAPACITY (gpm)	AQUIFER
CP 1	ALLENTOWN WATER DEPT. Allenhurst (Monmouth)		2	8	550	Wells #1	220	Englishtown
			4	18	550	#2 & #3	525	Englishtown
			1	8	550	TOTAL	200	Englishtown
			3 R	8	470	650	110	Englishtown
CP 2	ALLENTOWN WATER DEPT. Allentown (Monmouth)		1	10	273	260	260	Raritan
CP 3	ASBURY PARK WATER DEPT. Asbury Park (Monmouth)		Layne 1	8	655		200	Englishtown
			Amer. 1	10	1150	908	750	Raritan
			Amer. 2	12	1150		1000	Raritan
CP 4	ATLANTIC CITY WATER DEPT. Atlantic City (Atlantic)	Pleasantville	1	16	675	865	695	Kirkwood "800' sand"
			12	26	200	1390	1250	Cohansey "200' sand"
			3	26	213	1000	765	Cohansey "200' sand"
			5	26				Cohansey "200' sand"
			7	24	200	1250	1110	Cohansey "200' sand"
			9	26	200	1110	1040	Cohansey "200' sand"
			10	26	199	1400	1110	Cohansey "200' sand"
			11	26	199	1400	1180	Cohansey "200' sand"
			2	26	102	1000	1110	Cohansey "100' sand"
			6	26	91	700	1110	Cohansey "100' sand"
			8	26	97	1400	1390	Cohansey "100' sand"
			13	26	95	1110	1040	Cohansey "100' sand"
			4R	26	105	1000	975	Cohansey "100' sand"
CP 5	ATLANTIC COUNTY WATER CO. Somer's Point (Atlantic)	Somer's Point	6	10	99		350	Cohansey
		Somer's Point	3	10	118		350	Cohansey
		Somer's Point	4	12	115		350	Cohansey
	Pleasantville	Delilah Rd.		16	109		600	Cohansey
		Woodland Ave.	1	10	161		600	Cohansey
	Northfield	Mill Rd.	5	10	152		500	Cohansey
CP 6	ATLANTIC HIGHLANDS WATER DEPT. Atlantic Highlands (Monmouth)		1		580		750	Raritan
			2		260		350	Englishtown
			3		580		750	Raritan
CP 7	AVALON WATER DEPT. Avalon (Cape May)		1	12	600		700	Kirkwood
			2	8	900		350	Kirkwood
			3	6	860		150	Kirkwood
CP 8	AVON-BY-THE-SEA WATER DEPT. Avon (Monmouth)		1	6	610		600	Englishtown & Mount Laurel & Wenonah
			2	6	610		400	
			3	8	1140		700	Raritan
CP 9	BARNEGAT WATER CO. Barnegat (Ocean)			8 F	138	500	150	Kirkwood
				4 F	138			
CP 10	BARNEGAT LIGHT WATER CO. Barnegat Light (Ocean)		1	8	585	100	125	Kirkwood
CP 11	BEACH HAVEN WATER DEPT. Beach Haven (Ocean)		6	10	668		1000	Kirkwood
			7	10	664		1000	Kirkwood
CP 12	BEACHWOOD WATER DEPT. Beachwood (Ocean)		2	10	68	150	250	Cohansey
			1R	6	68		250	Cohansey
CP 13	BELMAR WATER DEPT. Belmar (Monmouth)		1	6	600		150	Englishtown
			3	6	600		100	Englishtown
			4	6	600		100	Englishtown
			5	6	600		150	Englishtown
			6	6	600		100	Englishtown
			7	6	600		150	Englishtown
			8	8	600		175	Englishtown
			1	12	600		300	Englishtown
			2	10	600		325	Englishtown
			3	8	600		325	Englishtown
			4	16	600		400	Englishtown
CP 14	BELLMAWR WATER DEPT. Bellmawr (Camden)		1	12	164		700	Raritan
			2	12	162		700	Raritan
CP 15	BERLIN WATER DEPT. Berlin (Camden)		1	8	335		135	Mount Laurel & Wenonah
			7	10	68		200	Cohansey
			8	12	337		450	Mount Laurel & Wenonah
			4 R	8-12	82	100	365	Cohansey
			5 R		82			Cohansey
			6 R		58			Cohansey
CP 16	BLACKWOOD WATER CO. Blackwood (Camden)		5	8	380		400	Raritan
			6	8	380		250	Raritan
CP 17	BORDENTOWN WATER DEPT. Bordentown (Burlington)		43 wells	1½-6	75-80		610±	Raritan
CP 18	BRIDGEPORT WATER CO. (NOW BRIDGEPORT DIVISION OF THE PENNSGROVE WATER SUPPLY CO. 4-3-42) Bridgeport (Gloucester)		1	8	41	111	100	Cape May
CP 19	BRIDGETON WATER DEPT. Bridgeton (Cumberland)		1	16	74	510	500	Cohansey
			2	12	92	700	600	Cohansey
			3	18	115	500	500	Cohansey
			4	18	98	400	400	Cohansey
			5					Cohansey
			6	18	105		500	Cohansey
			7	18	84		500	Cohansey
			8	18	94		500	Cohansey
			9	18	108		500	Cohansey
			10	16	103		500	Cohansey
CP 20	BRIELLE WATER DEPT. Brielle (Monmouth)		1	12	100	400	200	Kirkwood
			2	16	750		500	Englishtown
CP 21	BRIGANTINE WATER DEPT. Brigantine (Atlantic)		1	8	829	700	600	Kirkwood
			2	8	788	800	600	Kirkwood
			3	8	770		600	Kirkwood

R—Reserve Well
F—Flowing Well
1—Latest Reported Year—1953
2—Latest Reported Year—1942

GROUND-WATER DIVERSIONS

1954 (OR LATEST REPORTED YEAR)				1953		1952		1951		1950		1949	
ANNUAL		MAX. MONTH		ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH
(mg)	(mgd)	(mg)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)
55.592	.152	7.993	.258	.149	.255	.140	.192	.125	.213	.128	.287	.149	.270
28.000	.077	3.420	.110	(ALL SURFACE WATER SUPPLY UNTIL SEPTEMBER 1954)									
735.414	2.015	85.718	2.770	2.089	3.368	1.964	2.762	1.826	2.532	1.852	2.922	1.960	3.418
343.256 1,119.721	.940 3.068	32.847 222.308	1.060 7.171	10.081	17.035	10.508	17.274	11.089	17.804	10.577	17.058	10.760	17.827
479.820	1.314	83.334	2.688										
492.745	1.351	62.348	2.011	1.274	1.759	1.155	1.586	1.105	1.478	1.002	1.329	.920	1.346
208.333	.571	24.068	.776	.585	.749	.550	.670	.522	.624	.611	.710	.394	.587
54.804[1]	.147[1]	9.506[1]	.307[1]	.147	.307	.145	.312	.135	.290	.128	.379	.179	.334
71.210	.195	11.861	.383	.204	.404	.191	.370	.205	.368	.234	.442	.253	.439
12.025[2]	.066[2]	3.000[2]	.095[2]										
17.362	.048	2.960	.095	.048	.095	.040	.087	.035	.098	.026	.055	.027	.040
133.541	.366	22.724	.733	.346	.760	.365	.721	.344	.697	.303	.608	.338	.696
44.119	.121	7.330	.237	.093[?]	.150[?]	.078	.105	.080	.125	.070	.130	.074	.237
538.202	1.475	82.532	2.662	1.913	4.621	1.330	2.529	1.232	1.810	1.334	1.997	1.402	2.047
106.793	.293	13.251	.429	.247	.336	.226	.320	.197	.243	.175	.219	.170	.272
88.318	.242	12.339	.397	.211	.301	.210	.269	.205	.272	.184	.227	.173	.218
81.825	.224	11.701	.378	.157	.229	.160	.193	.155	.184	.151	.184	.147	.204
324.124	.888	27.572	.891	.886	.912	.874	.887	.893	.973	.794	.833	.959	1.032
11.147	.030	1.463	.049	.024	.036	.030	.044	.046	.055	.044	.053	.039	.058
1,253.231[1]	3.434	142.079	4.583	3.434	4.707	3.246	4.591	3.389	4.863	2.918	4.031	2.742	3.598
46.845	.129	8.038	.259	.142	.281	.128	.278	.126	.213	.127	.217	.130	.235
347.310	.951	38.106	1.270	.886	1.267	.699	.928	.540	.822	.396	.605	.400	.666

COASTAL PLAIN GROUND-WATER INVENTORY

NO.	COMPANY LOCATION (County)	STATION	WELL DATA WELL NO.	DIAM. (Inches)	DEPTH (Feet)	REPORTED WELL YIELD (gpm)	PUMP CAPACITY (gpm)	AQUIFER
CP 22	BROOKLAWN WATER DEPT. Brooklawn (Camden)		2	12	160	600	300	Raritan
			3	8	160		300	Raritan
CP 23	BURLINGTON WATER DEPT. Burlington (Burlington)		1R*	12	78		280	Raritan
			3	16	86	517	500	Raritan
CP 24	CAMDEN WATER DEPT. Camden (Camden)	Delair	3	26	131	1680	1800	Raritan
			2	26	141	1330	1330	Raritan
			1	26	126	1850	1850	Raritan
		Puchack	1	18	141	1250	1400	Raritan
			2	18	169	1250	1340	Raritan
			3	18	175	1250	1175	Raritan
			4	18	184	1250	1680	Raritan
			5	18	204	1250	1120	Raritan
		Morris	1	18	105	1180	900	Raritan
			2	18	115	1261	870	Raritan
			3	18	120	1200	1250	Raritan
			5	18	120	1530	1240	Raritan
			6	18	138	1515	1500	Raritan
			7	18	125	1630	1600	Raritan
			8	18	125	1412	1460	Raritan
			9	26	135	1820	1460	Raritan
		City Wells	1	12	169	1125	1050	Raritan
			2	18	182	1241	1240	Raritan
			3	18	115	1085	1160	Raritan
			4	26	162	1200	1200	Raritan
			5	18	174	1100	1100	Raritan
			6	18	136	1012	1012	Raritan
			7	18	164	975	1000	Raritan
			8	18		1085		Raritan
			9	26	146	1420	1420	Raritan
			10	26	155	1400	1200	Raritan
			11		159		1000	Raritan
			12		170		850	Raritan
			13					Raritan
			14	18	145	1034	1200	Raritan
			15	18	141	1000	1000	Raritan
			16	18	180	1000	1000	Raritan
			17	18	270	1000	1000	Raritan
CP 25	CAPE MAY CITY WATER DEPT. Cape May (Cape May)		1	12	317	830	900	Cohansey
			2	12	321	820	750	Cohansey
			3	12	305	860	850	Cohansey
			4R	8	625		500	Kirkwood
CP 26	CAPE MAY POINT WATER DEPT. Cape May (Cape May)		1	10	610	500		Cape May & Cohansey
CP 27	CLAYTON WATER DEPT. Clayton (Gloucester)		2	16	103	300	500	Cohansey
CP 28	CLEMENTON WATER DEPT. Clementon (Camden)		6	8	437	250	250	Mount Laurel & Wenonah & Englishtown
			8	10		650	650	Raritan
CP 29	CLIFFWOOD BEACH WATER CO. Clifford Beach (Monmouth)		1	8	143		75	Raritan
CP 30	COLLINGSWOOD WATER DEPT. Collingswood (Camden)		1	18	305	650-750 Each	1000	Raritan
			2	18	298		810	Raritan
			3	18	326		825	Raritan
			4	16	305		800	Raritan
CP 31	COLONIAL MANOR WATER CO. Woodbury (Gloucester)		1	8	134		300	Raritan
CP 32	CORSON'S INLET WATER CO. Ocean City (Cape May)		1	8	834		300	Kirkwood
CP 33	CRANBURY WATER CO. Cranbury (Middlesex)		1	8	254	160	300	Raritan
			2	8	109	135	225	Raritan
CP 34	CROSSWICKS WATER CO. Crosswicks (Burlington)		S					Pennsauken?
CP 35	DELAWARE RIVER WATER CO. Beverly (Burlington)		1	12	60		200	Cape May
			2	10	60		300	Cape May
			3		60		250	Cape May
			4	16	60		125	Cape May
			5	8	60	90± (each)	700A	Cape May
			8	8	60			Cape May
			9	8	60			Cape May
			10	8	60			Cape May
			11	8	60			Cape May
			12	8	60			Cape May
			13	8	60			Cape May
			15	12	57	1200	1000	Cape May
CP 36	EAST BRUNSWICK TWP. WATER CO. New Brunswick (Middlesex)		1	12	228	1000	1000	Farrington
CP 37	EAST GREENWICH TWP. WATER DEPT. Clarksboro (Gloucester)		1	10	200	280	395	Raritan
CP 38	EGG HARBOR CITY WATER WORKS Egg Harbor (Atlantic)		1	8	400	650	500	Kirkwood
			1-A	12	402		523	Kirkwood
CP 39	ELMER WATER CO. Elmer (Salem)		1	8	75	140	90	Cohansey
			3	8	63	52	100	Cohansey
CP 40	FARMINGDALE WATER DEPT. Farmingdale (Monmouth)		1	6	480	100	60	Englishtown
			2	6	480		90	Englishtown

*—Five wells on Burlington Island—1955
R—Reserve Well
S—Springs—No Wells
1—Latest Year Reported—1952
A—Air Lift

GROUND-WATER DIVERSIONS

1954 (OR LATEST REPORTED YEAR)				1953		1952		1951		1950		1949	
ANNUAL		MAX. MONTH		ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH
(mg)	(mgd)	(mg)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)
97.333	.266	13.792	.446	.255	.398	.256	.384	.268	.362	.230	.321	.231	.374
44.015	.121	9.912	.319										
8.280	.023		.224	1.344	2.557	1.523	2.785	1.318	2.646	.610	2.021	.549	2.550
1,394.742	3.820		4.752	3.546	4.167	4.244	5.276	4.611	5.217	4.746	5.244	4.716	5.440
2,255.810	6.180		6.324	5.956	6.395	6.176	7.014	5.910	6.635	7.838	8.860	7.378	8.764
3,708.056	10.160		14.283	9.149	11.610	9.206	10.975	8.579	10.375	8.481	10.574	8.306	10.138
471.990	1.293	70.991	2.290	1.514	2.925	1.415	2.061	1.311	2.112	1.026	1.861	1.153	2.239
27.315	.075	4.932	.159	.077	.155	.060	.097	.071	.124	.080	.152	.084	.166
78.539	.215	10.265	.331	.159	.199	.150	.192	.120	.142	.109	.126	.105	.140
183.062	.501	25.967	.839	.466	.699	.465	.714	.456	.604	.395	.599	.395	.626
13.423	.037	2.710	.087										
678.221	1.860	71.783	2.316	1.909	2.171	2.419	2.914	2.790	3.078	2.522	2.811	2.149	2.959
15.650[1]	.043	2.082	.067			.043	.067	.035	.046	.029	.037	.032	.046
10.574	.029	2.654	.085	.029	.091	.029	.091	.025	.071	.022	.066	.023	.065
25.764	.073	3.482	.112	.068	.098	.058	.083	.061	.087	.057	.074	.061	.094
10.450	.029	1.347	.043	.036	.043	.034	.047	.037	.049	.034	.041	.034	.049
366.360	1.001	41.899	1.351	.956	1.144	.895	1.087	.796	.913	.737	.799	.658	.804
169.950	.466	20.460	.660	.381	.591	.299	.437						
55.683	.152	9.183	.296	.172	.374	.120	.221	.106	.150	.085	.118	.095	.162
100.376	.275	10.515	.350	.268	.305	.254	.292	.242	.266	.219	.250	.222	.263
25.200	.069	2.500	.083	.070	.083	.068	.083	.068	.083	.069	.083	.064	.071
15.656	.043	1.800	.058	.040	.047	.040	.048	.039	.044	.038	.043	.040	.047

COASTAL PLAIN GROUND-WATER INVENTORY

NO.	COMPANY LOCATION (County)	STATION	WELL DATA WELL NO.	DIAM. (Inches)	DEPTH (Feet)	REPORTED WELL YIELD (gpm)	PUMP CAPACITY (gpm)	AQUIFER
CP 41	FLORENCE TWP. WATER DEPT. Florence (Burlington)		1	18	115	615	600	Raritan
			2	18	120	600	600	Raritan
			3	16	134		638	Raritan
			4	16	138		620	Raritan
CP 42	FORT DIX Fort Dix (Burlington)	Fort Dix Post	1	10	958		800	Raritan
			2	10	1051		900	Raritan
			3	10	869		750	Raritan
			4	10	1096		700	Raritan
		Br. La. Lodge	5	6	359		35	Englishtown
		S. Range House	7	6	525		25	Englishtown
		Bldg. 1083	8	6	155		10	Mount Laurel & Wenonah
		Rifle Range	9	4½-6	457	80	97	Englishtown
			10		449	60	60	Englishtown
		Han Fur Lake	11	6	480		25	Englishtown
CP 43	FREEHOLD WATER DEPT. Freehold (Monmouth)		1	16	496		550	Raritan
			2	16	536		550	Raritan
			1 AR	8	200	90	500	Englishtown
			2 AR	8	200	90	500	Englishtown
			3 AR	8	200	90	500	Englishtown
			4 AR	8	200	90	500	Englishtown
			5 AR	8	200	90	500	Englishtown
			6 AR	8	200	90	500	Englishtown
			7 AR	8	200	90	500	Englishtown
			8 AR	8	200	90	500	Englishtown
			9 AR	8	200	90	500	Englishtown
CP 44	GANDY BEACH WATER WORKS Newport (Cumberland)		1	6	402		200	Kirkwood
CP 45	GLASSBORO WATER DEPT. Glassboro (Gloucester)		1	12	650	400	450	Raritan
			2	12	620		500	Raritan
CP 46	GLOUCESTER WATER DEPT. Gloucester City (Camden)		2	8	175	250	300	Raritan
			30	8	176		300	Raritan
			32	8	176		400	Raritan
			33	16	240		350	Raritan
			34	6	175		200	Raritan
			35	6	125		350	Raritan
			36	6	120		300	Raritan
			37	6	120		350	Raritan
			38	8	300		500	Raritan
				16	103		600	Raritan
CP 47	GREENWICH TWP. WATER DEPT. Greenwich (Cumberland)		1	16	103	500	600	Cohansey
CP 48	HADDONFIELD WATER DEPT. Haddonfield (Camden)		1	12	230	800	600	Raritan
			2	12	245	600	500	Raritan
			3	8	222	500	500	Raritan
			4	12	243	800	600	Raritan
CP 49	HADDON TWP. WATER DEPT. Westmont (Camden)			8	470		800	Raritan
				8	470		800	Raritan
CP 50	HAMILTON SQUARE WATER CO. Hamilton Sq. (Mercer)		3	8	242		300	Raritan
			4	8	247		300	Raritan
CP 51	HAMMONTON WATER DEPT. Hammonton (Atlantic)		1	12	316	675	700	Kirkwood
			2	8	304		750	Kirkwood
			3	12	320		800	Kirkwood
CP 52	HANOVER WATER CO. Wrightstown (Burlington)		1					Englishtown
			2R	6	212		70	Englishtown
CP 53	HARVEY CEDARS WATER DEPT. Harvey Cedars (Ocean)		2	8	534		166	Kirkwood
CP 54	HIGHLANDS WATER DEPT. Highlands (Monmouth)		1	8	687	275		Englishtown
			2	6	263	225		Mt. Laurel & Wenonah
CP 55	HIGHTSTOWN WATER DEPT. Hightstown (Mercer)		1	12	205	1500	1500	Raritan
			2	12	205	1500	1500	Raritan
CP 56	ISLAND HEIGHTS WATER DEPT. Island Heights (Ocean)		1	5	365	300	95	Kirkwood
			2	5	365	300	95	Kirkwood
			7	8	385		285	Kirkwood
CP 57	JAMESBURG WATER CO. Jamesburg (Middlesex)		3	6	100	50		Raritan
			4	6	100	50	150-200	Raritan
			5	8	100	100		Raritan
CP 58	KEANSBURG WATER DEPT. Keansburg (Monmouth)		1	16	354	750	450	Old Bridge
			2	16	354	850	400	Old Bridge
			3	18	355		700	Old Bridge
			4	18	351		1000	Old Bridge
CP 59	KEYPORT WATER DEPT. Keyport (Monmouth)		1	12	271	500	500	Old Bridge
			2	8	290	250	500	Old Bridge
			3	10	240	100		Old Bridge
			4	10	285	1000	1000	Old Bridge
CP 60	LAKEHURST WATER CO. Lakehurst (Ocean)	Station #1	1	12	1037	250	200	Raritan
		Station #2	3 Wells		24-46	190 Total		Cohansey
		Station #3	5 Wells	4-6	30	150 Total		Cohansey
CP 61	LAKEVIEW HEIGHTS WATER CO. Pitman (Gloucester)		1	4	165	35	50	Kirkwood
CP 62	LAKEWOOD WATER CO. Lakewood (Ocean)		1	6	600		350	Englishtown
			2	10	615	400	500	Englishtown
			3	8	615	400	400	Englishtown
CP 63	LAUREL SPRINGS WATER WORKS DEPT. Laurel Springs (Camden)		1		142	300		Mount Laurel & Wenonah
			4	8	135			Mount Laurel & Wenonah
			6					Mount Laurel & Wenonah
			8					Mount Laurel & Wenonah
			W					

AR—Air Lift-Reserve
R—Reserve
W—One Well in Raritan Formation—1955

GROUND-WATER DIVERSIONS

1954 (OR LATEST REPORTED YEAR)				1953		1952		1951		1950		1949	
ANNUAL		MAX. MONTH		ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH
(mg)	(mgd)	(mg)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)
321.699	.881	39.250	1.266	.904	1.177	.810	.981	.823	.952	.616	.789	.482	.802
211.002	.598	38.783	1.251	.578	2.212	1.490	1.780	1.499	2.130	1.285	1.425	1.318	1.702
219.556	.602	21.748	.702	.628	.714	.606	.661	.644	.754	.575	.633	.591	.726
.541	.001	.105	.004	.001	.003								
235.615	.645	23.810	.768	.588	.756	.515	.589	.495	.579	.436	.496	.405	.456
853.122	2.337	79.440	2.563	2.298	2.514	2.320	2.603	2.353	2.557	2.238	2.313	2.261	2.518
186.335	.510	36.467	1.176	.366	.576	.307	.382	.264	.406	.188	.232	.171	.255
350.900	.961	43.660	1.408	.908	1.139	.872	1.110	.819	.945	.774	.929	.758	1.072
262.765	.720	30.913	.997	.617	.750	.230	.828						
79.917	.219	10.860	.351	.190	.263	.152	.268	.140	.164	.007	.007	.007	.010
285.982	.783	35.777	1.154	.694	.890	.599	.786	.591	.748	.603	.772	.608	.953
22.427	.061	2.347	.075	.060	.092	.061	.076	.060	.075	.053	.058	.048	.053
21.300	.058	3.000	.100	.039	.080	.031	.080	.031	.080	.020	.020	.010	.014
115.922	.318	16.735	.540	.354	.609	.325	.587	.305	.488	.303	.467	.371	.544
161.522	.442	16.354	.527	.544	.872	.423	.499	.493	.588	.480	.575	.454	.522
71.233	.195	11.961	.386	.190	.331	.185	.316	.186	.267	.177	.273	.182	.413
57.001	.156	5.550	.179	.146	.165	.131	.148	.120	.144	.108	.135	.115	.137
445.365	1.220	68.773	2.218	1.171	2.062	1.164	2.072	1.055	1.754	1.042	1.746	1.036	1.862
326.522	.895	36.843	1.188	.841	.995	.808	1.069	.820	1.024	.783	.862	.776	.966
53.100	.146	5.200	.168	.162	.193	.131	.153	.127	.135	.121	.130	.111	.122
1.394	.004	.142	.005	.004	.005	.004	.006	.004	.006	.004	.006	.004	.006
324.631	.889	30.549	.985	.820	.925	.799	.996	.786	.950	.802	.985	.722	.960
319.587	.875	40.840	1.361	.786	1.192	.701	1.094	.555	.770	.489	.599	.582	.910

COASTAL PLAIN GROUND-WATER INVENTORY

NO.	COMPANY LOCATION (County)	STATION	WELL DATA: WELL NO.	DIAM. (Inches)	DEPTH (Feet)	REPORTED WELL YIELD (gpm)	PUMP CAPACITY (gpm)	AQUIFER
CP 64	LAURENCE HARBOR WATER CO. Laurence Harbor (Middlesex)		2	10	218	100	380	Old Bridge
CP 65	LAVALLETTE WATER DEPT. Lavallette (Ocean)		1	12	1122	300	200	Englishtown
			2	12	1120	500	350	Englishtown
			3R	12	1180		500	Englishtown
CP 66	LONG BEACH WATER CO. Beach Haven (Ocean)	Beach Haven Terrace	2	8	618	350	500	Kirkwood
		Brant Beach	2	8	600	657	500	Kirkwood
CP 67	LONG BEACH TWP. WATER DEPT. Brant Beach (Ocean)		1	6	458	323	100	Kirkwood
CP 68	LONGPORT WATER DEPT. Longport (Atlantic)		1	10	800		500	Kirkwood
			2	12	804		700	Kirkwood
CP 69	LOWER PENNS NECK TWP. WATER DEPT. Pennsville (Salem)		1	10	222	357	350	Raritan
			2	10	232	403	450	Raritan
CP 70	LUMBERTON WATER CO. Lumberton (Burlington)		1	8	404	300	250	Raritan
CP 71	MANASQUAN WATER DEPT. Manasquan (Monmouth)		1	10	128	900	625	Kirkwood
			2	6	135		275	Kirkwood
			3	8	133		250	Kirkwood
			4R		133		150	Kirkwood
			5R		133		150	Kirkwood
CP 72	MANTUA WATER CO. Mantua (Gloucester)		1	8	241	100	100	Raritan
			2R	5	204		50	Raritan
CP 73	MAPLE SHADE TWP. WATER DEPT. Maple Shade (Burlington)		1R	8	129	230	330A	Raritan
			2R	10	117	230		Raritan
			3R	12	129	230		Raritan
			4	10	121	530	500	Raritan
CP 74	MARGATE CITY WATER DEPT. Margate City (Atlantic)		1	8	805	350	640	Kirkwood
			2	8	805	350	540	Kirkwood
			3	12	806	300	770	Kirkwood
CP 75	MARLTON WATER CO. Marlton (Burlington)		1	6	212		125	Englishtown
			2	6	212		125	Englishtown
CP 76	MATAWAN WATER DEPT. Matawan (Monmouth)		1	12	260		500	Raritan
			2	12	260		500	Raritan
CP 77	MAYS LANDING WATER DEPT. Mays Landing (Atlantic)		3	10	243	426	360	Cohansey
			4	10	242		360	Cohansey
CP 78	MEDFORD WATER DEPT. Medford (Burlington)		2	8	540	200	350	Raritan
CP 79	MERCHANTVILLE-PENNSAUKEN WATER CO. Merchantville (Camden)	Park Ave.	1	12	281	750	1000	Raritan
			5	12	290	750	1000	Raritan
			6	10	260	550	590	Raritan
			7	14	181	550	550	Raritan
			12	12	256	750	1000	Raritan
		Delaware Gardens	1W	12	144	700	1000	Raritan
CP 80	MILLVILLE MUNICIPAL WATER DEPT. Millville (Cumberland)		1*	8	106	136		Cohansey
			2*	8	96	136		Cohansey
			3*	8	94	260		Cohansey
			4*	8	108	150		Cohansey
			5*	8	104	168		Cohansey
			6*	8	103	480		Cohansey
			7*	8	105	470		Cohansey
			8*	8	107	230		Cohansey
			9*	8	121	30		Cohansey
CP 81	MONMOUTH CONSOLIDATED WATER CO. Long Branch (Monmouth)	Whitesville	1	12	662	300	200	Englishtown
			2	12	985	900	700	Raritan
		Jumping Brook	3	12	1065		1400	Raritan
		Ocean Grove	10	4	450		300	Mount Laurel & Wenonah
			12	4	450			Mount Laurel & Wenonah
			15	4	450			Mount Laurel & Wenonah
			16	4	450			Mount Laurel & Wenonah
			20	12	605		300	Englishtown
CP 82	MONROE TWP. WATER DEPT. Williamstown (Gloucester)		1	8	123	80	240	Cohansey
			2	8	95	90		Cohansey
			3	10	130	350	350	Cohansey
CP 83	MOORESTOWN TWP. WATER DEPT. Moorestown (Burlington)		1	12	300	500	500	Raritan
			2	12	300	700	700	Raritan
			3	12	300		840	Raritan
CP 84	MOUNT HOLLY WATER CO. Mount Holly (Burlington)		1	18	370	700	700	Raritan
			2	18	365	700	700	Raritan
CP 85	NATIONAL PARK WATER CO. National Park (Gloucester)		1	8	88		400	Raritan
			2	8	90	300	400	Raritan
CP 86	NEPTUNUS WATER CO. Cape May Court House (Cape May)		2-A	6	50	100	50	Cape May
			3-A	8	51	100	135	Cape May
			4R	6	42		15	Cape May
CP 87	NEW EGYPT WATER CO. New Egypt (Ocean)		1	6-8	238	250F		Englishtown
			2		238	80F		Englishtown
CP 88	NEWFIELD WATER DEPT. Newfield (Gloucester)		1	10	147	550	500	Cohansey
			2	10	147		500	Cohansey
CP 89	NEW JERSEY WATER CO. Ashland Terrace (Camden)	Ashland	9	12	405	50 (Est.)	20	Raritan

R—Reserve Well
W—New Well in Raritan Formation—1955
*—1939 Data
A—Air Lift
1—Latest Reported Year—1953
F—Flowing Well

GROUND-WATER DIVERSIONS

1954 (OR LATEST REPORTED YEAR)				1953		1952		1951		1950		1949	
ANNUAL		MAX. MONTH		ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH
(mg)	(mgd)	(mg)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)
85.012	.233	10.833	.349	.203	.348	.153	.239	.154	.237	.147	.243	.122	.223
120.105	.329	25.680	.828	.322	.792	.269	.725	.271	.646	.259	.596	.263	.560
134.573	.369	26.312	.849	.330	.866	.283	.722	.277	.668	.244	.587	.236	.611
10.688	.029	.927	.030	.027	.029	.025	.026	.023	.025	.023	.028	.019	.026
108.070	.296	19.470	.628	.270	.601	.248	.599	.231	.477	.186	.412	.170	.408
107.969	.296	14.078	.454	.288	.443	.249	.353	.255	.336	.279	.334	.241	.294
14.650	.040	3.037	.098	.038	.074	.033	.054	.032	.049	.029	.044	.031	.066
219.366	.601	36.559	1.179	.538	1.042	.644	1.268	.603	1.049	.506	.875	.530	.841
16.915	.046	1.903	.061	.042	.064	.041	.051	.039	.046	.034	.040	.033	.040
221.188	.606	26.144	.842	.507	.640	.470	.583	.398	.455	.371	.401	.327	.366
543.957	1.490	79.524	2.565	1.382	2.314	1.277	2.182	1.241	2.303	1.067	2.052	1.068	2.059
9.622[1]	.026[1]	1.070[1]	.036[1]	.026	.036	.025	.030	.028	.042	.025	.039	.029	.045
123.237	.338	13.539	.437	.330	.476	.300	.423	.282	.315	.263	.294	.257	.347
28.704	.079	2.418	.078	.079	.079	.079	.084	.079	.084	.079	.084	.079	.084
37.306	.102	5.456	.176	.091	.136	.083	.118	.081	.104	.087	.110	.087	.130
876.526	2.402	104.294	3.364	2.159	2.732	2.063	2.645	1.836	2.102	1.669	1.880	1.599	2.110
369.420	1.012	54.512	1.758	1.042	1.579	1.121	1.695	1.349	1.744	1.443	1.861	1.640	2.032
56.143	.154	25.449	.822	.095	.494	.072	.422	.084	.438	.092	.443	.136	.574
164.244	.450	48.345	1.560	.558	1.804	.687	1.964						
72.103	.198	26.742	.863	.221	.788	.211	.823	.174	.810	.017	.112	.126	.690
63.794	.175	6.608	.213	.157	.186	.133	.161	.140	.158	.127	.146	.129	.157
316.735	.868	35.795	1.154	.784	1.043	.674	.824	.635	.733	.564	.666	.567	.699
265.066	.726	27.683	.892	.642	.751	.606	.684	.559	.601	.618	.676	.572	.684
103.086	.282	12.528	.404	.220	.248	.272	.347	.272	.328	.274	.331		
36.151	.099	4.847	.156	.087	.126	.076	.109	.096	.136	.079	.106	.073	.120
25.824	.071	3.065	.099	.061	.068	.068	.075	.068	.074	.070	.077	.056	.066
30.257	.083	3.321	.107	.081	.112	.084	.112	.072	.083	.059	.072	.065	.102
5.312	.014	.630	.020	.015	.030	.007	.009	.007	.009	.006	.007	.006	.007

COASTAL PLAIN GROUND-WATER INVENTORY

NO.	COMPANY LOCATION (County)	STATION	WELL DATA: WELL NO.	DIAM. (Inches)	DEPTH (Feet)	REPORTED WELL YIELD (gpm)	PUMP CAPACITY (gpm)	AQUIFER
CP 90	NEW JERSEY WATER CO. Haddon Heights (Camden)	Egbert	6	8	202	360	350	Raritan
		Barrington	5	12	264	668	650	Raritan
		Runnemede	7	8	318	500	350	Raritan
		Haddon Heights	3	8	230			Raritan
			10	12	271	625	490	Raritan
			11	17	272		450	Raritan
			12	10	267		730	Raritan
CP 91	NEW JERSEY WATER CO. Camden (Camden)	Stockton	27	26	135		1050	Raritan
			37	12	168		700	Raritan
			39	10	160		700	Raritan
			43	10	170		700	Raritan
			44	12	186		1200	Raritan
			45	12	173		700	Raritan
			46	12	179		1200	Raritan
CP 92	OCEAN CITY WATER SERVICE CO. Ocean City (Cape May)		4	8	800	430	525	Kirkwood
			5	8	800	515	700	Kirkwood
			6	8	800	660	700	Kirkwood
			9	8	800		500	Kirkwood
			10	10	800		700	Kirkwood
			2	6	800	243	600	Kirkwood
			3 R	6	800	243		Kirkwood
			7	8	800	430	350	Kirkwood
			8	8	800		700	Kirkwood
CP 93	OCEAN COUNTY WATER CO. Bayhead (Ocean)	Bayhead	1	3	820	50	20	Englishtown
			3	3	825	50	66	Englishtown
			5	8	834	220	300	Englishtown
			6	10	818	338		Englishtown
		Mantaloking	3	4½	700		41	Mount Laurel & Wenonah
			4	6	750	70	41	Mount Laurel & Wenonah
			5	8	990	300	142	Englishtown
		Normandy	2	10	110			Kirkwood
			3	8	1479	348		Raritan
CP 94	OCEAN GATE WATER DEPT. Ocean Gate (Ocean)		1		374		260	Kirkwood
			2	16	366	498	220	Kirkwood
CP 95	PAULSBORO WATER CO. Paulsboro (Gloucester)		2	12	92	550	400	Raritan
			3	12	160		700	Raritan
			4	12	126		400	Raritan
CP 96	PEMBERTON WATER DEPT. Pemberton (Burlington)		1	12	300	160	150	Englishtown
CP 97	PEMBERTON TWP. WATER DEPT. Brown's Mills (Burlington)		1	6	276		100	Mount Laurel & Wenonah
			2	8	256		150	Mount Laurel & Wenonah
CP 98	PENNSGROVE WATER SUPPLY CO. Pennsgrove (Salem)		Ranney	156	32		400	Cape May
			2A	12	58		210	Raritan
			2B	12	58		306	Raritan
			9	12	152		500	Raritan
			10	12	155		400	Raritan
			11	12	178		583	Raritan
			6 R	10	170			Raritan
			7	10	60		125	Raritan
			11	10	396?		536	Raritan
CP 99	PERTH AMBOY WATER DEPT. Perth Amboy (Middlesex)	Runyon	Layne #1	12	291		1500	Farrington
			Layne #2	16	265		1200	Farrington
			Layne #3	16	68		700	Old Bridge
			1	10	45			Old Bridge
			3	10	58			Old Bridge
			4	8	40			Old Bridge
			5	10	56			Old Bridge
			7	4½	50			Old Bridge
			9	10	41			Old Bridge
			10	6	69			Old Bridge
			11	10	52			Old Bridge
			12	6	58			Old Bridge
			13	10	63			Old Bridge
			17	10	55			Old Bridge
			19	8	42 A			Old Bridge
			22	6	70			Old Bridge
			23	10	61			Old Bridge
			24	6	56			Old Bridge
			39	4				Old Bridge
			43	6	62			Old Bridge
			44	6	54			Old Bridge
			45	10	59			Old Bridge
			46	6	54			Old Bridge
			47	10	64			Old Bridge
			48	6	49			Old Bridge
			49	10	73			Old Bridge
			61	10	55			Old Bridge
			62	6	48			Old Bridge
			63	10	64			Old Bridge
			64	4½	45			Old Bridge
			65	10	64			Old Bridge
			66	4½	52			Old Bridge
			67	4½	65			Old Bridge
			68	10	94			Old Bridge
			69	4½	77 A			Old Bridge
			70	10	76			Old Bridge
			72	4½	80			Old Bridge
			73	10	87			Old Bridge
			77	10	74			Old Bridge
			78	10	52			Old Bridge
			79	10	66			Old Bridge
			81	8	54			Old Bridge
			84	10	60			Old Bridge

R—Reserve Well
A—Airlift

GROUND-WATER DIVERSIONS

1954 (OR LATEST REPORTED YEAR)				1953		1952		1951		1950		1949	
ANNUAL		MAX. MONTH		ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH
(mg)	(mgd)	(mg)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)
1,216.302	3.332	135.987	4.384	3.305	3.981	2.926	3.414	2.897	3.351	2.537	2.983	2.104	2.839
1,193.791	3.270	118.922	3.836	3.427	4.138	3.170	3.959	2.963	3.602	2.852	3.380	2.801	3.632
482.430	1.322	113.102	3.648	1.222	3.414	1.167	3.170	1.101	2.876	1.044	2.735	1.098	2.991
169.310	.464	39.798	1.284	.436	1.102	.405	1.019	.389	.856	.362	.834	.384	.835
41.422	.113	8.980	.290	.090	.263	.097	.225	.094	.217	.064	.158	.080	.194
363.599	.997	49.443	1.592	1.040	1.348	.985	1.968	.797	.907	.782	.904	.768	1.009
44.875	.123	6.802	.219	.116	.182	.098	.158	.106	.131	.096	.118	.110	.176
54.006	.148	6.222	.201	.162	.201	.112	.175	.085	.116	.081	.117	.069	.098
301.395	.826	33.079	1.067	.024	.036	.030	.044	.046	.055	.044	.053	.039	.058
8.970		9.674		9.100	10.048	9.025	9.720	9.050	9.777	8.501	9.468	8.909	9.875

COASTAL PLAIN GROUND-WATER INVENTORY

NO.	COMPANY LOCATION (County)	STATION	WELL DATA: WELL NO.	DIAM. (Inches)	DEPTH (Feet)	REPORTED WELL YIELD (gpm)	PUMP CAPACITY (gpm)	AQUIFER
CP 99	PERTH AMBOY WATER DEPT. *(Continued)*		87	10	58			Old Bridge
	Perth Amboy (Middlesex)		93	10	61			Old Bridge
			96	6	50			Old Bridge
			98	6	52			Old Bridge
			99	8	50			Old Bridge
			100	6	48 (A)			Old Bridge
			102	6	53			Old Bridge
			104	6	57			Old Bridge
			106	8	68			Old Bridge
			125	10	57			Old Bridge
CP 100	PITMAN WATER DEPT.		1	12	514	500	500	Raritan
	Pitman (Gloucester)		2	12	515		500	Raritan
CP 101	POINT PLEASANT BEACH WATER DEPT.		8	12	140		625	Kirkwood
	Point Pleasant Beach (Ocean)		9	12	133		1325	Kirkwood
			1		136		200	Kirkwood
			2		159		200	Kirkwood
			3		149		250	Kirkwood
			4 (R)		152	300-400	250	Kirkwood
			5		144		250	Kirkwood
			6		146		200	Kirkwood
			7		154		300	Kirkwood
CP 102	POINT PLEASANT BORO WATER DEPT.		1	10	755	200	250	Englishtown
	Point Pleasant (Ocean)		2	10	756	225	250	Englishtown
			3 W	16	741	325	500	Englishtown
CP 103	RED BANK WATER DEPT.		1	8	287	366	200	Englishtown
	Red Bank (Monmouth)		1-A	8	700		515	Raritan
			1-B	16	692		1000	Raritan
			2	12	276	416	280	Englishtown
			3	18	278	500	500	Englishtown
CP 104	RIVERTON & PALMYRA WATER CO.		Collector	156	26	2000	2900	Cape May
	Palmyra (Burlington)							
CP 105	SALEM WATER DEPT.	Salem	2	16	140	510	500	Mount Laurel & Wenonah
	Salem (Salem)		4	8	133		300	Mount Laurel & Wenonah
		Salem	1 (R)		140	209	200	Mount Laurel & Wenonah
		Quinton	3 (R)		130		300	Vincentown
			5-29	6-8	110-286	0.7 MGD		Vincentown
CP 106	SEA GIRT WATER DEPT.		1	10	159		350	Kirkwood
	Sea Girt (Monmouth)		2	10	160		300	Kirkwood
			3	8	730		335	Englishtown
			4	8	715		300	Englishtown
CP 107	SEA ISLE CITY WATER DEPT.		2	8	864	400	550	Kirkwood
	Sea Isle City (Cape May)		3	10	871	600	600	Kirkwood
			1R		860		250	Kirkwood
CP 108	SEASIDE HEIGHTS WATER DEPT.	Ortley Beach		10	156		450	Kirkwood
	Seaside Heights (Ocean)	Seaside Heights		12	169		735	Kirkwood
				12	439			Kirkwood
				16	174		500	Kirkwood
CP 109	SEASIDE PARK WATER DEPT.		2	8	525	230	300	Kirkwood
	Seaside Park (Ocean)		3	8	485	230		Kirkwood
			4	10	485	160	160	Kirkwood
			5					Kirkwood
CP 110	SEWELL WATER CO.		4	10	382		350	Raritan
	Sewell (Gloucester)		1		75		100	Raritan
			2 (R)		85		100	Raritan
			3		90		100	Raritan
CP 111	SHIP BOTTOM WATER DEPT.		2	8	571		300	Kirkwood
	Ship Bottom (Ocean)		3	8	568		450	Kirkwood
			1R	6	385		170	Kirkwood
CP 112	SOUTH AMBOY WATER DEPT.		5	12	52	900	500	Old Bridge
	South Amboy (Middlesex)		8	18	247		1000	Farrington
			9	16	47		450	Old Bridge
CP 113	SOUTH JERSEY WATER SUPPLY CO.		1	8	275	250	100	Raritan
	Mullica Hill (Gloucester)		2	8	275	250	100	Raritan
CP 114	SOUTH RIVER WATER DEPT.		1	8	191	800	250	Farrington
	South River (Middlesex)		2	12	198		700	Farrington
CP 115	SPRING LAKE HEIGHTS WATER DEPT.		1	8	600	200	800	Englishtown
	Spring Lake Heights (Monmouth)		2	8	711	500		Englishtown
CP 116	SPRING LAKE WATER DEPT.		1	16	710		500	Englishtown
	Spring Lake (Monmouth)		2	16	710		500	Englishtown
			3	16	710		500	Englishtown
CP 117	STONE HARBOR WATER DEPT,		1	6	890	500	707	Kirkwood
	Stone Harbor (Cape May)		2	8	890	600	707	Kirkwood
			3	8	890		688	Kirkwood
CP 118	SURF CITY WATER DEPT.		2	8	551		208	Kirkwood
	Surf City (Ocean)							
CP 119	SWEDESBORO WATER DEPT.		1	12	255	550	500	Raritan
	Swedesboro (Gloucester)		2	12	255	550	500	Raritan
CP 120	TOM'S RIVER WATER DEPT.		7	8	60			Cohansey
	Tom's River (Ocean)		8	8	60			Cohansey
			9	10	60 (A)	200	250	Cohansey
			10	10	60			Cohansey
			11	12	60	200	200	Cohansey
			13	12	60	500	600	Cohansey
			Layne #2	12	51	608	608	Cohansey
CP 121	TUCKERTON WATER WORKS		1	6	487	175	250	Kirkwood
	Tuckerton (Ocean)							

R—Reserve Well
W—One Well in Kirkwood Sand—1955
A—Airlift
1—Latest Reported Year—1952
2—Latest Reported Year—1951

GROUND-WATER DIVERSIONS

1954 (OR LATEST REPORTED YEAR)				1953		1952		1951		1950		1949	
ANNUAL		MAX. MONTH		ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH
(mg)	(mgd)	(mg)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)
146.159	.400	17.718	.571	.365	.472	.320	.415	.324	.375	.308	.359	.302	.400
243.134	.666	31.512	1.017	.714	1.212	.676	1.295	.580	.897	.584	1.114	.646	1.150
147.959	.405	27.438	.885	.364	.687	.512	.832	.484	.710	.399	.619	.342	.524
478.561	1.311	51.904	1.674	1.362	1.620	1.440	1.716	1.428	1.587	1.321	1.661	1.349	1.557
255.708	.701	30.061	.970	.634	.819	.617	.770	.560	.679	.510	.556	.465	.641
252.174	.691	31.654	1.021	.668	.828	.611	.705	.675	.932	.736	.856	.784	.923
112.897	.309	23.180	.748	.306	.706	.247	.586	.254	.581	.206	.466	.225	.562
133.491	.366	24.430	.788	.344	.741	.348	.752	.370	.758	.316	.631	.314	.672
146.136	.400	32.065	1.034	.377	1.017	.414	1.082	.383	.946	.345	.844	.362	.850
115.709	.317	21.247	.685	.411	.720	.413	.823	.318	.699	.301	.628	.324	.692
17.313	.048	2.040	.066	.027	.038	.025	.029	.026	.032	.026	.040	.024	.034
48.193	.132	9.847	.318	.122	.291	.106	.258	.104	.229	.110	.384	.100	.241
402.955	1.104	40.840	1.317	1.271	1.425	1.335	1.628	1.271	1.338	.999	1.164	1.138	1.274
29.152	.080	4.515	.146	.098	.144	.101	.139	.104	.120	.084	.098	.087	.103
263.129	.721	73.352 (3 Mo. Total)	.797	.516	.677	.485	.542	.460	.490	.459	.501	.470	.557
55.845	.153	8.384	.270	.078	.208								
165.921	.455	35.569	1.147	.501	1.020	.566	1.171	.567	1.193	.516	1.110	.493	.994
109.423	.300	24.492	.790	.272	.739	.245	.684	.233	.580	.196	.545	.233	.538
45.885[1]	.125[1]	9.465[1]	.305[1]			.125	.305	.123	.276	.104	.215	.119	.326
77.317	.212	9.069	.293	.158	.180	.199	.523	.140	.273	.120	.129	.135	.183
197.860	.542	32.561	1.050	.540	1.037	.468	.865	.406	.578	.360	.573	.377	.627
11.615[2]	.032[2]	1.700[2]	.055[2]					.032	.055	.031	.054	.075	.117

COASTAL PLAIN GROUND-WATER INVENTORY

NO.	COMPANY LOCATION (County)	STATION	WELL DATA WELL NO.	DIAM. (Inches)	DEPTH (Feet)	REPORTED WELL YIELD (gpm)	PUMP CAPACITY (gpm)	AQUIFER
CP 122	UNION BEACH WATER DEPT.		1	8	310	900	750	Farrington
	Union Beach (Monmouth)		2	8	125	500	500	Old Bridge
CP 123	VENTNOR WATER DEPT.		2	4	800±	200	75	Kirkwood
	Ventnor (Atlantic)		3	6	800±	250	450	Kirkwood
			4	8	800±	300	600	Kirkwood
			5	8	800±	300	600	Kirkwood
			6	8	800±	350	600	Kirkwood
			7	8	800±	350	600	Kirkwood
			8	12	800±	500	900	Kirkwood
CP 124	VINCENTOWN WATER DEPT.		1	8	150	(Flowing)	300	Mount Laurel & Wenonah
	Vincentown (Burlington)							
CP 125	VINELAND WATER DEPT.		1	26	160	1500?	1000	Cohansey
	Vineland (Cumberland)		2	26	160	1500?	1000	Cohansey
			3	26	160	1500?	1000	Cohansey
			4	26	180		1040	Cohansey
CP 126	WILDWOOD WATER DEPT.	Rio Grande	23	8	523		350	Kirkwood
	Wildwood (Cape May)		24	10	261		400	Cohansey
			27	16	50		200	Cape May
			28	16	245		1040	Cohansey
			29	16	233		1040	Cohansey
			30	16	233		1040	Cohansey
			31	8	155		500	Cohansey
		Pine Avenue	1	10	700		400	Kirkwood
			2	8	357		350	Cohansey
CP 127	WOODBINE WATER CO.		1	6	162	100±	104	Cohansey
	Woodbine (Cape May)		2	8	162	150±	250	Cohansey
			3	6	162	150±	125	Cohansey
			4	10	162	100±	350	Cohansey
CP 128	WOODBURY WATER DEPT.		11-S	12	315		1200	Raritan
	Woodbury (Gloucester)		12-S	12	325		1200	Raritan
			13-C	12	188		750	Raritan
CP 129	WOODSTOWN WATER DEPT.		1	12	715	300	390	Raritan
	Woodstown (Salem)		2	12	710	300	450	Raritan
CP 130	WENONAH WATER DEPT.		1	12	310	500	250	Raritan
	Wenonah (Gloucester)		2	12	320	1200	150	Raritan
CP 131	WESTVILLE WATER DEPT.		2	8	118	275	300	Raritan
	Westville (Gloucester)		3	8	140		450	Raritan

1—Latest Reported Year—1953

GROUND-WATER DIVERSIONS

1954 (OR LATEST REPORTED YEAR)				1953		1952		1951		1950		1949	
ANNUAL		MAX. MONTH		ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH
(mg)	(mgd)	(mg)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)
131.989	.362	16.898	.545	.364	.544	.342	.497	.296	.397	.248	.319	.295	.455
478.902	1.312	74.535	2.404	1.272	2.342	1.258	2.398	1.260	2.249	1.180	2.067	1.320	2.414
12.628	.035	1.309	.042	.033	.039	.032	.039	.028	.034	.028	.034	.025	.031
725.434	1.987	82.066	2.736	1.918	2.474	1.750	2.344	1.687	2.108	1.622	1.842	1.640	2.117
726.411	1.990	159.980	5.161	1.838	4.770	1.689	4.487	1.772	4.397	1.644	4.144	1.682	4.497
71.424	.196	8.169	.272	.174	.236	.136	.175	.144	.217	.132	.169	.132	.200
471.025	1.290	66.182	2.135	1.161	1.630	1.053	1.388	.908	1.037	.845	.968	.831	1.027
65.383[1]	.179	6.910	.223	.179	.223	.160	.195	.166	.191	.147	.188	.126	.161
48.950	.134	8.298	.268	.107	.190	.100	.127	.103	.127	.079	.095	.087	.122
95.279	.261	10.525	.340	.278	.331	.266	.332	.265	.299	.272	.300	.285	.361

PIEDMONT PLAIN GROUND-WATER INVENTORY

NO.	COMPANY LOCATION (County)	STATION	WELL DATA WELL NO.	DIAM. (Inches)	DEPTH (Feet)	REPORTED WELL YIELD (gpm)	PUMP CAPACITY (gpm)	AQUIFER
P 1	ALLENDALE WATER DEPT.		2	12	450	225	200	Brunswick
	Allendale (Bergen)		3	12	500	175	125	Brunswick
			4		550		175	Brunswick
P 2	BOGOTA WATER CO.		1	8	175	150-190	125	Brunswick
	Bogota (Bergen)		3	10	350		150	Brunswick
			4	12	235		120	Brunswick
			2R	10	550	125-190	120	Brunswick
P 3	BOONTON WATER DEPT.		1	26	45	382	350	Glacial Drift
	Boonton (Morris)		2	26	45		350	Glacial Drift
			3	26	40		250	Glacial Drift
P 4	CHATHAM WATER & LIGHT DEPT.		9	24	140		1000	Glacial Drift
	Chatham (Morris)		10	17	140		700	Glacial Drift
			1	6	125			Glacial Drift
			2	6	125			Glacial Drift
			3	6	125			Glacial Drift
			4 R	6	125		550	Glacial Drift
			5	6	125			Glacial Drift
			6	8	125			Glacial Drift
			7	8	125			Glacial Drift
P 5	COMMONWEALTH WATER CO.	Canoe Brook	Cont. 1	25	105		140	Glacial Drift
	(Essex)		Kelly 1	25	135	1470	750	Glacial Drift
			Kelly 2	25	135		1000	Glacial Drift
			Kelly 4	25	133		700	Glacial Drift
			Kelly 5	25	131		700	Glacial Drift
			Layne D	12	130		700	Glacial Drift
			Layne E	12	135		500	Glacial Drift
			38	8	309		500	Brunswick
			26	8	147			Glacial Drift
			32	10	303			Brunswick
			33	10	379			Brunswick
			36	12	303			Brunswick
			37 R	10	303		650-1000A	Brunswick
			40	8	300			Brunswick
			41	8	303			Brunswick
			42	10	304			Brunswick
			31	8	304			Brunswick
		Short Hills	A	24	90		900	Glacial Drift
			B	24	90		900	Glacial Drift
			C	24	90		1110	Glacial Drift
		Balustrol	15	8	300		650	Brunswick
			17	10	371		350	Brunswick
			18	10	461		280	Brunswick
			7	8	200			Brunswick
			8	8	201			Brunswick
			12 R	8	300		500A	Brunswick
			14	8	300			Brunswick
			16	8	300			Brunswick
P 6	EAST ORANGE WATER DEPT.	Slough Brook	North	10	280±		250	Brunswick
	Millburn (Essex)		Middle	10	280±	350-420	250	Brunswick
			South	10	280±		250	Brunswick
		Dickenson	North	24	133		1000	Glacial Drift
			Middle	24	129		1000	Glacial Drift
			South	24	126		500	Glacial Drift
		Canoe Brook	North	24	108		1400	Glacial Drift
			Middle	24	111		1400	Glacial Drift
			South	24	121		1050	Glacial Drift
	Florham Park (Morris)	Braidburn	North	24	123		1750	Glacial Drift
			Middle	24	126		1050	Glacial Drift
			South	20	123		800	Glacial Drift
P 7	ELIZABETHTOWN WATER CO.	Hummocks	1	8	326		244	Brunswick & Glacial Drift
	(Union)		2	8	238		62	Brunswick & Glacial Drift
			3	8	87		285	Brunswick & Glacial Drift
			5	8	91		201	Brunswick & Glacial Drift
			7	8	249		155	Brunswick & Glacial Drift
			12	8	97			Brunswick & Glacial Drift
			17	8	112		342	Brunswick & Glacial Drift
			19	8	455		122	Brunswick & Glacial Drift
			20	8				Brunswick & Glacial Drift
			23	8	120		137	Brunswick & Glacial Drift
			26	8				Brunswick & Glacial Drift
			28	8	96		122	Brunswick & Glacial Drift
			29	8	106		126	Brunswick & Glacial Drift
			41	8	83		162	Brunswick & Glacial Drift
			1-A	8	143		131	Brunswick & Glacial Drift
			2-A	8			244	Brunswick & Glacial Drift
			3-A	8	126		137	Brunswick & Glacial Drift
			4-A	8	125		171	Brunswick & Glacial Drift
			5-A	8	128		155	Brunswick & Glacial Drift
			6-AR	16	130		684	Brunswick & Glacial Drift
			7-A	8	124		125	Brunswick & Glacial Drift
			8-A	8	125		342	Brunswick & Glacial Drift
			9-A	8	126		127	Brunswick & Glacial Drift
			10-A	8	118			Brunswick & Glacial Drift
			11-A	8	125			Brunswick & Glacial Drift
			12-A	8	120		200	Brunswick & Glacial Drift
		Springfield	6	8	158		53	Brunswick & Glacial Drift
			8-R	8	130			Brunswick & Glacial Drift
			9-R	8	130		68	Brunswick & Glacial Drift
			12	8	159		71	Brunswick & Glacial Drift
			17	8	311		55	Brunswick & Glacial Drift
			19-R	8	130		132	Brunswick & Glacial Drift
			21-R	8	130		81	Brunswick & Glacial Drift
			23-R	8	130		118	Brunswick & Glacial Drift
			24	8	200		31	Brunswick & Glacial Drift
			25-R	8	130		50	Brunswick & Glacial Drift

R—Reserve Well
A—Airlift

GROUND-WATER DIVERSIONS

1954 (OR LATEST REPORTED YEAR)				1953		1952		1951		1950		1949	
ANNUAL		MAX. MONTH		ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH
(mg)	(mgd)	(mg)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)
65.860	.180	17.828 (For 3 Mos.)	.194	.171	.213	.144	.165	.126	.140	.124	.137	.127	.149
93.587	.256	9.088	.303	.287	.335	.312	.351	.307	.342	.252	.285	.270	.288
269.032	.737	26.314	.849	.750	.839	.826	.913	.824	.860	.646	.892	.487	.533
24.859	.681	28.380	.938	.686	.850	.623	.802	.561	.651	.509	.571	.540	.829
2,272.577	6.226	221.327	7.140	6.217	8.109	4.986	5.861	5.248	5.407	5.034	6.050	5.563	7.569
1,099.353	3.012	96.565	3.115	3.355	3.436	3.358	3.464	3.326	3.382	3.179	3.358	2.904	3.313
394.349	1.080	42.973	1.432	1.405	1.792	1.418	2.004	1.319	1.785	1.400	1.691	1.728	2.114
100.005	.273	22.664	.731	6.774	7.310	6.390	6.611	6.091	6.364	5.753	6.090	6.296	6.704
825.670	2.262	79.700	2.571										
766.470	2.100	74.173	2.393	2.228	2.425	2.341	2.457	1.963	2.142	2.083	2.164	2.269	2.710
510.986	1.400	71.440	2.304										
2,200.253	6.028	223.455	7.448	7.154	8.080	7.092	8.018	6.781	7.290	6.593	6.865	6.706	8.029

PIEDMONT PLAIN GROUND-WATER INVENTORY

NO.	COMPANY LOCATION (County)	STATION	WELL DATA WELL NO.	DIAM. (Inches)	DEPTH (Feet)	REPORTED WELL YIELD (gpm)	PUMP CAPACITY (gpm)	AQUIFER
P 7	ELIZABETHTOWN WATER CO. *(Continued)* (Union)	Springfield	28	8	200		80	Brunswick & Glacial Drift
			29	8	193		78	Brunswick & Glacial Drift
			30-R	10	130		92	Brunswick & Glacial Drift
			32	8	200		118	Brunswick & Glacial Drift
			34	8	167		40	Brunswick & Glacial Drift
			36	8	200		71	Brunswick & Glacial Drift
			41	8	338		85	Brunswick & Glacial Drift
			42	8	258		67	Brunswick & Glacial Drift
			44	8	200		76	Brunswick & Glacial Drift
			47	8	200		78	Brunswick & Glacial Drift
			50	8	129		190	Brunswick & Glacial Drift
			52	8	340		47	Brunswick & Glacial Drift
			53-R	20	65		760	Brunswick & Glacial Drift
			54	24	63		717	Brunswick & Glacial Drift
			55	12	70			Brunswick & Glacial Drift
			1-A	8	138		190	Brunswick & Glacial Drift
			2-A	8	158		275	Brunswick & Glacial Drift
			3-A	8	143		99	Brunswick & Glacial Drift
			4-A	8	143		142	Brunswick & Glacial Drift
			5-A	8	140		163	Brunswick & Glacial Drift
			6-A	8	141		300	Brunswick & Glacial Drift
			7-A	8	140		122	Brunswick & Glacial Drift
		Hillside	1	12	400	595		Brunswick & Glacial Drift
			2	12	600	192		Brunswick & Glacial Drift
			5	12	400	695		Brunswick & Glacial Drift
			4	12	400	895		Brunswick & Glacial Drift
			3	12	400			Brunswick & Glacial Drift
P 8	ESSEX FELLS WATER DEPT. Essex Fells (Essex)	Plant 1	1A	24	96		300	Glacial Drift
			5	10	295		400	Brunswick
			6	10	565		300	Brunswick
			7	24	90		400	Glacial Drift
			8	24	423		300	Brunswick
			9	20	364		400	Brunswick
		Plant 2	2	24	40		150	Glacial Drift
		Plant 4	4A	10	195		300	Brunswick
			4B	12	270		200	Brunswick
			4C	10	360		120	Brunswick
P 9	CHAS. N. EVANS DEV. WATER CO. Lincoln Park (Morris)		2	8	220	20	20	Brunswick
			3	8	100		20	Brunswick
			1R		50	20	30	Brunswick
P 10	FAIRLAWN WATER DEPT. Fairlawn (Bergen)		1	12	300	550	450	Brunswick
			2	12	300	180	100	Brunswick
			3	12	300	90	100	Brunswick
			4	12	300	240	100	Brunswick
			5	12	300	180	100	Brunswick
			6	12	500	220	150	Brunswick
			7	12	300		300	Brunswick
			8	10	430		250	Brunswick
			9	12	404		350	Brunswick
			10	12	300		500	Brunswick
			11	12	400		500	Brunswick
			12	12	400		150	Brunswick
			14	12	400		350	Brunswick
P 11	FLEMINGTON WATER CO. Flemington (Hunterdon)		Mine Hill	8	44		120	Brunswick
			Mine Hill	8	405		125	Brunswick
			7	8	418		75	Brunswick
			5R	8	235		350	Brunswick
P 12	FLORHAM PARK WATER DEPT. Florham Park (Morris)		3	20	81		500	Glacial Drift
				16	102		1000	Glacial Drift
P 13	FRENCHTOWN WATER CO. Frenchtown (Hunterdon)		1	10	286	140	180	Brunswick
P 14	GARFIELD WATER DEPT. Garfield (Bergen)		1	12	404		90	Brunswick
			2	12	358		125	Brunswick
			4	12	353		90	Brunswick
			5	12	353		274	Brunswick
			7	12	350		260	Brunswick
			8	12	354		166	Brunswick
			9	12	402		112	Brunswick
			10	12	350		194	Brunswick
			11	12	353		192	Brunswick
			12	12	350		140	Brunswick
			17				85	Brunswick
P 15	HACKENSACK WATER CO. Hackensack (Bergen)		1	20	168	1700	1750	Glacial Drift
			2	20	190	1700	1750	Glacial Drift
P 16	HAWTHORNE WATER DEPT. Hawthorne (Passaic)	Goffle Rd.	1	10	293		435	Brunswick
			3	6	300		150	Brunswick
			4	6	315		388	Brunswick
			5	10	300		183	Brunswick
			6	8	435		250	Brunswick
		Wagaraw Rd.	3	8	300		350	Brunswick
			4	8	300		350	Brunswick
			6	8	300		350	Brunswick
			8	8	300		350	Brunswick
		S. Wagaraw Rd.	1	10			450	Brunswick
P 17	HOHOKUS Hohokus (Bergen)			12	260	100	380	Brunswick
				12	260	100		Brunswick
P 18	HOPEWELL WATER DEPT. Hopewell (Mercer)		1	8	376	175	104	Brunswick
			2	8	243	250	124	Brunswick
P 19	KINGSTON WATER CO. Kingston (Middlesex)			12	280	275		Brunswick
P 20	LAWRENCEVILLE WATER CO. Lawrenceville (Mercer)		4	12	187		100	Stockton
			5	12	252		150	Stockton

R—Reserve Well

GROUND-WATER DIVERSIONS

1954 (OR LATEST REPORTED YEAR)				1953		1952		1951		1950		1949	
ANNUAL		MAX. MONTH		ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH
(mg)	(mgd)	(mg)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)
805.441	2.207	86.422	2.788	2.049	2.382	1.890	2.185	1.822	2.006	1.647	1.788	1.723	2.182
1.800	.005	.150	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005
801.276	2.195	100.757	3.358	2.142	2.859	1.891	2.898	1.636	2.169	1.507	2.090	1.262	1.738
72.002	.200	7.550	.243										
118.857	.326	19.496	.629	.287	.394	.264	.453	.213	.264	.170	.216	.185	.352
36.572	.100	3.345	.112	.145	.196	.195	.199	.190	.197	.182	.194	.205	.242
749.077	2.052	77.991	2.516	2.066	2.342	1.916	2.470	1.864	2.235	1.821	2.140	2.233	2.804
74.340	.204	44.160	1.424										
741.134	2.030	73.762	2.459	1.955	2.479	1.857	2.279	1.693	1.861	1.573	1.933	1.213	1.484
75.214	.206	11.102	.370										
41.797	.114	4.072	.131	.126	.145	.136	.139	.131	.139	.124	.137	.124	.140
23.119	.063	4.417	.147	.056	.098	.053	.138	.047	.075	.054	.108	.053	.103
22.666	.062	4.243	.137	.062	.109	.054	.085	.054	.075	.049	.062	.058	.090

Table

PIEDMONT PLAIN GROUND-WATER INVENTORY

NO.	COMPANY LOCATION (County)	STATION	WELL DATA: WELL NO.	DIAM. (Inches)	DEPTH (Feet)	REPORTED WELL YIELD (gpm)	PUMP CAPACITY (gpm)	AQUIFER
P 21	LINCOLN PARK WATER CO. Lincoln Park (Morris)		1	5	115	25	25	Brunswick
			2	8	109	50	30	Brunswick
P 22	LODI WATER CO. Lodi (Bergen)		1	8-12	300		160	Brunswick
			4		318		295	Brunswick
			5		301		130	Brunswick
			6		308		110	Brunswick
			7		332		150	Brunswick
			10		409		475	Brunswick
			9		373		500	Brunswick
P 23	MADISON WATER DEPT. Madison (Morris)		1	8	148			Glacial Drift
			2	8	100			Glacial Drift
			4	8	99			Glacial Drift
			5	8	85			Glacial Drift
			6	6	160			Glacial Drift
			7	6	97			Glacial Drift
			8	6	165			Glacial Drift
			9	6	145			Glacial Drift
			10	10	125		1650 (Total For All Wells)	Glacial Drift
			11	10	132			Glacial Drift
			12	10	140			Glacial Drift
P 24	MAHWAH TWP. WATER DEPT. Mahwah (Bergen)		1	8	300	48		Brunswick
			2	8	227	125		Brunswick
			3	8	288	100		Brunswick
			4	8	297	105		Brunswick
			5	8	303	225		Brunswick
			6	8	306	150		Brunswick
			7	8	655	100		Brunswick
			7½	8	36	15		Brunswick
			8	10		50		Brunswick
			9	10		165		Brunswick
			10	10		60		Brunswick
			11	10		125		Brunswick
			12	10	82	200		Brunswick
			13	10		125		Brunswick
			14	10	300	240		Brunswick
P 25	MANVILLE WATER DEPT. Manville (Somerset)		1E	72	18		1000	Glacial Drift
			1W	72	14			Glacial Drift
			2E	72	18			Glacial Drift
			2W	72	15			Glacial Drift
			3	72	16			Glacial Drift
			PH	88	17			Glacial Drift
P 26	MIDDLESEX WATER CO. Middlesex (Middlesex)		9	10	289			Brunswick
			10	10	286			Brunswick
			11	10	300			Brunswick
			12	10	266			Brunswick
			13	10	265 A			Brunswick
			14	10	259			Brunswick
			15	10	304			Brunswick
			16	10	295			Brunswick
			17	10	305			Brunswick
			18	12	74	1100	1400	Glacial Drift
			19	12	78	1000	1100	Glacial Drift
			20	12	84	1200	1400	Glacial Drift
			21	12	73		1000	Glacial Drift
			1 S.P.	12	403			Brunswick
			2 S.P.	12	409			Brunswick
			2	12	255			Brunswick
			3	10	292			Brunswick
			4	12	281	6000		Brunswick
			5	10	201 A	TOTAL		Brunswick
			6	10	298			Brunswick
			7	10	291			Brunswick
			8	10	288			Brunswick
P 27	MILFORD WATER DEPT. Milford (Hunterdon)			186	30	100	100	Glacial Drift
				8	90		205	Brunswick
				8	255	242		Brunswick
P 28	MORRISTOWN WATER DEPT. Morristown (Morris)	Littleton	1	24	60	700	750	Glacial Drift
			2	24	65		350	Glacial Drift
		Normandy	1	17	79		400	Glacial Drift
		Wing	1	17	138		950	Glacial Drift
			2	24				Glacial Drift
		Sand Spring	1	24	94		600	Glacial Drift
P 29	OAKLAND WATER DEPT. Oakland (Bergen)	Pine St.	1	8	200	87	62	Brunswick
			2	10	200	80	62	Brunswick
			3	10	107	110	100	Brunswick
		Martin Bush		6	127		240	Brunswick
			1-LR		100		12	Brunswick
P 30	ORANGE WATER DEPT. Orange (Essex)	Millburn		16	49		243	Glacial Drift
				18	90		1215	Glacial Drift
				18	130			Glacial Drift
				20	110		695	Glacial Drift
P 31	PARK RIDGE WATER DEPT. Park Ridge (Bergen)		1	16	247	210	210	Brunswick
			2	12	435	165	200	Brunswick
			3	12	500	160	125	Brunswick
			4	12	450		160	Brunswick
P 32	PARSIPPANY-TROY HILLS WATER CO. Parsippany (Morris)		1	16	151	745		Glacial Drift
			3	16	80		300	Glacial Drift
				8	169	100		Glacial Drift
P 33	PENNINGTON WATER DEPT. Pennington (Mercer)		1	6	150	50	50	Brunswick
			2	6	170	30	30	Brunswick
			3	6	653	45	48	Brunswick
			4	10	512		38	Brunswick

PH—Pump House
R—Reserve Well
A—Airlift

GROUND-WATER DIVERSIONS

1954 (OR LATEST REPORTED YEAR)				1953		1952		1951		1950		1949	
ANNUAL		MAX. MONTH		ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH
(mg)	(mgd)	(mg)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)
1.239	.003	.107	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003
565.933	1.550	51.487	1.661	1.658	1.889	1.622	1.933	1.500	1.614	1.337	1.444	1.264	1.434
387.962	1.063	39.000	1.258										
72.170	.198	8.019	.267	.278	.390	.264	.330	.204	.244	.200	.238	.205	.270
292.878	.802	28.939	.934	.750	.821	.785	.873	.710	.790	.808	.850	.836	.920
3,183.376	8.722	295.382	9.846	8.764	10.304	8.127	9.051	8.047	8.604	8.207	9.093	7.657	8.879
34.207	.094	3.874	.125	.083	.118	.077	.090	.080	.086	.069	.100	.050	.072
874.051	2.395	91.212	2.942	2.179	2.740	1.889	2.198	1.666	1.916	1.645	1.859	1.225	2.050
92.557	.254	15.830	.511	.235	.428	.162	.304	.150	.206	.141	.205	.123	.171
942.761	2.583	88.604	2.953	2.646	3.139	2.593	2.998	2.064	2.405	2.240	2.655	3.056	3.424
152.385	.417	17.115	.570	.409	.550	.353	.469	.315	.384	.310	.363	.329	.410
281.422	.771	38.298	1.235	.756	1.056	.656	.968	.575	.732	.553	.707	.602	.908?
40.442	.111	4.047	.131	.104	.124	.096	.123	.089	.092	.084	.093	.081	.908

PIEDMONT PLAIN GROUND-WATER INVENTORY

NO.	COMPANY LOCATION (County)	STATION	WELL DATA WELL NO.	DIAM. (Inches)	(Feet) DEPTH	REPORTED WELL YIELD (gpm)	PUMP CAPACITY (gpm)	AQUIFER
P 34	PLAINFIELD-UNION WATER CO.	Netherwood	1	10	350		140	Brunswick
			2	10	500		130	Brunswick
			3	10	350		325	Brunswick
			4	10	400		290	Brunswick
			5	10	350		400	Brunswick
			6	10	300		320	Brunswick
			7	10	304		280	Brunswick
			8	10	350		320	Brunswick
			9	10	350		340	Brunswick
			10	10	350		260	Brunswick
			11	10	350		300	Brunswick
			12	12	350		200	Brunswick
		Gravel	1	10	183		230	Glacial Drift
			2	10	253		230	Brunswick
			3	10	305		230	Brunswick
		Columbia Ave.	4	12	352		220	Brunswick
		George St.	Rock	12	300		150	Brunswick
		George St.	Gravel	12	85		700	Glacial Drift
		Scotch Plains	1	12	650		300	Brunswick
			2	12	665		350	Brunswick
			3	12	708		150	Brunswick
		Kenilworth	Newark	10	300		250	Brunswick
			Richfield	12	400		250	Brunswick
			Quinton	12	450		350	Brunswick
		Clinton Ave.	1	8	300		280	Brunswick
			1	12	300		280	Brunswick
			2	12	350		150	Brunswick
		Greenbrook	1	12	450		500	Brunswick
			2	12	376		500	Brunswick
			3	12	550		300	Brunswick
			4	12	400		400	Brunswick
			5	12	400		600	Brunswick
			6	12	400		600	Brunswick
			7	12	400		300	Brunswick
			8	12	46		300	Glacial Drift
		Westfield	1	12	533		500	Brunswick
			2	12	572			Brunswick
		Mountainside	1	12	454		500	Brunswick
			2	12	572			Brunswick
		N. Plainfield	1					
		Greenbrook Pk.	1					
P 35	PRINCETON WATER CO. Princeton (Mercer)		H 1		503		150	Stockton
			H 3		301		350	Stockton
			H 4		302			Stockton
			H 5		300		250	Stockton
			SB 2	10	293	800	1000	Stockton
			SB 3	10	353	250	250	Stockton
			SB 4	10	380		160	Stockton
			SB 6	8	305	350	550	Stockton
			SB 7	10	294	600	700	Stockton
			SB 8	10	301	800	905	Stockton
P 36	PRINCETON JUNCTION WATER CO. Princeton Jct. (Mercer)		1	4	90	17	30	PreCambrian
			2	6	306		15	PreCambrian
P 37	RAHWAY WATER DEPT. Rahway (Union)		1	10	52	355		Glacial Drift
			2	10	51	175		
P 38	RAMSEY WATER DEPT. Ramsey (Bergen)	N. Central Ave.	1		450	200	240	Brunswick
			2		310	155	145	Brunswick
		E. Oak St.	2	12	303	120	120	Brunswick
		Orchard St.	3	12	300	185	200	Brunswick
P 39	RARITAN TWP. WATER DEPT. New Brunswick (Middlesex)		1	8	353	260	260	Brunswick
			3	8	501	140	140	Brunswick
			4	10	382	275	275	Brunswick
			7	10	507		300	Brunswick
			8	8	503		128	Brunswick
			9	8	476		187	Brunswick
P 40	RIDGEWOOD WATER DEPT. Ridgewood (Bergen)	Wortendyke	2	8	1137	250	250	Brunswick
			6	10	337	212	200	Brunswick
			7	10	360	127	160	Brunswick
			1	10	201	650	600	Brunswick
			1	10	298	250	200	Brunswick
		Ridgewood Ave.	1	10	261	750	700	Brunswick
		Grove St.	1	10	402	370	350	Brunswick
		Linwood Ave.	3	12	352	380	300	Brunswick
		Fairview St.	5	12	350	125	175	Brunswick
		Ames	6	12	455	152	175	Brunswick
			7	12	352	118	175	Brunswick
			1	12	280	410	300	Brunswick
			1	9	414	163	150	Brunswick
		East Saddle Rd.	2	12	399	100	100	Brunswick
		Cedar Hill	3	12	500	116	100	Brunswick
			4	12	315	301	300	Brunswick
			5	12	379	108	150	Brunswick
			6	12	385	168	150	Brunswick
			1	12	420	400	350	Brunswick
			1	12	416	425	400	Brunswick
		Waldo	9 Wells			1 Mgd	750-900	Brunswick
		Midland Ave.					Total for	
		East Glen					9 Wells	
P 41	ROCKY HILL WATER DEPT. Rocky Hill (Somerset)		1	8	200		40	Brunswick
			2	8	200		170	Brunswick

1—Latest Reported Year—1953

PIEDMONT PLAIN GROUND-WATER INVENTORY

NO.	COMPANY LOCATION (County)	STATION	WELL DATA: WELL NO.	DIAM. (Inches)	DEPTH (Feet)	REPORTED WELL YIELD (gpm)	PUMP CAPACITY (gpm)	AQUIFER
P 42	SOUTH ORANGE WATER CO. South Orange (Essex)		1	8	274		300	Brunswick
			2	10	276		300	Brunswick
			3	10	275		350	Brunswick
			5	10	300		300	Brunswick
			7	10	300		300	Brunswick
			8	10	300		300	Brunswick
			11	8	350	400	650	Brunswick
			12	12	350	150-200	200	Brunswick
			13	12	350	600	900	Brunswick
			14	14	355		250	Brunswick
P 43	STOCKTON WATER DEPT. Stockton (Hunterdon)		1	6	145		96	Stockton
			2	6	145			Stockton
P 44	TWP. OF LIVINGSTON WATER DEPT. Livingston (Essex)		1	16	373		175	Brunswick
P 45	WALDWICK WATER DEPT. Waldwick (Bergen)		1	12	308		350	Brunswick
			2	8	256		350	Brunswick
			3	12	500		60	Brunswick
P 46	WALLINGTON WATER DEPT. Wallington (Bergen)							
P 47	WAYNE TWP. WATER DEPT. Wayne Twp. (Passaic)		1					

[1]—Latest Reported Year—1952

GROUND-WATER DIVERSIONS

1954 (OR LATEST REPORTED YEAR)				1953		1952		1951		1950		1949	
ANNUAL		MAX. MONTH		ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH
(mg)	(mgd)	(mg)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)
524.061	1.436	50.576	1.686	1.598	1.858	1.486	1.708	1.414	1.509	1.392	1.511	1.408	1.759
9.381	.026	.906	.029	.025	.027	.024	.026	.023	.026	.021	.025	.021	.026
85.072	.233	8.243	.275	.179	.269	.160	.199			.482	.607	.459	.600
141.360	.387	18.398	.593	.421	.610	.344	.423	.289	.346	.222	.283	.201	.300
194.076	.532	20.469	.682	.532	.640	.532	.596	.568	.718	.518	.576	.531	.719
3.240[1]	.009[1]	.270[1]	.009[1]			.009	.009	.011	.011	.006	.010	.002	.002

GROUND-WATER DIVERSIONS

1954 (OR LATEST REPORTED YEAR)				1953		1952		1951		1950		1949	
ANNUAL		MAX. MONTH		ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH
(mg)	(mgd)	(mg)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)
524.061	1.436	50.576	1.686	1.598	1.858	1.486	1.708	1.414	1.509	1.392	1.511	1.408	1.759
9.381	.026	.906	.029	.025	.027	.024	.026	.023	.026	.021	.025	.021	.026
85.072	.233	8.243	.275	.179	.269	.160	.199			.482	.607	.459	.600
141.360	.387	18.398	.593	.421	.610	.344	.423	.289	.346	.222	.283	.201	.300
194.076	.532	20.469	.682	.532	.640	.532	.596	.568	.718	.518	.576	.531	.719
3.240[1]	.009[1]	.270[1]	.009[1]			.009	.009	.011	.011	.006	.010	.002	.002

Table

HIGHLANDS GROUND-WATER INVENTORY

NO.	COMPANY LOCATION (County)	STATION	WELL DATA: WELL NO.	DIAM. (Inches)	DEPTH (Feet)	REPORTED WELL YIELD (gpm)	PUMP CAPACITY (gpm)	AQUIFER
H 1	ALPHA WATER DEPT. Alpha (Warren)		2 1R	10 10	230 340	200	150 150	Kittatinny
H 2	ANDOVER WATER DEPT. Andover (Sussex)		1 2	12 6	42 40		200 200	Glacial Drift ? Glacial Drift ?
H 3	CALIFON WATER CO. Califon (Hunterdon)		1S 2S			15 7		
H 4	CLINTON WATER DEPT. Clinton (Hunterdon)		3	8	228		165	Kittatinny ?
H 5	DENVILLE WATER DEPT. Denville (Morris)	Denville Randolph Twp.	1 2 3R	16 16 16	134 135 135		750 1450	Glacial Drift Glacial Drift Glacial Drift
H 6	DOVER WATER DEPT. Dover (Morris)		1 2 3	24 18 24	66 65 64		1150 750 1300	Glacial Drift Glacial Drift Glacial Drift
H 7	GLEN GARDNER WATER CO. Glen Gardner (Hunterdon)		2S 1	 10	 286	18	 180	Byram Gneiss Byram Gneiss
H 8	HAMBURG WATER DEPT. Hamburg (Sussex)		1 2	 12	 72	 100	 230	
H 9	JUNCTION WATER CO. Washington (Warren)		1 2 R 3	8 10 8	334 209 302	40	75 75 75	Kittatinny Kittatinny Kittatinny
H 10	LAKE HOPATCONG WATER CO. (Morris)		1 2 3 4R	6 8 8	82 147 74 150	55 35 75 25	85 60 100 50	Losee Gneiss Losee Gneiss Losee Gneiss Losee Gneiss
H 11	LAKE MOHAWK-SPARTA WATER CO. Sparta (Sussex)		1 5 6 7	12 12 8	118 30 25 203	 400 	260 385 225 70	Kittatinny Kittatinny Kittatinny Byram Gneiss
H 12	LAKE TAMARACK WATER CO. Hamburg (Sussex)		2 3 6 1R	6 10 8	96 60 76 300		8 40 35 4	?
H 13	LENAPE WATER CO. Andover (Sussex)		C A R B	8 24 24	73 21 14		90 50	?
H 14	LONG VALLEY WATER CO. Long Valley (Morris)		S					Kittatinny
H 15	MENDHAM WATER DEPT. Mendham (Morris)		1	10	260	132		Losee Gneiss
H 16	MORRIS & SUSSEX WATER SERVICES INC. Hopatcong Park (Sussex) Lake Rogerene (Morris)		1 1	8 6	250 90	42 30	30 30	?
H 17	MOUNTAIN LAKES WATER CO. Mountain Lakes (Morris)		3 4 1 R 2 R	17 17 14 14	60 60 60 60	 300 300	400 400 200 200	Glacial Drift Glacial Drift Glacial Drift Glacial Drift
H 18	NETCONG WATER DEPT. Netcong (Morris)		1 2	12 18	75 90		193 325	Glacial Drift Glacial Drift
H 19	OGDENSBURG WATER DEPT. Ogdensburg (Sussex)		1	16	120		250	Kittatinny ?
H 20	PEOPLES WATER CO. Phillipsburg (Warren)		S					
H 21	PROSPECT POINT WATER CO. Lake Hopatcong (Morris)		1	6	360		50	Byram Gneiss
H 22	RINGWOOD CO. Ringwood (Passaic) Lake Erskine (Passaic)	Awosting	2 1R 1 3 4	6 8 8 8 8	361 125 164 375 205	20 25 25 50 	20 20 20 50 100	Losee Gneiss Losee Gneiss Losee Gneiss Losee Gneiss Losee Gneiss
H 23	ROCKAWAY WATER DEPT. Rockaway (Morris)		1 3	10 12	56 150		310 650	Glacial Drift Glacial Drift
H 24	SHORE HILLS WATER CO. Landing (Morris)		1 2	8 10	64 98		50 225	Glacial Drift Glacial Drift
H 25	SPARTA MOUNTAIN WATER CO. Sparta Hills (Sussex)	Lake Shawnee Summit Lake	1 1	8 8	25 88		60 16	?
H 26	STANHOPE WATER DEPT. Stanhope (Sussex)		1 2	8 8	95 119	125	85 290	Glacial Drift Glacial Drift
H 27	STEWARTSVILLE WATER CO. Stewartsville (Warren)		1	12	250		50	Kittatinny ?
H 28	WANAQUE WATER DEPT. Wanaque (Passaic)	Haskell Midvale	1 2 3 1	180 180 180 	14 12 20 60	600 600 600 	300 300 500 200	Glacial Drift Glacial Drift Glacial Drift Glacial Drift
H 29	WASHINGTON WATER CO. Washington (Warren)		1R	10	311	250	250	Kittatinny
H 30	WEST JERSEY WATER SERVICES INC. Budd Lake (Morris)		1 2	8 6	340 50	15-20 40-60	12 50	Byram Gneiss Glacial Drift
H 31	WHARTON WATER DEPT. Wharton (Morris)		1	16	39	530	500	Glacial Drift
H 32	WILDWOOD SHORES Lake Hopatcong (Morris)		1 2	8 8	184 280		12 25	Byram Gneiss Byram Gneiss

R—Reserve Well
S—Spring
1—Latest Reported Year—1953

GROUND-WATER DIVERSIONS

1954 (OR LATEST REPORTED YEAR)				1953		1952		1951		1950		1949	
ANNUAL		MAX. MONTH		ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH	ANNUAL	MAX. MONTH
(mg)	(mgd)	(mg)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)	(mgd)
43.857	.120	5.075	.164	.105	.129	.087	.094	.079	.083	.074	.079	.071	.089
18.109	.050	1.813	.058	.044	.051	.037	.042	.034	.039	.033	.038	.029	.033
8.400	.023	.700	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023
19.399	.053	5.595	.180										
221.341	.606	33.624	1.085	.581	.881	.542	.770	.527	.700	.476	.654	.397	.612
607.960	1.666	59.400	1.916	1.399	1.745	1.267	1.459	1.166	1.281	1.173	1.331	1.131	1.325
9.995	.027	.828	.030	.028	.030	.028	.028	.027	.028	.028	.030	.026	.029
33.550	.092	4.050	.131	.138	.160	.101	.105	.123	.181	.108	.153	.066	.097
12.188	.033	1.890	.061										
17.219	.094	5.673	.183	.055	.184	.045	.158	.036	.124	.023	.100	.015	.064
122.727	.336	18.717	.604										
5.699	.016	1.094	.035	.015	.033	.012	.030			.012	.027	.007	.013
7.584	.021	1.094	.033										
3.780	.010	.315	.010	.010	.010	.008	.008	.008	.008	.008	.008	.008	.008
ALL SURFACE WATER SUPPLY UNTIL SEPTEMBER 1954													
1.410	.004	.270	.003	.004	.008	.004	.008	.004	.008	.003	.007	.003	.007
1.356	.004	.228	.007	.004	.008	.004	.008	.004	.008	.004	.008	.004	.008
84.183	.231	8.217	.265	.231	.265	.226	.287	.212	.273	.193	.215	.192	.254
84.187[1]	.231[1]	7.946[1]	.256[1]	.231	.256	.205	.231	.189	.207	.206	.240	.196	.224
20.051	.055	2.183	.070	.055	.062	.053	.060	.058	.085	.053	.059	.068	.080
1.045	.003	.350	.011	.007		.006		.006		.006		.004	
2.942	.008	.762	.025	.008	.023	.007	.023	.007	.019	.007	.018	.008	.022
21.379	.059	4.089	.132	.051	.122	.043	.104	.037	.084	.041	.099	.038	.097
98.085	.268	10.625	.343			.268	.343	.296	.393	.240	.265	.266	.344
20.315	.056	3.600	.116	.055	.112								
11.506	.032	2.340	.075	.021	.045	.015	.029	.007	.015	.003	.007	.003	.008
51.927	.142	6.725	.217	.148	.224	.138	.174	.144	.160	.154	.184	.156	.188
11.580	.032	1.157	.037	.028	.031	.029	.032	.045	.058	.046	.051	.043	.046
130.204	.357	11.331	.366	.273	.359	.159	.212	.111	.134	.077	.102	.064	.080
13.282	.036	3.442	.111										
50.549	.138	5.914	.191										
6.601	.018	1.805	.058	.025	.064	.026	.053	.026	.056	.026	.056	.023	.056
81.910	.224	7.690	.248										
2.515	.007	.460	.015	.007	.013	.005	.010	.007	.015	.006	.012	.003	.005

APPENDIX C

APPENDIX C

(Second Official Copy Reprint)

Assembly Joint Resolution No. 4

State of New Jersey
Introduced January 11, 1955
By Messrs. Beadleston, Mills and Bowkley

Referred to Committee on State, County and Municipal Government

A Joint Resolution providing for a commission to study and report to the Legislature as to the acquisition and development of the water supply resources of the State *and making an appropriation therefor.*

Whereas, The problem of the provision of additional adequate water supply for the citizens of this State in the immediate future is of paramount importance and requires solution at the earliest possible moment; and

Whereas, Numerous plans for the provision of additional water supply facilities in New Jersey have been made to the Legislature, many of which are of diverse and conflicting character and so much discussion has arisen as to the desirability of the adoption of any 1 of these plans that the Legislature deems it necessary that a complete over-all long range plan for the development and use of all water supply sources available to the State should be formulated in order that the facilities immediately to be provided for should form an appropriate and logical step in the development of such a plan; and

Whereas, In the judgment of the Legislature it is necessary that an engineering study of all the water supply resources of the State shall be made for the Legislature by an independent engineering organization of national reputation and that such an over-all long range plan for the development and use of such resources shall be prepared by such organization and submitted to the Legislature;

Be it resolved *by the Senate and General Assembly of the State of New Jersey:*

1. There is hereby created a legislative commission to be known as the Legislative Commission on Water Supply to consist of 7 members, *1 to be appointed by the Governor from the citizens at large of the State,* 3 to be appointed from the membership of the Senate by the President thereof and 3 to be appointed from the membership of the General Assembly by the Speaker thereof, not more than 2 of each of said groups of 3 members to be of the same political party and all of whom shall serve without compensation. Vacancies in the membership of the commission shall be filled in the same manner as the original appointments were made.

2. The commission shall organize as soon as may be after the appointment of its members and shall elect a chairman from among its members and a secretary who need not be a member of the commission.

3. It shall be the duty of said commission to undertake and supervise the conduct of a feasibility study of the use of the water resources facilities of the State including the proposals for the development of the Wharton Tract Water Supply Project, the Round Valley Water Supply Project and the Delaware River Valley Water Supply Project and all other water supply projects which may come to their attention and to report thereon to the Legislature from time to time as its study progresses.

4. The commission is authorized to

(1) Engage the services of competent engineering specialists in water supply and related fields

(a) to make surveys of the potentialities of the water supply resources of the State, including the aforementioned water supply projects and proposals and any other projects or proposals and

(b) to report thereon, from time to time, to the commission with their recommendations as to what areas shall be acquired for water supply purposes and in what order and what type of water supply and storage and conduction and distribution system or systems and facilities shall be constructed in connection with the use of such areas, in the carrying out of an over-all long range plan for the development and use of the water supply resources of the State, together with estimates of the probable cost of the acquisition of such areas and of the facilities required for the development thereof and estimates of the probable demand for water supply from such projects and the probable income to be derived from the sale of water delivered therefrom, and

(2) Make contracts for the rendering of such services and the payment of the cost thereof within the limits of appropriations made available.

5. The commission shall consult with the authorities of neighboring States in connection with the feasibility and possibility of the development of water supply resources by joint action of this State and such other State or States and shall consider and report to the Legislature upon any proposal for such action made by any other State.

6. The commission shall be entitled to call to its assistance and avail itself of the services of such employees of any State department or bureau or commission or agency as it may require and to employ a secretary and such

technical, stenographic and clerical assistants to fix and pay their compensation and to incur such traveling and other miscellaneous expenses as it may deem necessary in order to perform its duties and as may be within the limits of appropriations made to or made available to such commission.

7. The commission may hold hearings in any part of the State and call for the attendance of witnesses and the production of books, papers and records by any State officer, board, commission or agency, and shall receive and consider all proposals made to it in connection with the subject matter of its study.

8. *On or before August 1, 1955,* the commission shall make a report to the Legislature of the results of its study with its recommendations as to what areas shall be acquired by the State for water supply purposes [from time to time], in what order the same shall be acquired and what type of water supply and storage conduction and distribution system or systems and other facilities shall be constructed in connection with the use of such areas in the carrying out of an over-all long range plan for the development and use of the water supply resources of the State, with estimates of the probable cost of the acquisition of such areas and of the facilities required for the development thereof, the probable demand for water supply from such projects and the probable income to be derived from the sale of water delivered therefrom, which report shall be accompanied by appropriate legislative bills designed to implement and put in effect the recommendations contained therein.

9. *To carry out the purposes in this joint resolution set forth the sum of $200,000.00 is appropriated to the commission hereby created.*

10. This joint resolution shall take effect immediately.

APPENDIX D

New Jersey Water Resources Development
A Preliminary Report to the Legislature
by the
Legislative Commission on Water Supply
pursuant to A.J.R. 4 (1955)
August 1, 1955

Findings and Recommendations

1) There is a need for present action to expand the water supply for the Northeastern Metropolitan Region, the only region whose needs are critical at this time.

2) This expansion should be done in two stages. In the first stage, three additional supplies with a total yield of 77 million gallons daily should be constructed at three major existing public systems at a cost of $22,140,000. In the second stage, to provide for needs to the year 1975, the construction of a major supply development at Chimney Rock is recommended, after stated reservations are resolved, at a cost of the first, or 70 million gallon plan of $53,910,000.

3) A referendum bill, providing for a bond issue in the total amount of $76,050,000 is recommended. It is proposed that the State shall pledge receipts from water sales, the proceeds of a special tax to be apportioned among the benefited areas, and the real estate tax, as credit for the proposed bond issue.

4) It is recommended that a five man Water Supply Board be established in the Division of Water Policy and Supply in the Department of Conservation and Economic Development. The Board, whose members should be appointed by the Governor with the consent of the Senate, would be empowered to execute water developmental programs as provided by law.

5) It is recommended that the powers of the Water Policy and Supply Council be strengthened in various respects.

Background

The Legislative Commission on Water Supply was created pursuant to Assembly Joint Resolution 4 (1955) for the purpose of studying the water resources of the State, and recommending to the Legislature by August 1, 1955 what step or steps should be taken to ensure an adequate water supply for the immediate and more distant future. The Commission was empowered by the Joint Resolution to retain the services of a competent engineering firm to make a comprehensive survey of New Jersey's water resources and needs, which would provide the basis of the Commission's report to the Legislature.

At the outset it became obvious to the Commission that a detailed engineering report of the kind sought could not be produced within the time limit set by the Joint Resolution but that a preliminary report could be obtained by July 15, 1955, and a final report by December 15, 1955. Invitations to offer services were then submitted through trade papers and individual letters to a large number of well known engineering firms with experience in making water surveys. Thirty-five firms, acting singly or jointly, subsequently offered their services. From the large number of applicants, the firm of Tippetts-Abbett-McCarthy-Stratton of New York City was finally selected to make the water resources survey under a contract ceiling price of $165,000. Two factors explaining the selection of the firm should be emphasized. This firm has had extensive experience in various foreign countries, as well as in the United States, in planning large-scale water projects. In spite of its extensive experience with water problems, Tippetts-Abbett-McCarthy-Stratton, who shall hereafter be referred to as the Engineers, had not been identified with previous surveys or projects within, or affecting, New Jersey, and hence, could approach the State's water problems without preconceived ideas. In accordance with the terms of the contract, a report of a *Preliminary Survey of New Jersey Water Resources Development* was made to the Commission by the Engineers on July 15, 1955. This report, which will hereafter be referred to as PER (Preliminary Engineering Report), is the basis of the recommendations made by the Commission in the present report and will be referred to in support of this Commission's findings.

The State-Wide Water Problem

It is encouraging to note that "the total water resources of the State are adequate to meet the total future needs of the State for an indefinite period" (PER I-4). As the Engineers indicate, however, there are concentrations of population and industry which make it impossible for local sources to supply local needs, so that as population and water use increase it becomes necessary for certain areas to be supplied from ever-more remote sources. The basic problem, then, in a state with no foreseeable over-all shortage, is one of proper storage and distribution of an adequate natural supply of water.

Throughout a large part of the State there are isolated instances where whole towns or individual water users are without an adequate supply of water, usually in the Summer months. In some cases, this condition results from inadequate utilization of existing sources of water because of the failure of local water companies to provide additional storage capacity or to improve distribution facilities. However, it is the conclusion of this Commission that the supplying of water in adequate amounts to all citizens within this state is of such obvious importance that if local companies fail to perform their duties in this respect, it will be necessary to compel a higher standard of performance. For this reason the Commission concurs in the recommendation of the Engineers that the Water Policy and Supply Council within the Department of Conservation and Economic Development be empowered to enforce scrupulous observance of the terms of water company franchises, with suitable penalties for violations, even to the extent of revocation of franchise for repeated and prolonged violations (PER V-11, V-12). It should be emphasized, however, that we recognize that much of the blame for failure to develop adequately sufficient water sources rests with the State government and we are not trying to shift responsibility. It is not intended by this proposed substantial increase in regulatory powers to harass those companies which have, and are, providing adequate service. In addition the Water Policy and Supply Council should have power to protect ground water sources against pollution, or excessive depletion and should have the power to protect lower riparian owners by establishing legislative formulae for controlling stream flow (PER V-11, V-12). A bill providing for strengthening the powers of the Water Policy and Supply Council in these respects is being drafted and will be introduced for the consideration of the Legislature in the near future.

In addition to these increased supervisory powers over water company franchises, stream flow and ground water sources, there is another problem of state-wide significance that the Commission believes requires state action. This has arisen from the separate growth of independent public and private water companies, which are not interconnected in many instances and frequently find it uneconomical to interconnect. In other cases, interchange of water is hampered by cost differentials. Similarly, some water systems lack an adequate supply to meet peak demands, but find it uneconomical to make substantial investments to meet only occasional needs.

To encourage the development of interconnections and encourage the exchange of water between separate systems, the Commission proposes that the Legislature empower a newly created state agency to be known as the Water Supply Board in the Division of Water Policy and Supply, to integrate the available various water supplies by the construction and operation of interconnections, where private companies fail to do so, and to provide for the exchange of water between existing systems on a fair and rational basis (PER V-4, V-5). A bill to provide these powers is being drafted and will be introduced for the consideration of the Legislature when prepared. The purpose and, it is hoped, the effect of these powers, and those in the bill previously mentioned, will be to maximize the use of water supplies already in existence, but imperfectly utilized at present.

Regional Problems

For the purposes of this study, the Engineers divided the State into four regions, each of which is relatively homogeneous, with one or more distinguishing characteristics. Each region was studied with respect to its population, present and projected, and its water supply, current and projected, in order to determine whether or not a present or imminent water shortage existed (PER I-11 to I-20). The situation in each region was found to be as follows.

Southwestern Metropolitan Region

This area, which includes Burlington, Camden, Gloucester, Mercer and Salem Counties, consumes 15% of the state total and uses wells for the most part. While no shortages exist at the present time, there is the problem of salt water intrusion. The Commission feels that this region will benefit from a comprehensive ground water study of the kind proposed by the Engineers (PER II-2, IV-2 to IV-6). The final report of the Engineers to be rendered December 15, 1955 will treat this subject in some detail.

The Coastal Region

This region which includes Atlantic, Cape May, Cumberland, Monmouth and Ocean Counties, uses 8% of the total state consumption. Saline contamination from overpumping of some well systems presents a problem, but the vast potential ground water supply makes a future shortage unlikely. The subject of ground water resources in the vast Pine Barrens area will be treated in the final Engineers' report (See IV-2 to IV-6).

Northwestern Region

This region which includes Hunterdon, Morris, Somerset, Sussex and Warren Counties, consumes 6% of the state total, and has no foreseeable shortage. Existing surface supplies, supplemented by ground water use, should be sufficient.

Northeastern Metropolitan Region

Because of the heavy concentration of population and industry in the Northeastern Metropolitan Region of the State (Bergen, Hudson, Essex, Middlesex, Passaic and Union Counties) the demand for water in large portions of this region approaches closely the present dependable yield of developed supplies (PER I-17). This region, which uses 71% of the State's total consumption, is, according to the Engineers' findings, the only critical region at the present time (PER Ch. I, III-2). The specific proposals to meet the problems of the Northeastern Metropolitan Region will be considered more fully in the next section of this report.

The Northeastern Metropolitan Region

This region, which is defined to include Bergen, Hudson, Essex, Middlesex, Passaic and Union Counties, contains, as of 1950, 3,092,000 of the State's total population of 4,835,000 (PER I-8). By the year 2000 the region's projected population will be 4,704,000. It is also the most intensely industrialized area, whose water needs are substantial. An analysis of the available and developed water supplies for the entire State reveals that for the present, at least, only this region "faces a critical situation with consumption rapidly approaching the dependable yield of existing supply systems" (PER II-2).

It is the conclusion of the Engineers upon completion of population and water consumption studies (PER Ch. I) that for this region "the available dependable supplies may equal demand before a major new system can be completed by 1960 or 1961 and that even with the completion of a new 200 mgd (million gallons daily) supply the demand may again approach dependable yields less reasonable reserve by 1975" (PER III-2).

The Engineers propose a three stage development, with which the Commission concurs. In the first stage, the supply for the region will be expanded by short-range projects, financed by the State, to provide for needs to 1960. In a second stage, a major supply must be developed to provide for needs to the year 1975. A third stage envisages the development of a major supply to the year 2000 (PER III-2). In the Preliminary Report recommendations have been made concerning the first two stages only. Plans for dealing with the third stage will be covered in the Engineers Final Report to be submitted by December 15, 1955.

First Stage Development

Officials responsible for operation of the existing water supply systems in the Northeastern Metropolitan Region recognize that additional supplies are needed. However, while numerous projects have been proposed by companies within this region, it is important to note that to date none has been executed or started except for preliminary work on the De-Forest Lake reservoir on the Hackensack. Upon completion this project, which is located within New York State, will furnish an additional 20 mgd for the Hackensack Water Company and its New Jersey customers only until such time as the demand of the company's New York State users is sufficient to utilize all of this increased supply.

What must be understood by citizens living within this Northeastern Metropolitan Region as well as those living elsewhere in the State is the simple economic fact that as communities and regions require ever-greater quantities of water, it becomes necessary to go ever-farther to develop additional sources, which inevitably is translated into higher unit costs for the additional water obtained. It must be apparent also, that while any substantial development program undertaken by an existing water system is designed to meet present and foreseeable future demands, it will not, in most cases, be a profitable investment at the outset, since only a portion of the increased supply will be purchased immediately. Moreover, where one system by expansion obtains water in excess of its own needs, it may find it difficult to obtain long term contracts even from systems in need of water because of the higher unit cost of this water. Although the time may arrive when the need for water is so great that higher unit costs will become a negligible factor to prospective purchasers, that time has not yet been reached. Hence, many existing systems, although recognizing the need for substantial additions of supply within the next two decades are reluctant to undertake costly programs that will be unprofitable for at least a substantial period of time. In any event, it is apparent that no concrete plans are underway to produce the increases in supply needed by 1960 and the period following up to 1975.

The Engineers propose as a first stage the development of increased supplies through new construction at three locations within existing water systems: Newark-Pequannock, Jersey City-Rockaway, and Passaic Valley, yielding 77 mgd at a total cost of $22,140,000 (PER III-3 to III-7, IV-1 to IV-2). In order that this valuable and relatively inexpensive augmentation of supply proceed without delay it is proposed that the State, acting through a Water Supply Board to be created within the Department of Conservation and Economic Development will undertake the development of these new water supplies. It is recommended that the State shall make this water available at wholesale rates to distributing agencies served by these systems on an equitable basis. While it would be more desirable to have each of these projects executed by the system involved, it seems clear that if the water supply is to be increased to meet immediately foreseeable needs, action must be taken now.

The Commission recommends the adoption of legislation providing for a referendum under which the amount necessary ($22,140,000) will be made available through a newly created State Water Supply Board which will undertake the construction of these valuable and relatively inexpensive additions to present supply.

Intermediate Stage

The 3,350,000 persons served by the Northern New Jersey Systems used 420 mgd in 1953. The dependable yield at that

time was 456 mgd (PER II-2). With the proposed addition of 77 mgd a future supply of 533 mgd is thus assured. The estimated minimum average requirement of the Northeastern Metropolitan Region will be 471 mgd in 1960 and will rise to 526 mgd in 1970 and to 583 mgd in 1980. Because of the necessity of maintaining an adequate margin between average need and dependable supply, it becomes apparent that well before 1970 a critical point will be reached even with the addition of 77 mgd, and consumption will equal or outrun supply.

To meet this second stage requirement, and because of the long period necessary to plan and construct a major supply development, the Engineers have recommended the acquisition of a reservoir site, the construction of a dam, pumping stations and mains, and transmission lines to serve this region in which need is critical. The Commission concurs with this recommendation. It is evident that piecemeal, local efforts to meet what is essentially a vast regional problem will inevitably fail. Even if the State undertakes the three specific construction measures recommended above, only a temporary solution has been provided. What is needed is planning to meet water needs to the year 1975 long before the critical stage is reached.

It should be pointed out that the need for the creation of a new major supply for this region has been recognized for a considerable period of time. A water commission, a State agency, and the authors of several bills introduced in this and recent sessions of the Legislature have proposed the creation of a major supply at Round Valley in Hunterdon County. At the beginning of the investigation the Engineers were instructed by the Commission to study the advisability of developing a supply at Round Valley, from Wallpack Bend or some alternative plan on the Delaware River, on the Raritan, or any combination of these and other possible sources. No possible choice was foreclosed by any directives of this Commission. After their independent study of all feasible major sources (PER Ch. III), the Engineers narrowed their choice to two sites which had the potentiality of becoming major water supply sources for the intermediate stage. One of these—Round Valley (in Hunterdon County)—has been mentioned prominently in recent years as a possible reservoir site for an expanded supply for the Northeastern Metropolitan Region. The other—Chimney Rock (in Somerset County)—had not been examined seriously as a possible site in recent years, primarily because of the large number of families living there, as compared with those living at Round Valley. As the investigation of the Engineers progressed, it became apparent to them that a Chimney Rock development, somewhat different from those previously recommended, would be considerably less costly. Specifically, Chimney Rock would cost $8 million less at the first (70 mgd) stage of development ($53,910,000 compared with $59,940,000 for Round Valley) and, even more striking, at the ultimate stage of development (200 mgd), would cost $40 million less ($102,650,000 compared with $143,630,000) (PER III-7 to III-11). It should be noted that the cost of Round Valley as estimated by the Commission's Engineers is considerably higher for the 200 mgd stage than are estimates published elsewhere. First, however, it should also be noted that the data furnished by the Commission's Engineers is current (April-July, 1955). The cost estimates of our Engineers and those published elsewhere are comparable for the 70 mgd stage, ($59,940,000 including $3,900,000 for interest during construction by our Engineers compared with $54,345,165 exclusive of interest during construction published elsewhere). But when the ultimate 200 mgd stage is reached there is a sharp discrepancy between the estimates of our Engineers and those published elsewhere. The chief explanation for the lower figure given by its proponents for the ultimate stage of Round Valley is their assumption that the center of future need and the consequent center of transmission termination in the future will be in the area of Bound Brook. If this assumption is adopted for Chimney Rock as well, its saving of the latter over Round Valley will remain comparably large ($62,550,000 for Chimney Rock compared with $102,030,000 for Round Valley). In fact, no detailed cost estimates for the final stage of development of Round Valley have been published, previous to this report by the Commission's Engineers. Moreover, as the Engineers' report emphasizes, the development of Chimney Rock has the great advantage of permitting the utilization now of water wholly within the control of this State. Undoubtedly, there will be substantial development of the Delaware in the future. The Supreme Court decree of 1954 left the door open for New Jersey to return and secure the Court's consent to increased diversion. Reservoir sites will be needed and it is clear that the initiative in developing Wallpack Bend on the Delaware rests by law with the Commonwealth of Pennsylvania. Thus, even with the choice of Chimney Rock as the site for future major development of the resources of the Raritan Basin, the Commission recommends to the Legislature the passage of a bill providing for the acquisition of the last remaining major reservoir site, Round Valley (presently Assembly Bill #36). The relatively low cost of this step (approx. $3 million) suggests its wisdom as an insurance measure. While the Engineers who will not complete their study of possible projects for long range water development (to the year 2000 and after) until December 15, 1955, have not recommended this action, the Commission feels that action to acquire the site should be taken in the near future before increasing settlement of the area makes the cost of acquisition much higher. Existing properties could be leased to the present owners on favorable terms pending final decisions on eventual reservoir construction.*

There are sound grounds, conclude the Engineers, for the selection of the Chimney Rock site for the development of a major water supply over that of Round Valley. We are able to say that in a physical and engineering sense, we concur with the findings of the Engineers that Chimney Rock appears to be a feasible site. There are still reservations to be answered regarding dislocation of people, the effects upon industry, the extent of acquisition of real estate, causeways and sanitation steps, the need for low flow augmentation downstream, and continued quarry operations. Such factors must be weighed against a possible needless expenditure of $40 million, and the advantage of full state control of a Raritan development.

But acting under the mandate of the Legislature to report by August 1, 1955, this Commission did not have ample time to test with finality all of the Engineers' assumptions, or to resolve all doubts by asking for further engineering data and by holding public hearings.

Therefore, we recommend to the Legislature that the resolutions to these reservations be obtained through public hearings of the appropriate legislative committees. There should be ample time for such hearings prior to the deadline for the submission of referendum legislation. We believe that if our reservations regarding Chimney Rock are resolved under public scrutiny, then the Chimney Rock development will best create an additional major water supply for the Northeastern Metropolitan Region within the next five to ten years.

Legislative Action Required

State Water Supply Board

It has been recommended that the powers of the Water Policy and Supply Council be strengthened in various respects (p. 3, this report). In addition it will be necessary, in the judgment of the Commission to create a Water Supply Board within the Division of Water Policy and Supply in the Department of Conservation and Economic Development, authorized to acquire sites, construct dams, pumping stations and transmission lines as provided by legislation in order to make substantial amounts of water available on an equitable basis at wholesale rates to existing water systems. It is not recommended that the State engage in the retail distribution of water. It would seem feasible to establish this Board, preferably consisting of five members, appointed by the Governor, with the consent of the Senate, within an augmented Division of Water Policy and Supply, thereby gaining the assistance of state personnel experienced in water problems, without sacrificing the initiative and enthusiasm to be gained by a new agency.

Some of the powers requisite to the efficient function of this Board are set forth in PER V-3 to V-5. The Commission will

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* Senator Dumont wishes to reserve decision on this proposal until and if, such time as the Engineers recommend as wise and feasible the development of a supply at Round Valley.

in the near future recommend to the Legislature a bill setting forth the powers of the Board in detail. It is the recommendation of the Commission that when large scale additions to the water needs of a large area or region are required, it should be the responsibility of the Legislature after careful study in each instance, to propose the development of new water supplies, and to provide financial support by pledging through law the credit of the state and state taxing power. In this present instance the resources of the state are brought to the aid of the vast Northeastern Metropolitan Region. But in the decades to come, it is to be anticipated that similar measures will be undertaken in support of the fast-growing Southwestern Metropolitan Region. Nor is it likely that other areas in the other regions of the state to remain long without serious problems. At some points in the Coastal Region salt water intrusion threatens wells which provide the chief water supply for important localities. In the central part of the state some communities find their well systems inadequate for their rapidly growing populations. In the final report of the Engineers the results of a more detailed study of the ground water resources of New Jersey will be reported. From evidence already before this Commission, it is probable that the inception of a long range study, including test borings, of the Pine Barrens and other ground water areas, will be recommended to the Legislature by this Commission, if we are to meet and solve new water problems before they become acute.

Financing Water Resources Development

It is recommended that the cost of substantial developments, such as the three smaller supply additions recommended (p. 8, this report), and that of Chimney Rock (p. 10, this report), be financed in such a way that those immediately in need of water will not be required to pay a disproportionately high rate, but rather, in such a way that those living in the region receiving substantial benefit will help defray capital costs and carrying charges, as well as any short-run operating deficits, through a special tax. The basic plan is this. A State Water Supply Board will compute and allocate on the basis of a formula to be set forth by law, the respective shares of the total development and operating costs to a water district or districts, as will be defined by law. Water district boards, consisting of representatives appointed by the boards of Chosen Freeholders of the counties within the district, will then receive certified bills, which they in turn will apportion among the municipalities and governmental units within their district. A referendum bill providing for a bond issue in the amount of $76,050,000, to be financed in the method outlined, as well as by charges to users of the new water supply, will be introduced in the Legislature in the very near future. It is proposed that this referendum bill be presented to the people of New Jersey at the forthcoming general election (1955). In this bill the receipts from water sales, the proceeds of the special tax on benefited districts, as well as the general real estate taxing power of the state will be pledged in support of the recommended bond issue. Admittedly, this is a heavy financial undertaking at least for the immediate future. But there can be no great improvements in the social and economic life of our State without some financial sacrifice. Failure to plan for the future means that industry will go elsewhere, where a suitable supply of water is made available. Needless to say, the maintenance of our high standard of living requires continued availability of an adequate supply of water for industrial and domestic use. The referendum bill provides a method of taking action in the immediate future, so that an increase in supply will be available within three years, and a major addition will become productive by 1960-61. This step, coupled with the creation of an energetic State Water Supply Board in the Department of Conservation and Economic Development through a bill to be submitted later to the Legislature, and the strengthening, by a bill to be introduced shortly, of the existing powers of the Water Policy and Supply Council, will mark the substantial beginnings of a comprehensive program of water development. In December, 1955, after receiving the final report of our Engineers, this Commission will submit recommendations for a development program to provide major increases in water supply for the years 1975-2000 and beyond. The alternative to the adoption of a new and comprehensive long-range program to increase the State's water supply will be a series of water crises, which, it may be prophesied, will be met by hastily improvised short-run measures. We respectfully urge the Honorable members of the Legislature, and the citizens of New Jersey, to take action now, while time remains.

Respectfully submitted,

Senator Mark Anton

Assemblyman Alfred N. Beadleston

Senator Wayne Dumont, Jr.

Senator W. Howard Sharp

Assemblyman Milton W. Glenn

Assemblyman John A. Waddington

Commissioner Joseph E. McLean

APPENDIX E

APPENDIX E

Committee Substitute For
Senate, No. 372
State of New Jersey
Adopted September 19, 1955

An Act to authorize the creation of a State debt by the issuance of bonds of the State of New Jersey in the aggregate principal amount of $100,000,000.00 for the purpose of acquiring, constructing and developing dependable public water supplies for domestic and industrial uses and facilities appurtenant thereto, in any part of this State as need appears, and providing the ways and means to pay the interest of such debt and also to pay and discharge the principal thereof.

Be it enacted *by the Senate and General Assembly of the State of New Jersey:*

1. This act shall be known as and may be cited as the New Jersey Water Supply Bond Act.

2. The Legislature hereby finds that—

(a) Adequate supplies of wholesome water are essential to the health, welfare, commerce and prosperity of the people of the State. Such supplies will be best developed by plans, to be put into effect in stages during a period of years. The formulation and execution of such plans cannot safely be allowed to wait until the shortage of water in the State becomes critical in all parts of the State.

(b) In order to serve the needs of a growing population and industrial development within this State, and to provide the increased water supplies demanded by modern living and manufacture, it is necessary and desirable to construct and provide large-scale water supplies which anticipate Statewide needs of up to 50 years in the future, and such needs are beyond the financial capacity or proper responsibility of existing public and private water supply systems.

(c) It is necessary to supplement and integrate existing public and private water supplies in order to meet the present and future needs of the people of the State for adequate supplies of water.

(d) The planning and development of adequate additional supplies of water will best be accomplished by the issuance of State bonds to pay the cost thereof.

(e) An ample and adequate water supply is of special benefit to the region directly affected, and is of general benefit to the entire State in enhancing the health, safety and economic welfare of our interdependent areas of residence, employment and recreation.

3. (a) The Legislature further finds that upon the basis of independent engineering studies and a report thereof made by the Legislative Commission on Water Supply (pursuant to J. R. No. 3, of 1955), by report dated August 1, 1955, the water needs and resources of the State may be analyzed with reference to 4 regions:

I. Northeastern Metropolitan Region—Bergen, Hudson, Essex, Middlesex, Passaic and Union counties.

II. Coastal Region—Atlantic, Cape May, Cumberland, Monmouth and Ocean counties.

III. Southwestern Metropolitan Region—Burlington, Camden, Gloucester, Mercer and Salem counties.

IV. Northwestern Metropolitan Region—Hunterdon, Morris, Somerset, Sussex and Warren counties.

According to the engineering findings all 4 regions, with the possible exception of Region IV, have important water problems which must be solved without undue delay, and the condition of Region I is critical. This region accounts for approximately 71% of total present water consumption in the State. The engineering studies conclude that Region I above "faces a critical situation with consumption rapidly approaching the dependable yield of existing supply systems." With respect to this region, it is the conclusion of the engineers upon completion of population and water consumption studies that "the available dependable supplies may equal demand before a major new system can be completed by 1960 or 1961 and that even with the completion of a new 200 mgd (million gallons daily) supply the demand may again approach dependable yields less reasonable reserve by 1975."

(b) The Legislature therefore finds and determines that the health, welfare, commerce and prosperity of the people of the State require immediate action on the water problem of Region I with concurrent development of appropriate action with respect to Regions II, III, and IV.

4. As used in this act, unless the context indicates another or different meaning or intent:

(a) "Bonds" means the Water Supply Bonds authorized to be issued, or issued, under this act.

(b) "Board" means the New Jersey Water Development Board in the Department of Conservation and Economic Development, or its successor.

(c) "Construct" and "construction" mean, in addition to the usual meanings thereof, acts of construction, reconstruction, replacement, exten-

sion, improvement and betterment of a water supply system.

(d) "Cost" means, in addition to the usual meanings thereof, the cost incurred, or to be incurred, in planning, designing, constructing and putting fully in operation, all or any part of a water supply system, and of acquiring all or any real or personal property, or any agreements or franchises, necessary, useful or convenient therefor, or in connection therewith, and shall include without limiting the generality of the foregoing, provision for payment of interest during construction, the cost of engineering, architectural, legal, accounting and other professional surveys, studies, estimates, inspections, reports, plans, specifications and advice, insurance and administrative and all other expenses necessary or incident to the financing, acquisition, construction, and development of such water supply system.

(e) "Operating expenses" means, in addition to the usual meanings thereof, all costs and expenses of operating, maintaining, managing, repairing and reconstructing a water supply system and each and every part thereof including, without limiting the generality of the foregoing, administrative expenses, premiums on insurance, including use and occupancy insurance and casualty insurance, costs of collection of any revenues, legal and engineering expenses, payments to pension, retirement, health and hospitalization funds, expenses, liabilities and compensation of fiduciaries, and any other expenses required to be paid for or with respect to proper operation or maintenance of such water supply system.

(f) "Real property" means lands, within or without the State, and improvements thereof or thereon, any and all rights of way, water, riparian and other rights, any and all easements and privileges in real property, and any right or interest of any kind or description in, relating to or connected with real property.

(g) "Water supply system" means and refers to the real property and the plants, structures, machinery and equipment and other property, real, personal and mixed, acquired, constructed or operated, or to be acquired, constructed or operated by or on behalf of the State, for the purpose of making available a dependable public water supply, including without limiting the generality of the foregoing, dams, reservoirs, standpipes and other storage facilities, conduits, transmission mains, diversion tunnels, aqueducts, pipelines, mains, pumping stations, treatment plants, intake and balancing reservoirs and dams and structures appurtenant thereto, canals, open waterways and channels, connections and interconnections, roads, and other plants, structures, machinery, tools, equipment, boats, conveyances, and other real and personal property, and rights therein, and any and all appurtenances necessary, useful or convenient for the collection, storage, treatment, transmission, distribution, sale or exchange of water; or to preserve and protect a water supply system or any part thereof, or to provide for the conservation and development of future water supply sources, or to facilitate incidental recreational uses of either of them.

5. Bonds of the State of New Jersey are hereby authorized to be issued in the aggregate principal amount of $100,000,000.00 for acquiring, constructing, and developing dependable public water supply systems for domestic and industrial uses, and facilities appurtenant thereto, in any part of this State as need appears. The proceeds of such bonds shall be expended as follows:

(a) In an amount not exceeding $60,000,000.00 in the aggregate, for the cost of a water supply system (herein called the Chimney Rock System) including a reservoir in the vicinity of the place known as Chimney Rock in the county of Somerset; a suitable causeway across such reservoir and connecting roads approximately on the line of the present Chimney Rock road; and compensating reservoirs, dams, works and facilities on the Raritan river and its tributaries for the purpose of additional water supplies and river regulation;

(b) In the amount of the remainder of such proceeds, whenever and to the extent authorized by statute, for costs incident to a water supply system or systems including, without limitation thereto, the Wharton Tract as heretofore acquired by the State and any additions thereto, and any planning, designing, engineering, geological and hydrological studies and groundwater investigations in connection with water supply systems.

6. (a) The Governor, State Treasurer and Comptroller of the Treasury or any 2 of such officials (herein referred to as "the issuing officials") are hereby authorized to carry out the provisions of this act relating to the issuance of said bonds, and shall determine all matters in connection therewith subject to the provisions hereof. In case any of said officials shall be absent from the State or incapable of acting for any reason, his powers and duties shall be exercised and performed by such person as shall be authorized by law to act in his place as a State official.

(b) Said bonds shall be issued from time to time as money is required for the aforesaid purposes for which they are authorized, as certified by the board to the issuing officials.

(c) Said bonds shall be serial bonds and known as "Water Supply Bonds," and each such bond shall mature and be paid not later than 35 years from the date of its issuance.

7. (a) Bonds issued in accordance with the provisions of this act shall be direct obligations of the State of New Jersey and the faith and credit of the State are pledged for the payment of the interest thereon as same

shall become due and the payment of the principal at maturity.

(b) The principal and interest on such bonds shall be exempt from taxation by the State or by any county, municipality or other taxing district of the State.

8. Said bonds shall be signed in the name of the State by the Governor or by his facsimile signature, under the great seal of the State, and attested by the Secretary of State, or an assistant Secretary of State, and shall be countersigned by facsimile signature of the Comptroller of the Treasury. Interest coupons attached to said bonds shall be signed by the facsimile signature of the Comptroller of the Treasury. Such bonds may be issued notwithstanding that any of the officials signing them or whose facsimile signatures appear on the bonds or coupons shall have ceased to hold office at the time of such issue or at the time of the delivery of such bonds to the purchaser.

9. (a) Such bonds shall recite that they are issued for acquiring, constructing and developing dependable water supply systems for domestic and industrial uses and facilities appurtenant thereto and that they are issued in pursuance of this act and that this act was submitted to the people of the State at the general election held in the month of November, 1955, and that it received the sanction of the majority of the votes cast for and against it at such election. Such recital in said bonds shall be conclusive evidence of the authority of the State to issue said bonds and of their validity. Any bonds containing such recital shall in any suit, action or proceeding involving their validity be conclusively deemed to be fully authorized by this act and to have been issued, sold, executed and delivered in conformity herewith and with all other provisions of the statutes applicable thereto, and shall be incontestable for any cause.

(b) Such bonds shall be issued in such denominations and in such form or forms, whether coupon or registered, as to both principal and interest, as may be determined by the issuing officials.

(c) Whenever such bonds shall have been issued as coupon bonds, whether so issued originally or at the request of a holder thereof subsequent to the original issue, such bonds, or any of them, may be reissued by the issuing officials at the request of a holder as registered bonds, and all registered bonds, whether so issued originally or at the request of the holder subsequent to the original issue, may be reissued by the issuing officials, at the request of a holder, as coupon bonds.

(d) In case any coupon bonds and coupons thereunto appertaining or any registered bond shall become mutilated or destroyed, a new bond shall be executed and delivered of like tenor, in substitution for the mutilated or destroyed bonds or coupons, upon the owner furnishing to the issuing officials evidence satisfactory to them of such mutilation or destruction and also such security and indemnity as the issuing officials may require.

10. When bonds are issued from time to time, the bonds of each issue shall constitute a separate series to be designated by the issuing officials. Each series of bonds shall bear such rate or rates of interest, not exceeding 4% per annum, as may be determined by the issuing officials, which interest shall be payable semiannually; provided, that the first and last interest periods may be longer or shorter, in order that intervening semiannual payments may be at convenient dates.

11. Bonds of each series issued hereunder shall mature in annual installments commencing not later than 10 years and ending not later than 35 years after the date of issue of such series, and in such amounts as shall be determined by the issuing officials, but the issuing officials may reserve to the State by appropriate provision in the bonds of any series the power of election by resolution or resolutions of the issuing officials to call for redemption, and to redeem on any interest payment date beginning in a stated year, as a whole or in part in the inverse order of their numbers, bonds of that series prior to their maturity, upon notice by publication, at least once, at least 60 days prior to the date fixed for redemption, in a newspaper published in the city of Trenton and in a publication carrying municipal bond notices and devoted primarily to financial news, published in New York City or in New Jersey. On and after the date of redemption so fixed, interest on bonds so called for redemption shall cease to accrue.

12. Said bonds shall be issued and sold at such price not less than the par value thereof and accrued interest thereon and under such terms, conditions and regulations as the issuing officials may prescribe, after notice of said sale, published at least 3 times (the first notice shall be at least 7 days prior to the day of bidding) in at least 3 newspapers published in the State of New Jersey, and at least once in a publication carrying municipal bond notices and devoted primarily to financial news, published in the city of New York or in New Jersey. The said notice of sale may contain a provision to the effect that any or all bids made in pursuance thereof may be rejected. In the event of such rejection or of failure to receive any acceptable bid, the issuing officials are authorized to sell said bonds at private sale. The issuing officials may sell all or a part of the bonds of any series as issued to the sinking fund or funds for other bonds issued by the State or to the trustees for the support of public schools, the Teachers' Pension and Annuity Fund, or any other pension fund established for the benefit of State employees or to the trustees of the State Disability Benefit Fund, or to the Federal Government or any agency thereof, at private sale, without advertisement.

13. Until permanent bonds can be prepared, the issuing officials may, in their discretion, issue in lieu of such permanent bonds temporary bonds in such form and with such privileges as to registration and exchange for permanent bonds as may be determined by the issuing officials.

14. The proceeds from the sale of said bonds, exclusive of accrued interest and premiums, and all interest on deposits thereof received from depositories, shall be paid to the State Treasurer and be held by him in a separate fund, and be deposited in such depositories as may be selected by him to the credit of such fund, which fund shall be known as the "State Water Supply Fund." All accrued interest and premiums from the sale of said bonds, except as provided in section 19 hereof, shall also be held by the State Treasurer to the credit of the State Water Supply Fund.

15. The moneys in the State Water Supply Fund are hereby specifically dedicated to acquiring, constructing, and developing dependable public water supply systems for domestic and industrial uses and facilities appurtenant thereto and for paying the costs of water supply systems. Said fund shall be held for the demand of the board and shall be drawn upon and disbursed as are other moneys from the State treasury.

16. Pending their application to the purposes provided in this act, moneys in the State Water Supply Fund and Water Bond Fund, respectively, may be invested and reinvested as other trust funds in the custody of the State Treasurer, in the manner provided by law.

17. There is hereby established a separate fund, to be known as the "Water Bond Fund" which shall be held by the State Treasurer and which shall be used and applied only as expressly provided in this act. Moneys in the Water Bond Fund may be deposited in such depositories as may be selected by the State Treasurer. All revenues received from the operation of a water supply system in excess of the operating expenses of such water supply system and such reasonable reserves therefor as the board may determine shall constitute the net revenues from the operation of such water supply system and shall be paid to the State Treasurer and by him into the Water Bond Fund.

18. Except as hereinafter in this section provided, all moneys at any time in the Water Bond Fund are hereby appropriated and specifically dedicated and irrevocably pledged to the payment of, and shall be used by the State Treasurer to pay, the interest on and principal of the bonds as the same shall become due, including redemption premiums, if any, on bonds which become due by reason of being called for redemption; provided, however, that on any date when the moneys in said fund shall exceed an amount sufficient to meet all interest on all outstanding bonds becoming due within 2 years thereafter, and to pay any such bonds which mature during such 2 years, he may transfer such excess into the General State Fund of the State free and clear of any pledge, lien or other claim under the provisions of this act.

19. Any expense incurred by the issuing officials for advertising, engineering, printing, clerical, legal or other services necessary to carry out the duties imposed upon them by the provisions of this act shall be paid from accrued interest and premiums from the sale of bonds or, if these funds be insufficient, from the proceeds of the sale of bonds, by the State Treasurer upon warrant of the Comptroller of the Treasury, in the same manner as other obligations of the State are paid.

20. At any time the State Treasurer is hereby authorized to transfer from any available money in the treasury of the State to the State Water Supply Fund such sum or sums as may be deemed necessary for the purposes of this act by the board, which said sum or sums so transferred shall be returned to the treasury of the State by the State Treasurer from the proceeds of the sale of the first next ensuing series of bonds, before the proceeds of such sale are paid into the State Water Supply Fund.

21. To provide ways and means, exclusive of loans, to pay the interest of the debt created under this act as it falls due, and also to pay and discharge the principal thereof, there are hereby appropriated in the following order:

(a) The net revenues, as defined in section 17, from the operation of any water supply system, costs of which were financed by the proceeds of bonds issued under this act;

(b) Revenues derived from the franchise taxes collected under and by virtue of the Corporation Business Tax Act (1945) as amended.

(c) If in any year or at any time funds, as hereinabove appropriated, necessary to meet interest and principal payments upon outstanding bonds issued under this act, be insufficient or not available, then and in that case there shall be assessed, levied and collected annually in each of the municipalities of the counties of this State a tax on real and personal property upon which municipal taxes are or shall be assessed, levied and collected, sufficient to meet such interest and principal payments falling due prior to the end of the year following the year for which the tax is levied. The tax thus imposed shall be assessed, levied and collected in the same manner and at the same time as other taxes upon real and personal property are assessed, levied and collected. The governing body of each municipality shall cause to be paid to the county treasurer of the county in which such municipality is located, on or before December 15 in each year the amount of tax herein directed to be assessed and levied, and the county treasurer shall pay the amount of said tax to the State Treasurer on or before December 20 in each year.

22. If during the month of December in any year the issuing officials shall determine that there are moneys in the General State Fund, beyond the

25. If any section, clause, or part of this act shall be held invalid for any reason, such section, clause or part shall be deemed to be severable and such determination shall not invalidate the remainder of this act.

26. This section and section 24 of this act shall take effect immediately and the remainder of the act shall take effect as and when provided in section 24.

Committee Substitute For
Assembly, No. 595
State of New Jersey
Adopted September 19, 1955

An Act to provide for increased dependable public water supplies for domestic and industrial uses; creating a water development board and a Division of Water Development and prescribing the functions, powers and duties of such board and division, and of the Commissioner of the Department of Conservation and Economic Development, in connection therewith, and supplementing Title 58 of the Revised Statutes.

Be it enacted *by the Senate and General Assembly of the State of New Jersey:*

1. This act shall be known and may be cited as the "New Jersey Water Supply Law."

2. The Legislature hereby finds that—

(a) Adequate supplies of wholesome water are essential to the health, welfare, commerce and prosperity of the people of the State. Such supplies will be best developed by plans, to be put into effect in stages during a period of years. The formulation and execution of such plans cannot safely be allowed to wait until the shortage of water in the State becomes critical in all parts of the State.

(b) In order to serve the needs of a growing population and industrial development within this State, and to provide the increased water supplies demanded by modern living and manufacture, it is necessary and desirable to construct and provide large-scale water supplies which anticipate State-wide needs of up to 50 years in the future, and such needs are beyond the financial capacity or proper responsibility of existing public and private water supply systems.

(c) It is necessary to supplement and integrate existing public and private water supplies in order to meet the present and future needs of the people of the State for adequate supplies of water without, however, absorbing any existing public or private water supply system.

(d) The planning and development of adequate additional supplies of water will best be accomplished by the issuance of State bonds to pay the cost thereof.

(e) An ample and adequate water supply is of general benefit to the entire State in enhancing the health, safety and economic welfare of our interdependent areas of residence, employment and recreation.

3. The Legislature further finds that upon the basis of independent engineering studies and a report thereof made by the Legislative Commission on Water Supply (pursuant to J. R. 3, of 1955), by report dated August 1, 1955, the water needs and resources of the State may be analyzed with reference to 4 regions:

I. Northern Metropolitan Region—
Bergen, Hudson, Essex, Middlesex, Passaic and Union counties.

II. Coastal Region—
Atlantic, Cape May, Cumberland, Monmouth and Ocean counties.

III. Southwestern Metropolitan Region—
Burlington, Camden, Gloucester, Mercer and Salem counties.

IV. Northwestern Metropolitan Region—
Hunterdon, Morris, Somerset, Sussex and Warren counties.

According to the engineering findings all 4 regions, with the possible exception of Region IV, have important water problems which must be solved without undue delay, and the condition of Region I is critical. This region accounts for approximately 71% of total present water consumption in the State. The engineering studies conclude that Region I above "faces a critical situation with consumption rapidly approaching the dependable yield of existing supply systems." With respect to this region, it is the conclusion of the engineers upon completion of population and water consumption studies that "the available dependable supplies may equal demand before a major new system can be completed by 1960 or 1961 and that even with the completion of a new 200 mgd (million gallons daily) supply the demand may again approach dependable yields less reasonable reserve by 1975."

The Legislature therefore finds and determines that the health, welfare, commerce and prosperity of the people of the State requires immediate action on the water problem of Region I with concurrent development of appropriate action with respect to Regions II, III, and IV.

4. As used in this act, unless the context indicates another or different meaning or intent:

(a) "Board" means the New Jersey Water Development Board in the Division of Water Development in the Department of Conservation and Economic Development, or its successor.

(b) "Construct" and "construction" mean, in addition to the usual meanings thereof, acts of construction, reconstruction, replacement, extension, improvement and betterment of a water supply system.

(c) "Cost" means, in addition to the usual meanings thereof, the cost incurred, or to be incurred, in planning, designing, constructing and

putting fully in operation, all or any part of a water supply system, and of acquiring all or any real or personal property, or any agreements or franchises, necessary, useful or convenient therefor, or in connection therewith, and shall include without limiting the generality of the foregoing, provision for payment of interest during construction, the cost of engineering, architectural, legal, accounting and other professional surveys, studies, estimates, inspections, reports, plans, specifications and advice, financing charges and bond discount, insurance, administrative and other operating expenses and all other expenses as may be necessary or incident to the financing, acquisition, construction, and operation of a water supply system.

(d) "Commissioner" means the Commissioner of the State Department of Conservation and Economic Development.

(e) "Division" means the Division of Water Development in the Department of Conservation and Economic Development.

(f) "Net revenues" means all revenues received by the board or division from the operation of a water supply system, or any part thereof, in excess of the operating expenses thereof and provision for reasonable reserves therefor.

(g) "Operating expenses" means, in addition to the usual meanings thereof, all costs and expenses of operating, maintaining, managing, repairing and reconstructing a water supply system and each and every part thereof including, without limiting the generality of the foregoing, administrative expenses, premiums on insurance, including use and occupancy insurance and casualty insurance, costs of collection of any revenues, legal and engineering expenses, payments to pension, retirement, health and hospitalization funds, expenses, liabilities and compensation of fiduciaries, and any other expenses required to be paid for or with respect to proper operation or maintenance of such water supply system.

(h) "Project" means any part of a water supply system or work for the protection and preservation or for the development, conservation, regulation or recreational use thereof, which is separately planned, financed or identified by the board or division.

(i) "Real property" means lands, within or without the State, and improvements thereof or thereon, any and all rights of way, water, riparian and other rights, any and all easements and privileges in real property, and any right or interest of any kind or description in, relating to or connected with real property.

(j) "Water supply system" means and refers to the real property and the plants, structures, machinery and equipment and other property real, personal and mixed, acquired, constructed or operated, or to be acquired, constructed or operated by or on behalf of the State, for the purpose of making available a dependable public water supply, including without limiting the generality of the foregoing, dams, reservoirs, standpipes and other storage facilities, conduits, transmission mains, diversion tunnels, aqueducts, pipelines, mains, pumping stations, treatment plants, intake and balancing reservoirs and dams and structures appurtenant thereto, canals, open waterways and channels, connections and interconnections, roads, and other plants, structures, machinery, tools, equipment, boats, conveyances, and other real and personal property, and rights therein, and any and all appurtenances necessary, useful or convenient for the collection, storage, treatment, transmission, distribution, sale or exchange of water, or to preserve and protect a water supply system or part thereof or to provide for the conservation and development of future water supply sources, or to facilitate incidental recreational uses of either of them.

5. There is hereby created and established in the Department of Conservation and Economic Development the Division of Water Development consisting of a board to be known as the New Jersey Water Development Board and the officers and employees thereof. The said board shall consist of 5 members to be appointed by the Governor by and with the advice and consent of the Senate. Not more than 3 of the said members shall be of the same political party. The commissioners shall be appointed for a term of 4 years except that of those first appointed, 1 shall be appointed for a term of 1 year, 1 for 2 years, 1 for 3 years and 2 for 4 years. Each member of the Board shall serve until his successor has been appointed and qualified and any vacancy in the membership of the board shall be filled for the unexpired term in the manner provided for an original appointment. All actions of the board and the division pursuant to this or any other act shall be subject to the approval of the commissioner, which in his discretion may be given by general or special order.

6. The members of the board shall serve without compensation unless otherwise provided by law but they shall be entitled to reimbursement for their expenses necessarily incurred in the performance of their duties.

7. The board shall organize, as soon as it can practicably do so, and annually thereafter by the choice of 1 of its members as chairman and the appointment of a secretary, who need not be a member of the board.

8. (a) The board shall, through the division, acquire and operate a water supply system to be known as the New Jersey Water Supply System. Such system shall be acquired, constructed, operated and maintained by the division on behalf of the State and shall include a reservoir in the vicinity of the place known as Chimney Rock in the county of Somerset which shall be adequate in its first stage, hereby authorized to be constructed, to assure a dependable yield of 70,000,000 gallons daily and upon the completion of the second stage

the service of public and private water supply systems. Prior to undertaking any such project, the division shall upon the agreement of the water supply system or systems concerned, enter into a contract with such system or systems establishing the terms and conditions for the operation of such works, facilities and appurtenances and for the exchange or transfer of water between and among such systems or otherwise, and the establishment of rates for the purchase, sale, exchange and transmission of such water, and for such other or different purposes as may appear necessary and desirable to achieve a more effective integration of water supply systems.

13. Any plan, project or work approved by the board except any diversion of water from the Delaware and Raritan canal, shall not be subject to review, approval or other action by the State Water Policy and Supply Council, notwithstanding the provisions of any other law; provided that the board, division, or department, with or without such review, approval or action by said council, shall not withdraw water from the Raritan river at any time that the flow in the river falls below 130,000,000 gallons per day.

14. The board shall fix the rates to be charged for water sold or exchanged by any water supply system operated by the division. Such rates shall not be subject to revision or other action by any other department, commission, board or body.

The rates shall be fixed by the board after a public hearing thereon, upon reasonable notice to the public. They shall be based upon the cost of operation and maintenance of the water supply system or such part thereof as is in actual operation, and may include an equitable charge for capital costs as herein provided. Whenever the board shall find, after such public hearing, that the price of water supplied from the State system can include amortization of principal and interest on the debt incurred by the State to supply such water without adversely affecting the economy of the region or district and without unduly burdening consumers of water from newly developed water supplies as compared with those served by older water supplies, the board shall, to the extent it so finds, include the annual amortization and interest cost in the water rates so fixed. Differentiation in rates may be made on the basis of quantities of water to be supplied, distances between the reservoirs and points of distribution, connection and interconnection costs, and the like. The aggregate revenue produced by such rates shall, so far as practicable, be limited to costs to the State of operation and maintenance and of debt service and to the reimbursement of the State treasury of the amount of operating deficits, including annual payments of principal and interest, previously incurred by the State.

15. (a) Whenever, by this act, the division is authorized or directed to do or perform any act, such act may be performed by the commissioner and when so performed by him, such act shall have the same force and effect as though performed by the said division.

(b) The commissioner may assign to the division from among the personnel of the Department of Conservation and Economic Development such personnel as he may deem necessary to aid it in the performance of its functions and duties.

(c) Any specific enumeration of powers granted by this act to the board, division or commissioner shall not be deemed to be a limitation upon the general powers granted to the said board, division or commissioner.

16. (a) Whenever the power of condemnation is exercised by the division, pursuant to this act, the provisions of chapter 1 of Title 20 (Eminent Domain) of the Revised Statutes, as amended and supplemented, shall be applicable and such power shall include the condemnation of public as well as privately owned property; provided that this shall not include the power to condemn any public or private water supply system except to construct, develop or acquire a water supply system authorized by this act or other legislation.

(b) Whenever any person entitled to an award in condemnation proceedings instituted for the purposes of this act, or whenever any person deriving a right, title or interest under such person, shall remain in possession of the property taken after the date of the vesting title in the State, the reasonable value of the use and occupancy of such property subsequent to such time, as may be fixed by agreement or by the court in which such condemnation proceeding is pending, or by any court of competent jurisdiction, shall be a lien against such award and the interest thereon, subject only to liens of record at the time of such vesting of title in the State.

17. On or at any time after the institution of an action by the division for the condemnation of property, such division may file with the clerk of the Superior Court, a declaration of taking signed by the commissioner or other duly authorized officer of the division declaring that all or any part of such property is being taken for the use of the State. The said declaration of taking shall be sufficient if it sets forth: (1) a description of the property, sufficient for the identification thereof, to which there may be attached a plan or map thereof; (2) a statement of the estate or interest in said property being taken; (3) a statement of the sum of money estimated by the division to be just compensation for the property taken.

From the filing of the said declaration of taking and the deposit in court to the use of the persons entitled thereto of the amount of the estimated compensation stated in said declaration, title to the property described as being taken by said declaration shall vest in the State (free from the right, title, interest or lien of all persons), and said property shall be deemed to be con-

demned and taken for the use of the State and the right to just compensation for the same shall vest in the persons entitled thereto. Upon the filing of the declaration of taking, the court shall designate a day (not exceeding 20 days after such filing, except upon good cause shown), on which the persons in possession shall be required to surrender possession to the division.

The ultimate amount of compensation shall be determined pursuant to Title 20 of the Revised Statutes. If the amount so fixed shall exceed the amount so deposited in court by the division or otherwise paid to the persons entitled thereto, the court shall enter judgment against the division in the amount of such deficiency, together with interest at the legal rate on such deficiency from the date of the vesting of title to the date of the entry of the final judgment (subject, however, to abatement for use, income, rents or profits derived from such property by the owner thereof subsequent to the vesting of title in the State), and the court shall order the division to deposit the amount of such deficiency in court. The money deposited into court by the division shall be secured in such manner as may be directed by the court and shall be disbursed according to the order or judgment of the court to the persons found to be entitled thereto by the final award or judgment of the court. In case the amount deposited in court by the division as the estimated compensation for the property shall exceed the amount of the final award or judgment, such excess shall be returned to the division.

18. The division shall keep separate accounts for the operation, maintenance and debt service cost attributable to each project.

19. The board shall also have power to make reasonable regulations for the installation, construction, maintenance, repair, renewal, relocation and removal of tracks, pipes, mains, conduits, cables, wires, towers, poles and other equipment and appliances herein called "public utility facilities" of any public utility as defined in section 48:2–13 of the Revised Statutes, in, on, along, over or under any project. Whenever the board shall determine that it is necessary that any such public utility facilities which now are, or hereafter may be, located in, on, along, over or under any project, should be relocated, or should be removed from such project, the public utility owning or operating such facilities shall relocate or remove the same in accordance with the order of the board; provided, however, that the cost and expenses of such relocation or removal, including the cost of installing such facilities in a new location, or new locations, and the cost of any lands, or any rights or interests in lands, and any other rights acquired to accomplish such relocation or removal, less the cost of any lands or any rights or interests in lands or any other rights of the public utility paid to the public utility in connection with the relocation or removal of such property, shall be ascertained and paid by the division as a part of the cost of such project. In case of any such relocation or removal of facilities, as aforesaid, the public utility owning or operating the same, its successors or assigns, may maintain and operate such facilities, with the necessary appurtenances, in the new location or new locations, for as long a period, and upon the same terms and conditions, as it had the right to maintain and operate such facilities in their former location or locations.

20. This act shall take effect immediately but shall be inoperative unless and until the "New Jersey Water Supply Bond Act," enacted by the present Legislature, is approved by a majority of the legally qualified voters of the State voting on the question of the approval of said act at a general election.

APPENDIX F

APPENDIX F

PUMPED-STORAGE GENERATION

While the basic purpose of this report is the development of potable water supplies, certain other possibilities exist at some reservoir sites that offer a means of reducing the net cost of operation. One such possibility is the so-called "pumped-storage" scheme. This relates to hydro-electric installations combined with pumping plants to utilize power for pumping additional quantities of water during the night and utilizing such extra water for generating power at times when the so-called "peak-demands" exist. It is in essence a "storage-battery" charged at night and used only when the supply of power is needed for short periods, usually in the late afternoon or early evening hours. A single natural or artificial water storage reservoir cannot be so used, but in the studies covered in this report, several of the reservoir sites offer the possibility of "pumped storage" utilization. It is necessary to have an upper and lower reservoir of sufficient size to exchange water between them at different times of the day—without effecting their fundamental purpose, namely, water supply.

The first large scale pumped-storage plant in the United States was the Rock River plant in Connecticut, completed in 1928 by the Connecticut Light and Power Company. That plant used separate equipment for pumping and generating. Technical developments now permit pumps and motors to serve dual functions as turbine and generator with appreciable savings in cost, and no loss in hydraulic and mechanical efficiency. Several such installations are in successful operation now in the United States and abroad and many more sites are under study. Information regarding pump-turbine characteristics and tests are included in two recent papers presented to the American Society of Mechanical Engineers.* Appendix Plate A-10 shows a section through a typical pump-turbine plant as well as a section through a typical single-purpose pumping plant.

Most water supply reservoirs such as Wanaque and Boonton, are not susceptible of economic pumped-storage development because a secondary high or low level pool is not available. Construction of such a pool solely for hydro-electric use is usually not economically feasible. Several possible locations, where pumped-storage plants might be found practical, exist in connection with water supply plans presented in this report, and are listed below:

1. East Branch—Dock Watch Hollow (Plan CR-4).

2. North Branch—Chimney Rock (Plans CR-1 and CR-2, Alts. 1).

3. Hamden—Round Valley (All four RV plans).

4. Warrenville—Dock Watch Hollow (Plan RV-4).

5. Wallpack Bend (or Delaware River)—Flatbrook (Plans DG-1 to -5, DP-1 to -3).

Each site requires extensive analysis and study, but one proposed water supply plan—CR-4, has been selected as an example to illustrate the possibility of additional utilization of this site to reduce the cost of supplying water to the Northeastern Region. With a high level reservoir in Dock Watch Hollow and low level reservoir in the Chimney Rock area—either all or part of the entire site—the basic pumping plant could be augmented by hydro-electric units to accomplish this pumping-generating cycle.

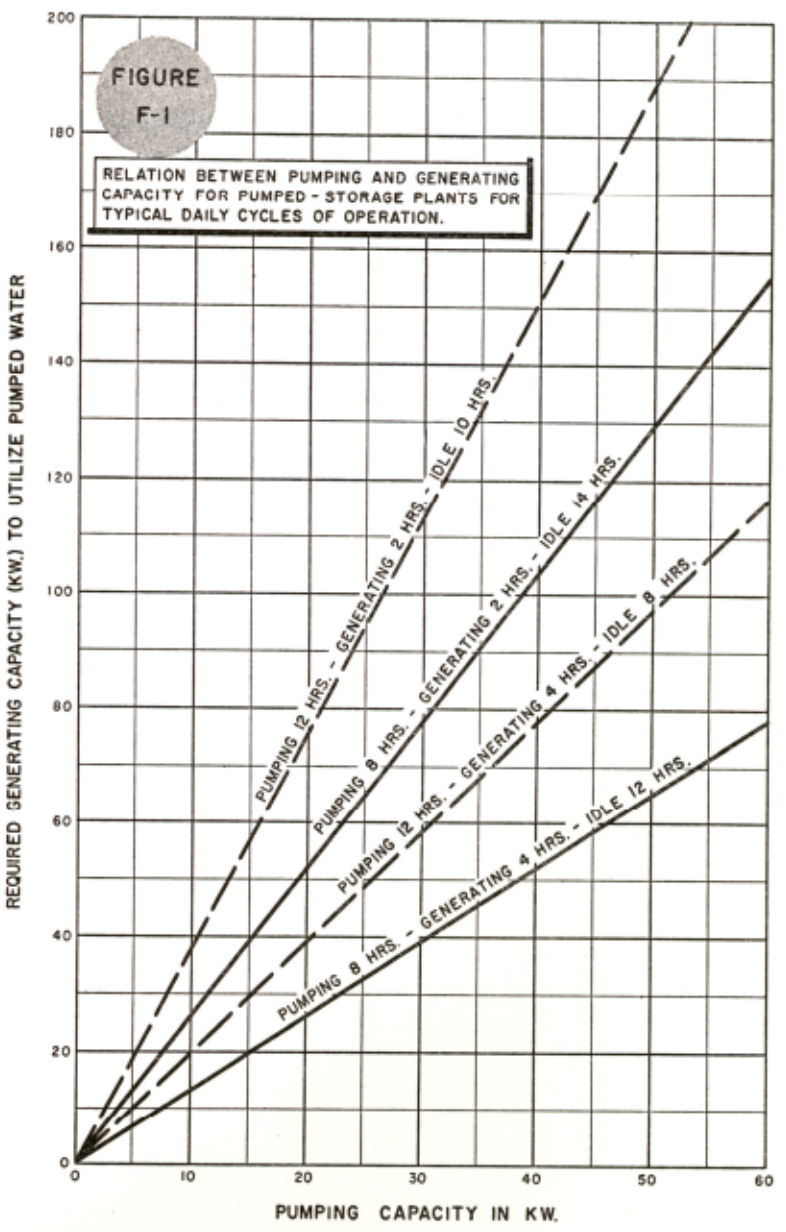
In Plan CR-4 (see Plate II-11) a pumping plant of 100 million gallons per day capacity is needed for water supply purposes to lift water to Dock Watch Hollow Reservoir. Since deliveries to the transmission system for distribution would be from the East Branch reservoir, reserve supplies needed from storage in Dock Watch Hollow for water supply could be released through outlets in the dam to flow by gravity to the East Branch reservoir via the natural channel of the East Branch of Middle Brook. Thus, for Plan CR-4, the minimum facilities required at this site, for water supply operations only, include a 100 mgd pumping plant, a 72 inch diameter pipeline 1,900 feet in length, and outlets in Dock Watch Hollow dam adequate to release 250 mgd to the natural stream channel. The capital cost of these facilities is estimated to be $1,964,000 and annual costs (including interest, amortization, operation and maintenance) would be about $158,000.

Since an annual expenditure of $158,000 would be required to operate the facilities needed for water supply, any acceptable pumped-storage generating plant used in lieu of the simple pumping plant must be assured of sufficient revenue from the electrical capacity and energy provided to result in a net annual cost to the overall project not in excess of $158,000. On the other hand, if the pumped-storage plant can be so designed as to provide capacity and energy with sufficient value to reduce the net annual cost to less than $158,000, the water supply project would benefit by reduced net costs.

Field tests under operating conditions prove that 65 percent of the energy used in pumping may be recovered when the water is returned for generation. This is a general figure and includes head losses, transmission losses and the inherent losses in pumping and generating machinery. It is possible to obtain a recovery ratio as high as 70 percent under ideal conditions or 60 percent for less favorable conditions.

Pumping can be accomplished in an 8 to 12 hour "off-peak" period with generation taking place preferably during shorter periods at the times of greater demand. For purposes of this analysis, data are presented for a 4-hour and a 2-hour generating period, assuming recovery of 65 percent of the pumping energy during such periods. The choice of capacities then becomes a function of the power required for pumping over a longer period of time as against that amount to be recovered over a shorter period at times when its value is greater.

Figure F-1 is presented to illustrate the relation between the required generating capacity and pumping capacity (expressed in kilowatts installed) for various daily pumping and generating cycles. The number of hours each day that the equipment would normally be idle is also indicated. This normal idle period is of some importance because the pumping capacity provided in the pumped-storage plant can be utilized during such periods to replace storage in Dock Watch



*Paper No. 55-A-29 "Field-testing a Reversible Pump-turbine" by Frank E. Jaski.
Paper No. 55-S-45 "Performance Characteristics of Francis Type Pump-turbines" by W. J. McCormack.

Hollow which had been withdrawn to supply water system demands, without interrupting the normal daily pumping and generating cycles for pumped-storage operation.

Table F-1 presents an economic analysis for four sizes for a pumped-storage plant to utilize the East Branch and Dock Watch Hollow reservoirs in Plan CR-4. In each case the dual purpose units used would have a rated motor capacity for pumping of 15,000 kilowatts and a rated generating capacity of 10,000 kilowatts. Additional single purpose turbine-generator units would be provided for the remainder of the assumed generating capacity. Estimated costs for purchase of energy used for pumping have been included under the heading "Annual Costs." The estimated purchase price was based on rate schedules for night use between the hours of 8 a.m. and 8 p.m., now in effect for utility companies in New Jersey.

In the analysis presented in Table F-1 a minimum value of $16.50 per kw of dependable capacity was used. Such a value is believed conservative and more detailed study may well establish a higher value for dependable capacity for peak load assistance. As indicated at the bottom of Table F-1, the sale price which must be received per kilowatt-hour for the energy generated, in order that the project costs will not exceed the minimum value required for essential water supply features, varies between $0.0089 and $0.0041 for the 4 sizes of plant examined. It should be understood that if a capacity value greater than $16.50 per kilowatt could be obtained, it would be possible to consider a lower energy value per kilowatt-hour.

On the basis of data shown on Table F-1, the largest size of pumped-storage generation plant analyzed (assumption D, with generating capacity of 60,000 KW and pumping capacity of 15,000 KW) appears to be most economical, since it would require the lowest sale price for the energy generated, $0.0041 per kilowatt-hour. Such a sale price is believed about equal to the cost of fuel consumed in steam generating plants. Thus, there appears to be no reason to doubt that such revenues could be realized.

Before a decision could be reached as to the desirability of pumped-storage generation, in lieu of a simple pumping plant, with any of the water supply plans it will be necessary to make detailed studies of the design, operation and economics of various sizes of plants in close cooperation with the utility company holding the franchise in the specific area. Should such studies, for example, confirm the capital and operating costs presented for assumption D in Table F-1 and establish sale values of $25.00 per kilowatt of capacity (instead of the assumed minimum of $16.50 per KW) and $0.0041 per kilowatt-hour of energy generated, the revenues from energy recovery would be sufficient to contribute $510,000 annually toward reductions of the overall annual project costs.

TABLE F-1

TYPICAL ECONOMIC ANALYSIS

EAST BRANCH—DOCK WATCH HOLLOW PUMPED-STORAGE PLANT—PLAN CR-4

Item	ASSUMPTION A	B	C	D
Pumping Data				
Motor rating as pumps—KW	15,000	15,000	15,000	15,000
Hours pumped each day	8	8	12	12
Energy used in pumping (annually in millions of kwh.)	43.7	43.7	65.7	65.7
Generating Data				
Rated capacity as generators—KW	20,000	40,000	30,000	60,000
Hours generating each day	4	2	4	2
Energy generated—(annually in millions of kwh.)	28.5	28.5	42.7	42.7
Capital Costs				
Construction (incl. contingencies)	$4,218,000	$7,668,000	$5,943,000	$11,118,000
Engr., Legal & Admin. costs	358,000	654,000	505,000	944,000
Interest during construction	193,000	345,000	264,000	500,000
Initial Capital Cost	$4,769,000	$8,667,000	$6,712,000	$12,562,000
Annual Costs				
Interest and amortization	$ 207,000	$ 373,000	$ 290,000	$ 543,000
Reserve for replacements	35,000	65,000	45,000	90,000
Operation and maintenance	130,000	170,000	155,000	190,000
Energy charge for pumping	263,000	263,000	395,000	395,000
Demand charge for pumping	106,000	106,000	106,000	106,000
Total Annual Costs	$ 741,000	$ 977,000	$ 991,000	$ 1,324,000
Annual Credits				
Alternative cost for 100 mgd pumping inst.	$ 158,000	$ 158,000	$ 158,000	$ 158,000
Minimum value of dependable generating capacity @ $16.50 per KW	330,000	660,000	495,000	990,000
Subtotal	$ 488,000	$ 818,000	$ 653,000	$ 1,148,000
Minimum revenue from energy generated to balance costs	$ 253,000	$ 159,000	$ 338,000	$ 176,000
Break-even price for energy per kwh of generation	$ 0.0089	$ 0.0056	$ 0.0079	$ 0.0041

APPENDIX F

TIPPETTS-ABBETT-McCARTHY-STRATTON
ENGINEERS
(KNAPPEN-TIPPETTS-ABBETT-McCARTHY)
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BARNETT SILVERSTON

November 30, 1955

Mr. W. G. Parry, General Sales Manager
New Jersey Power and Light Company
9 West Blackwell Street
Dover, New Jersey

Dear Mr. Parry:

In connection with the study of New Jersey Water Resources, which we are making for the Legislative Commission on Water Supply, there are a number of problems on power supply including the feasibility of pumped-storage generation possibilities which exist at several of the proposed reservoir sites. On November 22nd Mr. Logan Kerr and Mr. Rolland Kaser, representing this office, met with you and your associates to discuss these developments where they occur within the franchise area of the New Jersey Power and Light Company. The following is a brief review of the situation which we are making primarily for the purposes of clarification and record and on which we would appreciate having your comments.

Some of the reservoir sites under study are adaptable to a combination of pumping and generation depending upon the requirements of putting water into storage or of withdrawing water for the needs of the system or for stream regulation on the Delaware or other watersheds.

Development of power beyond the basic water supply requirements is also possible through the use of so-called "pumped storage". In this type of installation, upper and lower reservoirs can be used to permit pumping during off-peak periods, i.e. at night and over weekends and to generate substantial amounts of power during peak load periods. There are an almost infinite number of combinations of pumping and generation that could be studied at each potential site. Since our final report cannot contain detailed recommendations on all possible combinations we would like to have an expression of opinion from you on the following:

1. Would a pumped storage scheme with 15,000 kw pumping load and 10,000 kw generation feed back operated at the option of the water supply requirements only, be of interest to you?

2. Would the expansion of such a project to provide "off-peak" pumping and "on-peak" generation operated at the combined option of water

supply and power company requirements be of interest to you? For example, the "off-peak" pumping could amount to 20,000 kw and the 2-hour "on-peak" generation be 40,000 kw to 50,000 kw. It is possible to adjust these values for pumping load, generation and load factor beyond those stated, but more detailed studies would be required to determine the best installation considering economic aspects and power and water system requirements.

3. Would it be of interest to you (a) to have available reserve storage pumped at flood seasons to provide a potential 30-day reserve of 50,000 kw to cover outage or overhaul of a steam-turbine generator on your system or (b) have this reserve for the seasonal peak loads, i.e. November and December?

We realize that there are many problems involved in this situation and since time does not allow a detailed study for each case, may we ask one overall question, "would any or all of the three general programs be of interest to your company and if so would you be willing to investigate them at the appropriate time".

An early reply would be appreciated since we are in the final phases of the study and will shortly report to our client.

Very truly yours,

TIPPETTS-ABBETT-McCARTHY-STRATTON

Gerald T. McCarthy

NEW JERSEY POWER & LIGHT COMPANY
9 WEST BLACKWELL STREET · DOVER, NEW JERSEY
Telephone: Dover 6-1100

REDDY KILOWATT
Your Electric Servant

December 6, 1955

Mr. Gerald T. McCarthy
Tippetts-Abbett-McCarthy-Stratton
62 West 47th Street
New York 36, N. Y.

Dear Mr. McCarthy:

We have reviewed your letter of November 30, 1955 which outlines three general programs for the possible development of pumped storage generation within our service area.

In view of the continued growth of our territory and the importance of such projects to the general welfare and economic health of the whole State of New Jersey, we are greatly interested in your proposals. Too, we are always interested in securing generation on the most economical basis.

We, therefore, would be very pleased to have our organization investigate, at the appropriate time, any or all three programs.

Very truly yours,

W. G. PARRY
General Sales Manager

TIPPETTS-ABBETT-McCARTHY-STRATTON
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WALTHER PROKOSCH
BARNETT SILVERSTON

December 7, 1955

Mr. S. A. Moore, Manager of Sales
Public Service Electric and Gas Company
of New Jersey
80 Park Place
Newark, New Jersey

Dear Mr. Moore:

In connection with the study of New Jersey Water Resources, which we are making for the Legislative Commission on Water Supply, there are a number of problems on power supply including the feasibility of pumped-storage generation possibilities which exist at several of the proposed reservoir sites. On November 29th Mr. Logan Kerr and Mr. Holland Kaser, representing this office, met with you and Mr. S. L. Chapin to discuss these developments where they occur within the franchise area of the Public Service Electric and Gas Company of New Jersey. The following is a brief review of the situation which we are making primarily for the purpose of clarification and record and on which we would appreciate having your comments.

Some of the reservoir sites under study are adaptable to a combination of pumping and generation depending upon the requirements of putting water into storage or of withdrawing water for the needs of the system or for stream regulation on the Delaware or other watersheds. The specific locations within your franchise area are:

1. The Raritan River at Bound Brook. This installation would involve only the supply of power for pumping water from the river level at Bound Brook to the Chimney Rock and Dock Watch Hollow reservoir sites located north of Bound Brook.

2. A site located on the East Branch of the Raritan River at Chimney Rock involving both the pumping of water to Dock Watch Hollow and the generation of power by water returned from Dock Watch Hollow to East Branch.

3. Location at Warrenville involving the supply of power for pumping water to Dock Watch Hollow and the generation of power by the return of water to Warrenville.

Development of power beyond the basic water supply requirements is also possible through the use of so-called "pumped storage". In this type of installation, upper and lower reservoirs can be used to permit pumping during off-peak periods, i.e. at night and over weekends and to generate substantial amounts of power during peak load periods. There are an almost infinite number of combinations of pumping and generation that could be studied at each potential site. Since our final report cannot contain detailed recommendations on all possible combinations we would like to have an expression of opinion from you on the following:

1. Would a pumped storage scheme with 15,000 kw pumping load and 10,000 kw generation feed back operated at the option of the water supply requirements only, be of interest to you?

2. Would the expansion of such a project to provide "off-peak" pumping and "on-peak" generation operated at the combined option of water supply and power company requirements be of interest to you? For example, the "off-peak" pumping could amount to 20,000 kw and the 2-hour "on-peak" generation be 40,000 kw to 50,000 kw. It is possible to adjust these values for pumping load, generation and load factor beyond those stated, but more detailed studies would be required to determine the best installation considering economic aspects and power and water system requirements.

3. Would it be of interest to you (a) to have available reserve storage pumped at flood seasons to provide a potential 30-day reserve of 50,000 kw to cover outage or overhaul of a steam-turbine generator on your system or (b) have this reserve for the seasonal peak loads, i.e. November and December?

We realize that there are many problems involved in this situation and since time does not allow a detailed study for each case, may we ask one overall question, "would any or all of the three general programs be of interest to your company and if so would you be willing to investigate them at the appropriate time".

An early reply would be appreciated since we are in the final phase of the study and will shortly report to our client.

Very truly yours,

TIPPETTS-ABBETT-McCARTHY-STRATTON

Gerald T. McCarthy

MML:ev

80 SA

Public Service Electric and Gas Company

80 Park Place, Newark 1, New Jersey

December 12, 1955

Mr. Gerald T. McCarthy
Tippetts-Abbett-McCarthy-Stratton
62 West 47th Street
New York 36, New York

Dear Mr. McCarthy:

Thank you for your interesting letter of December 7, giving us additional information on the pumped-storage generation possibilities in connection with the study of New Jersey Water Resources which you are making for the Legislative Commission on Water Supply.

The three plans for pumped-storage generation are of interest but the degree of that interest, of course, can be ascertained only after a study at the appropriate time. At that time we would be quite willing to investigate the matter to determine the usefullness to us of these plans or others which might be developed.

It was a pleasure to meet Mr. Kerr and Mr. Kaser. If we can be of further assistance to you please let us know.

Sincerely yours,

S. A. Moore
General Manager-Sales

SAM:m

APPENDIX G

APPENDIX G

ACKNOWLEDGMENTS

Acknowledgment is due to many individuals and organizations who furnished valuable information and helpful cooperation during the conduct of the investigations. The members of the New Jersey Legislative Commission worked in close cooperation with members of this firm throughout the investigations and during the preparation of the reports. Valuable assistance in locating basic data for the investigation was obtained from the New Jersey Taxpayers Association through unlimited access to their comprehensive bibliography and to their files on the New Jersey Water Supply problem. Messrs. Howard T. Critchlow and George R. Shanklin of the Division of Water Policy and Supply were particularly helpful with their comments and files of basic information.

A list of individuals and organizations who were consulted during the course of the work follows. Their assistance is gratefully acknowledged.

Albright & Friel, Consulting Engineers
- Mr. Francis Friel

American Cyanamid Company (Calco Division)
- Col. John Fasoli, Field Representative
- Mr. M. N. Gaboury, Manager, Manufacturing Organic Chemical Division
- Mr. R. E. Watson, Private Counsel retained by American Cyanamid Co.
- Mr. William Rohrhurst, Manager, Power Department

American Water Works Association
- Mr. Harry E. Jordan, Secretary
- Mr. Charles G. Bourgin, Chairman, New Jersey Section

Atlantic City Electric Company
- Mr. J. B. Taylor, Vice-President
- Mr. John Kuhlmann

Atlantic City Water Department
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Bogert-Childs Engineering Associates
- Mr. Donald M. Ditmars

Bound Brook Water Company
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Clyde Potts Associates
- Mr. Weston Gavett, Partner

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- Middlesex County
  - Mr. Harold T. Letson, Director
- Monmouth County
  - Mr. Charles Pike, Director
- Morris County
  - Mr. Robert C. Hoover, Director
- Passaic County
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- Somerset County
  - Mr. John H. McMurray, Chairman

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- Mr. Henry E. Russell

Havens and Emerson, Consulting Engineers
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Johns-Manville Company
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- Mr. J. H. Zettel

Lock Joint Pipe Company
- Mr. Harvey Howe, Vice-President

Malcolm Pirnie Engineers
- Mr. Ernest W. Whitlock
- Mr. Malcolm Pirnie, Jr.

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New Brunswick Water Department
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- Mr. William Baumer

New Jersey Power and Light Company
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- Mr. W. E. Liepe, Manager of Rates
- Mr. E. J. VanDeusen, Supervisor of Industrial Sales

New Jersey State Chamber of Commerce
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- Office of Counsel to the Governor
  - Mr. Joseph Weintraub, Counsel
  - Mr. David C. Thompson, Assistant Counsel
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  - Dr. Thurlow P. Nelson, Chairman
- Law Revision and Legislative Services Commission
  - Mr. Charles De F. Besoré, Chief Counsel
  - Mr. John W. Ockford, Counsel for the Legislature
- Department of Conservation and Economic Development
  - Dr. Joseph E. McLean, Commissioner
  - Mr. Howard T. Critchlow, Director, Division of Water Policy and Supply
  - Mr. George R. Shanklin, Assistant Chief Engineer
  - Mr. R. L. Hardmann, Supervising Engineer
  - Mr. Benjamin A. Furman, Principal Engineer
  - Mr. Joseph Truncer, Engineer in Charge, Wharton Survey
  - Mr. Meredith E. Johnson, State Geologist
  - Mr. Kemble Widmer, Principal Geologist
  - Mrs. Gladys Ellsworth, Chief, Research and Statistics
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  - Mr. Walter Brennfleck, Principal Planner
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  - Mr. Walter J. Chertier, Supervisor, Labor Market Analysis Section
- Department of Health
  - Mr. Alfred H. Fletcher, Director, Division of Environmental Sanitation
  - Mr. Robert S. Shaw, Chief Engineer, Division of Public Health Engineering
  - Mr. Anthony Leahy, Principal Public Health Engineer
  - Mr. Leroy Forman, Principal Public Health Engineer
  - Dr. Marguerite Hall, Director, Division of Vital Statistics

New Jersey Taxpayers Association
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North Jersey Quarry Company
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Passaic Valley Water Commission
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Southern New Jersey Development Council
Mr. E. L. Gerber, Director

Trenton, City of
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U.S. Army, Office of the Chief of Engineers
Col. R. C. Miller, Division of Engineering Intelligence
Col. A. F. Clark, Jr., District Engineer, Philadelphia, Pennsylvania
Mr. Homer Fuller, Chief, Americas Branch, Geodetic Division, A.M.S.

United States Geological Survey
Mr. Henry C. Barksdale, District Engineer, Ground Water Branch
Mr. Oliver W. Hartwell, District Engineer, Surface Water Branch

APPENDIX H

APPENDIX H

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APPENDIX I

APPENDIX I

ESTIMATED COSTS FOR RECOMMENDED STAGE 1 CONSTRUCTION 70 MGD POTABLE SUPPLY FOR NORTHEASTERN REGION PLAN CR-3, EAST BRANCH RESERVOIR

Real Estate and Rights-of-Way

Real Estate Acquisition			
East Branch Reservoir — Including Land, Buildings and Bound Brook Water Company Rights	$8,280,000		
Spruce Run Reservoir	1,430,000		
Pumping Station and Diversion Dam at Bound Brook	50,000		
Headworks Site	20,000		
Sub-Total		$9,780,000	
Right-of-Way Acquisition			
Pumping Main — Bound Brook to East Branch	$ 135,000		
Transmission Mains including pavement removal and replacement	$1,000,000		
Sub-Total		$1,135,000	
TOTAL			$10,915,000

Reservoir Construction

East Branch Reservoir			
Dike	$2,542,000		
East Dam	3,682,000		
Clearing Reservoir Site	291,000		
Road and Utility Relocations	715,000		
Recreational and Security Facilities	350,000		
Sub-Total		$7,580,000	
Spruce Run Reservoir			
Dam	$2,385,000		
Clearing and Grubbing	215,000		
Road and Utility Relocations	90,000		
Sub-Total		$2,690,000	
TOTAL			$10,270,000

Pumping Station and Pumping Main

Pumping Station (at Bound Brook) including diversion works	$1,700,000	
Pumping Main to East Branch Reservoir	1,765,000	
TOTAL		$ 3,465,000

Headworks Including Treatment and Booster Pumps

Treatment Plant including coagulation, filtration and chlorination	$3,500,000	
Booster Pumping Station	1,350,000	
Administration and Control Building, Gate House, Shop and Garage	650,000	
TOTAL		$ 5,500,000

Transmission Mains

Transmission tunnel from East Branch Reservoir through First Watchung Mountain	$2,140,000	
Transmission main from tunnel to interconnections with existing system in Newark	14,990,000	
Transmission main from tunnel to lower Raritan Valley	2,740,000	
TOTAL		$19,870,000

Total of Real Estate, Rights-of-Way and Construction	$50,020,000
Engineering, Legal and Administrative Costs	3,640,000
Interest During Construction	2,990,000
Total Estimated Cost of Project	$56,650,000
Cost per Million Gallons of System Capacity	$ 809,300

APPENDIX J

APPENDIX J

QUALITY OF WATER

The various plans for use of surface waters in the Delaware and Raritan Basins are outlined in Chapter II. The properties of the raw water obtained from the different sources vary considerably but the water is of treatable quality at all of the diversion points considered. Generally speaking, complete treatment including coagulation, sedimentation, filtration and chlorination should be provided for all waters before they are considered suitable for a potable supply. Improvements in quality brought about by long term deep storage will reduce the operating cost of treatment required, but will not eliminate the need for such facilities.

The following tabulation lists the results of analyses of water samples taken recently at various points within the basins under study.

RARITAN BASIN
Results of Water Analyses

	Oct. 11 1948	Oct. 5 1949	Sept. 26 1950	Aug. 17 1955
North Branch of Raritan River Above Confluence with South Branch*				
Flow near Raritan N. J. (cfs)	64	39	45.0	
Dissolved Oxygen (ppm)	9.3	10.0	10.4	6.9
Biochemical Oxygen Demand (5 day 20°C) (ppm)	1.0	2.0	1.9	0.1
pH	7.8	7.5	6.8	7.3
Most Probable Number-Coliforms per Milliliter	0.7	2.4	2.5	80.0
Ammonia Nitrogen (ppm)		0.06		
Chlorides (ppm)	9.7	10.0	7.2	5.0
% Saturation (Dissolved Oxygen)	89.0	106.0	96.0	85.0
South Branch of Raritan River Above Confluence with North Branch*				
Flow at Stanton (cfs)	72	46	57.0	
Dissolved Oxygen (ppm)			10.0	6.3
Biochemical Oxygen Demand (5 day 20°C) (ppm)			1.1	0.3
pH			8.1	7.1
Most Probable Number Coliforms per Milliliter			0.6	110
Chlorides (ppm)			3.6	8.5
% Saturation (Dissolved Oxygen)			93	80
Iron (ppm)				1.0
Raritan River at Finderne*				
Flow at Manville (cfs)	149	97.0	106.0	
Dissolved Oxygen (ppm)		8.8	8.2	6.6
Biochemical Oxygen Demand (5 day 20°C) (ppm)	3.0	5.0	1.2	0.3
pH	7.7	8.2	7.1	7.4
Most Probable Number Coliforms per Milliliter	250.0	6.2	250	300
Ammonia Nitrogen (ppm)		.04		
Chlorides (ppm)	9.1	34.0	8.4	4.5
% Saturation (Dissolved Oxygen)	84.0	93.0	78.0	82.0
Iron (ppm)				1.1
Millstone River Above Confluence with Raritan River*				
Flow at Blackwells Mills (cfs)	80.0	85.0	103.0	
Dissolved Oxygen (ppm)	7.7	7.7	7.1	5.0
Biochemical Oxygen Demand (5 day 20°C) (ppm)	2.0	3.0	0.4	1.2
pH	7.0	7.7	6.7	6.6
Most Probable Number Coliforms per Milliliter	2.5	69.0	6.0	350.0
Chlorides (ppm)	16.0	13.0	12.0	15.0
% Saturation (Dissolved Oxygen)	75.0	80.0	69.0	63.0

* By Department of Sanitation, Rutgers University.

Note: Delaware Basin Data on page J-2

DELAWARE BASIN
Results of Water Analyses

Delaware River at Phillipsburg**

	Weekly Average Results			
	Wk. Ending Jan. 8, '55	Wk. Ending Apr. 30, '55	Wk. Ending June 11, '55	Wk. Ending Nov. 12, '55
Temperature °F	37°	55°	68°	43°
Turbidity	5.0	6.4	8.7	4.0
Alkalinity (ppm)	17.0	20.0	25.0	25.0
pH	7.2	7.2	7.4	7.2
Oxygen Consumed (ppm)	4.6	3.9	4.3	3.9
Average-Coliforms per Milliliter	2.0	2.0	1.0	1.0

Delaware River at Burlington, New Jersey***

	Jan. 3, '52	May 5, '52	July 7, '52	Nov. 6, '52
Flow at Trenton (cfs)	30,500	18,700	3,370	3,130
Temperature (°F)	39.0	57.0	81.0	49.0
Color	6.0	6.0	7.0	6.0
Hardness as $CaCO_3$ (ppm)	56.0	45.0	77.0	89.0
pH	7.2	6.9	7.0	6.5
Dissolved Oxygen (ppm)	10.7	9.3	4.5	9.2
Biochemical Oxygen Demand (5 day 20°C) (ppm)	1.4	1.1	.7	3.0
Chlorides (ppm)	3.0	3.6	6.0	11.0

** By City of Easton, Pennsylvania.
*** By City of Philadelphia and U.S. Geological Survey.