REPORT
of the
WATER POLICY COMMISSION

JANUARY 30, 1926
FEBRUARY 27, 1926

PART ONE

JANUARY 30, 1926

New Jersey

REPORT

of the

WATER POLICY COMMISSION

PART ONE

JANUARY THIRTIETH, 1926

DEALING WITH THE

PROPOSED COMPACT

AS TO THE

WATER RESOURCES OF THE DELAWARE RIVER

BETWEEN

THE COMMONWEALTH OF PENNSYLVANIA

THE STATE OF NEW JERSEY

THE STATE OF NEW YORK

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REPORT OF THE WATER POLICY COMMISSION

PART ONE

To the Senate and General Assembly of the State of New Jersey:

By Joint Resolution adopted March 21, 1925, it was provided, among other things, that this Commission, designated in such resolution as the "Water Policy Commission," should undertake:

(*a*) A study of the draft of the proposed compact among the State of New York, the Commonwealth of Pennsylvania, and the State of New Jersey, in relation to the waters of the Delaware River and its tributaries and recommend the approval, rejection or modification of the proposed compact by the Legislature of 1926; and,

(*b*) Consider and submit its conclusions as to the advisability of entering into treaty relationship with any other neighboring State for the development of resources upon any stream lying partly within and partly without the boundaries of the State of New Jersey.

We have studied and considered the subjects so referred to us, and recommend:

(1) That the proposed compact be not ratified or confirmed in the form submitted;

(2) That a commission be constituted to continue the negotiations which resulted in the proposed compact;

(3) That a commission be constituted to negotiate a compact between the State of New York and the State of New Jersey defining the rights of said States in the waters of the interstate streams of said States, including the Hackensack, Ramapo, Pochuck and Wallkill Rivers, and governing the development and use thereof.

These recommendations are based upon the following considerations:

WATER RESOURCES OF THE DELAWARE RIVER

The Delaware River has a *total* drainage area of twelve thousand (12,000) square miles above its mouth.

In considering the proposed compact, the drainage area of the river has been divided into the "Upper Basin," including that part lying above the point at which the New York-New Jersey State line intersects the river below Port Jervis, and the "Lower Basin," including the drainage basin below that point.

The proportion of the drainage area in the Upper and Lower Basins lying within the signatory States is as follows:

Upper Basin:		
In Pennsylvania.........	1,016 square miles	
In New York............	2,389 " "	
In New Jersey...........	10 " "	3,415 square miles
Lower Basin Above Philadelphia:		
In Pennsylvania.........	2,811 " "	
In New Jersey...........	1,602 " "	4,413 " "
		7,828 " "

YIELD OF THE DELAWARE

For water supply or power purposes New Jersey is only concerned in the watershed above Philadelphia.

According to stream flow records maintained at Port Jervis for twenty years past, the gross average daily yield of the Upper Basin has been three thousand nine hundred and thirty (3,930) million gallons daily and that of the Lower Basin above Philadelphia four thousand three hundred and ten (4,310) million gallons daily, a total of eight thousand two hundred and forty (8,240) million gallons daily above Philadelphia. Making deductions for the reserve flow which the proposed compact apparently requires shall be maintained in the river after diversion, the net average daily yield of the river at the New York-New Jersey State line is three thousand one hundred and thirty-five (3,135) million gallons daily and above Philadelphia three thousand two hundred and eighty-four (3,284) million gallons daily, a total of six thousand four hundred and nineteen (6,419) million gallons daily.

The regimen of the river, however, is variable, so that, to secure the average net yield, storage reservoirs will be necessary to impound water in times of flood to supplant the natural stream flow in times of drought.

It would be uneconomical, if physically possible, to secure and divert the full net yield of any portion of the drainage basin through storage.

The proposed compact limits the drainage area which may be developed by any of the signatory States to three-fifths (3-5) of that which lies within each State.

These factors taken into account, the probable net collectible and divertible yield from the Upper Basin will be two thousand one hundred (2,100) million gallons daily and from the Lower Basin one thousand six hundred (1,600) million gallons daily.

ESTIMATED PRESENT AND FUTURE CONSUMPTION

Estimates of consumption in the distant future are necessarily speculative and subject to wide variation. Such estimates, however, furnish a basis for judgment of the probable future public necessities of the four districts interested in a water supply from the Delaware River.

The estimated present and future consumption in these districts are as follows:

District (1)	1926 Million Gallons Daily (2)	1980 Million Gallons Daily (3)
Metropolitan District of New York, including New York City and Westchester County	850	3,000
Metropolitan District of Northern New Jersey, including Counties of Bergen, Hudson, Union, Middlesex, Essex and Passaic	250	1,000
Metropolitan District of Philadelphia, including Philadelphia and suburbs	400	1,000
Metropolitan District of Southern New Jersey	50	250
	1,550	5,250

POTENTIAL SOURCES

New York has large water resources which can be developed and diverted to its metropolitan district. If, however, the obstacles to utilizing the Delaware River were removed, that State would, no doubt, first turn to this source of supply and prepare at an early day to remove water from the Upper Basin because of the economic advantages which such a course offers.

Pennsylvania is also rich in water resources, and additional water for the Philadelphia metropolitan district could be secured from other watersheds, but at very much greater cost than it could be obtained from the Delaware River and its tributaries.

The water resources of New Jersey may be summarized as follows:

		Million Gallons Daily
Northern New Jersey:		
Long Hill or Chimney Rock Project as ultimately developed, excluding the Delaware		600
Passaic as now developed, including the Wanaque Reservoir and with the addition of proposed Great Reservoir		600
Water which may be secured from the Raritan in addition to the diversion as proposed for Long Hill or Chimney Rock Reservoir		300
Total		1,500
Hackensack River		40
Miscellaneous present sources		60
Total	1,600	1,600
Ultimate allotment from the Upper Basin of the Delaware River above the New York-New Jersey State line under the tri-State compact, depending upon its interpretation	425	700
Total	2,025	2,300
Additional water which may be secured from the Hackensack, Ramapo, Pochuck and Wallkill Rivers if an agreement were made with New York by which New Jersey could develop these streams	340	340
Total for Northern New Jersey	2,365	2,640
Southern New Jersey:		
Mullica and Wading Rivers and other local streams		380
Available by allotment from the Lower Delaware Basin, proposed compact		800
Miscellaneous present sources		50
Total for Southern New Jersey		1,230

	Million Gallons Daily	
Water resources of Northern New Jersey.....	2,365	2,640
Water resources of Southern New Jersey.....	1,230	1,230
Total for State....................	3,595	3,870
Present approximate consumption of water in Northern and Southern Metropolitan Districts of State.........		300

Net developable resources at least ten times present demand, or sufficient for possibly two hundred (200) years to come.

PRESENT NEEDS

The metropolitan district of New York is faced with the necessity of preparing for an additional supply of approximately one thousand (1,000) million gallons per day, which will be sufficient to satisfy its requirements for forty (40) years to come.

Philadelphia requires more water and proposes to secure an additional supply of five hundred (500) million gallons daily, which will be sufficient to meet its needs for possibly the next forty (40) years.

The metropolitan district of Northern New Jersey requires additional water.

The needs of the district for a number of years to come may be met by developing sheds lying wholly within the State. In any event, this district will not draw heavily upon the Delaware for many years and it will probably be sixty (60) years or more before the needs of this district will require any diversion from the channel of the Delaware River, and so utilize the waters of the Upper Basin.

The metropolitan district of Southern New Jersey is not, at this time, faced with a water problem as acute as that which confronts the other metropolitan districts. It will not be long, however, before it will be necessary to seek additional sources of supply for this district. The Mullica, Wading and other local rivers could be developed to yield possibly three hundred and eighty (380) million gallons per day, which in addition to the supply from present sources would be sufficient for the requirements of the district for a hundred years to come, but the Delaware will, no doubt, be utilized to secure some of the water needed by this section.

In considering the needs of the respective metropolitan districts in the three States it should be remembered that when New Jersey has developed the local watersheds before mentioned and exhausted its quota from the Delaware, additional supplies must come from the outside, whereas New York and Pennsylvania still have extensive intra-state resources to draw upon.


MAP NO. 2
STATE OF NEW JERSEY
WATER POLICY COMMISSION
DRAINAGE AREAS OF
PRINCIPAL STREAMS
NICHOLAS S. HILL, JR.
CONSULTING ENGINEER
NEW YORK CITY
DECEMBER 1925
Scale in Miles
PENNSYLVANIA
NEW YORK
DELAWARE
ATLANTIC OCEAN
WALLKILL
PASSAIC
HACKENSACK
RARITAN BASIN
DELAWARE RIVER BASIN
ATLANTIC COAST BASIN
FLAT BROOK
PAULINS KILL
PEQUEST
POHATCONG
MUSCONETCONG
PAPAKATING
POCHUCK
WANAQUE
RAMAPO
PEQUANNOCK
ROCKAWAY
WHIPPANY
UPPER PASSAIC
LOWER PASSAIC
SADDLE RIVER
RAHWAY
ELIZABETH
SOUTH BRANCH
NORTH BRANCH
LOWER RARITAN
MILLSTONE
LAWRENCE BROOK
SOUTH RIVER
NAVESINK
MANASQUAN
METEDECONK
TOMS RIVER
CEDAR CR.
ASSANPINK
CROSSWICKS CR.
BLACKS CR.
ASSISCUNK CR.
RANCOCAS
PENSAUKEN
COOPERS CR.
BIG TIMBER CR.
MANTUA CR.
RACCOON CR.
OLDMANS CR.
SALEM CR.
ALLOWAYS CR.
COHANSEY CR.
MAURICE RIVER
GREAT EGG HARBOR RIVER
TUCKAHOE
MULLICA
PHILADELPHIA
TRENTON

RIGHTS INDEPENDENT OF COMPACT

Independent of compact, neither of the three States has a right to all the waters arising within its boundaries and supplying this interstate stream, but each is entitled to an "equitable division" or "equitable apportionment" of the water of the stream. What constitutes an equitable division or apportionment must depend upon the circumstances. Its determination requires the consideration of many factors. These factors the foregoing statement of facts provides.

It is in the light of this statement of facts that the proposed compact should be considered.

THE PROPOSED COMPACT

The basic provisions of the proposed compact are those effecting the allotment of the water among the signatory States and prescribing reserve flow requirements.

The reserve flow requirements affect both the partition of the water among the States and the quantity of water which they will respectively secure.

That these basic provisions should be free from ambiguity will not be questioned.

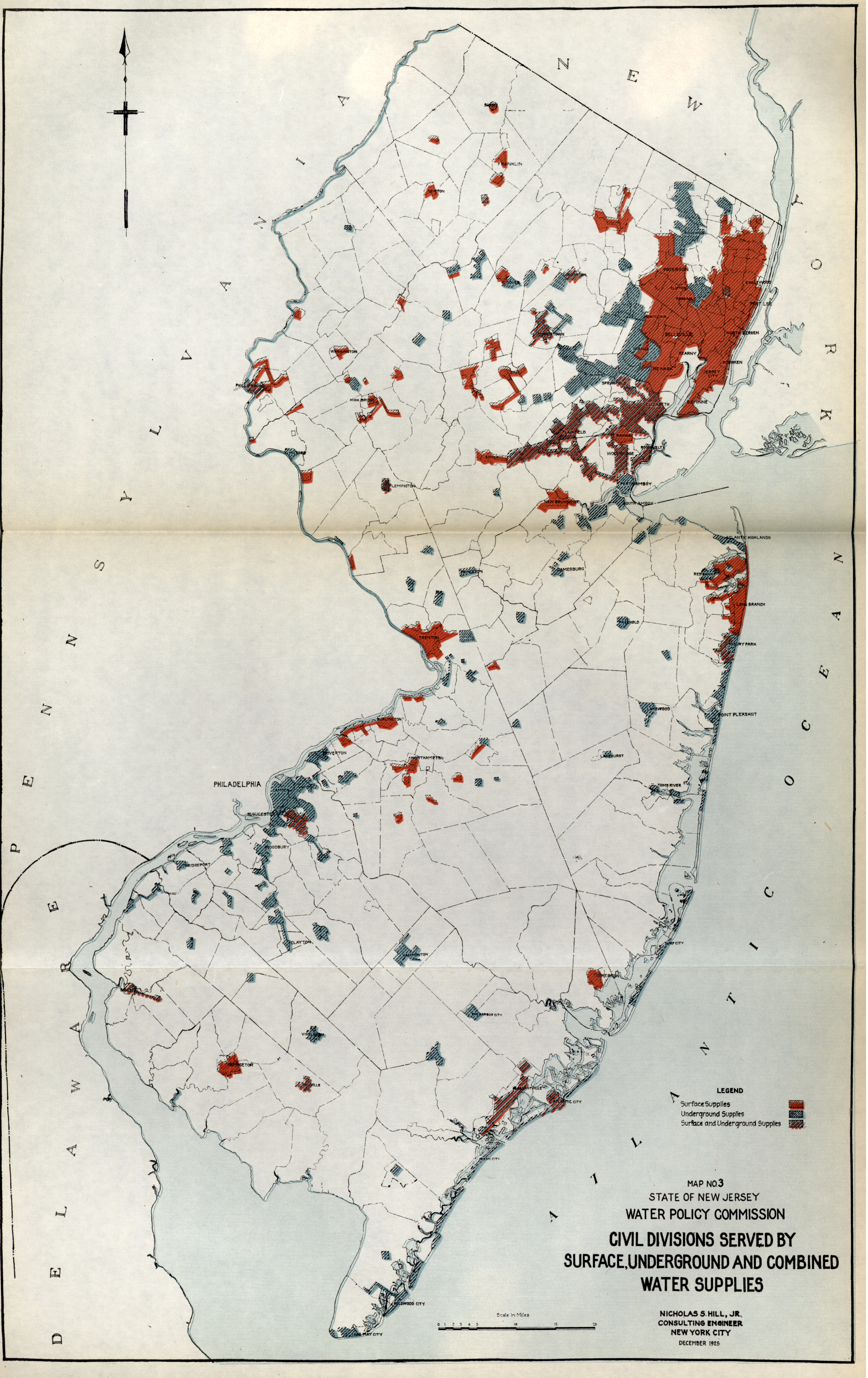
Unless they clearly, and without ambiguity, express the intent of the signatory States, the purpose to render definite and certain the interstate rights, which independent of compact are indefinite and uncertain, fails of accomplishment.

These basic provisions are contained in Articles V and VI.

Consideration of these articles leads to the conclusion that they are wanting in clarity and are susceptible reasonably of widely varying interpretations.

Article VI declares that "in case no tributary within the drainage area above the New York-New Jersey State line shall have been developed for diversion, then the allotment of each state at any point in the channel of the Delaware River above said state line * * * * shall be one-third (1/3) of the total water which may be flowing in the channel at that point."

There follows, however, a cumbersome rule for modifying this allotment in the event that any one or more of the signatory States impounds and diverts water from the Upper Basin. This rule is not alone cumbersome, but taken in connection with other requirements of Articles V and VI is reasonably subject to different interpretations,


NEW YORK
ATLANTIC OCEAN
DELAWARE
PENNSYLVANIA
PHILADELPHIA
TRENTON
PATERSON
NEWARK
LEGEND
Surface Supplies
Underground Supplies
Surface and Underground Supplies
Scale in Miles
MAP NO. 3
STATE OF NEW JERSEY
WATER POLICY COMMISSION
CIVIL DIVISIONS SERVED BY
SURFACE, UNDERGROUND AND COMBINED
WATER SUPPLIES
NICHOLAS S. HILL, JR.,
CONSULTING ENGINEER
NEW YORK CITY
DECEMBER 1925

which produce materially different results as to the proportion of water intended to be allotted to the respective States.

The question of the interpretation of these provisions and the application of this rule has been submitted not only to the Consulting Engineer, but to other engineers, and such submission has resulted in as many varying interpretations and conclusions as the number of those to whom the submission was made.

Generally speaking, under these differing interpretations and conclusions, the apportionment of the water from the Upper Basin to New York varies from one-third (1/3) to one-half (1/2) and to Pennsylvania and New Jersey from one-quarter (1/4) to one-third (1/3).

The requirements for a reserve flow in the channel of the river and its tributaries are scattered through both Articles V and VI. They appear at four different points. So separated, it is difficult to compare them.

When set up together, conflicts in their requirements appear. To indicate this we have brought the provisions relating to the reserve flow requirements together.

Paragraph 3, Article V (page 5), provides that:

"In the case of every such development located above the New York-New Jersey state line there shall be maintained below the point of development during the months of July, August, September and October, a reserve flow equal to the ordinary flow at that point, and also if at any other time during the year the flow in the tributary at the point of development is less than the ordinary flow at that point, then a reserve flow equal to the ordinary flow shall be maintained below the point of development. In the case of every such development located below the New York-New Jersey state line there shall, at all times, be maintained below the point of development a reserve flow equal to the ordinary low flow at that point."

Paragraph 1, Article VI (page 5), declares that:

"* * * Each of these states may divert from the said channel at any point, above the said state line, that portion of its allotment which is in excess of a reserve flow of fifteen hundredths (0.15) of a cubic foot per second for each square mile of drainage area above the point of diversion and at any point below the New York-New Jersey state line each of the said states may divert that portion of its allotment which is in excess of a reserve flow of twelve hundredths (0.12) of a cubic foot per second for each square mile of drainage area above the New York-New Jersey state line."

Paragraph 6, Article VI (pages 7 and 8), provides that:

"* * * All water so stored may be diverted or released from such reservoir or reservoirs by or under the authority of such state but the flow in the said channel below the point of storage must not be reduced below the ordinary flow whenever the flow above the point of storage is greater than the said ordinary flow. When and if the flow in the said channel above the point of storage is less than the ordinary flow then and in every such case a flow equal to that above the point of storage shall be maintained in the said channel below the point of storage * * *."

Paragraph 7, Article VI (page 8), declares that:

"It is the intention of this article that no water shall be diverted from the channel of the Delaware River above the New York-New Jersey state line whenever the flow in the said channel is less than forty-five hundredths (0.45) of a cubic foot per second for each square mile of the total drainage area lying above the point of diversion and it is further intended that no water shall be diverted from the channel of the Delaware River below the New York-New Jersey state line whenever the flow in the said channel is less than thirty-six hundredths (0.36) of a cubic foot per second for each square mile of the total drainage area lying above the point of diversion, * * *."

It is our conclusion:

1. That any compact that may be entered into should include a definite declaration of intention as to the proportions in which allotment to the signatory States respectively is made of the water which naturally flows into the Delaware River from the drainage areas which we have designated as "Upper Basin" and "Lower Basin," and that such declaration of intention should stand at the head of, and introduce, the provisions relating to allotment, reserve flow, diversion and the like, in order that all following provisions may be read in the light thereof and be controlled thereby.

2. That reserve flow requirements may, and should, be treated simply and definitely.

3. That the approval of the Commission to be set up under the proposed compact should be required for *every* project that involves the removal or diversion of water from the channel of the Delaware River *or its tributaries*.

Under the proposed compact a signatory State developing tributaries lying within its boundaries is not required to secure approval of such development, nor is such approval required to be secured for diversions involving the removal of two (2) millions of gallons of water per day or less.

The extension of the requirement of Commission approval to *every project* will furnish assurance that *every project* squares with the requirements of the compact and that no project is inconsistent with the terms of the compact.

Such requirement would seem to be essential if equitable distribution and adequate regulation are to be assured.

Through such requirement complete records of all developments will be maintained in one public office available for the inspection of the officials of each of the signatory States and of others who may be interested.

In order that these conclusions may be presented in concrete form a suggested draft of modifications of the affected articles of the proposed compact is submitted.

Articles III and IV Unchanged:

ARTICLE III

In the development, use or diversion of the waters of the Delaware River and in all considerations of quantity and preservation of quality the order of importance and public value of water shall be as follows: (A) domestic and municipal, (B) sanitation, (C) industry and power, and (D) navigation.

ARTICLE IV

Any administrative department, political subdivision, corporation, partnership, association or person authorized in that behalf by or under the laws of any signatory state may exercise the rights and privileges herein conferred on such state, subject to the duties and obligations herein imposed on such state.

Suggested Modification of Article VII and its Designation as Article V:

The channel of the Delaware River may be used as a carrier for conducting water designated as "water in transit." Under such use water may be stored above and conveyed in the channel to points below for utilization or diversion. Such water may be diverted from the channel at any time or place by or under the authority of the signatory State under whose auspices the water was stored for use at any point within or without the drainage area of the Delaware River.

The rate at which such water in transit is released or delivered shall be regulated so as not unduly to interfere with the rights of the signatory States or with other public rights or private interests along said channel.

The daily rate at which water in transit may be removed or diverted from the channel of the Delaware River shall not exceed the daily rate at which it is released or delivered to said channel, but no greater quantity may be diverted from below than could have been diverted from above under the provisions of Article VI.

Suggested Substitute for Articles V and VI, to be Designated Article VI:

The intention of this compact is that the water which naturally flows into the Delaware River from the drainage area above the New York-New Jersey State line, hereinafter called the "Upper Basin," shall be allotted to the signatory States in the following proportions:

New York	33.3%;
Pennsylvania	33.3%;
New Jersey	33.3%;

and that the water which naturally flows into the Delaware River from the drainage area below the New York-New Jersey State line, hereinafter called the "Lower Basin," shall be alloted to the signatory States in the following proportions:

New York	0%;
Pennsylvania	50%;
New Jersey	50%.

To this end each of the signatory States shall have the right to build dams for any purpose entirely or partly across the channel of the Delaware River at any point or points in or along said channel, and to construct such works as may be necessary to impound the water flowing in said channel.

Each of the signatory States may build dams or other necessary works and impound water for any purpose on any tributary or any part of any tributary of the Delaware River, within the limits of the signatory State in which such tributary is located.

Water so impounded by the construction of dams and other works, either upon or across the channel of the Delaware River or its tributaries, may be diverted for use at any point either within or without the drainage area of the Delaware River, or let down in transit for use or diversion at points on the said channel below, subject to the following conditions and limitations:

(*a*) All such works shall be built in accordance with the legislative provisions governing such matters in the State or States in which they are located.

(*b*) The approval of the Tri-State Delaware River Commission shall be secured for every project which involves the removal or diversion of water from the channel of the Delaware River or its tributaries.

(*c*) Every development for the diversion of water shall be so constructed as to effect the greatest economy in the use of the waters of the Delaware River and its tributaries and shall be so operated as not to interfere with the partition of water as hereinbefore set forth.

(*d*) The total drainage area of the Delaware River lying within any of the signatory States which may be developed for diversion under the provisions of this article shall not exceed sixty per cent. (60%) of the drainage area which lies within that State.

(*e*) A minimum flow equal to forty-five hundredths (0.45) of a cubic foot per second per square mile of drainage area above shall be maintained at all times below the point of diversion on any tributary of the Delaware River within the Upper Basin.

(*f*) In the absence of adequate storage at the point of diversion no water shall be diverted from the channel of the Delaware River within the Upper Basin when the flow of water in it is less than forty-five hundredths (0.45) of a cubic foot per second for each square mile of drainage area above the point of diversion.

(*g*) When the water is diverted from storage reservoirs created by constructing dams across the channel of the Delaware River within the Upper Basin a flow of not less than forty-five hundredths (0.45) of a cubic foot per second per square mile of tributary drainage area shall be maintained at all times when the flow in the channel above is greater than that amount, but when the flow of water in the channel above the dam is less than forty-five hundredths (0.45) of a cubic foot per second per square mile of tributary drainage area, then a flow shall be maintained below the dam at least equal to that in the channel above it.

(*h*) A minimum flow equal to fifteen hundredths (0.15) of a cubic foot per second per square mile of tributary drainage area above shall be maintained at all times below the point of each diversion on any tributary of the Delaware River within the Lower Basin.

(*i*) In the absence of adequate storage at the point of diversion no water shall be diverted from the channel of the Delaware River within the Lower Basin when the flow of water in it is less than thirty-six hundredths (0.36) of a cubic foot per second for each square mile of drainage area above the point of diversion.

(*j*) When water is diverted from storage reservoirs created by constructing dams across the channel of the Delaware River within the Lower Basin a flow of not less than thirty-six hundredths (0.36) of a cubic foot per second per square mile of tributary drainage area shall be maintained at all times when the flow in the channel above is greater than that amount, but when the flow of water in the channel above a dam is less than thirty-six hundredths (0.36) of a cubic foot per second per square mile of tributary drainage area, then a flow shall be maintained below the dam at least equal to that in the channel above it.

(*k*) All diversions from the main channel shall be subject to the restrictions that no water in transit, nor the allotments of other signatory States, shall be interfered with or diverted, but must at all times be permitted to pass the point of diversion.

(*l*) Nothing contained in this compact, however, shall be construed to limit or prevent the diversion of water in transit, the diversion of water under any existing vested right, or the diversion of water stored for diversion as hereinbefore provided, it being definitely understood that water stored for diversion and in transit may be diverted at any time or place from the channel of the Delaware River by or under the authority of the State under whose auspices the development is made, provided the reserve flow provisions stated in (*e*), (*f*), (*g*), (*h*), (*i*) and (*j*) are complied with at all times.

Suggested Modification of Article VIII, Which Becomes Article VII:

In the exercise of its authority, the Tri-State Delaware River Commission shall be governed and its power and authority shall extend to and be limited by the following principles, restrictions and reservations, to wit:

1. In the case of any project which, in the judgment of the Commission, will not interfere or conflict with any other use of the water flow in the channel of the Delaware River, the Commission shall approve said project without imposing any restrictions or conditions except such as may be necessary to insure compliance with the provisions of this compact;

2. As between any one or more proposed or possible conflicting uses, the action of the Commission shall be based upon the relative importance of the uses to which the water may be put, as fixed in Article III of this compact, and to the extent that conflict is irreconcilable, that possible and practicable project which will effect the use of water standing highest in the order of importance shall be approved without restrictions or conditions, except such as the Commission may deem necessary to insure compliance with the provisions of this compact. To the extent that conflict is avoidable by a reasonable modification of any or all of the projects which may be involved, the Commission shall fix the terms of such modification, but such terms shall not require, as against the higher use, pumping in place of gravity delivery of water, nor impose on the higher use any undue burden in either expense or convenience of operation. In case of conflict in uses of the same relative order of importance, preference shall be given to an established use over a proposed one, and the Commission shall have authority to determine the manner in which such conflicting uses may be harmonized, without imposing unreasonable expense or undue burden upon either or any of them.

Article IX Unchanged and Becomes Article VIII:

No water from the drainage area of the Delaware River shall be diverted to any point outside of the boundaries of the States signatory to this compact. No one of the signatory States may give, grant or dispose of to another signatory State, or to any holder of an authorization therefrom, any water developed by or allotted to it under the provisions of this compact, except by legislative act when necessary and then only with the approval of the Commission; but nothing herein contained shall be construed to prevent or prohibit the joint exercise by or under the authority of any two or more of the signatory States of the rights conferred by this compact, and such joint exercise of rights is hereby authorized.

WATER POWER PROVISIONS

Article X of the proposed compact provides that "with the approval of the Commission any signatory State may construct or authorize the construction of a dam, wing dam, headworks, power house or other structure in or across the channel of the Delaware River for the main purpose of the development of water power."

It further provides: "No project authorized and constructed under the provisions of this article shall at any time be operated so as to injuriously affect any project for municipal and domestic water supply which has been or may be established under the provisions of this compact. Subject to such conditions as the Commission may embody in its approval, water for the development of power may be removed from the channel of the Delaware River and carried in a canal or in a pipe to any point below a dam constructed under the provisions of this article, but said water shall be returned to the said channel within a distance of twelve miles below the point of removal measured along the center line of said channel and there shall always be maintained in the said channel immediately below the dam such regular and uniform flow of water as the Commission may determine to be reasonable and proper."

To these provisions no exception can be taken. They accord with the general purposes of the compact.

The article, however, proceeds to limit the signatory State as to the terms and conditions upon which it shall grant its authorization. The prescription of the terms and conditions upon which a signatory State grants its authorization is, it seems to us, primarily a matter of local policy and of internal concern.

The compact makes no similar provision with reference to the grant of like authorization by a signatory State for purposes other than the development of water power.

The provision to which this comment is directed reads as follows:

"Provided, that every such authorization shall be limited to such period not exceeding fifty years as the said state shall determine and set forth in its authorization. Provided further, that the holder of such authorization shall be entitled to extension and renewal thereof upon the same terms until such holder shall have received, through recapture or purchase by the authorizing state or by a duly authorized subsequent holder of like authority from said state, repayment of the capital prudently invested in the power project upon the faith of the authorization plus such reasonable damages, if any, to property of such holder which is valuable, serviceable and dependent for its usefulness upon the continuance of such authorization, but not recaptured or purchased, as may be caused by the severance therefrom of property taken. Provided further, that the authorizing state may, in the discretion of its appropriate agency, officer or employee empowered in that behalf, embody in its authorization such other terms, conditions and stipulations as such agency, officer or employee shall deem necessary to protect the present and future interests of each of the three signatory states and their people in the construction, maintenance and operation of the project and in the water and power resources to be utilized thereby and suitable to secure to the holder of such authorization a reasonable opportunity for a fair return on the capital prudently invested in the project."

This provision should consequently be exscinded.

It is suggested that if authorization was granted for the development of water power under this article as now framed the provisions of Article XVII might reasonably be argued to require payment for diversion rights if a water supply diversion followed such power development.

Such a result would contravene the spirit of the proposed compact which in Article III declares that the river has its most important use and greatest public value for purposes of domestic and municipal water supply.

It is therefore recommended that, if for any reason the provision is retained, it be reframed definitely to remove any possibility of basis for such a claim.

THE POWER OF EMINENT DOMAIN

That, independent of compact, the right of eminent domain of each of the signatory States is confined to, and can only be exercised within, the jurisdictional limits of such State, and that property within the limits of each State is held free from the power of eminent domain of another State, is settled.

That the intent and purpose of the proposed compact cannot be effectuated without conferring to some extent upon each of the signatory States the right of eminent domain within the territorial limits of the others is apparent.

Article XIV of the proposed compact, therefore, provides that "all lands, water rights or easements necessary for the construction and maintenance of any dam in or across the channel of the Delaware river may with the approval of the Commission be appropriated and condemned by any signatory state or by the holder of authorization therefrom."

This power is conferred not alone upon the signatory States but upon the grantee of an authorization therefrom as well.

Section IV of the proposed compact provides that "Any administrative department, political subdivision, corporation, partnership, association or person authorized in that behalf by or under the laws of any signatory state may exercise the rights and privileges herein conferred on such state, subject to the duties and obligations imposed on such state."

Since the intent and purpose of the proposed compact cannot be executed except as such power of eminent domain is to some extent vested in each of the signatory States, and since the signatory States must be left free either to exercise the rights and privileges conferred by the compact directly, or indirectly through delegation to others, these provisions are essential.

Article XIV, however, limits the power of eminent domain to the acquirement of lands, water rights or easements "*necessary for the construction and maintenance of any dam in or across the channel of the Delaware river.*"

Article VIII of the proposed compact provides that "In order to render possible the *utilization or diversion* of water flowing in the channel of the Delaware river, each signatory state shall have the right to build dams entirely or partly across said channel and to construct wing dams, headworks, intakes *or other necessary facilities at any point or points in or along said channel.*"

Article VI of the proposed compact provides that "dams may be constructed across the channel of the Delaware river by or under the authority of any one of the signatory states for the purpose of storing water developed for diversion, water in transit belonging to said state, or any part or all of the water alloted to it under the provisions of this article."

Article X of the proposed compact provides that "With the approval of the Commission any signatory state may construct or

MAP NO. 4
STATE OF NEW JERSEY
WATER POLICY COMMISSION
NORTHERN METROPOLITAN DISTRICT
PRINCIPAL EXISTING WATER SUPPLY DEVELOPMENTS

NICHOLAS S. HILL, JR.
CONSULTING ENGINEER
NEW YORK CITY

JANUARY 1926

authorize the construction of a dam, wing dam, headworks, power house or other structure in or across the channel of the Delaware river for the main purpose of the development of power."

The grant of power of eminent domain to each of the signatory States and the grantees of their authorizations is therefore apparently limited to the acquirement of lands, interests and rights, *"necessary for the construction and maintenance of any dam in or across the channel of the Delaware river."* The grant of the power to construct extends, however, to other works and generally to the construction at any point or points in or along the channel of the Delaware River of *"other facilities" necessary "to render possible the utilization or diversion of water flowing" in such channel.*

If it is the intent to make the grant of the power of eminent domain co-extensive with other rights and privileges granted, then the provisions of Article XIV of the proposed compact should accordingly be broadened.

If this course is adopted, then the provision granting generally power to construct any facilities necessary to render possible the utilization or diversion of water flowing in the channel of the river should be limited and restricted.

These terms "utilization" and "necessary facilities" are exceedingly broad, and all that may be implicit in them cannot be forecast with any degree of certainty.

In this discussion we have assumed that it was not the intent or purpose of the proposed compact to grant to any signatory State or any holder of the authorization of such State the right to construct, maintain and operate works such as conduits and transmission lines across the territory of another signatory State, nor to grant the power of eminent domain to that end; and that the conferring of such powers and rights was intended to depend upon the legislative action of such latter State alone, uncontrolled by the proposed compact.

Any other assumption would require the conclusion that it was the intent to take out of local control a subject involving local interests and considerations of local policy.

TAXATION

It is apparent that under the terms of the proposed compact, land and property in other form may and will be acquired and held by a signatory State, or grantees of its authorization, within the limits of another signatory State.

This situation raises the question whether such property so held will, or should, be subject to the power of taxation of the State within whose limits it is located.

No provision of the proposed compact deals with this question. The long continued controversy with reference to the power of taxation between the municipalities constructing works outside their limits and municipalities within whose borders such works are located, and the pending controversy as to the power to tax property held under the compact between the States of New York and New Jersey, constituting the Port of New York Authority, make clear the wisdom of incorporating in the proposed compact a definite provision with respect to the power of taxation.

VESTED RIGHTS

Provision must, of course, be made, as it is in the proposed compact, that the amount of water diverted under a vested right shall be charged against the State under whose authority or jurisdiction said right became vested.

This matter is dealt with in the proposed compact in Article XVII. That article, however, in addition to making such provision, declares that "nothing contained in this compact shall operate to impair any vested right of diversion or use of the waters of the Delaware river which may exist or have become vested at any time prior to the ratification hereof."

It then provides that "in each of the signatory states rights to divert or use the waters of the Delaware river or its tributaries together with property necessary to effect the same, though devoted to public use may be taken for any other public use higher in order of importance as set forth in Article III."

And it concludes: "Provided that nothing in this article shall be construed to authorize the taking of vested rights of property without just compensation to be determined by due process of law governing such matters in the respective states."

The provision that rights to divert or use the waters together with necessary property, though devoted to public use, may be taken for any other public use higher in the order of importance as set forth in Article III is essential.

The provisions, however, that nothing contained in the compact shall operate to impair any vested right of diversion or use existing or becoming vested at any time prior to the ratification of the compact, and the proviso that nothing in the article shall be construed to authorize the taking of vested rights or property without just compensation to be determined by due process of law governing such matters in the respective States, serve no useful purpose.

It has hereinbefore been indicated how, taking the provisions of Article X of the proposed compact in connection with these provisions, a basis might be provided for possible claims for damages, the award of which would be inequitable and contrary to the purpose of the proposed compact.

These provisions should be exscinded.

Article XV of the proposed compact provides that "All damages to persons or property resulting from the exercise of any right under this compact shall be determined under the rule of damages, in accordance with the procedure, and in such manner as is provided by the law of the state in which the damages are suffered."

This article also provides the manner in which the damages suffered shall be ascertained, recovered and paid.

This article is comprehensive.

If the provisions of Article XVII, which it is recommended should be exscinded, are consistent with the provisions of Article XV, they are redundant. If such provisions of Article XVII are inconsistent with the provisions of Article XV and admit of setting up bases for claims for damages and applying measures and standards of recovery other than those provided for by Article XV, they are unjustified.

At best the provisions the exscision of which is recommended do not contribute to clarity of the proposed compact as a whole.

In this connection question arises:

1. As to what vested property rights to "divert or use" the waters of the Delaware River exist through grants by the State of New Jersey other than those which have been granted to municipalities of the State, and to the Morris Canal and Banking Company, which company has passed into the control of the State.

2. As to the extent such existing vested property rights to "divert or use" affect the quantity of water which will be actually available to the State under the proposed compact.

Lack of available data makes it impossible to answer either of these questions.

No compilation of or index to grants of such rights by the State has, so far as has been ascertained, ever been made under public auspices.

The records of the Department of Conservation and Development are adequate and complete and that department has cordially cooperated in the effort to find a basis for answer to these questions. These records, however, cover only a comparatively brief period of time.

Answer to these questions would therefore require a search of the statutes of the State from the beginning of its history and a study, both from legal and engineering standpoints, of the statutes found through such search to make grants of such rights.

Such a search is under way in connection with the General Report to be submitted later, but such a study we have not felt warranted in undertaking because of the expenditure of time and money which would be involved.

In so far as such grants of rights now exist they fall within the protection of the Fourteenth Amendment of the Constitution of the United States.

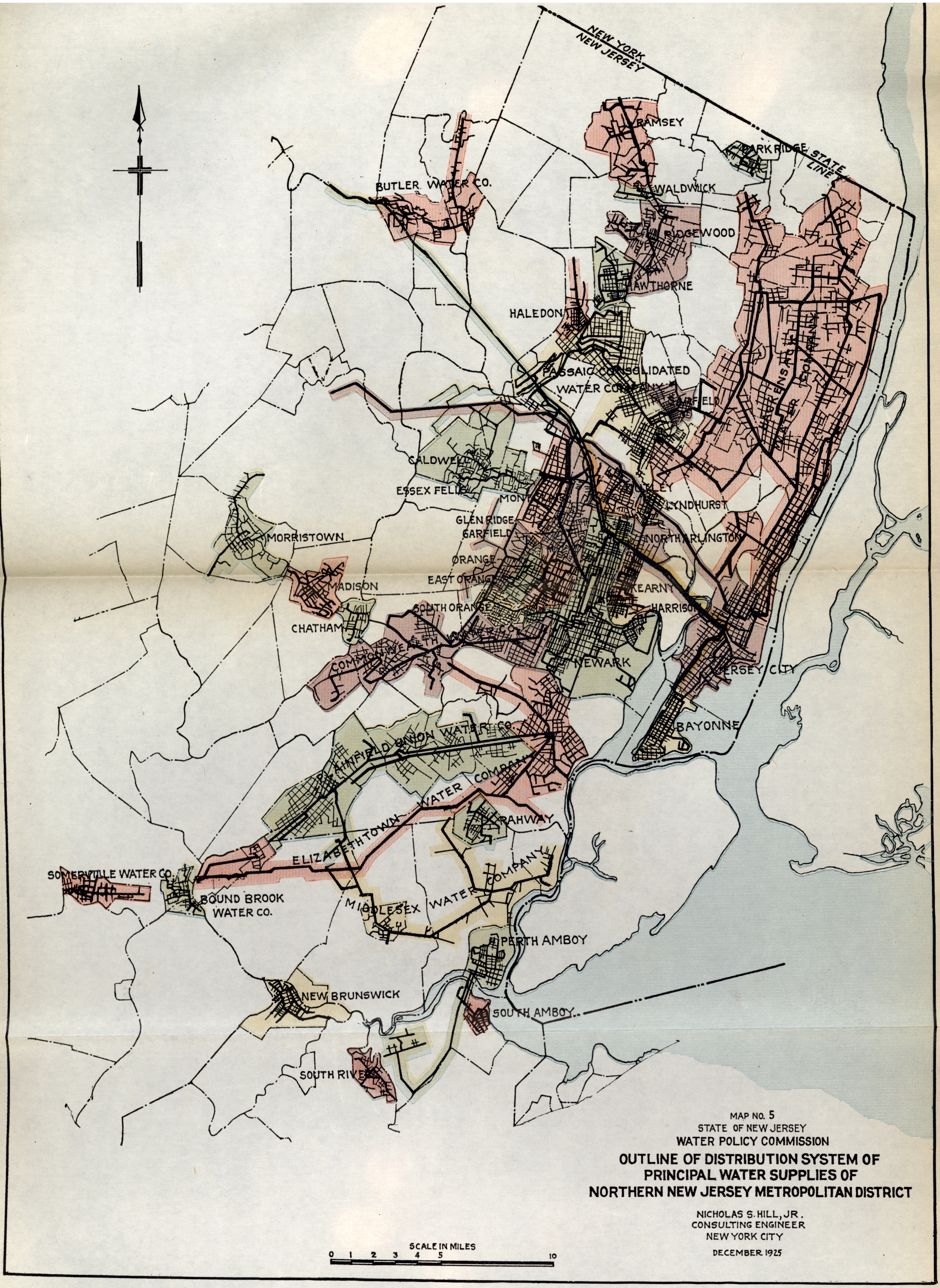
More cannot, therefore, be done in framing the proposed compact than to guard against providing any possible basis for claim that thereby such rights have been in anywise perfected, perpetuated or extended, and any possible basis for claims for compensation or damages not grounded solely upon the statutes making the grant of such rights and any possible basis for claim to the application of any measure or standard of compensation or damages that would not, except for the provisions of the compact, be required to be applied.

In the recommendations made herein for the recasting and revision of the proposed compact are included recommendations which if adopted will meet these requirements.

OTHER INTERSTATE STREAMS

The problem of fully developing the Hackensack, Ramapo, Pochuck and Wallkill Rivers to meet the water supply requirements of the State of New Jersey is complicated by the fact that these are also inter-state streams, in the waters of which the States of New York and New Jersey have interests.

These interstate streams are of comparatively little value to the State of New York, but of substantial value to the State of New Jersey for water supply purposes.



MAP NO. 5
STATE OF NEW JERSEY
WATER POLICY COMMISSION

OUTLINE OF DISTRIBUTION SYSTEM OF PRINCIPAL WATER SUPPLIES OF NORTHERN NEW JERSEY METROPOLITAN DISTRICT

NICHOLAS S. HILL, JR.
CONSULTING ENGINEER
NEW YORK CITY

DECEMBER 1925

The facts hereinbefore set out as to the water resources of the State of New Jersey and its present and future requirements make evident the advantage of clearing the way for the full utilization of the waters of these streams and of removing the obstacles to such use which arise out of the fact that these streams are interstate.

These considerations are the basis for the recommendation that a commission be constituted independently to negotiate a compact on behalf of the State of New Jersey with the State of New York, delimiting the rights of the States respectively in the waters of these streams and enabling the fullest possible development and use thereof to be effected, or, in the alternative, that added power to negotiate such a compact be conferred upon the commission recommended to be constituted to renew and continue the Delaware River negotiations.

GENERAL

The facts set forth herein are the result of a study made under the direct supervision of Mr. Nicholas S. Hill, Jr., Consulting Engineer, and the concrete suggestions for recasting and revising the proposed compact are based upon an analysis of the proposed compact made by him from the engineering standpoint.

In the consideration of the problems to which this report is directed the Commissioners who negotiated the proposed compact on behalf of the State afforded unreserved cooperation and placed data in their possession freely at our disposal. This attitude of helpful cooperation was also that of those who served such Commission in its negotiations.

The problems herein dealt with were approached with a keen appreciation of the responsibility which would be assumed in recommending action which would defer an amicable adjustment of the rights and interests of the signatory States.

They were approached with full recognition of the fact that the Commissioners representing the State of New Jersey had striven zealously in its interest, and that compacts are necessarily the result of compromise.

They were approached with a sincere desire to recommend approval and confirmation of the proposed compact unless substantially serious objections to such a course should appear.

The objections herein indicated are regarded as seriously substantial, and the doubts raised as fraught with the seeds of future misunderstanding and litigation. The recommendations herein for clarification and coordination consequently result.

This report is made before the General Report is submitted, because the proposed compact is now before a Special Session of the Legislature of the Commonwealth of Pennsylvania and has been ratified and confirmed with modifications by the State of New York.

We record with sorrow and a deep sense of loss the fact that one of the members of the Commission, Mr. Palmer Campbell, died early in December after an illness of several months.

This report has been confined to presenting the major objections which have been considered in the conferences of the Commission.

It has not been deemed necessary to present others of less relative importance.

Appendices are annexed which will be of interest in connection with the report and useful to the Commission hereby recommended to be constituted.

Respectfully submitted,

WILLARD I. HAMILTON, Newark
HENRY G. PARKER, New Brunswick
HARRY BACHARACH, Atlantic City
S. WOOD McCLAVE, Cliffside
CARROLL P. BASSETT, Summit
F. MORSE ARCHER, Camden

January 30, 1926.

APPENDIX A

AGREEMENT OF 1783

Chap. XX.

An ACT to ratify and confirm an Agreement made between Commissioners appointed by the Legislature of the State of Pennsylvania, and Commissioners appointed by the Legislature of the State of New-Jersey, for the Purpose of settling the Jurisdiction of the River Delaware, and Islands within the same.

WHEREAS Commissioners duly appointed on the Part of the State of Pennsylvania, and Commissioners duly appointed on the Part of the State of New-Jersey, for the Purpose of settling the Jurisdiction of the River Delaware and Islands within the same, have executed two Instruments of an Agreement for the Purposes aforesaid, one for each State, which Agreement is contained in the following Words:

AN Agreement made and concluded between George Bryan, George Gray and William Bingham, Commissioners appointed by the Legislature of the State of Pennsylvania, for settling the Jurisdiction of the River Delaware, and Islands within the same; and Abraham Clark, Joseph Cooper and Thomas Henderson, Commissioners appointed by the Legislature of the State of New-Jersey, for the like Purpose.

WHEREAS Inconveniences and Mischiefs have arisen, and may hereafter arise from the Uncertainty of Jurisdiction within and on the River Delaware; therefore to prevent the same, and in order that Law and Justice may hereafter in all Cases be executed and take Effect within and upon the said River from Shore to Shore in all Parts and Places thereof, where the same River is the Boundary between said States, the said Commissioners do agree and establish for and in Behalf of their respective States in Manner following; that is to say,

First. It is declared that the River Delaware from the Station-Point or northwest Corner of New-Jersey, northerly, to the Place upon the said River, where the circular Boundary of the State of Delaware toucheth upon the same in the whole Length and Breadth thereof is and shall continue to be and remain a common Highway, equally free and open for the Use, Benefit and Advantage of the said contracting Parties. Provided nevertheless that each of the Legislatures of said States shall hold and exercise the Right of regulating and guarding the Fisheries on the said River Delaware, annexed to their respective Shores in such Manner that the said Fisheries may not be unnecessarily interrupted during the Season for catching Shad, by

Vessels riding at Anchor on the Fishing-Ground, or by Persons fishing under Claim of a common Right on said River.

Secondly. That each State shall enjoy and exercise a concurrent Jurisdiction within and upon the Water, and not upon the dry Land between the Shores of said River, but in such Sort, nevertheless, that every Ship and other Vessel while riding at Anchor before any City or Town in either State where she hath last laded or unladed, or where it is intended she shall first thereafter either lade or unlade, shall be considered exclusively within the Jurisdiction of such State; and every Vessel fastened to or aground on the Shore of either State, shall in like Manner be considered exclusively within the Jurisdiction of such State; but, that all capital and other Offences, Trespasses or Damages, committed on said River, the juridical Investigation and Determination thereof shall be exclusively vested in the State wherein the Offender or Person charged with such Offence shall be first apprehended, arrested or prosecuted.

Thirdly. That all Islands, Eylots and dry Land within the Bed, and between the Shores of the said River, and between the said Station-Point, northerly, and the Falls of Trenton, southerly, shall, as to Jurisdiction, be hereafter deemed and considered as Parts and Parcels of the State to which such insulated dry Land doth lie nearest at the Time of making and executing this Agreement, and that from said Falls of Trenton to the State of Delaware, southerly, Biles's-Island near Trenton, Windmill-Island opposite to Philadelphia, League-Island, Mud or Fort-Island, Hog-Island and Little Tinnicum-Islands, shall be annexed to the State of Pennsylvania, and considered as Parts and Parcels thereof; and that Biddle's or Newbold's-Island, Burlington - Island, Petty's - Islands, Redbank - Island, Harmanus Helm's-Island, Chester-Island and Shiverse's-Island shall be annexed to the State of New-Jersey, and considered as Parts and Parcels thereof; and that all other Islands within said River, between the Falls of Trenton and the State of Delaware, which are not herein before particularly enumerated, shall be hereafter deemed and considered as Parts and Parcels of the State to which such Island doth lie nearest at the Date hereof; and that all Islands which may hereafter be formed within the said River, shall be classed and annexed to the Jurisdiction of either State according to the same Principle.

Fourthly. That this present Agreement, and every Article and Clause therein contained, shall be suspended and take no effect until each of the Legislatures of the State of Pennsylvania and New-Jersey respectively shall have passed Laws approving of and ratifying the same, which being done the said Agreement shall then be considered as a Joint-Compact between the said States, and the Citizens thereof respectively, and be forever thereafter irrevocable by either of the said contracting States without the Concurrence of the other. In

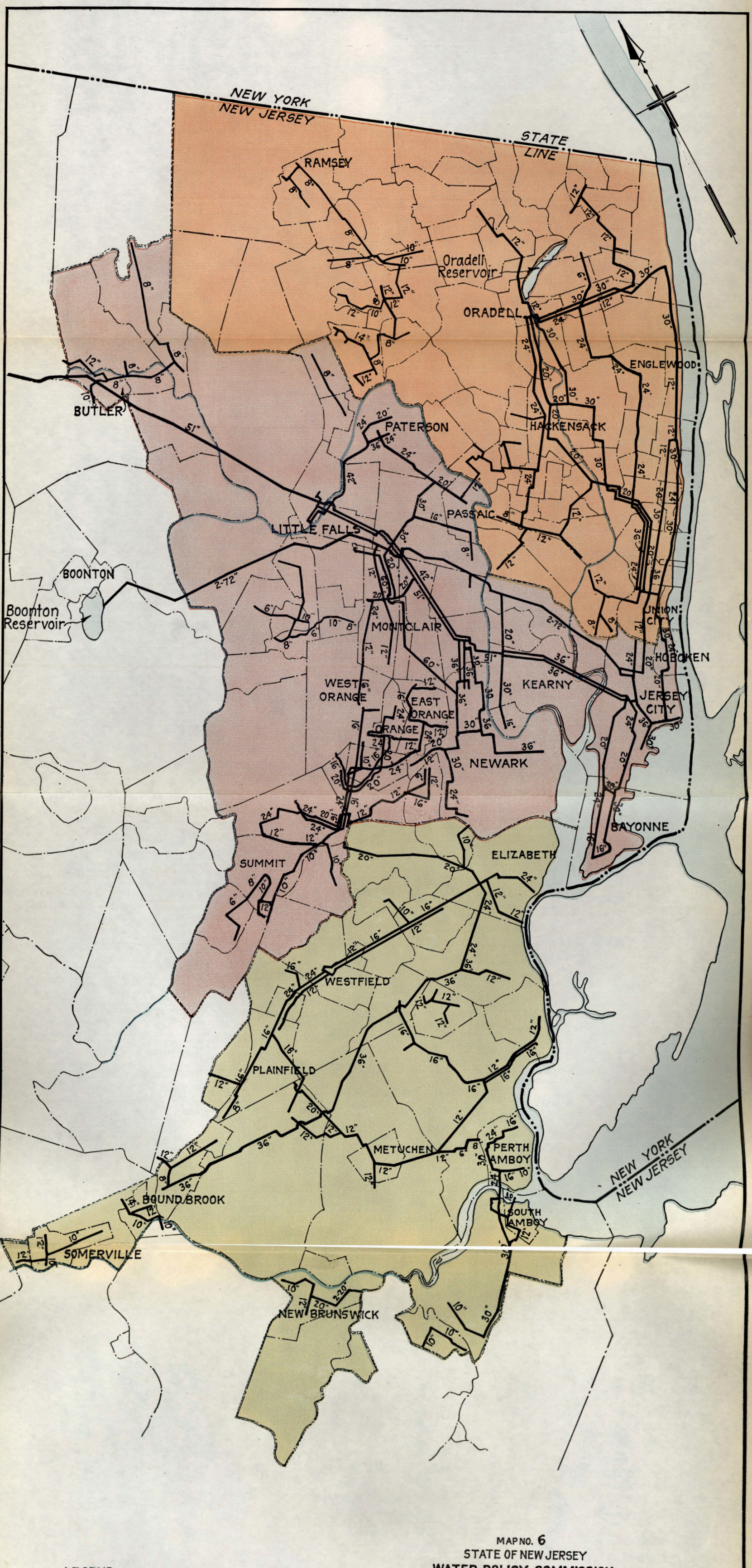
Witness whereof we, the Commissioners of the aforesaid States, have set our Hands and Seals to two Instruments of the Agreement, one for each State, dated this twenty-sixth Day of April, Anno Domini One Thousand Seven Hundred and Eighty-three.

Abraham Clark.	(L. S.)	George Bryan.	(L. S.)
Joseph Cooper.	(L. S.)	George Gray.	(L. S.)
Thomas Henderson.	(L. S.)	Wm. Bingham.	(L. S.)

Therefore,

BE IT ENACTED by the Council and General Assembly of this State, and it is hereby Enacted by the Authority of the same, That the aforesaid Agreement, and every Article, Clause, Matter and Thing therein contained, shall be and the same is hereby fully and amply ratified and confirmed, and shall be and ever hereafter remain in Force agreeably to the true Tenor and extent thereof.

Passed at Burlington, May 27, 1783.



LEGEND

Northern Section

Central Section

Southern Section

SCALE IN MILES

0 1 2 3 4 5 10

MAP NO. 6

STATE OF NEW JERSEY

WATER POLICY COMMISSION

WATER SERVICE AREAS AND TRANSMISSION MAINS
NORTHERN NEW JERSEY METROPOLITAN DISTRICT

NICHOLAS S. HILL, JR.
CONSULTING ENGINEER
NEW YORK CITY

DECEMBER 1925

APPENDIX B

AGREEMENT OF 1786

CHAP. CXXX.

An ACT to ratify and confirm an Agreement made between the Commissioners appointed by the Legislature of the State of Pennsylvania, and the Commissioners appointed by the Legislature of the State of New-Jersey, for the Purpose of agreeing upon, and accurately describing which of the Islands, Eylots and insulated dry Land, mentioned in the Agreement between the two States, bearing Date on the twenty-sixth Day of April, Seventeen Hundred and Eighty-three, belong to each of the said States according to the Purport of that Agreement.

WHEREAS Commissioners duly appointed on the Part of the State of Pennsylvania, and a Commissioner duly appointed on the Part of the State of New-Jersey, for the Purpose of dividing the Islands in the River Delaware, between the Falls of Trenton and the Station Point or Northwest Corner of the State of New-Jersey, have executed two Articles of Agreement, one for each State, which is contained in the following Words:

"An Agreement made and concluded upon between George Wall, John Okeley and Jonas Hartzell, Commissioners appointed by the Supreme Executive Council of the State of Pennsylvania, for dividing the Islands and insulated dry Land in the River Delaware with the State of New-Jersey, from the Falls at Trenton to the Station Point or Northwest Corner of the said State, and Moore Furman, Commissioner appointed by the said State of New-Jersey for the like Purpose.

"FIRST, The Parties aforesaid, in Pursuance of the Authority to them severally given, and in Behalf of the respective States aforesaid, do agree, that, from the said Falls of Trenton to the Station Point or Northwest Corner of the State of New-Jersey aforesaid. * * *"

(It is provided that certain islands designated in the agreement shall be annexed to the State of Pennsylvania, and certain other islands shall be annexed to the State of New Jersey.)

"SECONDLY, That all other Islands which may hereafter be formed within said River, between the Falls of Trenton and the Station Point or Northwest Corner of the State of New-Jersey aforesaid, shall hereafter be deemed and considered as Parts and Parcels of the State to which such Islands may be nearest. In Witness whereof, we the Commissioners of the States aforesaid have set our Hands and Seals to two Instruments of Writing, one for each State, dated this second Day of December, Anno Domini One Thousand Seven Hundred and Eighty-five. George Wall, L. S.; John Okeley, L. S.; Jonas Hartzell, L. S.; Moore Furman, L. S.

"Therefore,

"BE IT ENACTED by the Council and General Assembly of this State, and it is hereby Enacted by the Authority of the same, That the aforesaid Agreement, and every Article, Clause, Matter and Thing therein contained, shall be, and the same is hereby fully and amply ratified and confirmed, and shall be and ever hereafter remain in Force agreeably to the true Tenor and Extent thereof.

Passed at Trenton, March 16, 1786.

APPENDIX C

Pennsylvania and New Jersey

Agreements of 1783 and 1786 referred to in Article XIX of Proposed Compact

(Excerpt from Article in 34 Yale Law Review, 685-733)

"An agreement dealing with the respective claims of the two States to jurisdiction over certain islands in the Delaware River, was concluded between commissioners on April 31, 1783. This was ratified by Pennsylvania on September 20, 1783 (41) and by New Jersey on May 27, 1783 (42). Commissioners appointed under the terms of this agreement (43) contemplated a further agreement between the States looking forward to the improvement of navigation on the Delaware River and its branches (44). Such an agreement was reached on December 2, 1785, and ratified by New Jersey on March 16, 1786 (44a). Pennsylvania, by the act of September 25, 1786, made effective those terms of the compact that applied to her (44b). Further legislation under the terms of the agreement of 1783 was undertaken by Pennsylvania in 1786 (45) and by New Jersey in 1856 (46).

"(b) This agreement was considered in Comm. *v.* Frazee (1856, Pa.) 2 Phila. 191; State *v.* Davis (1856, N. J.) 1 Dutch 386; Att'y-Gen'l *v.* Dela. & Bound Brook R. R. Co. (1876) 27 N. J. Eq. 1."

(41) 11 Pa. Stat. at L. 1782, ch. 1035, p. 151.

(42) N. J. Rev. Sts. 1847, tit. III, ch. 5, p. 41, Nixon, Dig. N. J. Laws 1709-1855 . 1855) 824.

(43) Pa. Archives, 129.

(44) The Pennsylvania Commission was authorized to cooperate with the New Jersey Commission. See 9 Pa. Archives, 710. This authorization was communicated by Pennsylvania to the Governor of New Jersey. See 9 *ibid.* 458. See also Letter of Pres. Dickinson to the Governor of New Jersey, on December 14, 1783, 9 *ibid.*, 366.

(44a.) N. J. Rev. Sts. 1847, tit. III, ch. 6, p. 43.

(44b.) 12 Pa. Stat. at L. 1786, ch. 1245, p. 304.

(45) 12 Pa. Stat. at L. 1786, ch. 1245, p. 304.

(46) N. J. Laws, 1856, ch. 123, p. 242.

APPENDIX D

NOTES REFERRING TO MATTERS ARISING OUT OF THE AGREEMENTS OF 1783 AND 1786

The agreements of 1783 and 1786 between New Jersey and Pennsylvania were very simple documents, yet in each State difficulties subsequently arose which resulted in lengthy controversies, and for many years the Governors, Legislatures, various Commissions and Committees were engaged in attempts to interpret the compact, adjust differences and avoid continued litigation. A number of instances have been cited to illustrate the complications which developed and to emphasize by past experience the necessity of defining in the clearest possible terms the exact meaning of every provision in the vastly more important compact now before the Legislature for consideration.

1816. Relative to Pennsylvania resolution protesting against passage and operation of act of New Jersey Legislature to enable D. W. Coxe and others to erect wing-dam in Delaware River to connect Yard's Island with main land at Bloomsbury. (February 4, 1815) and supplement (February 10, 1816). Governor's message. (Dickerson) October 26, 1816.

1816. Report of Committee (Rutherford) to which was submitted correspondence between Governors of Pennsylvania and New Jersey, concerning erection of wing-dam in Delaware River (votes of Assembly 1815-1816, pages 160-161).

Note.—Committee's report, dated January 29, 1916, is that it is the opinion of the committee that the acts referred to above are not an infringement of any convention or law subsisting between the States, because (1) of the convention of April 26, 1783, which made the river within certain defined boundaries a common highway, and permitted the erection of wing-dams in certain circumstances (see text of convention), and (2) of an act of November 26, 1808, re: Fisheries in the River.

1817. Report of Committee (Williamson) to which was referred resolution of Pennsylvania Legislature protesting against the passage and operation of laws above referred to.

Note.—Committee report, dated January 6, 1817, recommends appointment of Commissioners "to settle and determine with more precision and certainty, than has heretofore been done, in any agreement between the two States, the right of the legislature of the said States respectively, or to citizens thereof to use the shores and waters of the River Delaware for the erection of mills, dams, banks and other works of public utility and benefit and which shall not materially injure or impede the navigation of the said river."

1817. Report of Commissioners appointed by act of the New Jersey Legislature for settling differences between the States. Printed by James J. Wilson, 1817—34 pages.

Note.—Report dated October 27, 1817, of Commissioners appointed by act of the Legislature January 31, 1817, to settle differences between New Jersey and Pennsylvania, concerning wing-dams in the Delaware River.

Copy of report found at New Jersey Historical Society.

After some correspondence, which is attached to the report, the Commissioners took a trip up the Delaware to Belvidere and down the Delaware to Trenton, during which they found several wing-dams on each shore, the greater number of which were more or less injurious to navigation.

Agreements (copies of which are also attached to the report) were submitted by either side and a final conference held.

The first question taken up was that of the general regulation of wing-dams. After the Commissioners had agreed with reference to a construction to be placed on the treaty of 1783, the question of enforcing regulations was discussed. Pennsylvania insisted that all wing-dams should be subject to condemnation as nuisances, unless the report of Commissioners concluded that the dams were according to the agreement. To the New Jersey Commissioners, such position meant that every wing-dam was subject to condemnation merely because the Commissioners had not reported on it.

No agreement was reached.

They then discussed the Coxe dam, and Pennsylvania insisted that either State should have the right to destroy the dam, without permitting the question as to whether or not it complied with regulations, or was according to the agreement, to be tried in a court of law. New Jersey refused and the conference then broke up.

The report states that Pennsylvania never took any notice of the third subject which ought to have been discussed, namely, to define with precision and certainty the right of both States to authorize dams, etc.

The report also says that there were a greater number of wing-dams on the Pennsylvania shore, which were equally as injurious to navigation as those on the New Jersey shore, but because of the usefulness of the dams, the New Jersey Commissioners believed the dams might be changed to produce little obstruction to navigation. They also recommended legislation to prevent the erection of any new dams in the river without the consent of Pennsylvania.

Among the letters attached are: (1) Pennsylvania Commissioners to New Jersey Commissioners, the fifth paragraph of which called for an admission by New Jersey that all laws passed by either State without the concurrence of the other to authorize wing-dams in any degree injurious to navigation were and would be an infraction of the agremeent of April 26, 1783; (2) New Jersey's reply, stating in substance that whether or not a dam was lawful or unlawful depended upon a question of fact, namely, whether it was obstructing navigation.

1822. Report of Committee (Newbold) as to whether the law authorizing the erection of certain dam across the Delaware at Bloomsbury has been complied with.

Note.—Committee report, dated November 21, 1822, found that the wing-dam referred to was affecting navigation and that the acts referred to above were being violated; recommended further extension of time for the building of locks and sluices.

1830. Report of Committee (Nevius) to which was referred documents relating to arrangements with Pennsylvania for mutual use of the waters of the Delaware.

Note.—Report of Committee, dated February 5, 1830, states that the committee had examined an agreement between the Commissioners, and recommended passage of an act relative to such agreement between the two States for the mutual use of the waters of the Delaware and also of an act to provide for the improvement of the river below Trenton.

Copy of the agreement referred to has not yet been located.

1830. Formation of compact by Commissioners from Pennsylvania and New Jersey, for use of waters above tide. Governor's message (Vroom) January 7, 1830.

1832. Resolution of Pennsylvania Legislature for appointment of Commissioners from New Jersey and Pennsylvania to confer in regard to wing-dam at Wells' Falls and right of two States to use of the waters of the River Delaware; submitted to the Legislature. Governor's message (Vroom) October 24, 1832.

1832. Report of Committee (Ludlow) to which was referred that part of the Governor's message relating to obstructions in the Delaware River.

Note.—Report of committee, dated October 30, 1832, provides for resolution for the appointment of Commissioners to view dam at Wells' Falls.

1833. Need of action respecting appointment of Commissioners to confer with Pennsylvania Commissioners in regard to Delaware River submitted to the Legislature. Governor's message (Southard) January 11, 1833.

1833. Garret D. Wall, Peter I. Striker and John M. Sherrard appointed Commissioners on behalf of New Jersey. Governor's message (Seeley) October 23, 1833.

1834. Governor's message (Vroom) October, 1834, relative to agreement to be concluded with Pennsylvania as to use of the waters Delaware.

1835. Governor's message (Vroom) transmitting report of Commissioners on obstructions in Delaware River.

Note.—Report of Commissioners appointed by joint resolution of January 17, 1833.

This document indicates that the New Jersey Commissioners ascertained that Pennsylvania was diverting the Lehigh River into the Pennsylvania Canal. Report recites the violation by Pennsylvania and then justifies it on the ground of public improvement. Having justified the Pennsylvania position, the Commissioners justified the New Jersey diversion of the Delaware into the Delaware and Raritan Canal on the theory that New Jersey had only followed suit. The report found that the dam at Wells' Falls was improper, but the removal thereof practically meant the destruction of the Pennsylvania Canal. Report was dated February 2, 1835.

The agreement entered into between the Commissioners was also annexed to the report and provided (1) that New Jersey might take such water as necessary to supply the Delaware and Raritan Canal; (2) that Pennsylvania, by the use of dams or feeders at Wells' Falls, might take sufficient water necessary to supply the Pennsylvania Canal with restrictions on the building of the dam; and (3) that New Jersey would cause obstructions at Scudder's Falls (violation having been found on November 22, 1834) to be removed by the Trenton and Delaware Falls Co.

Letters from the engineer of the committee were also attached.

APPENDIX E

PRELIMINARY LIST OF STATUTES OF NEW JERSEY WHICH MAY POSSIBLY BEAR UPON PROBLEM. (INCOMPLETE.)

1804. Ch. 123, p. 134. Incorporates Trenton Water Works. (1852, ch. 132, p. 289, Supplement. Authorizes corporation to take the water it may require either in whole or in part from Delaware River).

(1859, ch. 17, p. 38. Authorizes corporation to convey to City of Trenton.)

1804. Ch. 153, p. 433. Incorporates New Jersey Navigation Company, authorizes opening water communication from Raritan River at or near New Brunswick to Delaware River at Lamberton.

1809. Ch. 66, p. 228. Authorizes Samuel Wright, Jr., and George Dill to bring water of Delaware River into Assanpink Creek and to erect a wing-dam in river.

1811. P. 27. Authorizes James Ramsey and Thomas Barton, heirs and assigns, to erect, etc., wing-dam in Delaware River, extending from Ramsay and Barton's Island.

1811. P. 28. Authorizes Nicholas Albertson, heirs and assigns, to erect, etc., wing-dam in Delaware River, extending from Albertson's Island.

1814. P. 156. Authorizes William L. Prall and Jacob Lambert, heirs and assigns, to erect, etc., wing-dam in Delaware River at head of Howell's Falls below mouth of Wichetoak Creek.

1814. P. 220. Authorizes John Shurlock, heirs and assigns, to erect, etc., wing-dam in Delaware River at head of Foul Riff Falls.

1815. P. 149. Authorizes Daniel W. Coxe, Samuel Wright, Jr., and Peter S. Smith, heirs and assigns, to erect, etc., wing-dam in Delaware River below mouth so as to connect mainland of Bloomsbury with Yard's Island.

1816. P. 161. Supplement to above incorporates The Bloomsbury Wing Dam and Mill Company and vests in company all rights, privileges, etc., granted to Coxe, Wright and Smith.

1817. P. 42. Appoints Commissioners for settling differences with Pennsylvania over legislative authorization to erect dams, etc., in Delaware River. Refers to Coxe, Wright and Smith grants, above. (1835, p. 24. Act to repeal certain chartered rights, etc. Whereas Philemon Dickerson of Paterson has purchased of Daniel W. Coxe wing-dam connecting

Yard's Island with mainland and mills at Bloomsbury; and by recent construction of raceway and water power of Trenton Delaware Falls Company, "The Bloomsbury Wingdam and Mill Company" will be able to supply mill with water from raceway without aid of wingdam. So much of acts re Daniel W. Coxe et als. (1815 and 1816, above) as requires The Bloomsbury Wingdam and Mill Company to keep up a wingdam is repealed; company name changed to Bloomsbury Mill Company and authorized to contract with Trenton Delaware Falls Company, and take, etc., from said raceway such water power as may be necessary to carry on operations.)

1819. P. 74. Authorizes John Stevens, et als., to remove obstructions from Delaware River at or near Perriwig Island—to erect such wing-dams as necessary; in consideration whereof exclusive right to operate steamboats over certain part of river given for 15 years, etc.

1823. P. 166. Incorporates Orange and Sussex Canal Company. Authorizes canal from Delaware River to Hudson River.

1824. P. 175. Incorporates Delaware and Raritan Canal Company. Authorizes construction of canal from Delaware River to Raritan River; authorizes supplying canal with water from Delaware River, etc. (1826, p. 87. Re Delaware and Raritan Canal Company. Authorizes Governor to receive surrender of charter upon payment of $90,000.) (1830, p. 73. Incorporates Delaware and Raritan Canal Company. Perpetual. Authorized to supply canal with water from Delaware River by constructing feeder from any part of river.)

(1831, p. 64. Supplement to above.)

(1831, p. 124. Authorizes Delaware and Raritan Canal Company to consolidate with Camden and Amboy Railroad and Transportation Company.)

(1868, ch. 445, p. 1036. Re Delaware and Raritan Canal Company.) Lawful to straighten feeder as more water required; make wing-dam at head of Bull's Island; also to protect and complete wing-dams heretofore erected at Wells' Falls. See Joint Resolutions December 2, 1831, and January 17, 1833, re wing-dam at Wells' Falls.)

(1869, ch. 386, p. 1026. Act to enable United Companies to improve lands under water—includes Delaware and Raritan Canal Co.)

1824. P. 158. Incorporates Morris Canal and Banking Company to construct artificial waterway between Passaic and Delaware Rivers.

(See also 1828, p. 34; 1836, p. 262; 1849, p. 33; 1865, p. 264; 1867, p. 251; 1871, p. 444; 1873, p. 1347; 1906, p. 739.)

1829. P. 91. Act for effecting arrangement between New Jersey and Pennsylvania for mutual use of waters of Delaware for canals, etc. Appoints Commissioners.

1831. P. 131. Incorporates Trenton Delaware Falls Company to create water power at Trenton and vicinity. Perpetual. Right to acquire water privileges, etc. Lawful to erect wing-dam in Delaware River between mouth of Assanpink and head of Wells' Falls, and raceway; to cut raceway from dam to any point below Trenton Falls, etc., and such other raceway, etc., as company shall deem expedient for the purpose of creating water power for manufacturing, etc.

(1844, p. 85. Supplement to above. Authorizes receivers of Trenton Delaware Falls Company to sell, purchaser to be known as The Trenton Water Power Company.)

(1847, p. 76. Supplement to above. Authorizes Trenton Water Power Company to extend raceway along bank of Delaware River to a point near head of Taylor's Rift.)

(1870, ch. 91, p. 255. Company authorized to maintain and protect dam at Scudder's Falls.)

1836. 2, 17. Incorporates New Brunswick Manufacturing Company to manufacture wool, etc. Right to acquire such * * * water power as necessary (in New Brunswick).

1837. P. 410. Supplement to above. Gives right to use surplus waters of Delaware and Raritan Canal Company within corporate limits of City of New Brunswick.

1845. P. 198. Incorporates Camden Water Works Company.

(1854. Supplement to above. Authorizes holding of real estate, etc., in Pavonia—necessary to supply City of Camden and Pavonia with water from Delaware River.)

(1864, ch. 416, p. 723. Supplement to above. City of Camden authorized to become stockholder or owner.)

(1870, ch. 231, p. 539. Further Supplement. Lawful to sell and convey to City of Camden.)

1846. P. 13. Gives assent to act of Pennsylvania entitled "Supplement to act to incorporate Easton Water Company (March 24, 1817." (Approved January 15, 1846.) Authorizes company to construct wing-wall and dam in Delaware at any point north of confluence with Bushkill Creek and northern line of Borough of Easton; construct works, etc., as may be necessary for pumping, conducting, retaining and supplying a sufficiency of water to inhabitants of said borough * * * nor shall any water be drawn from said river for purpose of creating water power for manufacturing, nor except for purposes mentioned in act.

(1854, ch. 149, p. 384. Re same: Authorizes company to supply Phillipsburg.)

1847. Incorporates Trenton Iron Company. Lawful to issue to Peter Cooper 2,500 shares for property at South Trenton, known as "Trenton Iron Works," with all * * * water power and water privileges now held by said Peter Cooper, jointly with Trenton Water Power Company.

1848. P. 109. Incorporates Trenton and South Trenton Aqueduct Company to supply those municipalities. Lawful to use water of Delaware River, or Assanpink Creek, below dam, and to raise same into reservoirs, etc. Not to divert, take away, or in any manner injure, supply of water in fountains used by Trenton Water Works Company.

1852. Ch. 3, p. 9. Authorizes inhabitants of City of Trenton to construct works, etc. Commissioners authorized to use the waters of the Delaware River. Not to invade or infringe legal rights of Trenton Water Works Company.

1855. Ch. 13, p. 23. Increasing and defining powers of Rifton Manufacturing Company. In addition to powers already vested, given power to extend present raceway from eddy below Foul Rift, using water where deemed expedient * * * (By act of 1858, ch. 47, p. 90, Belvidere Manufacturing Company (February 26, 1828) was given foregoing name.)

1861. Ch. 91, p. 220. Authorizes Lehigh Water Company of Easton, Pennsylvania, to supply Phillipsburg with water (1863, ch. 121, p. 227. Supplement to above.)

1869. Ch. 567, p. 1437. Incorporates Delaware and Egg Harbor Canal Company. Perpetual. Authorizes construction of canal from waters of Delaware to waters of Egg Harbor River and Inlet. Authorizes supplying canal with water from Delaware River, etc. Requires consent by Pennsylvania.

1871. Ch. 625, p. 1541. Incorporates New Jersey Coast Canal Company. Perpetual. Authorizes construction of canals so as to connect navigable waters of Raritan Bay with navigable waters of Delaware Bay. Authorized, if necessary, to supply water by constructing feeders from any of the streams, crossed or connected by said canals, or from any of their tributaries.

1873. Ch. 670, p. 1587. Incorporates Delaware River Land and Improvement Company. Authorized to build canal and build property in Camden; canal to run from Delaware River (Line Ditch) to most convenient point on Cooper's Creek.

1873. Ch. 639, p. 1511. For protection of Morrisville Water Power. Authorizes Andrew K. Rowan and William C. Van Sant, present owners, to build and maintain wing-dam commencing at wing-wall of Delaware Bridge at Calhoun street, Trenton, and extending down river to entrance rock in falls at channel. Not to interfere with Trenton Water Works, water works of City of Trenton, or Trenton Water Power Company, nor to diminish supply of water flowing in river. Requires consent of Pennsylvania.

1876. Ch. 90, p. 103. Supplement to Revision, April 7, 1875. Lawful for any three or more persons, etc., to carry on * * * any lawful business or purpose whatever except such as shall need to possess right of taking land. Does, however, include damming of rivers and streams, including storage, transportation and sale of water, and water power and privileges, with right to take rivulets, raceways and lands, and erect and maintain dams, reservoirs, raceways, etc., upon filing of certificate.

Does not apply to any river or stream of less width and volume of water than the Delaware River, ordinarily at Phillipsburg, in this State, below its junction with the Lehigh, nor to any river or stream below the head of tidewater in the same.

Companies have power to cut or acquire main canals or raceways on each side of said rivers or streams, etc., provided water so diverted be returned again after being used for purposes aforesaid, and that water shall not be completely diverted so as to leave beds uncovered, etc.

1876. Ch. 193, p. 318. Act for construction of water works, etc. (See: 1879, ch. 206, p. 348; 1906, ch. 319, p. 703.)

1877. Ch. 85, p. 127. Re: Formation of Canal Companies.

1879. Ch. 195, p. 384. Authorizes organization of corporations to construct dams in rivers and streams—for water power purposes; to cut or acquire canals or raceways—water to be returned after use unpolluted. Denies power to supply public with water for potable or other domestic purposes; not to impair right of municipalities to take, without compensation, water for inhabitants.

1895. Ch. 283, p. 573. Concurs in act of Pennsylvania authorizing persons named to extend wing-dams constructed by Adam Hoops, with right to take water for use of mills.

1899. Joint Resolution No. 7, p. 475. Requests Pennsylvania to adopt legislation necessary to carry into effect acts of April 7, 1875, and April 12, 1876, re: dams.

APPENDIX F

Some Articles and Notes of Interest in Connection with the Basic Problems Dealt With

The Compact Clause of the Constitution—A Study in Interstate Adjustments.
Frankfurter and Landis, 34 Yale Review, 685.

Legislation Through Compacts.
Chamberlain, 9 Am. Bar Ass'n Journal, 207.

The Power of the States to Make Compacts.
31 Yale Law Journal, 635.

Interstate Compacts, as a means of settling disputes between States.
35 Harvard Law Review, 322.

Compacts and Agreements between States.
Bruce, 2 Minnesota Law Review, 500.

State Control of Navigable Waters.
Taft, 15 Columbia Law Review, 417.

Power of a State to divert an interstate stream.
French and Smith, 8 Harvard Law Review, 138.

Kansas-Colorado Water suit.
Costigan, 17 Green Bay, 587.

Interstate rights in interstate streams. (Kansas *v.* Colorado and Wyoming *v.* Colorado.)
Bannister, 36 Harvard Law Review, 960.

Some Problems of the Interstate Water War.
Rogers, 1923, Colorado Bar Ass'n Report, 107.

Application of the Reserve Treaty Powers of the States to Interstate Water Controversies.
Carpenter, 1921, Colorado Bar Ass'n Report, 45.

Colorado River Problem.
Corthell, 9 American Bar Ass'n Journal, 289.

One aspect of the Colorado River interstate agreement.
Wiel, 11 California Law Review, 145.

Use of the water in navigable streams for commerce and power.
Clayton, 94 Central Law Journal, 442.

The water power problem in the United States.
Brown, 24 Yale Law Journal, 12.

Federal Power of Legislation as to the Development of Water Power.
Howell, 50 American Law Review, 883.

The Federal Power Act.
Shields, 73 University of Pennsylvania Law Review, 142.

Some views respecting the Federal Water Power Act.
Hooper, 8 Marquette Law Review, 1.

Right of a State to restrain the exportation of natural resources.
Hardman, 26 West Virginia Law Quarterly, 224.

Limitation by a State of exportation of its natural resources.
24 Columbia Law Review, 64.

APPENDIX G

MEMORANDUM FOR THE DELAWARE RIVER TREATY COMMISSION*

November 13, 1924.

By Colonel William Kelly, Chief Engineer, Federal Power Commission.

The Federal Government's interest in the proposed treaty for the Delaware River may be summarized under two headings:—first, that the low water flow below Easton shall not be reduced to such a point as to interfere with present and possible future navigation on the Delaware River; second, that the Treaty shall be so drawn as to permit the fullest practicable use of the water resources. The proposal in the Treaty to make the municipal use of water the highest use is in accord with past practice of the Federal Government and I believe that there will be no dissension on that point.

My study of the present treaty draft has been directed principally to Articles 4 and 6. In conversation with the various State engineers, it appears that there is no intention to reduce the low water flow beyond the point where it would be satisfactory to the U. S. Government. However, as drawn, Articles 4 and 6 of the Treaty do not insure such a flow beyond reasonable doubt. Since all parties are agreed, however, as to the result to be obtained, there should be little difficulty in reframing these sections so as to make them perfectly clear.

In order to determine the possibilities for the use of water resources of the Delaware River, I have had a brief study made of the power resources. The information available is not sufficient to permit of accurate estimates being made but the figures given by my study are believed to be very conservative. A study of the stream flow data indicates that the flow at Port Jervis can be maintained at about 4,000 second feet by providing 1,200,000 acre feet of storage. It appears to be practicable to obtain that much storage above Port Jervis. From the rather meagre data available, it appears that nine power developments are feasible on the main river from Hawkins to a point below the Musconetcong River. The fall in the river between these points and the estimated amount of that fall which can be developed for power is shown on the following table:

*Submitted to the Commission which entered into proposed compact herein considered.

Estimate of Power Capable of Development on Delaware River

Dam Sites	Full possible development	Estimated development
1 Equinounk, Kellam's Bridge, Hawkins or Upper or Lower Callicoon Creek	160	80
2 Narrowsburg	65	60
3 Barryville	110	70
4 Below Mongaup River	105	80
5 Milford	70	35
6 Decker's Ferry	65	55
7 North Water Gap	35	30
8 Belvidere	60	50
9 Below Musconetcong River	110	30
	780	490

As indicated by the above table, it is believed that out of the 780 feet total fall at least 490 feet can be developed for power without serious flowage damage. The following table shows the amount of power that can be developed with a regulated flow of the river at these nine sites:

Estimated Power Output

No. designating dam site previous table	Drainage area sq. mi.	Est. water supply medium flow.	Head	Av. Kw. output at 85% efficiency.	Kw. Hrs. output per year. (1000 Kw. hr.)
1	1680	2200	80	12,700	111,000
2	1924	2500	60	10,800	95,000
3	2772	3600	70	18,100	159,000
4	3040	4000	80	23,000	202,000
5	3472	4500	35	11,400	100,000
6	3729	4900	55	19,400	170,000
7	3800	5000	30	10,800	95,000
8	4384	5700	50	20,500	180,000
9	6344	8200	30	17,700	155,000
					1,267,000

With the river regulated for power development, it is safe to assume that at least one billion and a quarter kilowatt hours can be developed per year. Probably the best use for this power would be to carry daily peaks in one of the large power consuming centers near the Delaware River; that is, either New York, the New Jersey Metropolitan District or Philadelphia. For this purpose the power would probably be used at about 25% load factor and the installed capacity would amount to about 530,000 K. W. It is probable that this power could be developed at a cost of less than $175.00 per K. W. installed and that the total cost of the project may be taken at $90,000,000. If the power be used for daily peaks, it should be worth at least one cent per kw. hr.; that is, it should produce an income of at least $12,000,000 per year.

The Treaty as drawn permits the diversion of about 75% of the water from the river and gives prior right to such diversion. If that amount of water be reserved for diversion, power development on the river will be impracticable. A memorandum of November 6, 1924, prepared by the State Engineers on "Studies of the flow in the channel of the Delaware River" provides for diversion of very much less water than that provided in the Treaty. If the diversions indicated by the memorandum of November 6th are the maximum probable diversions for municipal purposes, there will still be a possibility of some power development on the river and it would seem proper in the interest of conservation to modify the limits as at present set up by the Treaty so that they will not prevent the fullest feasible development of the river.

(signed) W. Kelly.

PART TWO

FEBRUARY 27, 1926

REPORT

of the

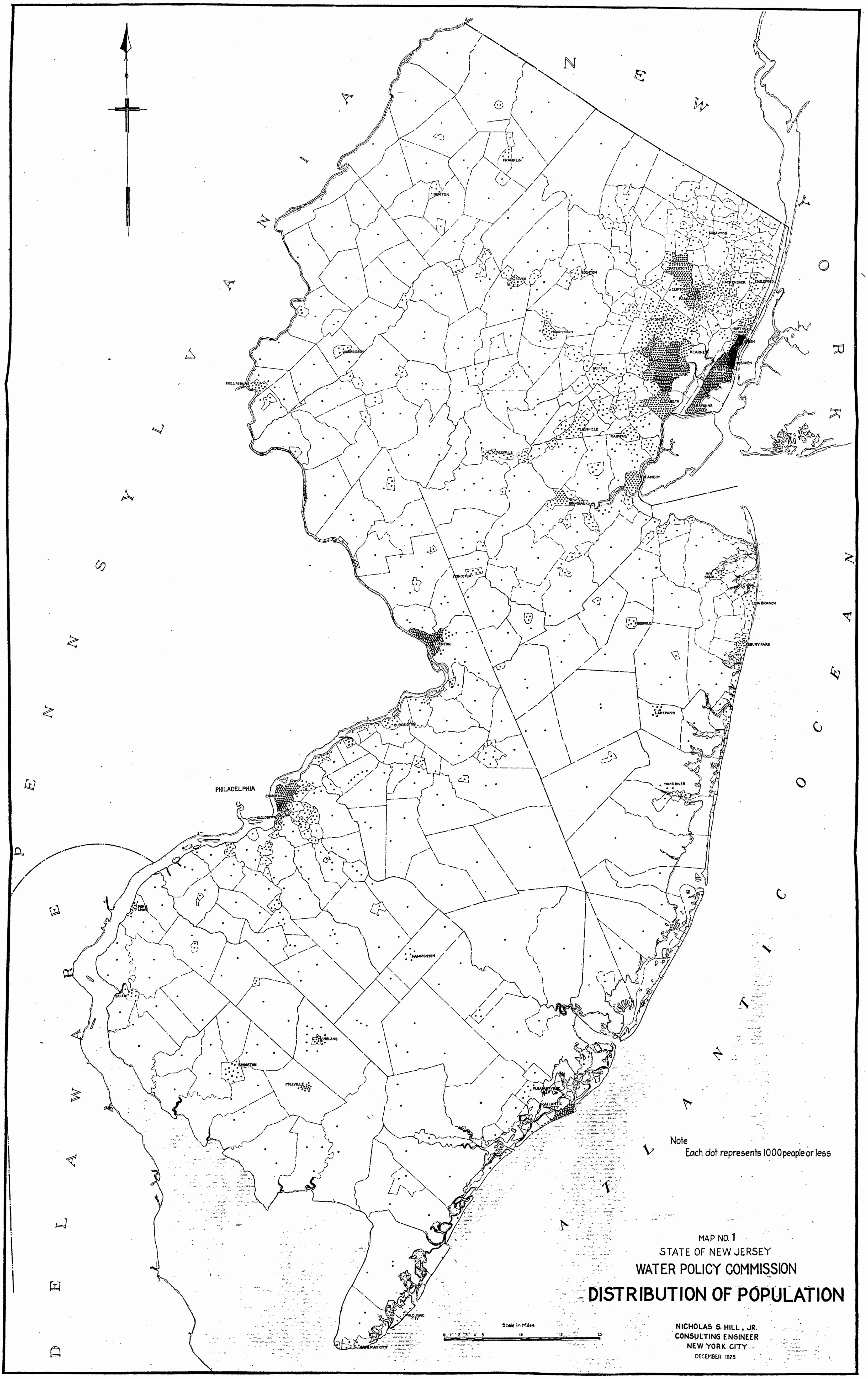
WATER POLICY COMMISSION

PART TWO

FEBRUARY TWENTY-SEVENTH, 1926

DEALING WITH

THE PROBLEM OF DEVELOPING AN ADEQUATE SUPPLY
OF POTABLE WATER
FOR THE ENTIRE STATE, AS REQUIRED
AND
THE METHODS TO BE EMPLOYED
IN SECURING SUCH SUPPLY



NEW YORK
PENNSYLVANIA
DELAWARE
ATLANTIC OCEAN
PHILADELPHIA
FRANKLIN
NEWTON
DOVER
BOONTON
MORRISTOWN
WASHINGTON
PHILLIPSBURG
PATERSON
CLIFTON
PASSAIC
RIDGEWOOD
HACKENSACK
ENGLEWOOD
MONTCLAIR
KEARNEY
NEWARK
HOBOKEN
ELIZABETH
BAYONNE
PLAINFIELD
RAHWAY
SOMERVILLE
NEW BRUNSWICK
PRINCETON
TRENTON
FREEHOLD
LONG BRANCH
ASBURY PARK
LAKEWOOD
TOMS RIVER
BURLINGTON
CAMDEN
GLOUCESTER
SALEM
VINELAND
BRIDGETON
MILLVILLE
HAMMONTON
ATLANTIC CITY
WILDWOOD CITY
CAPE MAY CITY
Note
Each dot represents 1000 people or less
Scale in Miles
MAP NO. 1
STATE OF NEW JERSEY
WATER POLICY COMMISSION
DISTRIBUTION OF POPULATION
NICHOLAS S. HILL, JR.
CONSULTING ENGINEER
NEW YORK CITY
DECEMBER 1925

REPORT OF
THE WATER POLICY COMMISSION

PART TWO

To the Senate and General Assembly of the State of New Jersey:

In addition to the consideration of the subjects which are dealt with in Part One of the report of this Commission, submitted under date of January 30, 1926, the joint resolution constituting this Commission directed "the formulation" by it "of a comprehensive State policy with reference to the development of the waters of the State, the recommendation of the instrumentality or instrumentalities through which such policy should be carried into effect, and the ways and means of financing thereof."

Part Two of the report of this Commission is now submitted in compliance with such direction.

Compliance with such direction required the bringing together of a large volume of existing data bearing upon the problems to be considered, and revising, supplementing and coördinating it.

This task was delegated to Nicholas S. Hill, Jr., Consulting Engineer. The maps, diagrams and tables incorporated herewith were prepared by his staff under his supervision. Maps and diagrams are inserted near that portion of the text referring to them. Appendices and tables, arranged in numerical order, follow the text.

GENERAL INTRODUCTION

Map No. 1 shows the distribution of population in this State.

It indicates that the bulk of the population of the State is within the so-called "*Northern Metropolitan District,*" which, roughly, comprises the counties of Bergen, Passaic, Essex, Hudson, Middlesex and Union, with a few outlying communities immediately adjacent thereto.

It shows a district embracing the counties of Mercer, Burlington, Camden and Gloucester and including the cities of Camden and

Trenton, with a population of five hundred and forty-two thousand (542,000) people, which is herein designated as the "*Southern Metropolitan District.*"

While the density of population in this area is not nearly so great as that of the Northern Metropolitan District, the district is growing rapidly in population.

Out of a total population of three million four hundred and fifty thousand (3,450,000) sixty-eight per cent. (68%) are now residents of the Northern and sixteen per cent. (16%) of the Southern Metropolitan District. In other words, eighty-four per cent. (84%) of the population of the entire State is in these two areas. Forecasts of future population indicate that fifty (50) years hence ninety per cent. (90%) of the entire population will reside within these two districts. The population density in the Northern Metropolitan District at present is two thousand three hundred and eighty (2,380) per square mile and in the Southern three hundred and fifty (350), whereas in the rest of the State it is but one hundred and twenty (120).

On the basis of this distribution of population the State is, for the purposes of this report, divided into (1) the Northern Metropolitan District, (2) the Southern Metropolitan District and (3) the rest of the State.

Northern Metropolitan District.

This territory comprises some one hundred and seventy-five (175) incorporated communities having a total population of two million three hundred and sixty thousand (2,360,000) people, ninety-three per cent. (93%) of whom are served from forty (40) public water supplies, of which twenty-two (22) are publicly and eighteen (18) privately owned. The total water consumed is approximately two hundred and fifty (250) million gallons daily, which is derived from sources with an available yield of three hundred (300) million gallons daily.

The existing available supplies in this district may possibly be made to suffice to meet the needs of the next four (4) years if effectively pooled by means of interconnecting existing systems. Through such pooling the shortages which menace parts of the district may be avoided or minimized until additional supplies are provided or new sources developed.

The Wanaque River development, now under construction by the North Jersey District Water Supply Commission, is to be completed by the close of 1928. This development is estimated by the engineers of that commission as affording a yield of one hundred (100) million gallons daily.

Notwithstanding this addition, shortages of serious proportions will exist in parts of the district.

This situation demands immediate action.

Various courses of action to meet the situation are open:

(1) To proceed without delay to utilize the local sources to meet local or regional needs and to defer undertaking one of the proposed major projects hereinafter discussed; or (2) to undertake a major project at once; or (3) to utilize undeveloped local resources in part and in so far as such development is not inconsistent with or uneconomic in view of the major project that may be adopted, and to put such major project underway as well. The advantages and disadvantages of these several possible programs will hereinafter be discussed.

Southern Metropolitan District

This area comprises some one hundred and five (105) incorporated communities having a total population of five hundred and forty-two thousand (542,000) people, eighty-seven per cent. (87%) of whom are served from forty-eight (48) public water supplies, of which nineteen (19) are publicly and twenty-nine (29) privately owned. In this district the present consumption is approximately fifty (50) million gallons daily and the safe yield of the sources as now developed is about eighty-four (84) million gallons daily, sufficient for possibly eight (8) or ten (10) years to come.

The situation in this area differs from the situation in the Northern Metropolitan District. Trenton has an unlimited supply available from the Delaware River. Camden has developed a supply of over sixteen (16) million gallons daily from underground sources. The bulk of the water used in the remainder of the district is developed in small units from wells, and such supply may be augmented by driving additional wells.

It may therefore be some time before the necessity for a large regional supply becomes actually imminent.

Rest of the State

In an area approximately double that of the two metropolitan districts combined there resides about one-sixth (1-6) of the population of the State. It is true there are two hundred and fifty (250) incorporated communities, but they are small and widely scattered. But sixty-seven per cent. (67%) of the population is supplied with water by one hundred and nine (109) plants, of which fifty-seven (57) are publicly and fifty-two (52) privately owned.

In this area the problem of water supply may, and probably will, become acute in a few places such as Atlantic City. It is not likely, however, that a general problem such as that existing in the Northern and Southern Metropolitan Districts will arise.

Outline of Water Resources

Available Surface Water.

Appendix I gives a list of the communities in New Jersey with water supplies. This appendix also shows the purveyor by whom the community is supplied.

Table No. 1 gives a list of producing water systems in the State supplying five hundred thousand (500,000) gallons per day or over, together with their output.

Table No. 2 gives the existing water supplies supplying five hundred thousand (500,000) gallons or over per day, classified by sources, and also indicates the total amount of water obtained from the various sources.

Map No. 2 shows the drainage systems of the State. It shows that the principal drainage basins in Northern New Jersey are those of the Hackensack, Passaic, Wallkill, Upper Delaware and Raritan, and in Southern New Jersey the Lower Delaware River and Atlantic Coast basins.

Table No. 3 gives the area of the effective watersheds of the principal rivers and their tributaries.

The Hackensack, Passaic, Wallkill, Upper Delaware and Raritan are naturally tributary to the northern section of the State. Some of the streams in the Atlantic Coast basin may be, and are, utilized in this section. The southern half of the State depends upon the Lower Delaware and its tributaries and streams in the Atlantic Coast basin.

Table No. 3 further shows that the total effective drainage area of the various rivers and streams within the State is four thousand five hundred and fourteen (4,514) square miles. Assuming that all were fully developed, it is probable that the surface sources within the State could yield three thousand six hundred (3,600) million gallons per day of water.

It is true, as will be seen by reference to Map No. 2, that a number of the watersheds in the Delaware and Atlantic Coast basins are small. It is also true, however, that a number of these small sheds may possibly be economically utilized for local supplies by towns and villages within or near these drainage basins.

Both the northern and southern sections of the State, where the population density is greatest, have available sources from which water may be obtained. The northern towns have the Hackensack River as well as the Passaic and Raritan and their tributaries, together with the tributaries of the Delaware, including the Musconetcong, Pequest, Paulins Kill and Flat Brook. If arrangements can be made with the State of New York, the drainage area of the Wallkill will also be available. In the south are the Rancocas River, Wading and Mullica Rivers, Great Egg Harbor River and Maurice River, all of which are streams of appreciable size. In addition to these sources, if, as proposed, a Delaware Tri-State Compact is entered into, approximately fifteen hundred (1,500) million gallons of additional water may be available from the Delaware for use in the northern and southern portions of the State.

Table No. 12 gives the principal available water resources for the Northern Metropolitan District. Similar data for the Southern Metropolitan District and the rest of the State will be found in Table No. 4. These tables indicate total available resources, including New Jersey's portion of the flow in the channel of the Delaware, of approximately four thousand (4,000) million gallons daily.

Underground Water.

In addition to the surface water available there are certain underground horizons in various parts of the State which yield appreciable quantities of water.

The importance of ground water as a source of supply in this State is shown by Table No. 6. This table shows that one hundred and one and one-half (101.5) million gallons daily out of a total daily output in 1924 of three hundred and fifty-four and one-half (354.5), or slightly more than one-quarter (¼), was ground water. Although by far the greater part of the population of the State is served with surface water, there are about three times as many systems serving ground water as there are serving surface water. Surface water systems supply most of the larger cities of the State, whereas many of the smaller communities are supplied from underground sources. There are, however, a number of large ground water supplies in the State serving from three (3) to sixteen (16) million gallons daily. In addition to the consumption from the public supplies, a large quantity of ground water is used from private wells for manufacturing and industrial purposes as well as by individuals.

Incomplete data obtained by the State Department of Conservation and Development from privately owned plants in some of the large cities show an average daily consumption of at least thirty-five (35) million gallons, distributed as follows:

Newark	10.4	million	gallons	daily
Camden	6.5	"	"	"
Paterson	5.5	"	"	"
Atlantic City	4.5	"	"	"
Miscellaneous	8.7	"	"	"

There is undoubtedly much ground water used in other cities from which similar data have not been obtained.

Data at present in hand are not sufficient to warrant a forecast of the probable ultimate yield of underground water in the State.

Except in Mercer County, where Trenton secures its supply from the Delaware River, the Southern Metropolitan District obtains the bulk of its supply from beneath the ground.

Map No. 3 shows the distribution of surface and underground water in the State.

Water Supply Statistics

Water supply statistics for the State are furnished in Table No. 5. This table shows that eighty-eight per cent (88%) of the population of the State is now served with water from public supplies, and that out of a total consumption of three hundred and fifty-four and one-half (354.5) million gallons daily seventy-one per cent (71%) is consumed in the Northern Metropolitan District and fourteen per cent. (14%) in the Southern Metropolitan District, leaving but fifteen per cent. (15%) used in the remainder of the State.

Polluted Sources

Neither in the foregoing statements as to developed supplies, and as to sources that may be developed, nor in the tables referred to in connection with such statements, has any deduction been made for developed supplies which it may be necessary to discontinue because of pollution, nor for sources that may be found unavailable for increased or new development because of existing or prospective contamination.

What deductions from the totals given should be made on this account cannot be satisfactorily determined on the basis of available data.

Even cursory consideration makes it evident that substantial deductions from totals may have to be made on this score.

The 1925 report of the North Jersey District Water Supply Commission contains material bearing upon this subject (chapter III, page 170 et seq., and Appendix 8) and indicates the view of that Commission so far as concerns present supplies in the Northern Metropolitan District, to be that "certain existing surface supplies pumped from polluted streams with a combined capacity of about 70 million gallons a day are becoming increasingly unsatisfactory to the communities served and may, for that reason, be eliminated from the list available for public consumption."

Whatever deduction from the totals may prove to be necessary will only serve to shorten the period during which the existing developed supplies, possible extensions thereof and possible minor new developments can be made to meet the need and shorten the period when major developments must be available.

Distribution of Water

Table No. 6 gives the distribution of water in this State. This table indicates that out of two hundred and forty-four (244) water works seventy-five per cent. (75%) of the water is supplied from those delivering five (5) million gallons daily or over.

It further shows that private water companies supply forty per cent. (40%) of the total water consumed in the State. The proportion is even greater in the Northern Metropolitan District. The total claimed value of the private water works is roughly $65,000,000.

Present and Future Population

The first question which arises in connection with the future is the probable quantity of water which will be required. As the amount consumed varies closely with the population supplied and population statistics may be easily and accurately secured, it is usual to base estimates of future consumption upon future population growth. Table No. 7 gives the present and estimated future

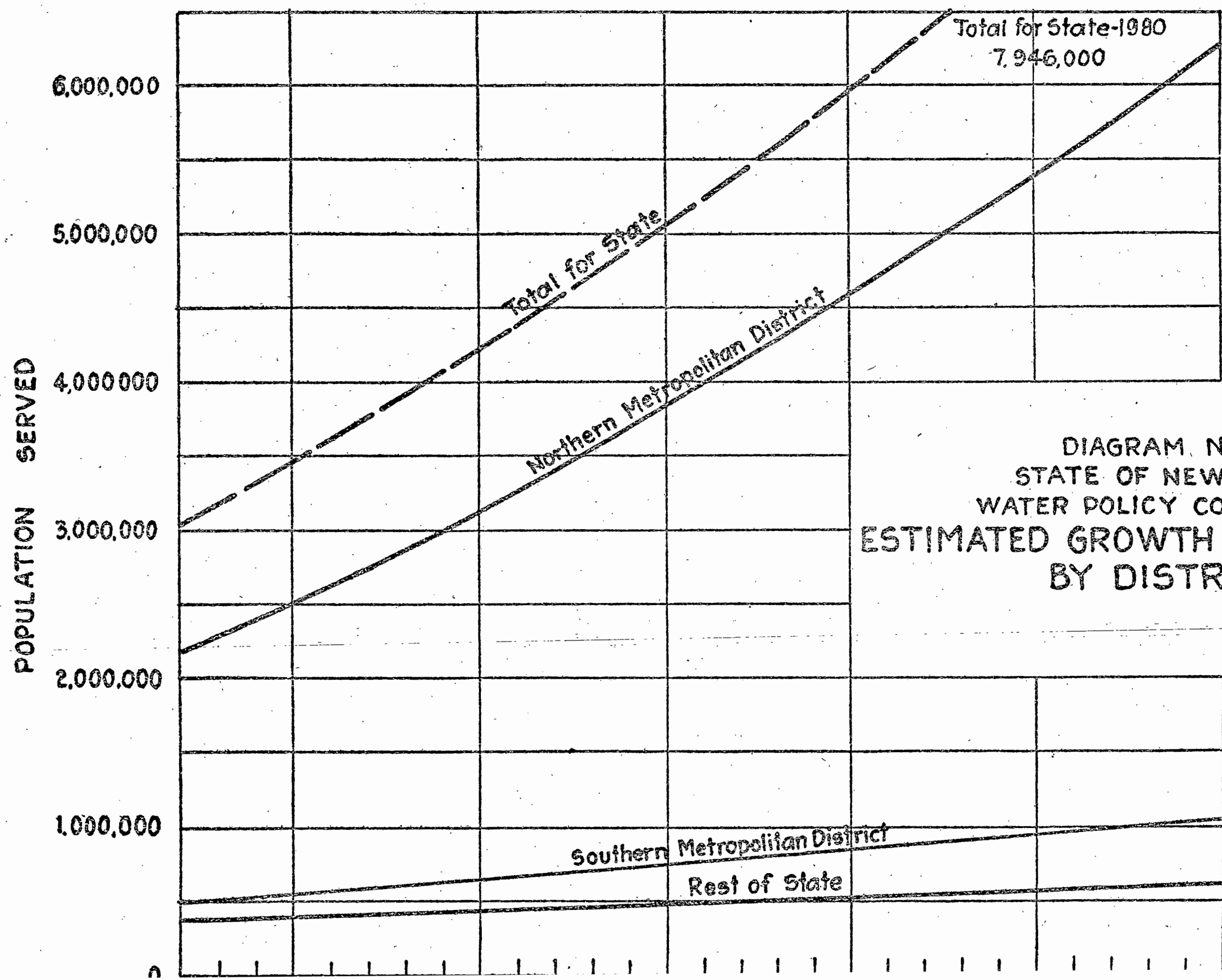


DIAGRAM NO. 1
STATE OF NEW JERSEY
WATER POLICY COMMISSION
ESTIMATED GROWTH IN POPULATION
BY DISTRICTS

population served, classified by districts and counties. Diagram No. 1 shows the estimated future growth of population graphically.

Population growth depends on many things which cannot be predetermined. For example, the recent World War had a marked effect on the rate of increase in population in many places. No population forecast can take into account an abnormal situation of this kind. In addition, in the matter in hand, bridges and tunnels under construction and to be constructed further connecting the State with the cities of New York and Philadelphia may result in local increases in population difficult to forecast. It is possible, however, to forecast with a reasonable degree of certainty for some years to come, and the results of such forecast, while not precise, are useful. Detailed studies of the communities in which the greatest growth in population will occur will be of great importance in the later design of water works systems, but for the purpose of this report general studies are sufficient. In any event, whether the population which is assumed for any given future period is precisely accurate or not matters little, for the only effect of overestimating will be that the time at which additional supplies will be needed or existing supplies enlarged will be somewhat delayed, and if underestimated, the time when additional supplies or enlargement of existing supplies will become necessary will be somewhat advanced. The ultimate requirements, rather than the precise period for which any given undertaking will be useful, are important. Population forecasts furnish a basis for estimating these future needs approximately.

The forecasts here presented have been compared with forecasts of the probable future population in New York and environs made by the American Telephone and Telegraph Company, as well as with one made by Professors Raymond Pearl and Lowell J. Reed, of the School of Hygiene and Public Health of the Johns Hopkins University, Baltimore, for the "Committee on Plan of New York and Its Environs." The predictions of these authors were in turn compared with estimates made by the late Mr. Nelson P. Lewis, Director of the Physical Survey of the "Committee on Plan of New York and Its Environs," as well as with those of Mr. Allen Hazen in his report on the water resources of New Jersey, made for the Department of Conservation and Development.

Present and Future Water Consumption

Having obtained the population data necessary, Table No. 8 was prepared to show the present and estimated future water consumption, classified by districts and counties. This table presents an estimate of the future water consumption expressed in million gallons daily for the entire State, subdivided by districts and counties. The quantities given for 1924 were obtained from information secured from the Department of Conservation and Development, from data available in the office of Nicholas S. Hill, Jr., Consulting Engineer, and from reports of the water utilities filed with the Board of Public Utility Commissioners of this State. The estimates of future consumption are based upon the population presented in Table No. 7, but an increase in the daily per capita consumption of water has been allowed, because experience in most towns and cities shows that the rate of per capita consumption increases as the population increases.

Domestic per capita use has increased because people live in houses with more fixtures, and also because water is so cheap that there is no great incentive to curtailment in its use, or even of waste, for ordinary waste does not increase water bills materially. The industrial use of water has increased because of the growth of manufacturing. Local private supplies are outgrown and industrial demands must be met by public systems. The increase in per capita consumption of water in the past may be expected to continue for some time in the future.

The assumptions with regard to the future per capita use of water in the State were made after comparing them with like assumptions for the future supply of such cities as New York, Boston, Philadelphia and Baltimore, taking into consideration, of course, present per capita consumption and local differences in conditions.

Diagram No. 2 gives the estimated growth in water consumption for the State, subdivided into districts.

Reference to Table No. 8 shows that the water requirements of the Northern Metropolitan District will have more than trebled in the next fifty (50) years and in the Southern Metropolitan District will have increased a little more than two and a half times. The total estimated water requirements of the State in 1980 will be as follows:

Northern Metropolitan District..........	1,039	million	gallons	daily
Southern Metropolitan District..........	169	"	"	"
Rest of the State......................	127	"	"	"

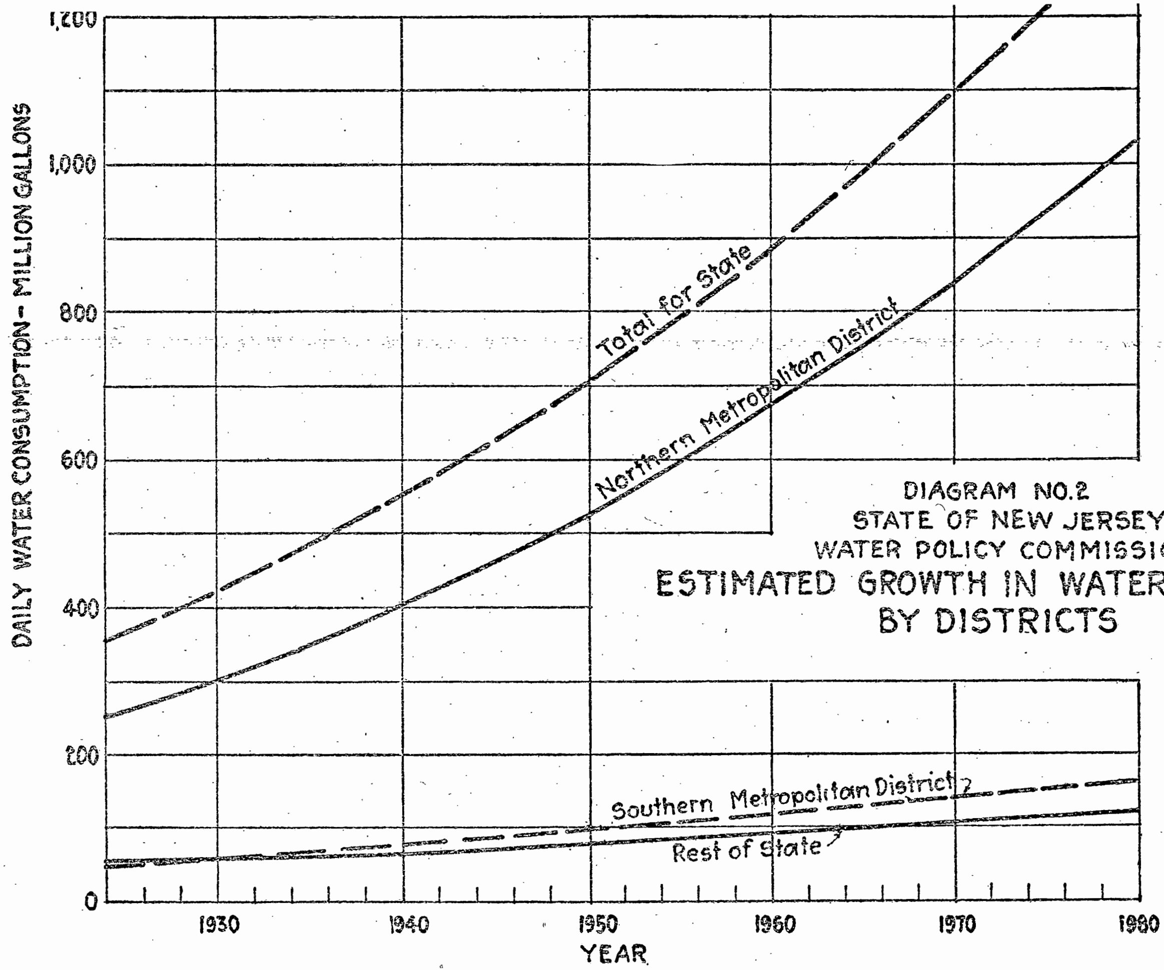


DIAGRAM NO. 2
STATE OF NEW JERSEY
WATER POLICY COMMISSION
ESTIMATED GROWTH IN WATER CONSUMPTION
BY DISTRICTS

THE REGIONAL WATER SUPPLY PROBLEM

These facts make it evident that there is not, and in all likelihood will not be for many years to come, any regional water supply problem outside of the two metropolitan districts. They also show that the problem in the Southern Metropolitan District is neither so acute nor pressing as that which confronts the Northern Metropolitan District.

Under these circumstances detailed discussion of present needs will be confined to the Northern Metropolitan District.

WATER PROBLEM IN NORTHERN METROPOLITAN DISTRICT

In order that the seriousness of the situation which confronts the Northern Metropolitan District may be fully appreciated, a brief outline of projects under way and of projects that have been and are now under consideration for relief from present or anticipated water shortages, and a brief description of sources now developed and of sources which are available are presented.

PROJECTS UNDER CONSTRUCTION AND PROJECTS UNDER CONSIDERATION

The past ten years have been marked by the proposal of numerous plans for meeting the existing and anticipated shortages. The projects proposed have varied from plans for local supplies, to meet the requirements of individual communities or groups of communities, to plans for supplies of sufficient magnitude to satisfy the demands of the district as a whole.

LOCAL PROJECTS

Wanaque.

The North Jersey District Water Supply Commission has had the development of the Wanaque River under way for some years and has announced its expectation to complete construction in the latter part of 1928.

This project is fully described in the report of that commission for 1925.

It involves constructing a dam at Midvale with a spillway elevation at 300′, which will impound twenty-seven thousand (27,000) million gallons of water, sufficient, as estimated by that commission, to furnish one hundred (100) million gallons per day.

The municipalities participating in this project and to which water has been alloted, based on an available supply of one hundred (100) million gallons daily, are:

	Million Gallons Daily
Newark	40.50
Paterson	20.00
Kearny	12.00
Passaic	11.00
Clifton	6.75
Montclair	5.00
Bloomfield	4.00
Glen Ridge	0.75

The cost of this project is estimated at $20,350,000.

Ramapo.

This watershed, which is bounded on the east in part by that of the Hackensack and on the west by that of the Wanaque, has a drainage area of one hundred and forty-seven (147) square miles. Although not yet developed for water supply purposes it has been considered in connection with a number of different projects. The city of Bayonne has desired to develop this shed for a number of years, and made application for State consent to do so. Its application, however, finally failed.

Stony Brook.

Recently Mr. Weston E. Fuller submitted a report to the city of Elizabeth on a plan for supplying water for that city and possibly other communities in Union and Middlesex counties, which plan includes the construction of a large reservoir on Stony Brook, just north of Plainfield, and augmenting the flow of this stream by pumping water in times of flood from the Passaic to the reservoir through a conduit of proper size. No action has as yet been taken on the basis of this report.

Raritan River.

The Elizabethtown Water Company, Consolidated, and affiliated companies, have secured permission from the Department of Conservation and Development of the State to divert water from the Raritan River at a point near its junction with the Millstone River. It was proposed initially to secure twenty (20) million gallons daily from this source. The plan for such diversion has not as yet been executed.

Minor Local Projects.

In addition to the projects above mentioned, the city of New Brunswick made application to the North Jersey District Water Supply Commission for permission to divert water from South River and to further develop Lawrence Brook. By this means it would be possible to obtain a supply adequate for fifteen (15) or twenty (20) years at a comparatively nominal cost. The application was recently denied.

The city of Perth Amboy recently completed additions to its well supply, which additions give it a safe margin for some years to come. The city can secure more water when required from South River, which is immediately adjacent.

There are a number of other communities which have recently provided for their wants by local development and which can continue to satisfy their needs in this way.

Major Projects.

In 1922 Mr. Allen Hazen prepared a report for the Department of Conservation and Development of this State, outlining plans for the development of a water supply for the entire Northern Metropolitan District, and more recently Mr. Morris R. Sherrerd, Consulting Engineer of the North Jersey District Water Supply Commission, submitted a plan which is a modification of one of the Hazen plans. Mr. Hazen considered four principal water supply developments:

1. Mullica and Wading Rivers and other southern streams.
2. Raritan River, supplemented ultimately, if needed, with water from the Delaware River.
3. Passaic River.
4. The so-called "Long Hill" project—Long Hill reservoir fed from streams in northwestern New Jersey.

Of the four plans considered, the Long Hill project is the only one which has received serious consideration.

Long Hill Project.

Under this plan the Long Hill reservoir would be located on the Upper Passaic above Millington.

The country north of this river is a series of ridges and valleys, which succeed each other with great regularity. These valleys include the upper reaches of the Raritan River, the valleys of the Musconetcong and Pequest Rivers, as well as those of Paulins Kill and Flat Brook, a total catchment area of six hundred and forty-five (645) square miles.

All of these valleys slope in a southwesterly direction. They are high enough at selected points to supply water to the Long Hill reservoir by gravity. Some of them have excellent reservoir sites, which could be utilized to hold back flood flows to be delivered as desired to the Long Hill reservoir through an aqueduct or tunnel. The capacity of the Long Hill reservoir would be sufficient to impound most of the stream flow which would be available from these sheds.

It is estimated that the Long Hill system, developed as above outlined, would yield more than six hundred (600) million gallons daily, after making due allowance for local requirements. This system may be further augmented by the diversion of water from the Wallkill River into the Long Hill reservoir This would add one hundred (100) million gallons of water daily by gravity. It would also be possible to divert Delaware River water by pumping it into the Flat Brook reservoir on Flat Brook, which is only one mile from the Delaware River and one hundred and fifty feet (150′) above it. With the addition of the Delaware and Wallkill as proposed, it is estimated that a supply of seven hundred and fifty (750) million gallons of water per day may be secured at a final cost of $173,000 per million gallons daily of capacity. The cost per million gallons per day of capacity, however, for the initial and intermediate construction will be appreciably higher than the figure above named.

In addition, it is estimated that with larger tunnels than proposed and by increasing the size of the reservoirs, it would be possible, if a Tri-State Delaware River Compact were entered into, to secure a much larger quantity of water from the Delaware.

Chimney Rock Project.

A modified Long Hill development has been suggested by Mr. Morris R. Sherrerd, Consulting Engineer of the North Jersey District Water Supply Commission, which centers about Chimney Rock reservoir. This reservoir would be located immediately to the north of Bound Brook.

As outlined above, Mr. Hazen proposed to divert the waters of the Raritan, Musconetcong, Pequest, Paulins Kill and Flat Brook by means of aqueducts or tunnels into the Long Hill reservoir, located on the Upper Passaic above Millington.

Under Mr. Sherrerd's plan, the Chimney Rock reservoir, located just north of Bound Brook, would be substituted for the Long Hill reservoir.

The first step in the development of this project would be the construction of diverting dams on the Raritan River, which would divert water through large conduits into the Chimney Rock reservoir. It is estimated that the resulting yield would be one hundred and fifty-eight (158) million gallons daily.

When required, the waters from the Musconetcong and Pequest Rivers would be similarly diverted into the Chimney Rock reservoir and the waters from Paulins Kill and Flat Brook may also be conveyed to this reservoir when needed. Ultimately water would be diverted from the Delaware into the Chimney Rock system, but at a point farther downstream than proposed by Mr. Hazen for the Long Hill system.

Mr. Sherrerd estimates that the same amount of water through the Chimney Rock development would finally be secured as would be secured through the Long Hill development, that is, seven hundred and fifty (750) million gallons per day, and that its cost would be about $230,000 a million gallons.

The two schemes are not dissimilar. Both possess one great advantage over the Passaic or Raritan projects in that they are capable of progressive development. The major part of the investment under the proposed Raritan or Passaic projects would have to be made at once. Either the Long Hill or Chimney Rock system could be carried out in successive steps and, therefore, the ultimate cost of development would not be incurred until the time when the consumption justified the expense.

An added claim in favor of the Chimney Rock project is that it permits a smaller initial capital outlay than the Long Hill project and, therefore, a deferred-payment plan which reduces the present worth of the ultimate cost, although the total final cost of the Chimney Rock project would apparently be greater than that of the Long Hill plan.

Studies made in the office of Nicholas S. Hill, Jr., Consulting Engineer, indicate, however, that the estimates of cost on Long Hill and Chimney Rock presented by the North Jersey District Water Supply Commission are not on a truly comparative basis, and that the saving in first cost effected by the Chimney Rock project may be more apparent than real. A detailed comparison of the Long Hill and Chimney Rock projects will be found in Appendix II.

For the purposes of this report it is not essential that the competing merits of these two proposed major projects be passed upon.

That task must remain to be performed by such permanent commission as may be charged with the responsibility of seeing that the present and future needs of the district are actually and adequately met.

It suffices for this report to take account of possible differences in judgment when the two projects are viewed from engineering and financial standpoints.

PRESENT WATER SUPPLIES IN NORTHERN METROPOLITAN DISTRICT

Reference to Map No. 4 will aid in visualizing existing conditions.

Newark now obtains an excellent supply from the Pequannock River, a tributary of the Passaic. The water from sixty-three and seven-tenths (63.7) square miles of watershed is diverted and conveyed to the city through two (2) pipe lines. The works as they stand will deliver fifty-seven (57) million gallons daily.

Jersey City has a dam on the Rockaway River near Boonton and impounds water from a catchment area of one hundred and nineteen (119) square miles. The present works have a safe yield of sixty (60) million gallons daily. The yield of this watershed could be increased by forty (40) million gallons daily by means of more storage reservoirs on the Rockaway River. The city acquired the right to divert seventy (70) million gallons daily at the time its Boonton dam was built. Its pipe lines have a capacity of one hundred (100) million gallons daily. The additional supply from the Rockaway may therefore be obtained at small cost. Jersey City, in addition to furnishing within its own limits, serves Hoboken and parts of Kearny township, Secaucus boro, and other places along its aqueduct from the Boonton reservoir.

The Passaic Consolidated Water Company, formerly known as the East Jersey Water Company, obtains a supply from the Passaic River at Little Falls. The natural flow of the stream at this point is sufficient to meet a draft of fifty-six (56) million gallons daily, although the water is subject to rapidly increasing pollution. This company furnishes water at retail to Paterson, Passaic, Clifton and Prospect Park boro, and at wholesale to Kearny, Harrison, East Newark, Bayonne, and other smaller places.

Some of the cities so supplied, including Paterson, Passaic, Clifton and Kearny, have as before noted, by contract with the North Jersey District Water Supply Commission and the city of Newark, joined as participants in the Wanaque River development.

The Hackensack Water Company derives its supply from the river of that name. This river has a catchment area of one hundred and fifteen (115) square miles above the Oradell dam at Oradell, New Jersey. At present the capacity of this system is forty (40) million gallons daily, but the Hackensack River may be developed to yield eighty-four (84) million gallons daily. Such a development would, however, lie partly in the State of New York. In the absence of an agreement between the State of New York and this State, regarding the development of interstate streams, the full yield of this source may not be available. It is safe to assume, however, that an additional ten (10) to twenty (20) million gallons daily may be secured from this source by intrastate development. This company supplies Union City, Guttenberg, Weehawken, West New York and Secaucus in Hudson county, and practically all of the towns and villages in Bergen county east of the Saddle River and as far north as the New York-New Jersey state line, including Hackensack and Englewood,—about fifty (50) communities in all.

The Elizabethtown Water Company, Consolidated, derives its water from five (5) sources, one surface, the Elizabeth River, and four underground, having a total yield of eleven and one-half (11.5) million gallons daily. As the consumption is greater than the yield of its sources this company purchases water from outside. It has caused a thirty-six inch (36″) pipe line to be constructed from Bound Brook to Elizabeth and secured rights on the Raritan River in anticipation of developing an additional supply from this source. It supplies water in some fourteen (14) communities in Union and Middlesex counties, including the cities of Elizabeth and Linden, Piscataway, North Plainfield and Raritan townships, and Dunellen and Middlesex boros.

The Plainfield-Union Water Company serves fifteen (15) communities in Union county, including Plainfield, Cranford, Westfield and other places along the line of the New Jersey Central Railroad. Its principal source of supply is wells located at Netherwood, which will yield about seven (7) million gallons daily. It is necessary for this company at times to purchase water from outside sources in order to meet the demands on its system. Plans have been considered for some time by which it would join with the Elizabethtown Water Company, Consolidated, in the development of the Raritan River.

The Middlesex Water Company secures its supply from two (2) main sources, Robinsons Branch of the Rahway River and at Park Avenue pumping station, Plainfield, from wells. The company also has a smaller station at North Plainfield. The total yield of the three plants is approximately eight (8) million gallons daily. This company furnishes water to six communities in Middlesex county, including the boros of Metuchen, Carteret and Woodbridge, and sells water wholesale to the Elizabethtown and Plainfield-Union Water companies. The Middlesex company has had under consideration joining the two companies just mentioned in the development of the Raritan River.

The Commonwealth Water Company secures water from wells near Summit, one group in the valley of Green Brook and the other adjacent to the confluence of Canoe Brook and the Passaic River. These sources will yield approximately seven and one-half (7.5) million gallons a day. The company supplies eight places, including the city of Summit, the towns of Irvington and West Orange and the townships of Millburn and Maplewood.

New Brunswick obtains water from Lawrence Brook and is now supplying approximately six and one-half (6.5) million gallons a day in New Brunswick and the adjacent communities of Highland Park boro and North Brunswick township.

Perth Amboy secures water from wells and has a developed supply which will yield approximately fourteen (14) million gallons daily. This plant is furnishing water not only in Perth Amboy but also in Sayreville boro and a portion of Woodbridge township.

Rahway obtains water from the river of that name at a point north of the city. The plant has a safe yield of four (4) million gallons daily.

In addition to those enumerated, there are a number of other publicly and privately owned plants, including those at Ramsey, Ridgewood, Butler, Essex Fells, Orange, East Orange, South Orange, Chatham, Madison, Morristown, Somerville, Bound Brook and South Amboy.

Map No. 5 shows in outline the distribution pipes of the principal water systems in the Northern Metropolitan District, as well as the areas served by them.

It should be noted in this connection that:

1. There are some fifty (50) communities in North Hudson and Bergen counties supplied by the Hackensack Water Company through a distribution system which is designed to convey water from the north to the south.
2. The cities of Hoboken, Jersey City, Bayonne, Newark, Paterson, Passaic, Kearny, Harrison, East Newark, Montclair, Glen Ridge and Bloomfield, together with some other places which lie in the central zone of the Metropolitan District, secure water from the Passaic River through the Passaic Consolidated Water Company, or from Newark or Jersey City.
3. In addition to serving contiguous territory, the conduits and supply lines of the Passaic Consolidated Water Company and the cities of Newark and Jersey City, which furnish one hundred and sixty (160) million gallons daily, approximately eighty-five per cent. (85%) of the water systems in the counties of Passaic, Hudson and Essex, parallel each other in places and there is actually physical connection between their pipe lines at various points, so that interchange of water may be secured at comparatively nominal cost.
4. That the communities served by the Commonwealth Water Company, as well as the territory served by the water systems of Orange, East Orange, South Orange and Essex Fells, lie adjacent to the area now served with Passaic River water, and interconnection between these towns and the Passaic system would be simple. In fact such connections now exist, as, for example, between Newark and East Orange.

Map No. 5 also shows that the supply lines forming the backbone of the Passaic system pass through the larger centers of population in Passaic, Essex and Hudson counties.

A large part of the area in Union and Middlesex counties is served by the Elizabethtown, Middlesex and Plainfield-Union Water companies, the systems of which companies are interconnected at various points.

The Elizabethtown Water Company, as shown on Map No. 5, has a large water main already installed, running from Bound Brook to Elizabeth, which would serve as an artery for the distribution system in this territory.

It is true that Bound Brook, New Brunswick (if allowed to make the development for which permission is sought), Perth Amboy, Somerville and South Amboy, the principal communities in this territory not served by the three last mentioned water companies, have their own supplies and are in a position to meet their needs for some years to come, but the pooling and interchange of water between these systems could be effected at small capital outlay. The systems of Perth Amboy and the Middlesex Water Company are, in fact, already interconnected.

Subdivision of Northern Metropolitan District.

From this outline it is apparent that following the natural lines of past development the district divides itself into three sections:—the Northern, including the area now served by the Hackensack Water Company and other territory in Bergen county; the Central, which, except for a few independent supplies such as those at Essex Fells, Orange, East Orange, South Orange and the Commonwealth Water Company, is supplied from the Passaic and its tributaries; and the Southern, which includes the territory now supplied from the lines of the Plainfield-Union, Elizabethtown and Middlesex Water companies.

THE VARIANCE IN MARGIN BETWEEN CONSUMPTION AND SAFE YIELD IN THE SECTIONS OF THE NORTHERN METROPOLITAN DISTRICT

Table No. 9 gives the consumption of water in the Northern Metropolitan District divided into sections. By comparing these figures with the yield of the supplies now in use, as given in Table No. 10, it is seen that there is at best but a margin of a few years before the consumption in the district as a whole will exhaust the present sources.

Statistics of the total consumption and safe yield show that the margin between the present developed yield and consumption is not the same in all sections of the Northern Metropolitan District:

	Total Consumption 1924 (M.G.D.)	Safe Yield (M.G.D.)
Hackensack Water Company	26.34	40.0
Jersey City Water Works	60.32	60.0
Passaic Consolidated Water Company	49.54	56.0
Elizabethtown Water Company, Consolidated Plainfield-Union Water Company Middlesex Water Company	27.1	26.5
Newark Water Works	50.24	57.0
East Orange Water Works	3.56	7.0
Commonwealth Water Company	4.83	7.5
New Brunswick Water Works	6.36	5.5
Perth Amboy Water Works	7.68	14.0

The foregoing tabulation indicates how varied are the conditions as to the margin between the present developed yield and consumption in the several sections of the district

The northern section of the district supplied by the Hackensack Water Company has a safe margin for several years to come.

Jersey City is now using and selling the minimum safe yield of its present development. It can, however, as before indicated, obtain an additional supply of forty (40) million gallons daily from its own sources.

The territory in Middlesex and Union counties served by the Elizabethtown, Middlesex and Plainfield-Union Water companies is, taken as a whole, faced with a serious situation which requires that an additional supply be provided immediately.

The demand on the Newark system is about equal to the supply, but upon completion of the Wanaque River project that city and other municipalities participating in the development will have provided for their needs for a number of years to come.

In East Orange, Perth Amboy and the territory served by the Commonwealth Water Company, safe margins, varying in proportions, exist.

In New Brunswick, under present conditions, the margin has disappeared and the consumption exceeds the safe yield.

The situation in the territory served by the Passaic Consolidated Water Company will be affected if upon the completion of the Wanaque development at the close of 1928, Paterson, Passaic, Clifton and Kearny, discontinue drawing water from the Passaic Consolidated Water Company and put in use their contract allotments in the Wanaque development.

Interchange of Water.

If the water resources of the Northern Metropolitan District could be effectively pooled and interchanged between sections, the need for an additional supply after the completion of the Wanaque development would, subject to the qualification hereafter noted, not become imminent until 1937 or 1940, the date depending upon whether that development will afford a yield of seventy-four (74) million gallons daily, as estimated by some, or one hundred (100) million gallons daily, as estimated by the engineers of the North Jersey District Water Supply Commission.

The extent to which water is interchanged at the present time is not generally realized. The total volume of water so interchanged amounts to approximately fifty (50) million gallons daily.

Table No. 11 illustrates the present extent of pooling. This interchange, however, is not intersectional, but chiefly between adjacent systems.

The statement before made, that under a system of effective pooling and interchange between sections the need for an additional supply after the completion of the Wanaque development would not become imminent until 1937 or 1940, is qualified by various factors, as for instance, that certain of the developed sources of supply have for various reasons proved undesirable and consequently will soon be abandoned, and that others are subject to rapidly increasing pollution. Any attempt to bring such sources into interchange may reasonably be expected to be met with stout resistance on the part of those served with waters from uncontaminated sources.

The effective pooling and sectional interchange of the waters of developed sources which are not subject to objection on the ground of pollution would, at all events, serve to alleviate the seriousness of existing conditions.

The pooling and sectional interchange of such waters should therefore be encouraged.

Adequacy of Available Water Resources.

The estimated ultimate development of sources of supply for the Northern Metropolitan District is given in Table No. 12.

Table No. 9 shows that the great bulk of water supplying the Northern Metropolitan District is used in the central section. It further indicates that this will be the case for many years to come.

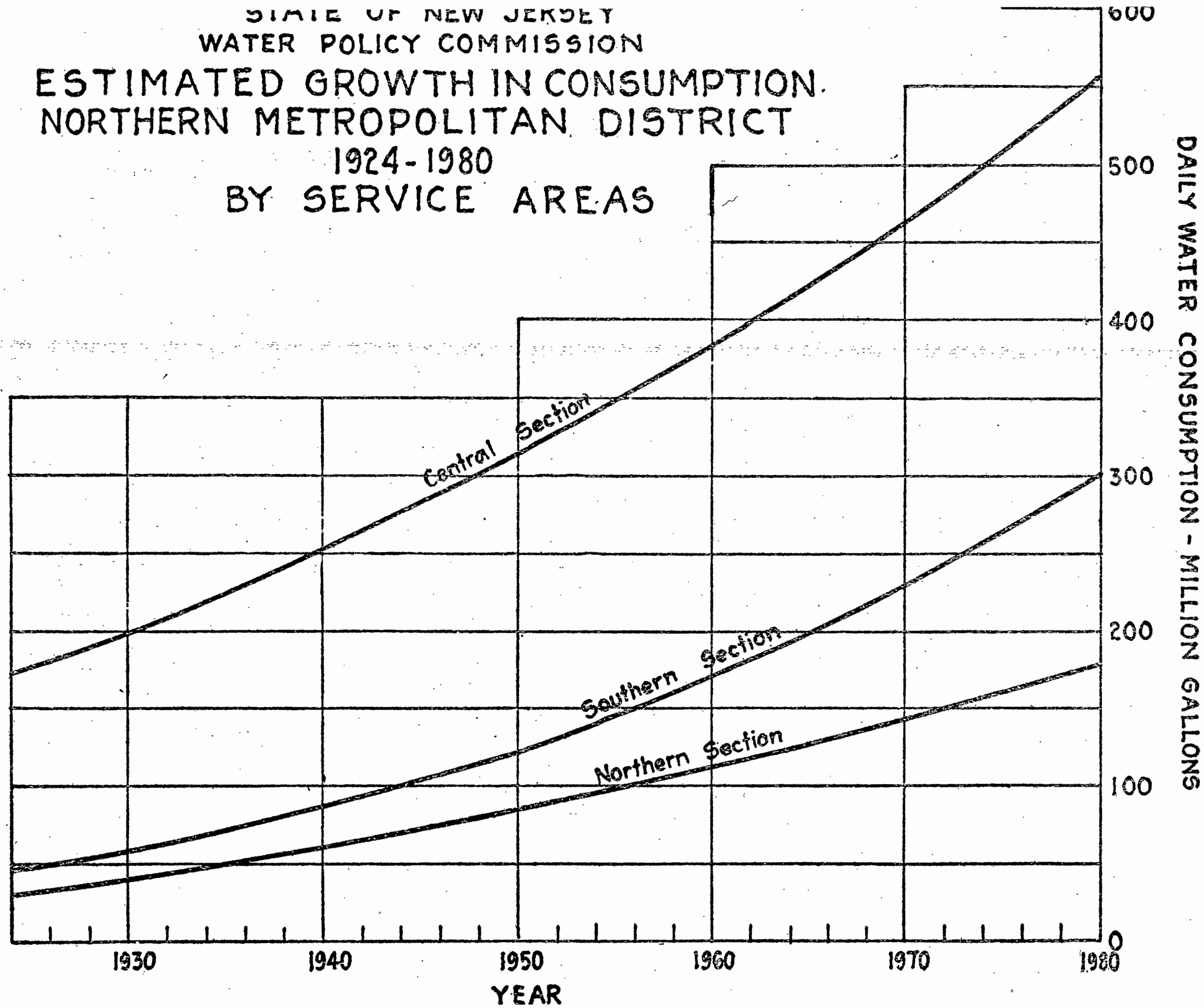
Diagram No. 3 shows the estimated growth in consumption for the three sections of the district for about fifty (50) years to come.

This diagram shows that in 1950 the northern section will require eighty-five (85), the central section three hundred and ten (310), and the southern section one hundred and twenty-three (123) million gallons daily.

It is therefore evident that the sufficiency of available sources is unquestioned. Their estimated yield is approximately ten times the present consumption, sufficient possibly for two hundred (200) years.

This sufficiency of available sources will not be substantially affected for practical purposes by the fact that it may prove necessary to abandon and to refrain from developing or further developing certain of the sources included in the estimates, because of pollution or other causes.

Looking ahead for the next fifty (50) years, or say, until 1980, it is probable that the sources shown in the table on page 28 are those most worthy of consideration for use or development:


STATE OF NEW JERSEY
WATER POLICY COMMISSION
ESTIMATED GROWTH IN CONSUMPTION
NORTHERN METROPOLITAN DISTRICT
1924-1980
BY SERVICE AREAS
Central Section
Southern Section
Northern Section
DAILY WATER CONSUMPTION - MILLION GALLONS
0
100
200
300
400
500
600
1930
1940
1950
1960
1970
1980
YEAR

Watershed (1)	Ultimate Daily Yield (Mil. Gals.) (2)	Total Ultimate Daily Yield (Mil. Gals.) (3)
Hackensack		50
Passaic	210	
Pequannock	57	
Ramapo	40	
Wanaque	100	
Rockaway	100	507
Raritan:		
North Branch	120	
South Branch	175	
Millstone	150	
Lawrence River	16	
South River	18	
Miscellaneous	29	508
Delaware:		
Musconetcong	110	
Pequest	140	
Paulins Kill	112	
Flat Brook	57	419
Ground water		60
		1,544

By reference to Table No. 8 it will be seen that the estimated requirements in the Northern Metropolitan District in 1980 will be a little over one thousand (1,000) million gallons daily, so that the selected sources will be adequate for fifty (50) years to come and will allow latitude for choice in the sequence of development.

The question now arises as to the best sequence to follow.

PIECEMEAL OR MAJOR CONSTRUCTION

In this question there is involved the further question whether there is not some method of piecemeal construction by which the sectional requirements of the district may be met and reasonable future needs satisfied at less cost than through the immediate embarking upon one of the major projects, so deferring the construction of such major project to a later time when the needs of the district as a whole will demand its execution. In such piecemeal construction should be included only such developments as may be utilized after the completion of the major project which may be adopted, unless the cost of such piecemeal developments is such that it will be cheaper to amortize their cost than to pay interest upon the larger project until it is required.

Provision for effective pooling or intersectional interchange of water will be essential for either local or major projects unless use thereof is to be confined to one section or unless equivalent but more costly independent conduit lines are constructed to convey the water to different parts of the district.

A glance at Map No. 6, which gives an outline of the larger mains in the three sections in the Northern Metropolitan District, shows that interconnection between sections will not be difficult. The majority of the present interconnections are either local or too small for proper interchange of water between sections.

If all of the existing water resources in the Metropolitan District, including the Wanaque, could be pooled and interchanged, it would be possible to meet the demands of the district until 1937 or 1940, depending, as before stated, upon whether the Wanaque is good for seventy-four (74) or one hundred (100) million gallons daily. Whether this source is good for the lower or the higher figure will not materially affect the situation.

The cost of connections to secure satisfactory interchange of water for some years to come will not exceed six million seven hundred thousand dollars ($6,700,000).

If, in conjunction with pooling, the following projects were completed as required:—

1. Diversion of twenty (20) million gallons daily from the Ramapo to Woodcliff reservoir on Pascack Creek, a tributary of the Hackensack;

2. Installation of a pumping station and filter plant on the Raritan River with an ultimate capacity of one hundred (100) million gallons daily, together with the construction of storage on the upper reaches of this stream which could subsequently be utilized in conjunction with either the Long Hill or Chimney Rock schemes, if desired; and,

3. The construction of two small additional reservoirs on the Rockaway to yield forty (40) million gallons daily;—

one hundred and sixty (160) million gallons could be added to the supply available.

The sequence and cost of this piecemeal construction are given in Table No. 13.

The cost of similar sequences for the Long Hill and Chimney Rock schemes is given in Tables Nos. 14 and 15.

In studying the relative economy of piecemeal as compared with a single great development at Chimney Rock or Long Hill, it has been assumed that in the interest of economy the pooling of existing sources will be carried out in all three cases, and that in 1937 to 1940, when these resources will have been exhausted, additional supplies will have been developed and placed in readiness for service as needed.

The period covered by the comparison extends to 1953.

It has been shown that the existing sources will supply two hundred and ninety-seven (297) million gallons daily. If to this is added one hundred (100) million from Wanaque, the total will be three hundred and ninety-seven (397) million gallons daily. (This conclusion is, of course, subject to the comment heretofore made with respect to polluted sources.)

Reference to Diagram No. 2 shows that the water requirements in 1953 will be five hundred and sixty (560) million gallons daily. If, therefore, in round figures, an additional supply of one hundred and sixty (160) million gallons daily is provided it will suffice until 1950.

It is estimated by Mr. Sherrerd that the first step in the Chimney Rock development will yield one hundred and fifty-eight (158) and by Mr. Hazen that the first three steps in the Long Hill project will yield one hundred and sixty-eight (168) million gallons daily. Comparison, therefore, of the piecemeal developments listed above with the first step in the Chimney Rock and the first three steps in the Long Hill schemes is equitable. The dates at which specific elements of construction under the three schemes will be required are given in column (2) of Tables Nos. 13, 14 and 15. Column (3) shows the estimated construction cost including overheads, column (4) construction cost reduced to present worth, and column (12) the total annual cost. Column (13) gives the average total cost per million gallons.

As will be seen, the relative capital outlay required for securing an adequate supply for the next twenty-five (25) years is as follows:

Piecemeal construction	$38,366,000
Long Hill	67,900,000
Chimney Rock	56,985,000

The average annual costs will be:

Piecemeal construction	$1,927,646
Long Hill	2,979,522
Chimney Rock	2,994,195

And the cost per million gallons supplied:

Piecemeal construction	$59
Long Hill	92
Chimney Rock	92

In making these comparisons the capital expenditures charged against piecemeal development have, if anything, been rather higher than lower in order to obviate any possible invidious comparison with the Chimney Rock and Long Hill projects. The estimated costs for the Long Hill project are based on Mr. Sherrerd's modification of Mr. Hazen's figures. The estimated costs for the Chimney Rock project are based on Mr. Sherrerd's estimates for that project.

In order that these two plans, however, may be on all fours, filtration has been included in both and the transmission system from reservoir site to the point of distribution has been placed on identical terms. (For details see Appendix II.)

The apparent margin of saving in favor of piecemeal construction is great. Cheapness, however, is not the only factor that must be taken into account. Other factors are of equal, if not greater, importance, among them the quality of water.

The outlined plan of piecemeal construction involves the use, as before noted, in some instances of water subject to rapidly increasing pollution and in others of water produced at excessive cost.

In favor of both the major projects hereinbefore considered and compared, weighs the fact that through these projects a large volume of water from the sparsely settled highlands is to be secured by gravity.

Table No. 16 gives the relative cost per million gallons of water from different sources delivered to the three sections of the Northern Metropolitan District.

CONCLUSIONS

On the basis of this data we conclude:

(a) That the situation which confronts many of the communities of the district is serious in the extreme and will become more serious during the next three years unless constructive remedial measures are adopted and made effective without delay.

(b) That the completion of the Wanaque development in the latter part of 1928 will in a measure ameliorate the gravity of the situation as it affects certain communities, but will not wholly meet, even temporarily, the conditions which give rise to serious concern.

(c) That it is feasible, both from the engineering and financial standpoint, to interconnect existing systems of supply and so provide for interchange of waters.

(d) That plans for such interconnections of systems and interchange of waters, at least insofar as such waters are not objectionable on the grounds of pollution, should be promptly adopted and put into execution.

(e) That where such interconnection will not serve to meet local needs temporarily, local supplies should be extended and expanded.

(f) That it will be necessary in addition to effecting such interconnection of systems and interchange of waters, and the extension and expansion of certain local supplies, to execute certain of the minor projects included in the possible piecemeal construction program hereinbefore outlined, in order that the conditions which will exist until supplies developed through a major project are available may be met. In the selection of such minor projects for development the problem presented by pollution will of course have to be considered.

(g) Into the selection of such minor projects for development the question whether a particular development may be utilized after the completion of a major project, or whether the cost of such minor project will be such that it will be cheaper to amortize such cost than to pay interest on the cost of the major project will enter.

(h) That because of the years required in planning for, securing the adoption of, acquiring lands and rights for, and constructing a major project, the major project to be undertaken should now be finally determined upon, and its execution put under way.

Because of the reasons hereinbefore indicated, we have not undertaken to determine which of the two major projects outlined should be adopted, nor to what extent, or through the selection of which of the possible minor developments, the program of piecemeal construction herein outlined should be executed. The determination should, in our judgment, be made and controlled by the permanent commission having jurisdiction within the district.

The situation is critical. The consequences of delay in meeting it effectively are menacing. It demands immediate, continuous, constructive action.

On the data considered by us and incorporated herewith, we are convinced that only by combining the interconnection of existing systems and the interchange of their supplies, the extension and expansion of certain of the local supplies, and the execution of one or more of the minor projects can the period between the present and the time when a major project is completed, be, with any reasonable degree of safety, tided over, and that the selection and construction of a major project will not admit of delay.

THE REGIONAL PROBLEM OF THE SOUTHERN METROPOLITAN DISTRICT

The facts before set out indicate that a regional water supply problem will soon confront this district. The safe yield of the available sources as now developed will, it is true, possibly suffice to meet requirements during eight (8) or ten (10) years to come.

Experience in the Northern Metropolitan District, however, demonstrates that this margin of time is brief, in view of the delays that are unavoidably incident to the planning for and executing a major development such as is required to meet ultimate regional needs.

If a repetition in the Southern Metropolitan District of the acute and pressing conditions which now confront certain of the communities of the Northern Metropolitan District is to be avoided, effective steps toward meeting the need that will be imminent eight (8) or at most ten (10) years hence must be taken without delay.

As early as 1911 the approach of a regional problem in this district was foreseen by the then State Water Supply Commission. The problem and the means of meeting it were considered in a report submitted to that commission by Harry R. Humphreys, one of its members. (Report 1911, p. 40.)

We quote from that report (p. 41.): "What is known as the 'Wharton Tract' are the lands acquired by the late Joseph Wharton, in the counties of Burlington and Atlantic, comprising about 100,000 acres, or 156 square miles, entirely within the boundaries of the watershed of the Mullica River and its tributaries. The main part of the tract lies above the forks of Mullica River at Batso, and covers 91 square miles, or forty-two per cent. of the total drainage above that point, 221 square miles. The balance is chiefly on the drainage of Wading River, a lower tributary of the Mullica River. Eighty-eight per cent. of the drainage area is forested, and of the Wharton lands not less than ninety-five per cent. are wooded. The upper Mullica River alone is capable of supplying all of the water that the cities of the State south of the Raritan River are likely to need for many generations. The total population on the tract does not exceed 100.

"The drainage area of those branches of Mullica River under the Wharton control is 399 square miles, which will supply with storage 240,000,000 gallons daily throughout the year. Storage reservoirs for the waters of the river at the highest level (70 feet above tide), including some small reservoirs on the headwaters of Rancocas Creek, could be constructed with a capacity of 25,284,000,000 gallons. Storage reservoirs for the same waters at lower levels could be constructed with a capacity of 18,138,000,000 gallons. A distributing reservoir for the same waters could be built on Cooper River at 61 feet, holding 2,000,000 gallons.

"Also near to the tract and adjoining it is the watershed of the Great Egg Harbor River. This river above Mays Landing drains 215 square miles, and with storage reservoirs to hold as provided, 13,267,-000,000 gallons will supply 143,800,000 gallons daily. Other minor sources on the headwaters of Rancocas Creek could add 13,000,000 gallons.

"Within the drainage area of the east branch of Wading River and Bass River, the State owns 4,400 acres, and east of it is a large area held by many owners that is even less populous than the Wharton tract. I am informed that these properties could be acquired at even a lower price than the lands of the Wharton tract, inasmuch as they are not nearly so desirable for many purposes and resemble only the very poorest of the lands in the Wharton tract. Within the 4,400 acres owned by the State there is a hill known as Bear Swamp Hill, the elevation of which is 165 feet. The character of the hill is such that there could be built thereon a reservoir covering 40 acres at an elevation of 120 feet." * * * * * "The New Jersey Geologists report states: 'The analyses given in the report of 1893 shows the general character of these Southern New Jersey waters to be exceptionally good. We have no waters in the State, not even the excellent waters of the Highlands, which make so good a showing as these for softness and purity.'

"The waters of these streams are seldom, if ever, muddy or turbid * * * * *

"To comprehend the project of utilizing the South Jersey streams, it is necessary to understand that the region lying between the Delaware River and the Atlantic Ocean, having an approximate width of 50 miles, is drained mostly into the Atlantic because the broad highest level of that region lies comparatively near the Delaware; the divide being, in fact, but 12 to 15 miles eastward from that river, and approximately parallel to it. Thus the streams running eastward are much more important than those flowing into the Delaware, for the former drain about three-fourths of the intervening territory. * * *

"The most available streams for our purposes are those which converge to form Mullica River. * * * * They empty into that river not far from its entrance into Great Bay and spread out their tributaries fanlike far and wide into the interior of the State until the extreme headwaters reach within about fifteen miles of the Delaware River. * * * The course of one of those streams, the Atsion River, is such that its sources almost interlock with those of Rancocas Creek and Cooper River, so that a canal of but few miles length * * * would unite the waters of the Atsion with those of the north branch of Cooper River.

"The project to which your attention is called is, in brief, to dam at or near the head of tidewater the several streams forming Mullica River, gather their waters by back flow into a reservoir at the village of Atsion, where the C. R. R. of N. J. can deliver coal cheaply: then to force them farther upstream, or westward, into a reservoir having an elevation of 70 feet above tide, let them flow by gravity through the canal above mentioned to a reservoir at the elevation of 61 feet, to be formed by damming the north branch of Cooper River. From the lower or western end of this latter reservoir, called on the map Haddon Reservoir, a sufficient quantity would flow through pipes to a distributing reservoir for the supply of Camden and many other nearby rapidly growing communities. We are officially informed that both Camden and Atlantic City will need additional water from this or some other source within five to eight years. Trenton needs it at once.

"Batso, at the forks of Mullica River, where a collecting reservoir is indicated, is 18 miles from Atlantic City's pumping station at Absecon, 42 miles from Trenton, 80 miles from Jersey City. All these distances are measured by straight lines, for south of Trenton any construction could follow the most direct course.

"Newark's pipe line is 27 miles long and Jersey City's 19, so the disadvantage of distance by comparison with Newark and Jersey City is not so great after all. * * * * *

"Naturally any system of water distribution would provide for main lines with laterals wherever needed. To provide means of distribution for other than those who could be supplied from the Camden scheme, it is suggested that the hills found in the neighborhood may serve as sites for reservoirs into which the water would be pumped, thence to be delivered by gravity. These hills, Apple Pie Hill, 200 feet high, being the highest, are of gravel or soft sandstone.

"There are few, if any, riparian rights to be satisfied on any of the streams considered in this plan.

"Practically the ownership and absolute control over what is virtually two entire drainage areas extending to tide water, each comprising 100,000 acres of land, can now be secured for less than two (2) million dollars. Such a low cost for land would justify a large outlay for distribution works (much more than will be necessary), and provide water at a very low cost per million gallons."

We deem it sufficient for the purposes of this report that this statement be presented by quotation. We have not submitted the matters set forth therein to checking.

Subsequent to the submission of this report the State Water Supply Commission entered into a contract to purchase the Wharton tract, giving in payment $1,000,000 of the commission's bonds.

This action of the commission in so contracting was made the subject of a "test-suit" to determine whether it violated the constitution of the State. The Court of Errors and Appeals, reversing the Court of Chancery, finally determined that the proposed issue of bonds could not be effected without the affirmative vote of the people of the State. In 1915 the Legislature accordingly enacted a statute submitting the proposal to issue the bonds to the electorate of the State at the general election in that year. The submission resulted in the rejection of the proposition.

It is, nevertheless, our conviction that the sources of supply, and lands necessary to their conservation and protection, referred to in the foregoing quoted statement should, without further delay, be acquired in public ownership. It is also our conviction that the sources of supply, and lands necessary to their conservation and protection, required for the major development that may be adopted to meet the regional needs of the Northern Metropolitan District should without loss of time be acquired in public ownership.

Experience in the Northern Metropolitan District, and elsewhere, shows that delay, though for a comparatively short time only, in acquiring in public ownership sources and lands essential in the prosecution of projects such as those here considered, results in the creation of conditions which substantially increase the difficulties and cost of acquisition.

It will be necessary again to advert to this subject in connection with our consideration of policies for the future.

EXISTING LEGISLATION

With this background of fact, the existing legislation of the State, relating to the problems considered, is now briefly reviewed.

BOARD OF CONSERVATION AND DEVELOPMENT

The Board of Conservation and Development is a State administrative agency, consisting of eight members appointed by the Governor by and with the advice and consent of the Senate.

By virtue of section 5, of chapter 241 of the Laws of 1915, this Board succeeded to, and is now vested with, the jurisdiction and powers of the State Water Supply Commission, except in so far as such jurisdiction and powers are restricted by the statutes constituting and relating to Water Supply Districts. (P. L., 1916, p. 70; P. L., 1916, p. 71).

By chapter 252 of the Laws of 1907 it is charged with "a general supervision over all the sources of potable and public water supply to the end that the same may be economically and prudently developed for the use of the people of the State."

SURFACE WATERS

This statute, among other things, by section 2 thereof, provides that "No *municipal corporation, corporation or person* engaged in supplying or proposing to supply the inhabitants of any municipal corporation with water shall have power to condemn lands or water for any new or additional source of water supply, or to divert water from such new or additional source, until such municipal corporation, corporation or person has first submitted descriptions thereof" to said Board, "and said Board shall have approved the same; provided, nothing in this section shall be interpreted to restrict any municipality in acquiring, by purchase or condemnation, any existing or operating water works supplying said municipality with water. * * * Nothing in this act contained shall be construed to take from any municipality in this State the right to use and take all the water which it has the right to use or appropriate by purchase or condemnation."

The statute prescribes in detail (Sec. 3) the procedure in accordance with which application shall be made by any municipal corporation, corporation or person for the approval of its plans for obtaining such new or additional source of water supply and the procedure which shall be followed by the Board in acting upon such application. It provides that "After due hearing, the Commission shall decide whether the plans proposed are justified by public necessity or reasonably anticipated public use, and whether such plans interfere unduly with the opportunity of other municipalities to obtain a water supply by the taking of waters necessary for their use, or whether the reduction of the dry-season flow of any stream will be caused to an amount likely to produce unsanitary conditions or otherwise unduly injure public or private interests."

It requires that "the Board either approve such application, reject it entirely, or approve the same subject to such reasonable terms and conditions" as the Board may prescribe.

It further provides that the approval of the Board "shall constitute the State's assent to the diversion of water and the construction and operation of the water-works in accordance with the terms of the decision and the plans filed therewith. The decision" of the Board "shall at all times be subject to review by the courts for reasonableness, legality or form."

Subsurface and Percolating Waters

By chapter 304 of the Laws of 1910, the Board is given "the same jurisdiction and supervision over well, subsurface or percolating water supplies now or hereafter furnished to the inhabitants of any municipal corporation as it now has over surface water supplies so furnished, except as such jurisdiction and supervision may be herein modified."

This act in its provisions as to subsurface, well or percolating waters substantially parallels the requirements of chapter 252 of the Laws of 1907, relating to surface waters, previously referred to.

This statute by its fifth section further provides: "Whenever application is made" to the Board "in conformity to this act or the act to which this is a supplement" (P. L., 1907, chapter 252) "by any municipal corporation, or whenever any municipal corporation now legally engaged in diverting and supplying water, either surface, subsurface, well or percolating, to the inhabitants of any municipal corporation, shall request * * * * by petition in writing for permission to exercise the right of eminent domain for the acquisition of the necessary lands and water rights, either in case of surface, subsurface, well or percolating waters for the purpose of diverting the same for the supply of the inhabitants of any municipal corporation, the" Board "may, in its discretion, grant such permission, first being satisfied that it is for the public interests so to do, and after such permission is granted the necessary lands, water rights and interests in lands and water rights affected may be condemned by the applicant in the manner now provided by law."

Acquirement of Lands, Water Rights and Interests Therein by the Board for Appropriating or Conserving Potable Waters of the State

By chapter 318 of the Laws of 1912 (amended by chapter 128 of the Laws of 1913) the State Water Supply Commission was authorized to acquire lands, water rights, and interests therein for the purpose of appropriating or conserving the potable waters of the State. In Attorney-General *vs.* State Water Supply Commission, 84 New Jersey Equity Reports 150, the Court of Errors and Appeals construed this act and held that the bonds contracted to be issued by the commission in purchase of the Wharton tract before referred to, would constitute a debt of the State and could not be issued except in accordance with the provisions of section VI, article V, of the Constitution of the State requiring the approval of the electorate of the State. This limitation has made this statute practically inoperative.

Dams

Chapter 243 of the Laws of 1912 (as amended by Chapter 44 of the Laws of 1919) among other things provides that (sec. 1):

"No *municipal corporation, corporation or person* shall, without the consent of the" Board "build any reservoir or construct any dam on any river or stream in this State or between this and any other State which will raise the waters of such river or stream more than five feet above their usual mean low-water height, nor repair, alter or improve dams now existing which so raise the waters without such consent; but this act shall not affect or relate to dams where the drainage area above the same shall be less than one square mile in extent; provided that in case the water surface created by any such dam or reservoir is less than one hundred acres in extent, the necessity for obtaining the approval of the" Board "for the repair of any such dam which would raise the water less than eight feet above the surface of the ground shall not be necessary unless complaint be made in writing to the" Board "raising a question as to the safety of the existing structure."

(Sec. 2.) "Every *municipal corporation, corporation or person,* before the erection by it of any dam or reservoir subject to the provisions of this act shall apply to the" Board "for the approval of the plans of such dam or reservoir, which approval said" Board "is authorized to grant with such modifications, limitations or changes as in its judgment may be necessary for the protection of life and property."

WATER SUPPLY DISTRICTS AND COMMISSIONS

Chapter 70 of the Laws of 1916 (amended P. L. 1919, p. 62) divides the State into two districts for the purpose of municipal water supplies, one to be known as the *North Jersey Water Supply District* and the other as the *South Jersey Water Supply District.*

The North Jersey Water Supply District consists of the counties of Sussex, Warren, Hunterdon, Passaic, Morris, Monmouth, Somerset, Bergen, Hudson, Essex, Union and Middlesex.

The South Jersey Water Supply District consists of the remaining counties of the State.

The act after dividing the State into these two districts provides:

"Each of said districts shall be entitled to all of the authority and shall be subject to all of the laws of the State concerning water districts so created."

Chapter 71 of the Laws of 1916, as amended, authorizes the appointment of district boards of water supply commissioners in the water supply districts created by the act dividing the State into two water supply districts.

The Commission to be appointed for the North Jersey Water Supply District is designated the North Jersey District Water Supply Commission, and that for the South Jersey Water Supply District, the South Jersey District Water Supply Commission.

Each of the commissions is to be appointed by the Governor and is to consist of four (4) members who shall be residents of the water supply district which they represent, and "not more than two of said commissioners shall be of the same political party."

The commission is constituted a body corporate.

A commission is to be appointed for a district only upon the adoption of a resolution by the body having charge of the water supply in a municipality of the district, determining that it is in the interest of said municipality that a district water supply commission be appointed for the water supply district wherein such municipality is located for the purpose of "developing, acquiring and operating a water supply or new or additional water supply for the use of such municipality and such other municipalities as may be authorized to join with it according to the terms of" the act, and the presentation of a petitition to the Governor praying for the appointment of such a commission.

The statute provides that a municipality of the district for which a commission has been appointed may petition the commission "for a water supply or a new or additional water supply;" it provides for public hearing on such petition; that upon such hearing "any municipality appearing may signify its desire to acquire such existing water supply or to obtain such new or additional water supply, and its willingness to join with other municipalities to that end;" that thereupon the commission shall formulate plans for obtaining a water supply or a new or additional water supply for said municipality and any other municipalities that may desire water from such joint water supply, and report said plans to said municipalities together with a form of contract; that if it shall be necessary to redraft said form of contract either because of suggested modifications or the failure of any municipality to accept it, or because of the withdrawal of any municipality from further participation, the form shall be redrafted and resubmitted "until a form of contract has been agreed upon by said commission and one or more municipalities;" that when such contract is executed the commission shall "proceed to carry out the same." Powers, including the power of eminent domain, for the execution of such contract are, in great detail, conferred upon the commission.

The statute provides for the distribution of the cost of construction and acquisition, and the cost of operation, among the contracting municipalities "in proportion to the amount of water contracted to be taken in the contract between each of said municipalities" and the commission.

It further provides that upon the completion of such water supply plant the commission is to retain and have sole control and charge thereof, except such part of the same as the commission may convey to one of the contracting municipalities, "*in trust*, however, for each of the contracting municipalities, and such other municipalities as may be entitled to share in the said water supply."

It provides that the commission shall have power to convey any part or all of any distribution system or water plant acquired by it to the municipality in which the same is located at the cost thereof.

The statute makes provision for the supplying of water by the commission to municipalities, other than the contracting municipalities, applying therefor after, or in the course of, the construction, acquirement or operation, of any plant by the commission and also for the acquirement of part ownership in such plant by said other municipalities, if the water supply is adequate.

The commission is without power to act upon *any* petition for a municipality for a water supply or a new or additional water supply, until it has obtained the consent of the Board of Conservation and Development to the diversion of waters for such water supply, which consent can only be granted after public hearing.

It should be noticed that, consequently the commission is without power to act except as a municipality contracts with it, and that it is without power to contract with a municipality, except as it obtains the consent of the Board of Conservation and Development to the diversion of the required waters.

The only control that the commission has over developments in its district is by virtue of the following provision of the statute: "Whenever any district commission has been brought into being by virtue of this act, it shall be unlawful for any municipality within the water supply district represented by said commission to obtain any new or additional water supply from any watershed other than the watershed or watersheds from which said municipality obtains its existing supply, without the consent of said district water supply commission."

The North Jersey District Water Supply Commission has been created under this statute.

No steps to constitute the South Jersey Water Supply Commission have been taken.

Municipalities

"An Act Concerning Municipalities," Chapter 152 of the Laws of 1917, Article XXXII, provides among other things that: Every municipality may provide and supply water or an additional supply of water, for the public or private uses of such municipality, in any one or more of the following methods:

(a) Any municipality may, either singly or with one or more other municipalities, enter into a contract or contracts with the district board of water supply commissioners in which such municipality is situate.

(b) Any municipality may enter into a contract or contracts from time to time, for a period not exceeding fifteen years, with any other municipality in this State having water works, or with any private corporation having or controlling water works, to obtain a supply of water for public and private uses of such first mentioned municipality and its inhabitants.

This provision must be considered in connection with section 15 of Article XXXII, which provides that: It shall be lawful for the governing body of any municipality owning or controlling water works to enter into and make a contract or contracts with any municipality or municipalities to furnish a supply of water for such other municipalities and their inhabitants, for public and private uses, for the term of a year or years; provided there shall first be obtained the approval of the Department of Conservation and Development or other State board or department having jurisdiction of such matters, which approval or consent said commission or other board or department may withhold or grant upon such terms as it may deem proper, but in case approval and consent are withheld, the reason for such withholding shall be furnished by said department or board to the municipality applying therefor. It must also be considered in connection with section 16 of Article XXXII (as amended by Chapter 63 of the Laws of 1920, which makes it lawful for any municipality owning or controlling water works to supply dwellers and other consumers of water in other municipalities through which their mains may pass.

This provision is also affected by Chapter 194 of the Laws of 1923, which enacts that: Any municipality, or two or more municipalities, of this State, may make and enter into a contract with any water company, or more than one water company, for a supply of water or additional water for domestic and public use for a period not exceeding thirty years, on such terms and conditions, at such rates and with such exclusive provisions for revision of rates from time to time as may be agreed on, and any such company or companies is and are thereby authorized to make and enter into such contract provided that nothing therein shall be construed to limit or in anywise restrict the right of any municipality entering into such contract to acquire the works of any water company or water companies, party thereto, either by purchase or condemnation under any law in force at any time during the term of such contract. In case any water company is or two or more water companies are supplying water in two or more municipalities, any such contract may be made by such company or companies and any two or more of such municipalities having according to the last preceding national or State census more than a majority of the population of all the municipalities in which such company is or companies are supplying water at the time such contract is made, and in that case water shall be supplied in both or all of the municipalities in which the company or any of the companies, party or parties to such contract, is or are supplying water for domestic and public use, on the terms and conditions and at the rates prescribed in the contract or fixed from time to time as therein provided.

(c) Any municipality may purchase or lease from any person or persons, corporation or corporations owning water works supplying such municipality with water or adapted to furnish such supply, and any such person or persons, corporation or corporations, are hereby authorized to sell and convey or lease all or any part of the real estate, personal property and works, and all or any part of the corporate rights, powers, franchises and privileges of said person or persons, corporation or corporations, for such sum as may be mutually agreed upon by and between the said municipality and the said person or persons, corporation or corporations. * * * In case of any disagreement between the said municipality and the said person or persons, corporation or corporations, as to the amount of compensation to be paid, said municipality may condemn said real estate, personal property and works, and all the corporate rights, powers, franchises and privileges of said person or persons, corporation or corporations.

In connection with this provision, Chapter 62 of the Laws of 1920 and Chapter 183 of the Laws of 1923 must be taken into account, which enact that in case any municipality which did not provide and supply its inhabitants with water by or from water works owned and operated by it at the time of the approval of the act shall desire to acquire by purchase, lease or condemnation any existing water works system or plant, or any part thereof, for the purpose of supplying water for the public or private uses of such municipality, any resolution or ordinance providing for the same shall not become effective until after the expiration of thirty days from the passage or adoption and publication thereof and that within such period a referendum vote may be demanded by ten (10) per centum of the legal voters who voted at the last general election held for members of the General Assembly in such municipality.

(d) Any municipality may purchase, condemn or otherwise acquire the necessary lands, and rights or interests in lands, and water rights and rights of flowage or diversion, within or without such municipality, for the purpose of a water supply, or an additional water supply. The municipality may construct, erect, maintain and operate dams, canals, acqueducts, reservoirs, basins, standpipes, buildings, purification plants, and all necessary pipe-lines and other works; and may drill, dig, construct, operate and maintain artesian wells, when in its judgment the same may be needed for the purpose of such water supply, and may provide for the protection of the same from pollution by the construction of sewers or by other means. Such municipality may completely furnish and equip any water works with all necessary and useful machinery and other appliances.

Section 31 of Article XXXII provides: "*Nothing in this act shall be construed to effect the power or authority of the Department of Conservasion and Development, of the Department of Health of the State of New Jersey or of the North Jersey Water Supply Commission or the South Jersey Water Supply Commission.*"

Chapter 195 of the Laws of 1923 makes a new departure, and provides for creating in addition to the Board of Conservation and Development and the Water Supply District Commission local commissions based on two or more municipalities. This act provides that the governing body of *two or more municipalities in this State in which water is supplied for domestic use by privately owned waterworks*, whether such water works are owned by one or more corporations or parties, may make application to any justice of the Supreme Court for the appointment of a commission in their behalf to acquire such water works, either by purchase or condemnation, together with all rights and franchises relating thereto, and the rights and franchises to obtain an additional supply of water, and any or all other property of the owner of such water works that may be necessary to maintain, operate, enlarge or extend the water works so acquired, and to enlarge, extend, maintain and operate the same to supply water in the municipalities acquiring such water works and in all other municipalities theretofore supplied with water by the same water works, *provided* that all of the municipalities so supplied with water shall be notified in writing of such application at least sixty days before the same is made and may join therein.

The commission to be appointed is to consist of not more than five persons, residents of the municipalities making the application for their appointment, or joining therein. The commission is to proceed to negotiate for the purchase of the *entire* water works supplying water in the municipalities making the application for its appointment, and in the other municipalities, if any, supplied with water from the same water works. The term water works (section 3) is construed to include one system or more than one system of water works, whether or not such water works extend into or supply water in other municipalities than those proposing to acquire or owning the same, and water works, rights and franchises owned by one corporation or party, or more than one, and shall include rights and franchises to obtain an additional supply of water, and any and all other appurtenant property of such owner or owners.

The commission is empowered to enter into contract to purchase such water works for compensation to be agreed upon, or fixed by condemnation.

The contract is to be submitted to the municipalities that may have made or joined in the application and is to become binding only as to such two or more of the municipalities that made such application and joined therein, as shall by resolution file their assent thereto within three months.

If the commission and the owner of the water works cannot agree on terms for the sale thereof, or if such proposed contract shall not become binding, the commission shall make application for the appointment of commissioners to condemn the water works.

Any municipality may withdraw from the condemnation proceedings at any time within thirty days after the award of the commissioners shall be made.

The water works acquired by the commission shall be the property of the municipalities making the application for the appointment of the commission and joining therein, "as if they constituted a single municipality."

The commission appointed pursuant to the first section of the act is given power to enlarge and extend the water works, and operate the same, or to contract for periods not exceeding ten years for the operation thereof by any individual, firm or corporation, and subject to specified restrictions is empowered to prescribe rates.

At any time water works shall have been acquired under the act the governing bodies of the municipalities owning the same may enter into an agreement prescribing a method of electing or appointing a commission to succeed the original commission for the maintenance, operation, extension and enlargement of the water works and the management of its affairs, which agreement and amendments thereof shall be valid when consented to by the governing bodies of the municipalities containing at least two-thirds of the population of all municipalities owning such water works according to the last preceding national or State census.

Power is conferred upon the commission, so constituted by agreement, to "sell any part of the property in its charge not needed for public use, and also to sell to any municipality the distributing system or mains therein and enter into a contract to supply water in quantity to the municipality purchasing such distribution system, *provided*, that no distributing system shall be sold to any municipality without the consent of the governing bodies of the municipalities owning the same having by the last national or State census at least two-thirds of the population of all such municipalities.

The act also provides that after the appointment of the commission by the justice of the Supreme Court, any municipality in which water is supplied by water works which it is proposed to acquire, or which may have been acquired under the act, may be permitted to join with the municipalities making or joining in the application for appointment of commissioners or joining therein, or owning the water works, on such terms and conditions as may be agreed upon; *provided* that municipalities containing at least two-thirds of the population according to the last State or national census of all of the municipalities seeking to acquire or owning such water works shall agree to permit such other municipalities to join.

The act repeals all acts and parts of acts inconsistent therewith.

General Power for Joint Municipal Action

Paragraph 12 of Article XXXVII of "An Act Concerning Municipalities," before referred to (Laws 1917, p. 319), provides that:

"Two or more municipalities may join together to do any act, maintain any department or render any service which one municipality is empowered to do, maintain or render.

"Before so joining said municipalities shall cause to be drawn up a written contract setting forth the proportion of cost of the doing of such act, maintaining of such department or rendering of such service each shall assume, and specifying all the details of the management thereof, and such other matters as may be deemed necessary for insertion therein; any such contract may be amended from time to time by the consent of the contracting municipalities; upon any such contract being approved by the governing bodies of each of said municipalities it shall be signed by the chief executive officer of each and sealed with the municipal seals.

"For the purpose of carrying into effect any such contract, municipalities may acquire lands as tenants in common by purchase or by condemnation, and may erect buildings thereon and equip the same, and may acquire and hold any personal property in common, and may appoint such officers and employees as may be necessary for the joint enterprise, and may jointly enter any contract which a single municipality is authorized to enter into under this act."

The serious lack of harmony in the mass of legislation relating to water supplies and the grave doubts and uncertainties that it raises as to the extent of repeal through implication, and as to powers and procedure, are so evident on the bare outline of the legislation that detailed indication thereof seems unnecessary.

In framing this mass of legislation particular objects desired, from time to time, to be accomplished seem only to have been kept in view, and the necessity of framing new legislation so that it will fit into the old framework has been disregarded.

Under such a complex and disharmonious body of legislation no municipality or group of municipalities can, with any sense of confidence or degree of certainty, be advised as to powers or procedure, or as to when action can be taken independently and when the consent of a State board or district commission is required.

As the legislation stands, through lack of clarity, it may well afford a ready means to private companies to obstruct and delay a municipality or group of municipalities desiring to acquire an existing water supply system, or to develop a new or additional supply, and may well afford a ready means to coerce municipal assent to inequitable terms and conditions in order that a vital and imminent need may be met without protracted delay.

The subject admits of comparatively simple legislative treatment with due regard for public and private interests.

These statutes should be unified, harmonized and simplified.

Consents to Diversion

The variances in the requirements for consent to diversion imposed by this legislation are marked. The consent of the Water Supply District Commission is only required when a municipality within the water supply district seeks to obtain any new or additional water supply from any watershed other than the watershed or watersheds from which such municipality obtains its existing supplies.

The requirement extends to municipal corporations *alone,* and not to other corporations or persons engaged in supplying water, and to municipal corporations *only* where they seek to enter a watershed other than that from which they obtain their existing supplies. Apparently the requirement does not extend to subterranean or percolating water sources.

The consent of the Board of Conservation and Development, however, is required to *all* diversions for a new or additional supply of water *by any municipal corporation, corporation or person* engaged in supplying water.

The requirement for such consent extends to well, subsurface and percolating water supplies as well as surface supplies.

The result is on the one hand to leave the Water Supply District Commission without effective control over developments within the district and on the other hand to require a municipality seeking to avail itself of a watershed other than that from which its existing supply is obtained to obtain, first, after public hearing, the consent of the Water Supply District Commission, and, second, after public hearing, the consent of the Board of Conservation and Development. If the proposed Delaware River Tri-State Compact is adopted, it will in the case of diversion from channel or tributaries of the river require such municipality to obtain a third consent, that of the Tri-State Commission.

Such conditions make against harmonious and effective administration.

Policy in Existing Legislation

The statutes under which the Board of Conservation functions and Water Supply District Commissions may be created, make evident a legislative intent to develop a policy under which no municipality may take for itself alone a source of water supply irrespective of the requirements of other municipalities and the fact that such other municipalities may economically and advantageously be served from such source as well.

Such legislative intent is manifested by the requirement in the statutes governing the Board of Conservation and Development that upon applications for consent to that Board they shall determine whether the plans proposed are justified by public necessity or reasonably anticipated public use, *and whether such plans interfere unduly with the opportunity of other municipalities to obtain a water supply by* *the taking of waters necessary for their use* or whether the reduction of the dry-season flow of any stream will be caused to an amount likely to produce unsanitary conditions *or otherwise unduly injure public or private interests.*

The statutes providing for Water Supply District Commissions further make clear the intent to develop such policy by specifically providing for the admission of municipalities other than the originally contracting municipalities into participation on equitable terms in developments after they have been made.

The policy so evidenced the Board of Conservation and Development has now furthered, through its power to impose conditions in granting consent, by adopting in effect the principle that important watersheds may be developed by a single municipality only as trustee for all municipalities which can naturally be supplied therefrom and that the partial development of an important watershed by a single community in its own interest to the exclusion of other communities which may need the water must not be permitted.

The policy so legislatively declared should be maintained and broadened.

Constitutional Provisions that Must be Especially Considered in Inaugurating a Comprehensive State Policy

Article IV, Section VI, paragraph 4 of the Constitution of the State provides: "The legislature shall not, in any case, create any debt or debts, liability or liabilities, of the State which shall singly or in the aggregate with any previous debts or liabilities at any time exceed *one hundred thousand dollars,* except for the purposes of war, or to repel invasion or to suppress insurrection, unless the same shall be authorized by a law for some single object or work, to be distinctly specified therein, which law shall provide the ways and means, exclusive of loans, to pay the interest of such debt or liability as it falls due, and also to pay and discharge the principal of such debt or liability within thirty-five years from the time of the contracting thereof, and shall be irreparable until such debt or liability, and the interest thereon, are fully paid and discharged; and no such law shall take effect until it shall, at a general election, have been submitted to the people and have received the sanction of a majority of all the votes cast for or against it at such election; and all money to be raised by the authority of such law shall be applied only to the specific object stated therein, and to the payment of the debt created thereby. This section shall not be construed to refer to any money that has been, or may be, deposited with this State by the government of the United States."

It was this provision of the Constitution of the State that in *Wilson* v. *State Water Supply Commission*, 84 New Jersey Equity Reports, 150, reversing the decision of the Chancellor in 82 New Jersey Equity Reports, 32, proved fatal, as before noted, to the contract entered into by the State Water Supply Commission for the acquisition of the Wharton tract for $1,000,000 in bonds.

In *VanCleve* v. *Passaic Valley Sewerage Commissioners*, 71 New Jersey Law Reports, 574, the Court of Errors and Appeals declared that: "The decisions of this State establish two propositions touching the delegation of the power of general taxation—*first*, that the legislature can delegate the taxing power only to *political districts* of the State, to be exercised within their respective limits; and *second*, that some power of local self-government is essential to every political district."

It was these principles that proved fatal to the original statute creating the Passaic Valley Sewerage Commission.

Article IV, Section VII, paragraph 11, provides that: "The legislature shall not pass private, local or special laws in any of the following enumerated cases, that is to say: * * * Regulating the internal affairs of towns and counties; appointing local officers and commissions to regulate municipal affairs * * * The legislature shall pass general laws providing for the cases enumerated in this section * * *"

Memoranda will later be filed dealing in some detail with the questions raised by these constitutional provisions and principles.

CONCLUSIONS AND RECOMMENDATIONS

In the light of the foregoing facts, the existing statutes, and the controlling constitutional provisions and principles, the following conclusions have been reached:

1. That there is no single State problem of water supply development; that there is a regional problem in what we have designated the Northern Metropolitan District, including the counties of Essex, Hudson, Bergen, Passaic, Middlesex and Union; that there is also a regional problem in what we have designated the Southern Metropolitan District, including the counties of Mercer, Burlington, Camden and Gloucester; that the problems in the remaining counties of the State are local rather than regional; that the regional problem in the Northern Metropolitan District varies in imminence and seriousness in the three sections into which the district divides itself; that the regional problem which confronts the Southern Metropolitan District is neither so acute or pressing as that in the Northern Metropolitan District, but that preparation to meet it can not wisely be delayed.

2. That no attempt should be made to meet these varying problems through centralizing jurisdiction, control and *power to make developments* in a single State agency; that the attempt to meet these problems through the establishment of the State Water Supply Commission, as such a single State agency, failed; that the necessity of submitting to the electorate of the *entire* State from time to time, for their approval, proposals involving State expenditures for developments in the interest of the people of part of the State would involve in doubt the authorization of imperatively demanded regional developments and occasion costly delay.

3. That the State should, however, proceed without unnecessary delay to acquire in ownership, *as distinguished from actual development for water supply purposes*, the remaining undeveloped major sources of water supply, and the lands necessary for their conservation and protection, and to provide for the forestration of such lands.

4. That as a progressive step in this direction, there should be submitted to the electorates of the State a proposal for the issuance of the State bonds essential in the acquirement of the sources of supply and necessary lands referred to herein under the heading "*The Regional Problem of the Southern Metropolitan District*" and the sources of supply and protecting lands required in the execution of the next major project that may be determined to be most advantageous to meet the regional needs of the *Northern Metropolitan District.*

5. That it may ultimately be necessary in maintaining a comprehensive policy to extend the acquisition by the State of sources of supply to the acquirement of already developed or partially developed major sources. But that the acquirement by the State of the remaining undeveloped major sources is of immediate importance and a matter of present concern.

6. That in the acquirement of such sources of supply and lands, and in their care and administration, no new State agency need be created and that for such purpose the Board of Conservation and Development be constituted the agency of the State.

7. That the division of the State into the two (2) water supply districts be continued; and that the act providing for a North Jersey District Water Supply Commission and a South Jersey District Water Supply Commission be maintained.

8. That the North Jersey District Water Supply Commission having been brought into existence, and the fact being indicated by the data herein set out that a like commission may usefully serve in the South Jersey District, the South Jersey District Water Supply Commission should be constituted. Until such South Jersey District Water Supply Commission is brought into existence all of the power, authority and jurisdiction which would be possessed by such commission should be vested in and exercised within the district by the Board of Conservation and Development.

9. That the district commissions, in addition to the powers now vested in them, should be directed to prepare, and, after public hearings, adopt comprehensive plans to meet both the local and the regional needs within their respective districts

and that after the adoption of such comprehensive plans no development for purposes of public water supply should be permitted to be made within the respective districts except in accordance with such comprehensive plans by any municipal corporation, corporations or persons without the specific consent of the commission of the district.

In such comprehensive plans opportunity should be afforded to connect privately owned public supply systems with any major development provided for by such plans, and to take their water therefrom for such system, upon just and reasonable compensation, where such connection and taking can be effected with economy and without disadvantage to the municipalities participating in such development or that may later join therein.

Where such connection and taking is effected, the existence of such connection and such right to take water should not be capitalized beyond the actual cost of making such connection; nor by reason of such connection and right should added value be attributed to the system beyond such actual cost in any condemnation or rate-prescribing proceeding.

10. That the direction for the preparation and adoption of such comprehensive plans should in nowise affect the full exercise of the powers and jurisdiction of the commissions respectively, pending the fulfilment of such direction. Nor, on the other hand, should the fact that such comprehensive plans are in course of preparation result in denying to communities that may be locally served consent to make extensions of their systems reasonably to meet their needs temporarily.

11. That power should be further vested in the district commissions respectively to require by order, after hearing, the interconnection of public water supply systems, whether in public or private ownership, and the interchange of water, on equitable terms and conditions affording fair compensation to be prescribed by such commissions.

12. That in general, the power, authority and control originally vested in the State Water Supply Commission by the several statutes hereinbefore referred to, which power, authority and control is now vested in the Board of Conservation and De-

velopment as the successor to that commission, together with the powers vested in the Board of Conservation and Development by the Act Concerning Municipalities, should be transferred to and vested in the district commissions to be exercised within their respective districts.

13. That the number of members of the district commission should be increased from four (4) to seven (7); that the present restriction as to their political affiliations should be eliminated; that four of the seven members should be residents of the counties making up the metropolitan region of each district and the remainder residents of the counties within the district and outside of the metropolitan region; that the term of office should be seven years instead of four years, the term of one member to expire each year; and that appointment should not be as now by the Governor alone, but by the Governor by and with the advice and consent of the Senate.

14. That whenever any development to be made by one district commission involves the utilization of or affects sources of supply in the other district, application for the consent of the commission of the latter district should be required. If agreement between the district commissions can not in such case be reached, jurisdiction should be vested in the Board of Conservation and Development to determine the issue between the commissions.

15. In order that there may be readily available at one point all data with respect to consents to diversion, each district commission should be required to file with the Board of Conservation and Development a certified copy of all grants of consent made.

    The Board of Conservation and Development should also continue to study stream flow, occurrence and movements of underground waters, and to collect statistics of water consumption as it now does.

16. That the Board of Conservation and Development should be empowered to complete the compilation in part made by us of grants of rights of diversion heretofore made by the State to, and now held by, municipal corporations, corporations and persons.

The completion of this compilation will show the extent to which rights of diversion have been granted in the past and are now outstanding, and the extent to which such outstanding rights are vested and subject to recapture only upon the making of just compensation. It will show, among other things, the existence in private corporations of important rights of diversion of vaguely defined and uncertain extent; and that in some instances such corporations holding such rights were created by the State through the enactment of special statutes before the importance was realized of reserving to the legislature in the grant of corporate charters the power to alter, amend or repeal the same.

The facts which this compilation will furnish when completed will require special consideration and, probably, special action.

17. That sources of supply acquired by the State as hereinbefore suggested should be made available to the municipalities of the two water supply districts through the respective district commissions on equitable terms.

18. That the acts of the district commissions should be subject to complete judicial review.

19. In view of the fact that the respective district commissions will under the plan suggested function in a two-fold capacity—(1) as the agency of the State within the district in controlling and regulating diversion, in formulating and adopting comprehensive plans for the district as a whole, in requiring the interconnection of systems and interchange of waters; and (2) as the trustee and agent of contracting municipalities in acquiring, constructing and operating systems—appropriation should be made by the State to each of such commissions to cover the costs of administration which are attributable to the performance by such commissions of the State functions assigned to them.

20. That Chapter 318 of the Laws of 1912, as amended by Chapter 128 of the Laws of 1913, which has become practically inoperative in consequence of the decision in Wilson *v.* State Water Supply Commission, 84 New Jersey Equity, 150, should be repealed; that Chapter 194 of the Laws of 1923, and

Chapter 195 of the Laws of 1923, which have not been acted upon by any municipality and have only served to render more complex a situation already sufficiently complicated, should also be repealed; and that the statutes relating to public water supplies in general should be revised, unified, harmonized and simplified.

21. That the situation which faces communities in the State and especially in the Northern Metropolitan Region is serious in the extreme and does not admit of delay; that a prompt determination of the future general policy of the State is essential, since regional interest in undertaking a major development is difficult of unification to the point of action so long as expectation or hope of the undertaking by the State itself of a major development prevails.

The plan outlined is not ideal. Nor could any ideal plan be made effective as the Constitution of the State is now interpreted. It has, however, one practical advantage in that it builds upon such parts of the legislation of the State as alone have proven to be effective in furthering progress toward widening the margin between water consumption and safe yield.

The limitations of time and of appropriation have made it impossible to formulate and present bills which would give effect to these conclusions.

We are, however, ready to give such aid as we may to the Attorney-General, or any other official or body you may designate to perform this task.

Acknowledgment is made of the spirit in which the Board of Conservation and Development and the North Jersey District Water Supply Commission and their officers and employees have coöperated with us and with our Consulting Engineer.

Respectfully submitted,

WILLARD I. HAMILTON, Newark
HENRY G. PARKER, New Brunswick
HARRY BACHARACH, Atlantic City
S. WOOD McCLAVE, Cliffside
CARROLL P. BASSETT, Summit
F. MORSE ARCHER, Camden

February 27, 1926.

APPENDICES

APPENDIX I

COMMUNITIES IN NEW JERSEY WITH WATER SUPPLIES

Municipality (1)	County (2)	Supplied by (3)
Absecon City	Atlantic	Atlantic City Water Co.
Allendale Boro	Bergen	Boro of Ramsey
Allenhurst Boro	Monmouth	Boro of Allenhurst
Allentown Boro	"	Monmouth County Water Co.
Alpine Boro	Bergen	Hackensack Water Company
Anglesea	Cape May	City of Wildwood
Annandale	Hunterdon	Clinton Water & Water Sup. Co.
Asbury Park City	Monmouth	City of Asbury Park—Monmouth County Water Co.
Atlantic City	Atlantic	City of Atlantic City
Atlantic Highlands Boro	Monmouth	Boro of Atlantic Highlands
Audobon Boro	Camden	New Jersey Water Service Co.
Avalon Boro	Cape May	Boro of Avalon
Avon by the Sea	Monmouth	Boro of Avon
Bartley	Morris	William Bartley and Sons, Inc.
Barnegat City Boro	Ocean	Barnegat Water Company
Barrington Boro	Camden	New Jersey Water Service Co.
Basking Ridge	Somerset	Bernards Water Co.
Bay Head Boro	Ocean	Bay Head Water Company
Bayonne City	Hudson	Passaic Consolidated Water Co.
Beach Haven Boro	Ocean	Boro of Beach Haven
Bedminster Township	Somerset	Gravity Water Supply Co.
Belleville Town	Essex	City of Newark
Belmar Boro	Monmouth	Boro of Belmar
Belvidere Town	Warren	Buckhorn Springs Water Co.
Bergenfield Boro	Bergen	Hackensack Water Company
Berkley Township	Ocean	Toms River Water Company
Berlin Township	Camden	Berlin Township
Bernards Township	Somerset	Bernards Water Company
Bernardsville Boro	"	Bernards Water Company—Frank B. Allen
Beverly Township	Burlington	Delaware River Water Co.
Beverly City	"	Delaware River Water Co.
Blackwood	Camden	Blackwood Water Company
Blairstown Township	Warren	Blairstown Water & Elec. Co.
Bloomingdale	Passaic	Butler Water Company
Bloomfield Town	Essex	City of Newark—Passaic Consolidated Water Co.
Bloomsbury Boro	Hunterdon	Bloomsbury Water Company
Bogota Boro	Bergen	Bogota Water Co.—Hackensack Water Company

Municipality (1)	County (2)	Supplied by (3)
Boonton Town	Morris	Town of Boonton
Bordentown City	Burlington	City of Bordentown
Bound Brook Boro	Somerset	Bound Brook Water Company
Bradley Beach Boro	Monmouth	Monmouth County Water Co.
Branchville Boro	Sussex	Boro of Branchville
Bridgeport	Gloucester	Bridgeport Water Company
Bridgewater Township	Somerset	Superior Thread & Yarn Co.—Bound Brook Water Co.
Bridgeton City	Cumberland	City of Bridgeton
Brooklawn Boro	Camden	City of Gloucester
Brown's Mills	Burlington	Brown's Mills Water Co.
Burlington City	Burlington	City of Burlington
Butler Boro	Morris	Butler Water Co.
Caldwell Boro	Essex	Essex Fells Boro. Water Dept.
Califon	Hunterdon	Califon Water Co.
Camden City	Camden	City of Camden—Merchantville Water Co.—Stockton Water Co
Camp Dix	Burlington	Camp Dix
Cape May City	Cape May	City of Cape May
Cape May Court House	"	C. M. C. H. Water and Light Co.
Cape May Point Boro	"	Boro of Cape May Point
Carlstadt Boro	Bergen	Hackensack Water Co.
Carney's Point	Salem	E. I. Du Pont de Nemours & Co.
Carteret Boro	Middlesex	Middlesex Water Co.
Center Township	Camden	New Jersey Water Service Co.—City of Gloucester
Chatham Boro	Morris	Boro of Chatham
Chesterfield Township	Burlington	Crosswicks Water Co.
Chester Township	"	Chester Township Water Works
Cinnaminson Township	Burlington	Riverton—Palmyra Water Co.
Clark Township	Union	Elizabethtown Water Co. Cons.—Middlesex Water Co.—Plainfield-Union Water Co.
Clayton Boro	Gloucester	Clayton-Glassboro Water Co.
Clementon Boro	Camden	Clementon Spring Water Co.—Laurel Springs Water Supply Co.—Lakeside Park Water Co.
Cliffside Park Boro	Bergen	Hackensack Water Co.
Cliffwood	Monmouth	Cliffwood Beach Co., Inc.
Clifton City	Passaic	City of Jersey City—Passaic Consolidated Water Co.
Clinton Boro	Hunterdon	Clinton Water and Water Supply Co.
Closter Boro	Bergen	Hackensack Water Co.

Municipality (1)	County (2)	Supplied by (3)
Collingswood Boro	Camden	General Water Supply Co.
Columbus	Burlington	Columbus Water Co.
Corson's Inlet	Cape May	Corson's Inlet Water Co.
Cragmere Park	Bergen	Cragmere Water Company
Cranbury Township	Middlesex	Cranbury Water Co.
Cranford Township	Union	Plainfield-Union Water Co.
Cresskill Boro	Bergen	Hackensack Water Co.
Crosswicks	Mercer	Crosswicks Water Co.
Deal Boro	Monmouth	New Jersey Water & Light Co. Tintern Manor Water Co.
Delaware Township	Camden	Merchantville Water Co.—General Water Supply Co.—New Jersey Water Service Co.
Demarest Boro	Bergen	Hackensack Water Co.
Denville Township	Morris	Diamond Spring Water Co.—Cedar Lake Water Co.
Deptford Township	Gloucester	Gloucester County Water Co.—Westville & Newbold Water Co.
Dover Town	Morris	Town of Dover
Dumont Boro	Bergen	Hackensack Water Co.
Dunellen Boro	Middlesex	Elizabethtown Water Co., Cons.
East Atlantic City	Atlantic	Brigantine Water Co.
East Newark Boro	Hudson	New Jersey Suburban Water Co.
East Orange City	Essex	City of East Orange
East Rutherford Boro	Bergen	Hackensack Water Co.
Eatontown Township	Monmouth	Tintern Manor Water Co.
Edgewater Boro	Bergen	Hackensack Water Co.
Edgewater Park Township	Burlington	Delaware River Water Co.
Egg Harbor City Boro	Atlantic	Boro of Egg Harbor City
Egg Harbor Township	Atlantic	Atlantic County Water Co.
Elizabeth City	Union	Elizabethtown Water Co., Cons. Plainfield-Union Water Co.
Elmer Boro	Salem	Elmer Water Company
Emerson Boro	Bergen	Hackensack Water Co.
Englewood City	"	" " "
Englewood Cliffs Boro	"	" " "
Essex Fells Boro	Essex	Essex Fells Boro Water Dept.
Ewing Township	Mercer	City of Trenton—Crestmont Realty Co.
Fair Haven Boro	Monmouth	Tintern Manor Water Co.—Rumson Improvement Co.
Fairlawn Boro	Bergen	Pomona Water Co.
Fairview Boro	Bergen	Hackensack Water Co.
Fanwood Boro	Union	Plainfield-Union Water Co.

Municipality (1)	County (2)	Supplied by (3)
Far Hills Boro	Somerset	Gravity Water Supply Co.
Farmingdale Boro	Monmouth	West Monmouth Water Co.
Flemington Boro	Hunterdon	Flemington Water Co.
Florence Township	Burlington	John A. Roebling's Sons Co.—Florence Pipe Foundry and Machine Co.
Florham Park Boro	Morris	Boro of Madison
Fort Lee Boro	Bergen	Hackensack Water Co.
Fort Wood	Hudson	City of Jersey City
Franklin Boro	Sussex	New Jersey Zinc Co.
Franklin Township	Somerset	City of New Brunswick
Freehold Town	Monmouth	Town of Freehold
Frenchtown Boro	Hunterdon	Frenchtown Water Co.
Galloway Township	Atlantic	Boro of Egg Harbor City
Garwood Boro	Union	Plainfield-Union Water Co.
Garfield City	Bergen	Passaic Consolidated Water Co.
Gibbsboro	Camden	John Lucas & Co.
Gibbstown	Gloucester	E. I. Du Pont de Nemours & Co.
Gillette	Morris	Gillette Water Co.
Glassboro Boro	Gloucester	Clayton-Glassboro Water Co.
Glen Gardner Boro	Hunterdon	Junction Water Co.—Glen Gardner Water Co.
Glen Rock Boro	Bergen	Village of Ridgewood
Glen Ridge Boro	Essex	Butler Water Co.— City of Newark
Gloucester City	Camden	City of Gloucester
Greenwich Township	Gloucester	Lopatcong Water Co.—E. I. Du Pont de Nemours & Co.
Guttenberg Town	Hudson	Hackensack Water Co.
Hackensack City	Bergen	"
Hackettstown Town	Warren	Town of Hackettstown
Haddonfield Boro	Camden	New Jersey Water Service Co.—Boro of Haddonfield
Haddon Heights Boro	Camden	New Jersey Water Service Co.—Egbert Water Co.
Haddon Township	Camden	New Jersey Water Service Co.
Hainsport Township	Burlington	Mount Holly Water Co.
Haledon Boro	Passaic	Boro of Haledon
Hamilton Township	Atlantic	Mays Landing Water Power Co.—City of Trenton
Hamilton Square	Mercer	Hamilton Square Water Co.
Hamilton Township	Mercer	City of Trenton—Crosswicks Water Company
Hammonton Town	Atlantic	Town of Hammonton
Hampton Boro	Hunterdon	Junction Water Co.—Whippany Water Co.

Municipality (1)	County (2)	Supplied by (3)
Hanover Township	Morris	Brooklawn Farms Water Co.—Town of Morristown—Normandy Water Co.
Harding Township	Morris	Town of Morristown
Harmony Township	Warren	Lopatcong Water Co.
Harrington Park Boro	Bergen	Hackensack Water Co.
Harrison Town	Hudson	New Jersey Suburban Water Co
Harvey Cedars Boro	Atlantic	Boro of Harvey Cedars
Hasbrouck Heights Boro	Bergen	Hackensack Water Co.
Haskell	Passaic	E. I. Du Pont de Nemours & Co.
Haworth Boro	Bergen	Hackensack Water Co.
Hawthorne Boro	Passaic	Boro of Hawthorne
Helmetta Boro	Middlesex	Boro of Helmetta
High Bridge Boro	Hunterdon	Borough of High Bridge
Highland Park Boro	Middlesex	City of New Brunswick
Highlands Boro	Monmouth	Boro of Highlands; J. M. Johnson
Highstown Boro	Mercer	Boro of Highstown
Hillsdale Boro	Bergen	Hackensack Water Co.
Hillside Township	Union	Elizabethtown Water Co., Cons.
Hoboken City	Hudson	City of Jersey City
Hohokus Boro	Bergen	Village of Ridgewood
Holmdel Township	Monmouth	Monmouth County Water Co.
Hopewell Boro	Mercer	Boro of Hopewell
Interlaken Boro	Monmouth	Monmouth County Water Co.
Irvington Town	Essex	Commonwealth Water Co.
Island Heights Boro	Ocean	Boro of Island Heights
Jamesburg Park	Middlesex	Jamesburg Park—Property Owners Cooperative Ass'n.
Jamesburg Boro	Middlesex	Jamesburg Water Co.
Jersey City	Hudson	City of Jersey City
Keansburg Boro	Monmouth	Borough of Keansburg—Ideal Beach Water Co.
Kearny Town	Hudson	City of Newark—New Jersey Suburban Water Co.—City of Jersey City
Kenilworth Boro	Union	New Orange Park Water, Heat and Light Co.—Plainfield-Union Water Co.
Keyport Boro	Monmouth	Boro of Keyport
Lakehurst Boro	Ocean	Lakehurst Sewer Co.
Lakewood Township	Ocean	Lakewood Water Co.
Lamberville City	Hunterdon	Lambertville Water Co.
Landis Township	Cumberland	Boro of Vineland
Laurel Springs Boro	Camden	Laurel Springs Water SupplyCo.
Lawrence Harbor	Middlesex	Lawrence Harbor Water Co.

Municipality (1)	County (2)	Supplied by (3)
Lavalette Boro	Ocean	Boro of Lavalette
Lawrenceville	Mercer	Lawrenceville Water Co.
Lebanon Township	Hunterdon	Beaver Brook Water Co.—Junction Water Co.
Leonia Boro	Bergen	Hackensack Water Co.
Lincoln Park Boro	Morris	Boro of Lincoln Park—Mountain View Water Co.
Linden Township	Union	Elizabethtown Water Co., Cons.
Linden Boro	Union	Elizabethtown Water Co., Cons. Plainfield-Union Water Co.
Linwood Boro	Atlantic	Atlantic County Water Co.
Little Falls Township	Passaic	Little Falls Water Co.
Little Ferry Boro	Bergen	Hackensack Water Co.
Little Silver Boro	Monmouth	Tintern Manor Water Co.
Livingston Township	Essex	Livingston Water Co.
Lodi Boro	Bergen	Boro of Lodi—Hackensack Water Co.
Lodi Township	Bergen	Hackensack Water Co.
Long Beach Township	Ocean	Long Beach Water Co.
Longport Boro	Atlantic	Boro of Longport
Long Branch City	Monmouth	Tintern Manor Water Co.
Lopatcong Township	Warren	Lopatcong Water Co.—Lehigh Water Co. (Easton, Pa.)—Peoples Water Co.
Lumberton Township	Burlington	Mount Holly Water Company—Lumberton Light, Water and Sewer Co.
Lyndhurst	Bergen	City of Jersey City
Madison Boro	Morris	Boro of Madison
Magnolia Boro	Camden	Laurel Springs Water Supply Co.
Mahwah	Bergen	Cragmere Water Co.—Albert and John Winters
Manasquan Boro	Monmouth	Boro of Manasquan
Mantoloking Boro	Ocean	Louis D. F. Downer
Mantua Township	Gloucester	Mantua Water Co.
Maplewood Township	Essex	Commonwealth Water Co.
Margate City	Atlantic	Margate City
Marlton	Burlington	Marlton Water Co.
Matawan Boro	Monmouth	Boro of Matawan
Mays Landing	Atlantic	Mays Landing Water Power Co.—Boro. of Mays Landing
Maywood Boro	Bergen	Hackensack Water Company
Medford Township	Burlington	Medford Water Co.
Mendham Boro	Morris	Boro of Mendham
Merchantville Boro	Camden	Merchantville Water Co.
Metuchen Boro	Middlesex	Middlesex Water Co.

Municipality (1)	County (2)	Supplied by (3)
Mickleton	Gloucester	August Eichler—Jeremia Haines
Middle Township	Cape May	City of Wildwood
Middlesex Boro	Middlesex	Bound Brook Water Co.—Elizabethtown Water Co., Cons.
Middletown Township	Monmouth	Tintern Manor Water Co.
Midland Township	Bergen	Hackensack Water Co.
Midland Park Boro	Bergen	Village of Ridgewood
Milford Boro	Hunterdon	Mine Springs Water Co.—Warren Manufacturing Co.
Millburn Township	Essex	Commonwealth Water Co.
Millington	Morris	Millington Water Co.
Milltown Boro	Middlesex	Boro of Milltown
Millville City	Cumberland	Millville Water Co.,—City of Millville
Monmouth Beach Boro	Monmouth	Tintern Manor Water Co.
Monroe Township	Gloucester	Monroe Township Water Co.
Montclair Township	Essex	Passaic Consolidated Water Co. —City of Newark
Moonachie Boro	Bergen	Hackensack Water Co.
Moorestown	Burlington	Moorestown Water Works
Morris Plains	Morris	Town of Morristown
Morris Township	"	Town of Morristown—Normandy Water Co.
Morristown	Morris	Town of Morristown
Mountain Lakes Boro	Morris	Hillcrest Water Co.
Mountain View	Passaic	Mountain View Water Co.
Mountainside Boro	Union	Plainfield-Union Water Co.
Mount Holly	Burlington	Mt. Holly Water Co.
Mount Tabor	Morris	Camp Meeting Association
National Park Boro	Gloucester	Boro of National Park
Neptune Township	Monmouth	Monmouth County Water Co.
Neptune City Boro	"	"
Netcong Boro	Morris	Boro of Netcong
Newark City	Essex	City of Newark
New Brunswick City	Middlesex	City of New Brunswick
New Egypt	Ocean	New Egypt Light, Heat, Power and Water Co.
New Lisbon	Burlington	Burlington County Water Co.
New Providence Boro	Union	Commonwealth Water Co.
Newton	Sussex	Town of Newton
Northampton Township	Burlington	Mount Holly Water Co.
North Arlington Boro	Bergen	City of Jersey City
North Bergen Township	Hudson	Hackensack Water Co.
North Brunswick Township	Middlesex	City of New Brunswick

Municipality (1)	County (2)	Supplied by (3)
North Caldwell Boro	Essex	Essex Fells Boro. Water Dept.
Northfield City	Atlantic	Atlantic County Water Co.
North Haledon Boro	Passaic	Boro of Haledon
North Plainfield Boro	Somerset	Plainfield-Union Water Co.
North Plainfield Township	Somerset	Elizabethtown Water Co., Cons. Plainfield-Union Water Co.
Northvale Boro	Bergen	Hackensack Water Co.
North Wildwood City	Cape May	City of Wildwood
Norwood Boro	Bergen	Hackensack Water Co.
Nutley Town	Essex	Passaic Consolidated Water Co. —City of Jersey City
Oaklyn Boro	Camden	New Jersey Water Service Co.
Ocean City	Cape May	Ocean City Water Co.
Ocean Gate Boro	Ocean	Ocean Gate Water Co.
Ocean Grove Boro	Monmouth	Ocean Grove Camp Meet. Assoc.
Oceanport Boro	"	Tintern Manor Water Co.
Ocean Township	"	Tintern Manor Water Co.—Monmouth County Water Co.
Ogdensburg	Sussex	Boro of Ogdensburg
Oradell Boro	Bergen	Hackensack Water Co.
Orange City	Essex	City of Orange
Oxford Township	Warren	Buckhorn Springs Water Co.
Palisades Park Boro	Bergen	Hackensack Water Co.
Palisades Township	"	"
Palmyra	Burlington	Riverton-Palmyra Water Co.
Paramus Boro	Bergen	Hackensack Water Co.
Park Ridge Boro	"	Boro of Park Ridge
Passaic City	Passaic	Passaic Consolidated Water Co. New Jersey Suburban Water Co.
Paterson City	"	Passaic Consolidated Water Co. Boro of Haledon
Paulsboro Boro	Gloucester	Boro of Paulsboro
Peapack-Gladstone Boro	Somerset	Boro of Peapack-Gladstone—J. L. Peapack; Dr. M. C. Smalley
Pedricktown	Salem	Pennsgrove Water Supply Co.
Pemberton Boro	Burlington	Pemberton Township Water, Sewerage and Light Co.
Pemberton Township	"	Pemberton Township Water Sewerage and Light Co.
Pennington Boro	Mercer	Boro of Pennington
Pennsgrove Boro	Salem	Pennsgrove Water Supply Co.
Pensauken Township	Camden	Stockton Water Co.—Merchantville Water Co.

Municipality (1)	County (2)	Supplied by (3)
Perth Amboy City	Middlesex	City of Perth Amboy
Phillipsburg Town	Warren	Lehigh Water Co. (Easton, Pa.) Lopatcong Water Co.—Peoples Water Co.
Piscataway Township	Middlesex	Middlesex Water Co.—Elizabethtown Water Co. Cons. —Plainsfield-Union Water Co.
Pitman Boro	Gloucester	Pitman Water Co.—N. J. Conference Camp Meeting Association
Plainfield City	Union	Plainfield-Union Water Co.
Pleasantville City	Atlantic	Atlantic County Water Co.
Point Pleasant Beach Boro	Ocean	Boro of Point Pleasant Beach
Point Pleasant Boro	"	"
Pompton Lakes Boro	Passaic	Butler Water Co.
Princeton	Mercer	Princeton Water Co.
Prospect Park Boro	Passaic	Passaic Consolidated Water Co.
Quinton	Salem	City of Salem
Rahway City	Union	City of Rahway
Ramsey Boro	Bergen	Boro of Ramsey
Raritan Boro	Somerset	Somerset Water Co.
Raritan Township	"	Middlesex Water Co.—Elizabethtown Water Co. Cons.
Red Bank Boro	Monmouth	Boro of Red Bank—Tintern Manor Water Co.
Ridgefield Park Village	Bergen	Hackensack Water Co.
Ridgefield Boro	"	"
Ridgewood Village	"	Village of Ridgewood
Ringwood Township	Passaic	Ringwood Co.—Awosting
Riverdale Boro	Morris	Boro of Pompton Lakes
Riverside Boro	Bergen	Hackensack Water Co.
Riverside Township	Burlington	Delaware River Water Co.
River Edge Boro	Bergen	Hackensack Water Co.
Rio Grande	Cape May	City of Wildwood
Riverton Boro	Burlington	Riverton-Palmyra Water Co.
Rivervale Township	Bergen	Hackensack Water Co.
Rochelle Park	"	Rochelle Park
Rockaway Boro	Morris	Boro of Rockaway
Roseland Boro	Essex	Essex Fells Boro Water Works
Roselle Boro	Union	Plainfield-Union Water Co.—Elizabethtown Water Co. Cons.
Roselle Park Boro	"	Plainfield-Union Water Co.
Rumson Boro	Monmouth	Rumson Improvement Co.—Tintern Manor Water Co.
Rutherford Boro	Bergen	Hackensack Water Co.

Municipality (1)	County (2)	Supplied by (3)
Sayreville Boro	Middlesex	City of Perth Amboy
Salem City	Salem	City of Salem
Scotch Plains Township	Union	Plainfield-Union Water Co.
Sea Bright Boro	Monmouth	Tintern Manor Water Co.
Sea Girt Boro	"	Boro of Sea Girt
Sea Isle City	Cape May	City of Sea Isle City
Seaside Heights Boro	Ocean	Boro of Seaside Heights
Seaside Park Boro	"	Boro of Seaside Park
Secaucus Boro	Hudson	Hackensack Water Co.—City of Jersey City
Sewell	Gloucester	Sewell Water Co.
Ship-Bottom-Beach, Arlington Boro	Ocean	Beach Arlington Water Co.
Short Hills	Essex	Short Hills Water Co.
Shrewsbury Township	Monmouth	Tintern Manor Water Co.
Somers Point City	Atlantic	Atlantic County Water Co.
Somerville Boro	Somerset	Somerville Water Co.
South Amboy City	Middlesex	City of South Amboy
South Bound Brook Boro	Somerset	Bound Brook Water Co.
South Cape May Boro	Cape May	City of Cape May
South Orange Village	Essex	Village of South Orange
South Plainfield	Middlesex	Middlesex Water Co.
South River Boro	"	Boro of South River
Springfield Township	Union	Commonwealth Water Co.—Short Hills Water Co.—Elizabethtown Water Co., Cons.
Spring Lake Boro	Monmouth	Boro of Spring Lake
Stanhope Boro	Sussex	Boro of Stanhope
Stirling	Morris	Stirling Water Co.
Stockton Boro	Hunterdon	Boro of Stockton
Stone Harbor Boro	Cape May	Boro of Stone Harbor
Stratford Boro	Camden	Laurel Hill Water Supply Co.
Strathmere	Cape May	Corson's Inlet Water Co.
Summit City	Union	Commonwealth Water Co.
Surf City Boro	Ocean	Surf City Water Co.
Sussex Boro	Sussex	Boro of Sussex
Swedesboro Boro	Gloucester	Boro of Swedesboro
Teaneck Township	Bergen	Bogota Water Co.—Hackensack Water Co.
Tenafly Boro	"	Hackensack Water Co.
Teterboro Boro	"	"
Toms River	Ocean	Toms River Water Co.
Totowa Boro	Passaic	Passaic Consolidated Water Co.
Trenton City	Mercer	City of Trenton
Tuckerton Boro	Ocean	Tuckerton Water Co.
Union City	Union	Hackensack Water Co.

Municipality (1)	County (2)	Supplied by (3)
Union Township	Union	Commonwealth Water Co.—Elizabethtown Water Co., Cons.
Ventnor City	Atlantic	City of Ventnor
Verona Boro	Essex	Essex Fells Boro. Water Dept.
Vincentown	Burlington	Vincentown Water Co.
Vineland Boro	Cumberland	Boro of Vineland
Waldwick Boro	Bergen	Boro of Waldwick
Wallington Boro	"	Boro of Wallington—Hackensack Water Co.
Wanaque Boro	Passaic	Boro of Pompton Lakes
Washington Boro	Warren	Washington Water Co.
Washington Township	Morris	Long Valley Water Co.—E. C. Welsh; M. T. Welsh
Weehawken Township	Hudson	Hackensack Water Co.
Wenonah Boro	Gloucester	Boro of Wenonah
West Caldwell Boro	Essex	Essex Fells Boro. Water Dept.
West Cape May Boro	Cape May	City of Cape May
West Deptford Township	Gloucester	Westville & Newbold Water Co.
Westfield Town	Union	Plainfield-Union Water Co.
West Long Branch Boro	Monmouth	Tintern Manor Water Co.
West New York Town	Hudson	Hackensack Water Co.
West Orange Town	Essex	Commonwealth Water Co.
West Paterson Boro	Passaic	Little Falls Water Co.
Westville Boro	Gloucester	Westville-Newbold Water Co.
Westwood Boro	Bergen	Hackensack Water Co.
West Wildwood Boro	Cape May	West Wildwood Water & Power Co.
Wharton Boro	Morris	Boro of Wharton
Whiting	Ocean	Tuckerton R. R. Co.
Wildwood City	Cape May	City of Wildwood
Wildwood Crest Boro	"	"
Williamstown	Gloucester	Monroe Township Water Works—C. D. Tice and Son
Woodbine Boro	Cape May	Woodbine Light, Water and Power Co.
Woodbridge Boro	Bergen	Hackensack Water Co.
Woodbridge Township	Middlesex	Iselin Radio Association, Inc.—Middlesex Water Co.—City of Perth Amboy
Woodbury City	Gloucester	City of Woodbury
Woodbury Heights Boro	"	City of Woodbury through Woodbury Heights Water Co.
Woodlynne Boro	Camden	General Water Supply Co.
Woodstown Boro	Salem	Boro of Woodstown
Wrightstown Boro	Burlington	Hanover Water Co.

NEW JERSEY STATE INSTITUTIONS

Institution (1)	County (2)	Supplied by (3)
State Tuberculous Sanitarium (Glen Gardner	Hunterdon	Institution
Home for Feeble Minded Women (Vineland)	Cumberland	Institution
Home for Boys (Jamesburg)	Middlesex	Institution
State Village for Epileptics (Skillman)	Somerset	Institution
Home for Disabled Soldiers and Sailors (Vineland)	Cumberland	Institution
State Home for Girls (Trenton)	Mercer	City of Trenton
Training School (Vineland)	Cumberland	Institution
State Camp (Sea Girt)	Monmouth	State Camp
State Reformatory (Clinton)	Hunterdon	Clinton Water and Water Supply Co.
State Hospital for Insane (Trenton)	Mercer	Institution

APPENDIX II

A study made by Mr. Nicholas S. Hill, Jr., of the so-called Chimney Rock and Long Hill development projects, in which conditions are equalized so that the two plans may be considered on a comparable basis.

COMPARISON OF LONG HILL AND CHIMNEY ROCK PROJECTS

Proximity to Centers of Distribution

A glance at a map will show that Chimney Rock reservoir has no advantage of location as compared with Long Hill reservoir. In fact the advantage of location is in favor of Long Hill, which is nearer to all important centers of distribution, including Elizabeth.

Comparative Flow and Minimum Draft Lines

In addition, the flow line and minimum draft line of Long Hill reservoir will be higher than in the case of the completed Chimney Rock reservoir, so that the head available for loss in friction will be greater, not only because of the shorter distance between the reservoir and the centers of distribution, but also because of the higher maximum and minimum elevations of the water at the source. The flow line of the Long Hill reservoir will be three hundred twenty feet (320′) as compared with three hundred four feet (304′) for Chimney Rock. The minimum draft line in the Long Hill reservoir will be two hundred eighty feet (280′) as compared with two hundred fifty feet (250′) for Chimney Rock.

Reservoirs, Collecting Tunnels and Delaware River Pumping Station

In comparing the two projects, Mr. Sherrerd's revision of Mr. Hazen's prices in an upward direction is used throughout. The basic details as prepared by Mr. Sherrerd are presented at the close of this Appendix. It is also assumed that under the successive steps of development these estimated costs of delivering water from the source of supply to Long Hill or Chimney Rock reservoirs are fairly comparable and truly reflect the relative economic advantages of the two schemes. This is assumed although an examination of Mr. Sherrerd's estimates indicates that he spreads his capital investment in collecting tunnels over the years, and hence reduces the present worth of these investments, by the device of constructing a succession of parallel tunnels, one from each source of supply to Chimney Rock reservoir, whereas Mr. Hazen would construct a single tunnel of ultimate size, merely extending it at the time each new source is brought in. It is obvious that if it is economical for Mr. Sherrerd to employ this device, it could be employed with equal advantage by Mr. Hazen, but it is impossible to place the estimates on a strictly comparable basis in this regard because Mr. Hazen does not state separately the costs of his collecting tunnels and the costs of his impounding reservoirs. The following estimates, therefore, favor Chimney Rock to the extent above indicated.

The comparative costs allowed by Mr. Sherrerd and Mr. Hazen for reservoirs, collecting tunnels and Delaware River pumping station are given in Table No. 17.

Transmission Conduits and Tunnels

That the position of Chimney Rock reservoir with respect to centers of distribution compares unfavorably with the location of Long Hill reservoir in both distance and elevation is supported by Mr. Sherrerd's estimated comparative costs of the transmission conduits and tunnels required between these reservoirs and centers of distribution, the amounts allowed are as indicated in Table No. 18.

It is apparent from the above figures that the ultimate first cost of the transmission conduits and tunnels required to distribute water from Chimney Rock reservoir will be forty-seven per cent. (47%) greater than in the case of Long Hill on the basis of Mr. Sherrerd's figures. This is to be expected because of the lower elevation and greater distance of Chimney Rock from the distribution centers previously mentioned.

Inspection of a map will show that, if there is any advantage in doing so, water can be distributed from the Long Hill reservoir through pipe lines which will follow the same routes, be of the same length, and may be constructed at the same times as those contemplated by Mr. Sherrerd in connection with the Chimney Rock project. As a matter of fact the capital outlay thus required to give equivalent service would be somewhat smaller in the case of Long Hill as compared with Chimney Rock because of the greater head available for loss in friction and consequent reduction in size of conduits and tunnels required.

Neglecting this last mentioned factor, however, and thus favoring Chimney Rock to that extent, it appears that a fairer comparison of the two schemes may be made by including Mr. Sherrerd's transmission system under both projects. This is so because if there is any advantage in Mr. Sherrerd's system of transmission it can be availed of in connection with Long Hill as readily—and even more readily—than in the case of Chimney Rock. The comparison of the two schemes on this basis will be fairer than the comparison made by Mr. Sherrerd, because in laying out his transmission system Mr. Sherrerd spreads his capital expenditures over the years, and hence reduces their present worth by employing the device of constructing a succession of parallel conduits and tunnels between the reservoir and distribution centers, whereas Mr. Hazen would construct a single large distributor of ultimate size at once.

Filtration Plants

The ultimate first cost of filtration will be the same in the two projects because they tap practically the same sources at practically the same points. That this fact is recognized by Mr. Sherrerd is apparent from a comparison of the total capital outlay required for the filtration plants as taken from his estimates and presented in Table No. 19.

It will be seen from inspection of the figures in Table No. 19 that whereas the total amount allowed by Mr. Sherrerd for filtration plants is practically the same in the case of Chimney Rock as in the case of Long Hill, he reduces the present worth of the filtration cost under the Chimney Rock scheme by deferring the date of installation of filtration plants. It appears from what has been said that if these capital outlays can be deferred in the case of the Chimney Rock project they may also be deferred with equal reason in the case of the Long Hill development. Therefore, in order to place the estimates upon a more comparable basis it will be assumed that filtration plants under the Long Hill scheme will have to be installed in the same years as assumed by Mr. Sherrerd for the Chimney Rock project, and that the first cost of these filtration plants will be the same in both cases.

Desirability of Making the First Development of Less Than 158-168 Million Gallons Daily Capacity

If all resources of the Metropolitan District are pooled and interchanged there will be no need of an additional supply, after completion of Wanaque, until *1937-1940*, depending upon whether Wanaque is considered good for 74 or 100 M.G.D.

At that time a development of 42 M.G.D. from Long Hill will suffice for four (4) years, or until *1941-1943*, depending upon whether Wanaque is considered good for 74 or 100 M.G.D. In 1941 or 1943 an additional development of 67 M.G.D. from Long Hill will suffice for six (6) years, or until *1947-1949*, depending upon whether Wanaque is considered good for 74 or 100 M.G.D. In 1947 or 1949 an additional development of 59 M.G.D. from Long Hill will suffice for four (4) years, or until *1951-1953*, depending upon whether Wanaque is considered good for 74 or 100 M.G.D.

The Long Hill development, down to and including the reservoir, can and should be made in the manner indicated, because by carrying out the work progressively in this way, the capital outlay will be spread over the years with resulting savings in fixed charges. On the other hand, the Chimney Rock development, down to and including the reservoir, must be constructed at once of 158 M.G.D. capacity, sufficient until *1951-1953*, as planned by Mr. Sherrerd. Although this is an appreciable advantage in favor of Long Hill it is not taken account of in the following economic comparison in which it is assumed that a first development of 158-168 M.G.D. will be made at one time in both cases.

Comparative Total Capital Expenditures Actual and Reduced to Present Worth

In his comparison of the capital outlay required under the two projects, Mr. Sherrerd shows that the total actual capital expenditures for the Chimney Rock development will be very much greater than for the Long Hill development, but he states that due to the deferment of these expenditures the ultimate cost of Chimney Rock when reduced to present worth at four and one-half per cent. (4½%) will be less than in the case of Long Hill.

In making his calculation, Mr. Sherrerd has assumed that the deferments in years after completion of the first development will be as follows under both projects:

2d development	16 years	
3d	"	28 "
4th	"	42 "
5th	"	55 "

Taking my estimate of the growth in consumption in the Metropolitan District, assuming that the safe yield of available existing sources as now developed in 297 M.G.D., and assuming that the safe yield of the Wanaque supply will be 100 M.G.D. as claimed by Mr. Sherrerd, and that the first development at Long Hill or Chimney Rock will be 168 M.G.D. and 158 M.G.D., respectively, the years of deferment of the second, third, fourth and fifth steps after the completion of the first step will be as shown in Table No. 20.

It will be seen from Table No. 20 that the year of deferment will be shorter than estimated by Mr. Sherrerd if my estimate of growth in future consumption is correct. It will also be remembered that this estimate of growth in consumption in the Metropolitan District corresponds with the estimate made independently by Mr. Hazen and others.

Using my estimate of the dates upon which the successive steps in the development will have to be taken, the comparative capital outlays and the comparative present worths under the two projects are shown in Table No. 21. In calculating the present worth I have used five per cent. (5%) instead of four and one-half per cent. (4½%) as used by Mr. Sherrerd. This five per cent. (5%) is made up of interest at four and one-half per cent. (4½%) and provision for bond retirement at five-tenths per cent. (5-10%). The latter figure is equivalent to a fifty (50) year sinking fund drawing four and one-half per cent. (4½%) interest. This change is proper, because by deferring investments the State will save not only the interest on the deferred expenditures, but also the sinking fund payments. The change from four and one-half per cent. (4½%) to five per cent. (5%) favors the Chimney Rock development.

Inspection of the figures in the last line of Table No. 21 shows the ultimate total actual cost of the Chimney Rock development to be two hundred twenty-three (223) million dollars as compared with one hundred seventy-four (174) million dollars for the Long Hill project, and that the present worth of capital expenditures for the Chimney Rock development will be one hundred two (102) million dollars as compared with ninety-six (96) million dollars for the Long Hill project. It will also be recalled that in making these estimates, certain factors, the omission of which favored the Chimney Rock project, were not taken into account because of the lack of sufficient data or for other reasons, as follows:

A. Estimates on Chimney Rock assume the construction of a succession of parallel collecting tunnels from each source of supply to Chimney Rock reservoir, whereas estimates on Long Hill assume the construction of single tunnels of ultimate size at the time each new source is brought in.

B. The estimates on Long Hill take no account of the reduction in size which may be made in the transmission lines, because of the higher elevation of the flow line and minimum draft line in Long Hill reservoir as compared with Chimney Rock reservoir.

C. The estimates on Long Hill take no account of the fact that the first development of 168 M.G.D. may be made in steps of 42, 67 and 59 M.G.D., respectively, thus spreading the investment over a number of years with consequent savings in carrying charges.

It is believed that in all cases where estimates are not on a strictly comparable basis the assumption favor Chimney Rock, in spite of which fact this project proves to be more costly, both in actual capital outlay required and in the present worth of future capital expenditures.

There is one further fact to which Mr. Critchlow of the Department of Conservation and Development has called attention, which is not taken into account in the foregoing comparison, and which may be worthy of mention. This is the higher cost of pumping water from the Delaware River under the Chimney Rock project.

The details of Mr. Sherrerd's estimates on which the foregoing comparison is based as obtained from the North Jersey District Water Supply Commission are presented in Tables Nos. 22 to 28.

APPENDIX III

DATA ON UNDERGROUND SOURCES OF WATER SUPPLY IN NEW JERSEY

KEY TO GEOLOGIC FORMATIONS

Rock Formations

Trb— Brunswick formation (Triassic-Newark group)—soft red shale with sandstone beds, the latter more abundant toward the northeast.

Trs— Basalt flows (Triassic-Newark group)—fine-grained trap-rock in extensive flows, chiefly in the Watchung Mountains.

Trbs— Stockton formation—gray feldspathic sandstone (arkose), conglomerate and red shale.

Omb— Martinsburg ("Hudson River") shale (Ordovician)—black slaty shale with thin beds of sandstone.

Ign— White graintoid gneiss (Losee gneiss).

Bgn— Byram gneiss—gray graintoid gneiss.

Clay and Marl Formations

Tsr— Shark River marl—mixture of greensand (glauconite) and light colored earth, chiefly north of Asbury Park. (Eocene.)

Kht— Hornerstown marl—dark green glauconitic marl with varying amounts of quartz, fine earth and clay.

Kns— Navesink marl—dark green glauconitic marl with shell bed at the base.

Kwb— Woodbury clay—black to dove-colored clay, usually nonglauconitic.

Sandy Clay Formations

Kmr— Magothy and Raritan formations (Cretaceous)—dark lignitic sand and clay, containing some glauconite near the top (Magothy) overlying with slight unconformity variable sands and clays, chiefly light colored (Raritan). Formed of alternating layers of sand and clay extremely variable in thickness and distribution.

Kmv—Merchantville clay (Cretaceous)—black sandy clay, usually glauconite.

Sand Formations with Some Clay

Tkw— Kirkwood sand—fine micaceous sands with local beds of dark clay (Miocene).

Qcm— Cape May formation (Quarternary)—low terraces and plains of gravel and sand with some clay, including some recent alluvium and swamp muck. Merges into stratified drift in the Delaware and Raritan valleys.

SAND AND GRAVEL FORMATIONS

Tch— Cohansey sand—chiefly quartz sand with local beds of clay and gravel (probably Miocene).

Kvt— Vincentown sand—glauconite quartz sand alternating with beds of lime sand (coral fragments, etc.), the latter mostly consolidated.

Krb— Red Bank and Tinton sands—coarse, rusty sand, consolidated in places by iron oxide. In Monmouth county is overlain by a bed of hard, green clayey and sandy loam (Tinton).

Kmw—Mount Laurel and Wenonah sands—coarse glauconitic sand (Mt. Laurel) overlying fine uncaceous sand (Wenonah).

Ket— Englishtown sand—white and yellow sand with little mica and glauconite and local thin layers of clay.

Qsd— Stratified drift (Quarternary)—sand and gravel plains, deltas, eskers, kames and terraces, chiefly north of the terminal moraine and in the valleys leading south from it; also includes deposits of extinct Lake Passaic.

Qrm— Recessional moraine (Quarternary)—smaller morainic accumulations north of the terminal moraine, including some stratified drift of kame-like habit, and marking pauses in the recession of the last ice-sheet.

Qtm— Terminal moraine (Quarternary)—a belt of irregular hummocky accumulations of clay, sand, gravel and boulders in confused mixture.

Qps— Pensauken formation (Quarternary) (interglacial and early glacial)—gravel and sand on higher terraces and capping hills and divides.

Qbs— Beach sand and gravel—includes dunes and dune sand along the coast; not everywhere distinguished from Cape May formation.

Qbt— Bridgeton formation (probably earliest glacial and interglacial age)—gravel and sand, in part solidified by iron oxide, capping higher hills and divides along the southeast side of the Amboy-Trenton and Delaware valleys.

DATA ON WELLS IN THE STATE OF NEW JERSEY USED AS SOURCES OF PUBLIC WATER SUPPLY

(Arranged by Districts and Counties. Underground Water from Other Sources Not Included.)

NORTHERN METROPOLITAN DISTRICT

Purveyor (1)	County (2)	Number, Size and Depth of Wells (3)	Geologic Formation in Which Wells are Located (4)	Average Daily Output during 1924 Total (Gallons) (5)	Average Daily Output during 1924 Per Well (Gallons) (6)
Bogota Water Company	Bergen	1—275′	Trb and Qsd	100,000	100,000
Fairlawn (Pomona Water Co.)	"	2—6″x(65′ & 80′)	"	16,000	8,000
Garfield City	"	2—500′:10—200′	Trb	932,000	78,000
Lodi Boro	"	3 deep:4—6″x(300′-350′)	Trb and Qsd	444,000	63,000
Mahwah	"				
Cragmere Water Co	"	3—8″x(300′-600′)	Trb	15,000	5,000
John Winters	"	1—84′	"	2,000	2,000
Park Ridge Boro	"	1—252′:1—435′	Trb and Qsd	160,000	80,000
Ramsey Boro	"	1—20′x28′:5—8″x(127′-700′)	Trb	148,000	25,000
Ridgewood Village	"	22—8″x(182′-199′):1—12″x500′	Trb: Trb and Qsd	858,000	37,000
Rochelle Park	"				
William Colling	"	1—212′	Trb and Qsd	2,000	2,000
Fred E. Koch	"	1—8″x206′	"	17,000	17,000
Marie E. Schaefer	"	1—200′	"	4,000	4,000
Mrs. Henry Thiem	"	1—8″x204′	"	2,000	2,000
Geo. E. Warde	"	1—90′	"	10,000	10,000
Waldwick Boro	"	3—8″x(206′-335′-347′)	Trb	100,000	33,000
Wallington Boro	"	4—8″x(270′-290′)	"	254,000	64,000
Total in Bergen County		**69 Wells**	**Trb and Qsd**	**3,064,000**	**44,000**
Commonwealth Water Co. *u*	Essex	44—10″(40′-300′):1*—18″x825′	Trb	3,923,000*u*	89,000
East Orange City	"	43 (125′-250′)	Trb and Qsd	3,557,000	83,000
Essex County Institutions	"	4	"	612,000	153,000
Essex Fells Boro	"	4—4″x45′; 1—6″x80′:1—8″x110′	Qsd over Trbs	526,000	88,000
Livingston Water Co	"	1	Trb and Qsd	3,000	3,000
Short Hills Water Co	"	13—(60′-80′):1—328′	"	1,088,000	78,000
South Orange City	"	8—8″(274′-400′)	Trb	779,000	97,000
Total in Essex County		**120 Wells**	**Trb and Qsd**	**10,488,000**	**87,000**

*Infiltration gallery.

Purveyor (1)	County (2)	Number, Size and Depth of Wells (3)	in Which Wells are Located (4)	Total (Gallons) (5)	Per Well (Gallons) (6)
Kearny (N. J. Soldier's Home)	Hudson	1—612′	Trb	230,000	230,000
Total in Hudson County		**1 Well**	**Trb**	**230,000**	**230,000**
Cranbury Water Co	Middlesex	2—8″x(104′&267′)	Kmr-Qcm-Qps	16,000	8,000
Elizabethtown Water Co. Cons. *u*	"	19—8″x125′:11—6″&8″x165′	Trb and Qsd: Trb	2,792,000*u*	93,000
Helmetta (Geo. W. Helme & Co.)	"	1—24′:1—32′:1—280′	Kmr	13,000	4,000
Iselin (Radio Assn. Inc.)	"	5—6″x(200′-225′)	Trb and Qsd	20,000	4,000
Jamesburg Park Asso	"	1	Kmr	3,000	3,000
Jamesburg Water Co	"	4—6″x75′	Kmr and Qcm	59,000	15,000
Jamesburg (N. J. State Home for Boys)	"	2—500′	Kmr and Qps	114,000	57,000
Laurence Harbor Water Co	"	1—134′	Kmr at edge of Kmv and Qcm	20,000	20,000
Middlesex Water Co	"	1—8″x300′:12—12″x250′:16—12″x300′	Trb and Qsd	2,097,000	72,000
Perth Amboy City	"	88—6″(60′-90′): 14—6″x250′ (artesian)	Kmr and Qcm	7,677,000	75,000
South Amboy City	"	2—8″x48′:3—10″x(235′-248′)	Kmr and Qps (?)	1,001,000	200,000
South River Boro	"	1—150′: 1 collecting well	Kmr	291,000	145,000
Total in Middlesex County		**186 Wells**	**Trb, Kmr, Qsd, Qps, Qcm**	**14,103,000**	**76,000**
Awosting (Ringwood Co.)	Passaic	1—136′	Qsd	3,000	3,000
Haskell (DuPont de Nemours & Co.)	"	2—25′x(24′& 30′) dug wells	Qsd	203,000	102,000
Hawthorne Boro	"	4—(113′-250′)	Trb and Qsd	468,000	117,000
Total in Passaic County		**7 Wells**	**Trb and Qsd**	**674,000**	**96,000**
Commonwealth Water Co. *e*	Union	10—6″x394′:5—30′diam. x 22′	Trb and Qtm	904,000*e*	60,000
Elizabethtown Water Co. Cons. *m*	"	22—8″x(100′-500′):32—6″&8″(135′-709′)	Trb and Qsd	6,007,000*m*	111,000
Kenilworth (New Orange Pk. Water, Heat & Light Co.)	"	1—275′	Trb and Qrm	17,000	17,000
Plainfield-Union Water Co	"	40—(6″-10″)x(75′-500′)	Trb and Qtm	7,162,000	179,000
Total in Union County		**110 Wells**	**Trb and Qsd, Qrm, Qtm**	**14,090,000**	**128,000**
Total in District		**493 Wells**	**Trb, Kmr, Qsd**	**42,649,000**	**87,000**

u See also under Union County
e See also under Essex County
m See also under Middlesex County

DATA ON WELLS IN THE STATE OF NEW JERSEY USED AS SOURCES OF PUBLIC WATER SUPPLY

(Arranged by Districts and Counties. Underground Water from Other Sources Not Included.)

Southern Metropolitan District

Purveyor (1)	County (2)	Number, size and Depth of Wells (3)	Geologic Formation in Which Wells are Located (4)	Average Daily Output During 1924 Total (Gallons) (5)	Average Daily Output During 1924 Per Well (Gallons) (6)
Browns Mills Water Co.	Burlington	1—300′	Kmw (Tkw)	39,000	39,000
Chester Township	"	1—6″x376′	Kmv or Kwb and Qcm	62,000	62,000
Columbus Water Co.	"	1—4″x235′:1—6″x235′	Ket and Qps	16,000	8,000
Delaware River Water Co.	"	6—8″x60′:5—10″x60′:1—16″x62′	Kmr and Qcm	428,000	36,000
Marlton Water Co.	"	2—6″x(212′&239′)	Kmw (Tch and Qps)	17,000	9,000
Moorestown Township	"	3—8″x(250′-490′):2—12″x(314′& 493′)	Ket	508,000	102,000
New Lisbon (Burlington Co. Hospital for Insane)	"	1	Tkw	30,000	30,000
New Lisbon (Burlington Co. Water Co.)	"	2—392′	Tkw	45,000	23,000
Riverton and Palmyra Water Co.	"	3—8″x55′:3—10″x55′:1—13′x22.5′	Kmr and Qps	674,000	96,000
Smithville (N. B. Smith Mch. Co.)	"	2—108′	Kmw and Qcm	30,000	15,000
Wrightstown (Hanover Water Co.)	"	2—8″x135′	Tkw	6,000	3,000
Total in Burlington County		**37 Wells**		**1,855,000**	**50,000**
Asyla (Camden County Asylum)	Camden	2—(150′& 247′)	Tkw and Qps	60,000	30,000
Berlin Township	"	3—8″x(70′-312′)	Tch	300,000	100,000
Blackwood Water Co.	"	4—6″x(47′-100′)	Kvt and Qps	96,000	24,000
Camden City	"	120—8″x(60′-130′): 4—12″x130′:9—24″x180′	Kmr and Qps	16,139,000	121,000
Camden (Stockton Water Co.)	"	26—8″x(50′-184′):1—38″x135′	Kmr and Qcm	2,151,000	80,000
Clementon Spring Water Co.	"	2—6″x170′:4—8″x(163′x240′)	Kvt (Tkw and Qcm)	173,000	29,000
Gibbsboro (John Lucas & Co., Inc.)	"	2—160′	Kvt	28,000	14,000
Gloucester City	"	6—8″x(175′-180′)	Kmv and Qcm	1,864,000	311,000
Grenloch Real Estate Co.	"	2—(100′& 160′)	Kvt (Tkw and Qps)	30,000	15,000
Haddonfield	"	2—8″x225′:2—10″x225′:1—12″x225′	Ket and Qps	396,000	79,000
Haddon Heights (Egbert Water Co.)	"	1—8″-162′	"	1,000	1,000
Laurel Springs Water Supply Co.	"	4—4½″ and 5—8″x(86′-500′)	Kvt (Tkw and Qps)	217,000	24,000

Purveyor (1)	County (2)	of Wells (3)	Wells are Located (4)	(Gallons) (5)	(Gallons) (6)
Kirkwood (Lakeside Pk. Water Co.)	Camden	1—106′	Kvt (Tkw and Qps)	4,000	4,000
Merchantville Water Co.	“	7—8″x(115′-251′): 2—10″x(120′-181′): 1—12″x182′	Kmr and Qps	2,125,000	213,000
N. J. Water Service Co.	“	2—8″x190′:3—8″x240′	Kwb and Qcm	518,000	104,000
Total in Camden County		**216 Wells**		**24,102,000**	**112,000**
Bridgeport Water Co.	Gloucester	4—4½″x35′	Kmr and Qcm	33,000	8,000
Clayton-Glassboro Water Company	“	8—6″x100′:1—7″x100′:1—16″x100′	Tch and Qbt	121,000	12,000
Gibbstown (E. I. DuPont de Nemours & Co.)	“	2—16′:1—90′	Kmr and Qcm	40,000	13,000
Glassboro Boro	“	1—6″x222′	Tkw and Qcm	11,000	11,000
Mantua Water Company	“	1—4″x98′:2—4″x205′:1—5″x204′	Kmv	50,000	13,000
Mickleton:					
August Eichler	“	1—170′	Kmv	2,000	2,000
Mrs. Jeremiah Haines	“	1—238′	Kmw or Kmv	1,000	1,000
Mullica Hill (Harrison Heights Improvement Co.)	“	2—260′	Kns-Kht	92,000	46,000
Paulsboro Boro	“	11—(60′-120′)	Kmr	289,000	26,000
Pitman Boro:					
Municipal Supply	“	1—4″x50′:6—6″x150′:5—8″x150′	Tkw or Tch and Qbt	204,000	17,000
N. J. Conf. Camp Meeting Asso.	“	2—185′	Tch and Qbt	108,000	54,000
Sewell Water Company	“	1—6″x85′:1—8″x75′	Kht	16,000	8,000
Swedesboro Boro	“	7—(4″-6″)x(135′-150′)	Kmv and Qcm	107,000	15,000
Wenonah Boro	“	6—3″x180′:1—8″x217′	Kmv and Qps	81,000	12,000
Westville and Newbold Water Co.	“	4—(4″& 6″)x(113′-117′)	Kmv and Qcm	104,000	26,000
Williamstown (Monroe Twp.)	“	3—8″x(112′-124′)	Tch and Qbt	27,000	9,000
Woodbury City	“	10—8″x296′	Kht	906,000	91,000
Total in Gloucester County		**84 Wells**		**2,192,000**	**26,000**
Hamilton Square Water Co.	Mercer	1—6″x140′:1—10″x144′	Kmr and Qps	30,000	15,000
Hightstown Boro	“	(5—6″& 8″)x200′	Kmv and Qps	256,000	51,000

DATA ON WELLS IN THE STATE OF NEW JERSEY USED AS SOURCES OF PUBLIC WATER SUPPLY

(Arranged by Districts and Counties. Underground Water from Other Sources Not Included.)

SOUTHERN METROPOLITAN DISTRICT—Continued

Purveyor (1)	County (2)	Number, size and Depth of Wells (3)	Geologic Formation in Which Wells are Located (4)	Average Daily Output During 1924 Total (Gallons) (5)	Average Daily Output During 1924 Per Well (Gallons) (6)
Hopewell Boro	Mercer	2—8″x(243′& 375′)	Trb	62,000	31,000
Lawrenceville Water Co	〃	1—6″x65′:1—8″x230′	Trs and Qps	27,000	14,000
Pennington Boro	〃	2—6″x(159′& 186′)	Trb	37,000	18,000
Princeton Water Company	〃	7—(8″& 10″)x(300′-500′)	Trs and Qps	758,000	108,000
Trenton (State Hospital for Insane)	〃	9—(250′-588′)	〃	493,000	55,000
Total in Mercer County		**29 Wells**		**1,663,000**	**57,000**
Total in District		**366 Wells**		**29,812,000**	**82,000**

REST OF STATE OUTSIDE OF THE TWO METROPOLITAN DISTRICTS

Atlantic City	Atlantic	32—10″x(100′-200′)	Tkw (Tch and Qcm)	4,765,000	149,000
Atlantic County Water Co	〃	1—8″x120′:1—16″x110′	〃	23,000	12,000
Brigantine Water Co	〃		Tkw (Qbs)		
Egg Harbor City	〃	4—(6″-12″) (132′-400′)	Tch	304,000	76,000
Hammonton Town	〃	5—6″x300′:1—8″x315′	Tch and Qbt	386,000	64,000
Longport Boro	〃	2—6″x850′	Tkw (Qbs)	55,000	28,000
Margate City	〃	3—6″x815′	〃	189,000	63,000
Mays Landing Boro	〃	2—8″x(211′& 228′):1—12″x243′	Tch and Qcm	48,000	16,000
Ventnor City	〃	3—6″x825′:3—8″x(812′-825′-825′)	Tkw (Qbs)	1,007,000	168,000
Total in Atlantic County		**58 Wells**		**6,777,000**	**117,000**
Avalon Boro	Cape May	1—4″x900′:1—6″x900′	Tkw (Qbs)	44,000	22,000
Cape May City	〃	23—4″x(100′-575′)	Tch and Qcm	980,000	43,000
Cape May Court House Water & Light Co	〃	1—2″x35′:1—4″x35′:1—6″x35′	〃	68,000	23,000
Cape May Point Boro	〃	1—4½″x604′	〃	24,000	24,000
Corsons Inlet Water Co	〃	1—4″x820′	Tkw (Qbs)	12,000	12,000
Ocean City Water Co	〃	1—6″x840′:3—8″x840′	Tkw	653,000	163,000

Purveyor (1)	County (2)	Number, Size and Depth of Wells (3)	Geologic Formation in Which Wells are Located (4)	during 1924 Total (Gallons) (5)	Per Well (Gallons) (6)
Wildwood City	Cape May	9—6″x110′:9—6″x210′:7—8″x50′: 2—12″(511′ & 523′)	Tch, Qcm and Qbs	883,000	33,000
Woodbine Light, Power & Water Co.	"	5—(150′-160′)	Tch and Qcm	100,000	20,000
Total in Cape May County		**71 Wells**		**3,109,000**	**44,000**
Millville City:					
Municipal Plant	Cumberland	6—8″x108′	Tch and Qcm	1,389,000	232,000
Millville Water Co	"	16—(135′-400′)	"	1,048,000	66,000
Vineland Boro:					
Municipal Plant	"	10—(4″, 6″& 8″)x130′	Tch and Qbt	1,046,000	105,000
N. J. State Institutions—					
Home for Disabled Soldiers	"	1—124′	"	33,000	35,000
Home for Feeble Minded	"	2—135′	"	170,000	85,000
Training School	"	3—(100′-120′)	"	142,000	47,000
Total in Cumberland County		**38 Wells**		**3,830,000**	**101,000**
Flemington Water Co	Hunterdon	1—6″x405′	Trb	145,000	145,000
Milford Boro:					
Mine Springs Water Co	"	1—16′22′:1—8″	"	33,000	16,000
Warren Manufacturing Co	"	8 dug wells 50′	"	590,000	74,000
Stockton Boro	"	2—6″x165′	Trs	22,000	11,000
Total in Hunterdon County		**13 Wells**		**790,000**	**61,000**
Allenhurst Boro	Monmouth	2—4″x550′:3—8″x550′	Tsr and Qcm	175,000	35,000
Asbury Park City	"	9—1100′	Kmr (Tkw and Qcm)	1,097,000	122,000
Atlantic Highlands Boro	"	2—20″x130′	Ket or Krb and Qcm	380,000	190,000
Avon-by-the-Sea	"	2			
Belmar Boro	"	5—6″x650′:3—8″x650′	Tkw and Qcm	475,000	59,000
Deal (N. J. Water and Light Co)	"	2—6″x250′:3—8″x600′	Tsr and Qcm	199,000	40,000
Farmingdale (West Monmouth Water Company)	"	1—6″x100′:1—6″x480′	Tkw and Qcm	10,000	5,000
Freehold Town	"	9—8″x200′	Krb or Kns	333,000	37,000
Highlands Boro	"	2—6″x240′:1—8″x686′	Krb	148,000	49,000

DATA ON WELLS IN THE STATE OF NEW JERSEY USED AS SOURCES OF PUBLIC WATER SUPPLY

(Arranged by Districts and Counties. Underground Water from Other Sources Not Included.)

REST OF STATE OUTSIDE OF THE TWO METROPOLITAN DISTRICTS—(Continued)

Purveyor (1)	County (2)	Number, size and Depth of Wells (3)	Geologic Formation in Which Wells are Located (4)	Average Daily Output During 1924 Total (Gallons) (5)	Per Well (Gallons) (6)
Keansburg Boro:					
Municipal Plant	Monmouth	2—8″x360′	Kwb and Qcm	164,000	82,000
Ideal Beach Water Co	"	1—8″x157′	Ket and Qcm	32,000	32,000
Keyport Boro	"	5—6″x240′:1—10″x250′	Kwb and Qcm	319,000	53,000
Manasquan Boro	"	3—6″x120′	Tch and Qcm	171,000	57,000
Matawan Boro	"	2—6″x200′:1—6″x325′	Kwb and Qps	160,000	53,000
Monmouth County Water Co	"	7—6″x1000′:3—8″x1000′:3—10″x1000′	Tch and Qcm	602,000	46,000
Ocean Grove Camp Meeting Ass'n	"	16—4″(400′-600′)	"	401,000	25,000
Red Bank Boro	"	5—8″x230′	Krb and Qcm	644,000	129,000
Rumson Improvement Co	"	5—(191′-335′)	"	66,000	13,000
Sea Girt Boro:					
Municipal Plant	"	1—8″x36′:1—10″x26′	Tch and Qbs	51,000	26,000
N. J. State Camp	"	1—750′	"	38,000	38,000
Spring Lake Boro	"	6—700′	Ket and Qcm or Qbs	523,000	87,000
Total in Monmouth County		**106 Wells**		**5,988,000**	**57,000**
Chatham Boro	Morris	1—4″x125′:6—6″(98′-150′): 2—8″(125′-150′)	Trb and Qsd	392,000	44,000
Dover Town	"	7—75′	Qtm over Bgn	536,000	77,000
Gillette Water Company	"	1—410′	Trb and Qsd	2,000	2,000
Hanover Township:					
Brooklawn Farms Water Co	"	1	"	11,000	11,000
Normandy Water Company	"	28—5″x(40′-80′)	Trb and Qtm	84,000	3,000
Lincoln Park Boro:					
Chas. N. Evans Development Co.	"	1	Trb and Qsd	75,000	75,000
Lincoln Park Water Co	"	1—5″x106′:1—8″x106′	"	65,000	32,000
Mountain View Water Co	"	1	"	10,000	10,000
Madison Boro	"	9—(5″& 8″)x(50′-160′)	Trb	512,000	57,000
Millington Water Co	"	2—16′x20′	"	79,000	40,000

Purveyor (1)	County (2)	Number, Size and Depth of Wells (3)	in Which Wells are Located (4)	Total (Gallons) (5)	Per Well (Gallons) (6)
Morristown Town	Morris	8—(45′-60′)	Trb and Qsd	302,000	38,000
Mt. Tabor Camp Meeting Ass'n	"	2—12′x22′	Qtm	16,000	8,000
Mountain Lakes (Hillcrest Water Company)	"	3—(341′-469′)	"	50,000	17,000
Rockaway Boro	"	1—22″x150′:1—65′	"	150,000	75,000
Stirling Water Company	"	3—6″x(62′-82′):2—8″x(128′& 200′)	Trb and Qsd	46,000	9,000
Total in Morris County		**81 Wells**		**2,330,000**	**28,000**
Barnegat Water Co.	Ocean	1—8″x158′	Tch and Qcm	39,000	39,000
Bay Head Water Co.	"	4—(3″-6″)x(700′-860′)	Tkw and Qbs	108,000	27,000
Beach Haven Boro	"	4—6″x600′	Qbs	171,000	43,000
Harvey Cedars Boro	"	1—350′	"	1,000	1,000
Island Heights Boro	"	2—5″x365′	Tch and Qcm	94,000	47,000
Lakehurst Sewer Co	"	1—8″x125′	Tch	11,000	11,000
Lakewood Water Co.	"	3—6″x(595′-621′)	Tkw and Qcm	689,000	230,000
Lavallette Boro	"	1—1551′	Kmr (Qbs)	50,000	50,000
Mantoloking (Louis D. F. Downer)	"	3—(900′-1000′)	"	20,000	7,000
New Egypt Light, Heat, Power & Water Co.	"	1—8″x238′	Kvt	15,000	15,000
Ocean Gate Water Co.	"	1—8″	Tch and Qcm	30,000	30,000
Point Pleasant Beach Boro	"	4—6″x150′:2—8″x150′	Tkw and Qcm	345,000	58,000
Seaside Heights Boro	"	2—6″x500′	Qbs	40,000	20,000
Seaside Park Boro	"	4—8″x(139′-530′)	"	84,000	21,000
Surf City Water Co.	"	1—564′			
Toms River Water Co.	"	4—6″x40′	Tch and Qps	152,000	38,000
Whiting (Tuckerton R. R. Co.)	"	1—148′	Tch	3,000	3,000
Total in Ocean County		**40 Wells**		**1,852,000**	**47,000**
Elmer Water Company	Salem	1—6″x117′	Tch and Qbt	136,000	136,000
Pennsgrove Water Supply Company	"	8—165′	Kmr and Qcm	312,000	39,000
Salem City	"	28—(6″& 8″)x(110′-265′)	Tkw and Qcm	582,000	21,000
Woodstown Boro	"	7—(6″& 8″)x(150′-350′)	Kmw and Qps	365,000	52,000
Total in Salem County		**44 Wells**		**1,395,000**	**32,000**

DATA ON WELLS IN THE STATE OF NEW JERSEY USED AS SOURCES OF PUBLIC WATER SUPPLY

(Arranged by Districts and Counties. Underground Water from Other Sources Not Included.)

REST OF STATE OUTSIDE OF THE TWO METROPOLITAN DISTRICTS—Continued

Purveyor (1)	County (2)	Number, Size and Depth of Wells (3)	Geologic Formation in Which Wells are Located (4)	Average Daily Output during 1924 Total (Gallons) (5)	Average Daily Output during 1924 Per Well (Gallons (6)
Bound Brook Water Co.	Somerset	20—(4″& 6″)x(125′-150′)	Trb and Qsd	26,000	1,300
Total in Somerset County		**20 Wells**		**26,000**	**1,300**
Stanhope Boro	Sussex	1—10″x90′:1—12″x81′	Qtm	38,000	19,000
Total in Sussex County		**2 Wells**		**38,000**	**19,000**
Blairstown Water and Electric Co.	Warren	3—8″x300′	Omb	149,000	50,000
Total in Warren County		**3 Wells**		**149,000**	**50,000**
Total in District		**476 Wells**		**26,284,000**	**55,000**
Total in State		**1335 Wells**		**98,745,000**	**74,000**

MEMORANDUM ON INVESTIGATION OF QUANTITIES OF GROUND WATER AVAILABLE FOR PUBLIC AND INDUSTRIAL SUPPLIES IN NEW JERSEY

The State of New Jersey, through its Geologic Survey and its successor, the Department of Conservation and Development, has been one of the foremost States in collecting data in regard to the use of its ground water resources. The earlier investigations related principally to determining the distribution of water-bearing beds, the depth at which the beds will be struck, the relative yield of wells, and the relative quality of the water. This information is utilized almost daily to reply to inquiries from municipalities, water companies, manufacturing firms or individuals who use wells.

In some places large developments of ground water have caused a lowering of the water level or a decrease in the yield of the wells, so that recently it has been realized that a further step must be taken and studies must be made to determine the safe ultimate yield of the water-bearing horizons in different parts of the State—whether additional large supplies may be developed or whether the maximum supply has already been obtained. An investigation of this problem has been carried on since July 1, 1923, by the Department of Conservation and Development, with the coöperation of the United States Geological Survey. The work is being done by David G. Thompson, an Associate Geologist of the Federal Survey, under the supervision of O. E. Meinzer, Geologist in Charge of the Division of Ground Water of the Geological Survey, in consultation with Dr. H. B. Kummel, Director, and H. T. Critchlow, Chief, Division of Waters, of the Department of Conservation and Development. The greater part of the expense of the work is being borne by the Department of Conservation and Development. Expenditures in the fiscal year ended June 30, 1924, by the Department were $5,994.64 and by the Federal Survey $3,629.00; for the year ended June 30, 1925, by the Department $6,558.68 and by the Survey $1,161.72. The following data are summarized from a preliminary report which is now nearing completion.

PRESENT CONDITIONS

The importance of ground water as a source of water supply in New Jersey is shown to some extent in the following table, which summarizes statistics regarding public supplies from both surface and underground sources for certain years. The data for intervening years between 1917 and 1924 show slight variations from year to year.

SUMMARY OF NUMBER OF SYSTEMS, CONSUMPTION OF WATER, AND POPULATION SERVED FROM PUBLIC SUPPLIES IN NEW JERSEY—1893, 1905, 1917 AND 1924

	Number of Systems						Average Daily Consumption				Population Served			
	Surface Water		Ground Water		Combination Surface and Ground Water (*a*)		Surface Water		Ground Water		Surface Water		Ground Water	
Year		% of Total		% of Total		% of Total	Thousands of Gals. per Day	% of Total	Thousands of Gals. per Day	% of Total	Thousands	% of Total Served	Thousands	% of Total Served
1893 *b*.....	58	70.8	22	26.8	2	2.4	98,762	91.2	9,078	8.9	904	90.8	92	9.2
1905 *c*.....	32	23.4	85	62.0	20	14.6	151,395	74.8	50,903	25.2	1,258	72.4	479	27.6
1917 *d*.....	48	21.5	161	72.2	14	6.3	225,853	72.2	87,171	27.8	1,914	71.2	773	28.8
1924 *d*.....	45	22.2	144	70.9	14	6.9	244,973	71.4	97,899	28.6	2,081	70.9	856	29.1

a The consumption from combination systems in 1893 and 1905 is not easily separable into that from ground water and surface sources. The figures given have been arrived at after a study of data given in several reports and are believed to be not far from correct.

b Data for 1893 from New Jersey Geological Survey, Vol. III, Water Supply, pp. 315-317.

c Data for 1905 from report of the Potable Water Commission, pp. 79-88. The summaries in this report contain several mistakes in the addition of figures for individual systems, which have been corrected in the above table.

d Data for 1917 and 1924 from consumption reports filed with the Department of Conservation and Development.

The significant features shown by this table are: (1) During the past few years the consumption of ground water has been somewhat more than a quarter of all the water used from public supplies. (2) The percentage of population supplied with ground water relatively is a little higher in comparison with the quantity of water used. (3) Although by far the greater part of the population is served with surface water, there are about three times as many systems serving ground water as surface water. Many of the ground water systems are small, whereas some of the surface water systems supply the large cities of the State. Nevertheless there are a number of large ground water supplies with average daily consumption in 1924 as follows: Camden Water Department, 16,091,000 gallons; Elizabethtown Water Company Consolidated, 8,798,000 gallons; Perth Amboy Water Department, 7,677,000 gallons; Plainfield-Union Water Company, 7,635,000 gallons; and Atlantic City Water Department, 4,765,000 gallons.

In addition to consumption from public supplies a large quantity of ground water is used from privately owned wells of manufacturing plants and individuals. A very large percentage of the rural population is dependent upon such supplies. Incomplete data from privately owned plants in some of the large cities show an average daily consumption of at least 35 million gallons a day, distributed as follows: Newark, 10.4 million gallons; Camden, 6.5; Paterson, 5.5; Atlantic City, 4.5; Garfield and vicinity, 2.7; Paulsboro, 2.3; Elizabeth, 2.0; and miscellaneous, 1.7 million gallons. There is undoubtedly much ground water used in other cities, as in Trenton, concerning which data have not yet been obtained. The consumption from private wells would undoubtedly be much greater were it not for the fact that in certain localities of great industrial activity, as in Jersey City and Bayonne, repeated attempts have failed to develop well supplies of satisfactory quality and quantity.

The consumption of ground water continues to increase. From July 1, 1916, when the Board of Conservation and Development succeeded to the rights and powers of the State Water Supply Commission, to June 30, 1925, grants for the diversion of ground water amounted to about 54 million gallons per day, with that quantity practically all actually developed. On the other hand, in the same period grants of surface water actually developed were only about 1,225,000 gallons a day. To be sure, during this period a grant was made of about 100 million gallons a day for the Wanaque project, but this will not be completed for some time. Although the increase in ground water diversion is slow but continuous as compared to the large but spasmodic surface water developments, there is reason to believe that the present ratio between consumption of ground water and surface water may be maintained for some time to come. To illustrate present conditions, attention may be called to the record of one of the principal well-drilling companies which, introducing into the State a comparatively new type of well, in the past three and a half years has developed systems for public supply having a capacity of 39 million gallons a day and for private industrial supplies of more than 15 million gallons a day.

Coastal Plain

From the standpoint of water-bearing capacity of the rock formations, the conditions for the development of ground water are most favorable in the area known as the Coastal Plain, which comprises all of the State southeast of a line that runs northeasterly from Trenton to a point about midway between Elizabeth and Perth Amboy. In this region the deposits are largely unconsolidated sand, gravel and clay. In this province there are two important water-bearing beds that are widely distributed. One is the Raritan formation, which in 1924 yielded an average of about 30 million gallons a day in Camden and vicinity, nearly 10 million gallons in the Perth Amboy region, and more than a million gallons daily at Asbury Park. The second important formation is the Kirkwood, which yielded an average of about 6.5 million gallons daily in Atlantic City and neighboring cities. There are other water-bearing sands, but they are not comparable to the Raritan and Kirkwood formations in water-bearing capacity. Ground water is important on the Coastal Plain, for in may places it is the only supply available at a reasonable cost. This is especially true at the many coast resorts situated on the string of islands that reach from Point Pleasant to Cape May. For these places, many of them small, the only other sources of supply would be surface water brought from the mainland through costly pipe lines. At many places on the mainland portion of the Coastal Plain conditions are unfavorable for the development of surface water, so that ground water must be developed.

Piedmont Plain

Next in importance to the Coastal Plain is that section of the State that immediately adjoins it on the northwest, known as the Piedmont Plain, which is underlain by sandstones, shales, and trap rock. Conditions are especially favorable in the northern part of the province, where glacial deposits over-lying the bed rock yield large quantities of water. This part of the province includes the metropolitan district, in which large ground water supplies have been developed by the City of East Orange, the Plainfield-Union Water Company, the Elizabethtown Water Company, the Commonwealth Water Company, the Short Hills Water Company, and by industries in Newark, Paterson, East Orange, Garfield, Lodi, Elizabeth and other cities. Although it is possible that additional large supplies may be developed in the Piedmont Plateau, conditions affecting the occurrence of water in this province are more "spotty" than in the Coastal Plain province and the chances of getting a large supply of water in new localities are more uncertain. For this reason, together with the feasibility of getting adequate supplies from surface water projects now under construction or contemplated, probably there will be no great increase in ground water consumption. Nevertheless, even now, projects to develop three to five million gallons are under consideration.

HIGHLANDS AND APPALACHIAN VALLEY PROVINCES

In the northwestern part of the State, northwest of a line that passes in general a short distance west of Pompton, Boonton, Morristown and Frenchtown, in the provinces known as the Highlands and Appalachian Valley, conditions are not favorable for the occurrence of large quantities of ground water and no important supplies have been developed. This area however is abundantly supplied with surface water.

INDICATIONS OF OVERDRAFT

In several localities pumping has already produced sufficient lowering of the water table to serve as a warning that additional large developments from the present sources can not be made without serious results. Such areas include the Atlantic City region, the Asbury Park region, the Plainfield-Union Water Company's well field, and certain areas in Newark and neighboring communities. On the other hand, at a few places the pumpage of large quantities of water seem to have shown no unfavorable conditions. For example, in the Camden region an average of about 30 million gallons a day was pumped in 1924 without any observable lowering of the general water level. The problems relating to the quantity of water that may be developed in the future so far are mainly localized in the areas of heavy pumping, which are either industrial regions or shore resorts. However, in several places they are of importance to a number of communities, as in the Atlantic City region, where heavy pumpage in the city appears to have had some effect on the static head for several miles in each direction along the coast and a comparable distance inland. In the present investigation, therefore, the work has been confined largely to the areas where problems are now pressing, although it has not been possible to study every area in which such work is desirable.

METHODS OF OBSERVATION

Very few accurate data of a quantitative nature were available at the start in any of the areas investigated. It has been necessary to collect much data in the field and to develop methods for determining the safe yield of the different well fields. The method that is giving the best results so far involves observations on fluctuations of the water level in wells as affected by pumpage, rainfall, evaporation, etc. Continuous records of the fluctuations of wells are now being obtained with eight water-level recorders, and more or less periodic measurements have been made on nearly 100 wells. Daily measurements of evaporation are being made at the Atlantic City Water Works and the

Perth Amboy Water Works. The following statements summarize briefly the more important data obtained so far in the several localities studied.

Atlantic City Region

More detailed work has been done in this region than in any other part of the State. The region covered in this study extends from Brigantine to Corsons Inlet and includes the mainland towns from Absecon to Somers Point. The public water supply for Atlantic City, averaging 11 million gallons a day in 1924, is obtained partly from Absecon Creek and partly from wells 100 to 200 feet deep on the mainland. The supply for the mainland towns, about half a million gallons daily, comes from a small creek and relatively shallow wells. The supply for all the beach towns from Brigantine to Ocean City and for many hotels and industrial plants in Atlantic City is pumped from wells penetrating the so-called Atlantic City or 800-foot sand which lies at that depth. This is the only horizon that can be utilized along the beach, all other beds yielding only salt water or too small quantities to be of value. The total average daily quantity now pumped from this horizon is estimated to be about 5 million gallons in winter and 10 million in summer. The surface water supplied to Atlantic City, although safe from the sanitary standpoint, at times is dirty and has a bad odor; therefore it has been proposed to develop ground water to replace it.

At first thought it may seem that the required quantity of water can be developed from the 800-foot horizon in Atlantic City, but the present investigation shows that it will be very unwise to attempt this. Since the first wells were drilled, in 1893, the static head on the formation in Atlantic City has been lowered from its original position of about 20 feet above sea level to 60 feet or more below sea level, a total drop of about 80 feet. It has likewise been lowered from 30 to 70 feet in all wells between Brigantine and 55th Street, Ocean City, and as much as 25 feet at the Atlantic City Water Works on the mainland, where there had been no pumping until May, 1925. There is evidence that the area in which there has been a lowering of the head extends several miles beyond the points mentioned and presumably several miles oceanward. Except for the past year and a half no accurate data as to the rate of lowering are available, but it appears to be more or less directly related to the rate of pumping and therefore to progress according to the yearly increase in pumpage. When the pumpage decreases in fall and winter the head rises somewhat and drops again as pumpage increases in summer. From observations on wells in Atlantic City and Longport up to July 15, it appears probable that in 1925 the head will be from 5 to 10 feet below the lowest level in August, 1924.

If an additional draft of 6 to 10 million gallons per day, that necessary to replace the surface water supply for immediate needs alone, is imposed upon the formation in Atlantic City, it is evident that the static head will be lowered very greatly, probably to at least

150 feet below sea level. Accordingly a question arises as to the depth from which it will be economical to lift water.

Even more important is the possible invasion of the horizon by salt water if the head is pulled down too far. Although several wells have "gone salt," it has been rather conclusively shown that the salt water has entered from overlying beds through defective casings. When these difficulties have been remedied the chloride content has been reduced to the normal for the region—as low as 6 parts per million. So far as the writer has been able to ascertain, conditions at Atlantic City, so far as they relate to the salt water problem, are without a parallel, in that where wells situated so close to the ocean, with salt water horizons above, and probably below, have been pumped heavily without drawing in salt water. Wells at one plant on Long Island showed increase in chloride of about 100 parts per million in one year when pumping about 4 million gallons daily, and rose to nearly 500 parts per million in four years, although the pumpage was reduced to about 1.5 million gallons. Even after three years of pumping at the rate of only half a million gallons a day the chloride was more than 150 parts per million. Although certain unknown but possible geologic conditions beneath the ocean may prevent a similar contamination of the 800-foot horizon at Atlantic City, the more probable conditions favor invasion by salt water at almost any time. Experience in other localities shows that if this does occur it may take place rapidly, and once it has happened the formation may be permanently spoiled. This would very seriously affect the shore communities which are now entirely dependent upon the 800-foot horizon.

The 800-foot horizon may be penetrated at a less depth on the mainland, and it may be asked whether it cannot be drawn upon there to increase the Atlantic City supply. There is little question but that any large draft would cause a considerable lowering of the head over an area comparable to that resulting from the present pumping in Atlantic City. The head in Atlantic City would undoubtedly be lowered considerably, although perhaps not as much as if the additional draft occurred right in the city. There would nevertheless be the danger of invasion by salt water. It is the opinion of the writer that the horizon should not be drawn upon at any point for the Atlantic City public supply, but should be left for those smaller beach communities which cannot now afford to go to the mainland for their water.

There remains for the use of Atlantic City the shallow horizons on the mainland and the streams some distance inland. It appears that a considerable quantity of water can be obtained from the shallow horizons. However, if shallow wells are placed too near the bay there is danger of salt water, so that in the development of such wells the city should proceed with caution, making tests to be sure contamination from this source is eliminated by the proper location of the wells.

A fact to be emphasized is that the problem of the economic and prudent utilization of the ground water resources of the Atlantic City region is not that of Atlantic City alone, but of all the communities in a considerable area. The question may fairly be raised as to whether it will not be desirable in the near future for these communities to form a district for the purpose of developing its water resources in the wisest and most economic manner with due regard for the natural conditions that control the occurrence of the ground water supplies.

Camden Region

The water supply for Camden and practically all of its suburbs is derived from underground sources. The greater part of the water is obtained from the Raritan formation. The average daily consumption from this horizon in 1924 was as follows: Camden Water Department, 16 million gallons; Stockton Water Company (supplying part of Camden), 2 million gallons; Merchantville Water Company, 2 million gallons; Gloucester Water Department, 1.9 million gallons; minor public supplies, 1.5 million gallons; and private industrial supplies, 6.5 million (estimated); a total of about 30 million gallons a day. The consumption both in the city and the suburbs has been increasing rapidly in the last few years, and is expected to continue to do so as a result of the building of the Camden-Philadelphia bridge.

The wells drawing on the Raritan formation are scattered over a stretch about six miles long, but fully 12 million gallons daily come from an area only about a mile and a half long and half a mile wide, adjacent to Delaware River between Delair and Morris Stations. In this area the Camden Water Department has three well fields, the Morris field, with a capacity of 17 million gallons a day, the Delair field with a capacity of 5 million gallons a day, and the recently developed Puchack Run field with a capacity of about 9 million gallons a day. In addition the department has four wells in the city, each with a capacity of about a million gallons a day. Thus the capacity of the entire system is about 35 million gallons a day. With one possible exception this is believed to be the largest development of ground water for public use anywhere in the United States.

The Camden city system has not yet been pumped to capacity. During the acceptance test of the Puchack Run field, the Delair field was idle and the Morris field was not pushed. It is therefore impossible to say just what will be the effect when all the fields are pumped to their capacity. It is believed that trustworthy evidence has been obtained to show that the areas of influence of the three fields intersect each other and that there is some interference between them. So far this interference has not been found to be very serious, but it is sufficient to warrant careful observation as the draft in the fields is increased. As a matter of fact, the water-yielding capacity of the Raritan formation in the Camden region appears to be much greater than the formations studied so far in any other part of the

State. Nevertheless it is not safe to assume that there is no limit to its yield.

Water for the Camden suburbs within a radius of ten miles, like the Camden supply, is derived mainly from the Raritan formation. The total consumption from these is not yet great, and so far there appears to be no serious problem resulting from the pumping of them. However, in view of the possible considerable increase in consumption in the entire territory it is believed that a careful study should be made of the entire situation, with observations on the different well fields extending over a period of years. Such continuing observations would be of great value in forming a basis for planning for future increases in the supply.

Asbury Park Region

The water supplies for Asbury Park and nearby coast towns are obtained from three horizons, namely, in descending order, the Mount Laurel-Wenonah, the Englishtown, and the Raritan. The Raritan lies at a depth of about 900 to 1100 feet and contains so much iron that water from it has to be filtered. For these reasons it is more costly to develop than the other formations and it has been used only by Asbury Park. The Mount Laurel-Wenonah formation is nearest the surface and accordingly offers the most attractive source of water for small towns. However, its water-bearing capacity is rather poor. This is attested by the fact that the static head in the summer of 1924 was some 50 feet or more below the original head, although the daily consumption is estimated to have been less than two million gallons a day; and recently completed wells of the most modern type show the unusual drawdown of about 100 feet when pumping only about 350 gallons a minute. The Englishtown formation appears to have a somewhat greater water-bearing capacity than the Mount Laurel-Wenonah. The lowering of the static head from the original conditions has been comparable to that of the Mount Laurel-Wenonah, but the pumpage from the horizon is greater. The Raritan apparently has not been affected seriously by pumping, but this may be an erroneous opinion resulting from inadequate data. The situation in this locality should be carefully watched. On the basis of the present information, in granting future applications it is believed that further diversion should be limited to the Raritan formation.

Princeton Region

Although the Princeton Water Company pumped from its field during 1924 an average of only 758,000 gallons daily and a maximun of about 1,250,000, it faced a water shortage on several occasions during the past few years. Actual famine has been prevented only by pumping water on the land from a nearby stream, the water percolating into the ground and raising the water table. The water bearing rocks are sandstone, which evidently do not have much storage. As a result the water level is subject to considerable fluctuation in accordance with variations in the rainfall. During the first six months of 1925 the level in observation wells showed a range of about 125 feet. There seems to be no great hope of materially increasing the ground water supply except at a distance of several miles from the city. Although the Princeton supply is relatively small, the problems presented are typical of those met in some of the smaller communities of the hard rock areas of the State.

Runyon Area

The water supply for Perth Amboy, in 1924 an average of about 7.7 million gallons daily, is obtained from a well field at Runyon. In 1918 war industries raised the consumption to an average of 10.5 million gallons. Two horizons are available in the field, both of which are part of the Raritan formation. Extensive studies of these horizons have not been made, but it appears that they are not as good water-bearing beds as the Raritan at Camden. Certain puzzling conditions have been found, possibly resulting from the geologic structure in the region. Pending the solution of these conditions and the completion of other studies, definite conclusions have not been reached.

Northern Metropolitan District

No detailed work has been done in the Metropolitan district. Large supplies for public use are obtained from wells by the Plainfield-Union Water Company, the Elizabethtown Water Company, the Commonwealth Water Company, the City of East Orange, and lesser supplies by the cities of Garfield and Ridgewood. Additional large supplies are pumped by industries in Newark, Paterson, Garfield, Lodi, Elizabeth and other places. In some of these areas, notably in the Plainfield-Union field, in the southeast part of Newark, and in Garfield, there has been more or less lowering of the water table. The fact that no serious effects of pumping have been reported in other localities may be due in part to lack of adequate observations. Detailed studies in these several areas are urgently needed. In two localities pollution of the ground water has recently been reported under conditions that suggest that this may become a serious problem in other parts of the region where there is heavy pumping, resulting from its built-up character and the more or less open texture of the rocks.

The city of Garfield is undertaking to develop at least three million gallons in virgin territory. This project offers an opportunity to follow the effect of heavy pumping of a field from the very first, and it is hoped that observations can be made in this field.

General Problems

Certain conditions brought out during the investigation suggest the desirability of a closer control by the State on the development of the ground water resources, as follows:

1. In some localities bordering on the ocean there is a real danger of salt water invading fresh water horizons and spoiling them either for all time or for a long period of years. Some individual wells have already been contaminated in this way, but the owners generally have taken care to prevent widespread damage by filling the wells. There is nevertheless a possibility that a well owner may refuse to do this or may not do it properly. At the present time there are no laws giving to any State department power to remedy any condition which may arise engendering the contamination of a fresh water horizon by salt water.

2. In the present investigation the difficulty in obtaining accurate data emphasizes the advisability of requiring the operators of public supplies to keep more accurate data on the performance of their well systems. In the past the Board of Conservation and Development has required only the filing of consumption reports. Fully as important, if not more so, in ground water developments are data as to fluctuations of the water level, for such data covering a period of years is the only reliable evidence as to the actual effect of heavy pumping. It is therefore desirable that the operators be required to make and report the observations that are deemed necessary. It would be better, perhaps, if the operators could be educated to make the necessary observations of their own volition, but the experience of the present investigation shows that this will be very difficult to bring about.

3. An important problem, and one that is puzzling, is the relation between the rights of public water supplies and of supplies of private corporations and individuals. At present the Board of Conservation and Development may reject the application of a municipal corporation, corporation or person to develop ground water for public supply if upon proper evidence it is shown that such development will unduly injure public or private interests. On the other hand it has no control to prevent manufacturing corporations or individuals from making similar developments for private use which may just as much injure existing interests. To be sure, the injured party may now have recourse to law, but in the meantime irreparable damage may be done to an important and needed source of ground water supply. If the State could control the private water supplies as well as public in the few cases of serious interference that might arise, it could doubtless provide for an allocation of supplies that in the long run would result in a more economical and wise development of the ground water resources.

In conclusion it may be said that if the mandate of the people as expressed in the law creating the Water Supply Commission is to be properly carried out,—namely, to provide "a general supervision over all sources of potable and public water supply, to the end that the same may be economically and prudently developed for the use of the people of this state"—in so far as this relates to the ground water resources the present investigation can be considered only a beginning. It is a well recognized fact in the study of surface water supplies, that, in order to be of real value, observations must cover a period of years and their value increases in accordance with the length of record. This is even more true of observations on ground water supplies. So many more factors affect the occurrence of ground water that, in contrast to surface water studies, a year's or even two or three years' observations may not show the true conditions. It is therefore important that provision be made for a continuance of the observations already begun and for the extension of the work to areas where there are indications of possible depletion of the supply but where no studies have yet been made.

(Signed) DAVID G. THOMPSON,
Associate Geologist.

July 30, 1925.

IMPORTANT GROUND WATER HORIZONS IN NEW JERSEY

A Memorandum prepared by M. W. Twitchell, Assistant State Geologist

UNFAVORABLE ROCKS IN NORTHERN NEW JERSEY

Because of their relatively non-porous character we can dismiss as unfavorable for yielding large supplies of ground water the following types of rocks:

1. The *Pre-Paleozoic (or Pre-Cambrian) Rocks*, including gneisses, granites, etc., that underlie most of the Highland area, and a small area at Trenton.

2. The *Paleozoic Rocks*, including limestones, slates, etc., that underlie the Kittatinny Mountain and Valley and several valleys and ridges within the Highland area.

3. The *Triassic Igneous (or Trap) Rocks*, that underlie certain areas within the Piedmont Plain, including the Palisades, Watchung Mountains, Sourland Mountain, Rocky Hill and some others of minor importance.

4. *The Triassic Argillites*, which are peculiar, hard, dense rocks, allied to and looking like shale but much harder, that constitute the chief rocks underlying those areas within the Piedmont Plain mapped on our geologic maps as the *Lockatong* subdivision of the Triassic (Newark) sedimentary rocks. One of the areas extends from Somerset *via* Princeton to Monmouth Junction, another borders Sourland Mountain from the neighborhood of Neshanic southwestward, and a third extends from near Byram *via* Croton to and beyond Pittstown.

FAVORABLE ROCKS IN NORTHERN NEW JERSEY

The Stockton Sandstones.—In a few areas within the Piedmont Plain, sandstones are known to predominate over shales, a fact which naturally leads one to expect that in these areas the conditions are favorable for ground water supplies. The areas are those mapped on our geologic maps as underlain by the Stockton subdivision of the Triassic (Newark) sedimentary rocks. One of the areas extends from near Trenton and Trenton Junction northeasterly to near Princeton and Monmouth Junction; another runs northeast and southwest past Hopewell; a third extends from Stockton and Raven Rock on the Delaware northeasterly to and beyond Sand Brook; and a fourth forms a narrow border on each side of the Palisades from Bayonne northward. These Stockton sandstones are usually reddish in color, have a prevailing dip toward the northwest of about 12 to 15 degrees, and are cut by highly inclined joint cracks. Layers of shale frequently occur between the sandstone beds. Water circulates in these rocks chiefly in the pores of the sandstones and to a less extent in the joint cracks and along the bedding planes.

Each area of Stockton sandstones constitutes a water horizon of considerable potential value. The extent of these areas is indicated on our geologic map. The areas near the Palisades are of less value than others because of their narrowness, and because their proximity to the trap rock has resulted in a partial baking of some of the layers, thereby reducing their porosity. However, five wells in Stockton sandstones at Hoboken, drilled prior to 1901, yielded 65, 100, 350, 357 and 427 gallons per minute; and one at Englewood yielded 120 gallons, thus indicating a relatively favorable condition at some points in even these narrow areas. The most important of the Stockton areas is that near Trenton, Princeton, etc. The relatively favorable character of the rocks within this area has already been demonstrated at a number of points, including Wilburtha, Asylum Station, Ewingville, Lawrenceville and Princeton. In 1917, at the State Asylum near Asylum Station northwest of Trenton, three wells, 3, 4 and 3 inches in diameter and 205, 202 and 215 feet in depth respectively, yielded 186, 243 and 116 gallons per minute separately and 506 gallons when pumped together, the drawdown while pumping the 506 gallons being 8, 9.3 and 10.5 feet respectively. A well drilled for the Princeton Water Co. in 1915, 304 feet deep and 8 inches in diameter at the bottom, yielded originally 600 gallons per minute; and a new 290-foot well, 10 inches in diameter at the bottom, drilled in 1923, gave 500 gallons per minute. These are, of course, the most successful wells and indicate the maximum yields the Stockton sandstones can be expected to give under the most favorable conditions. We have on record 30 wells in all known to obtain their supply from the Stockton sandstones. These 30 wells range in depth from 50 to 600 feet and their average depth is 270 feet; their range in yield is from 10 to 600 gallons per minute and average yield 103 gallons. As the average yield of 762 wells utilizing the various types of Triassic sedimentary rocks is 80 gallons per minute, the average for the 30 Stockton wells alone is 23 gallons more than the general average, which is a further corroboration of their more favorable character.

No individual water horizons, such as a particular water-bearing sandstone, can be traced more than a very short distance in these Stockton areas. This is chiefly because of the steepness of the dip, which averages about one foot vertical to four feet horizontal. Adjacent wells can be made to strike the same water-bearing layer by taking into consideration the amount and direction of the dip; varying the depth of the wells according as they are up or down the dip, or keeping the wells all of about the same depth if they are placed in a line at right angles to the direction of the dip. It is only within such narrow limits as these that knowledge of the fact that some wells of a certain depth have been successful may be made use of. Because of the structural features described, it is also usually impracticable to estimate the extent and capacity of individual water-bearing sandstones from which a well or group of wells obtains its supply. One approach to a capacity estimate is to *take the well field as the unit,* rather than a single water-bearing layer. These well fields, or areas where a group of wells are furnishing a supply, usually have wells of varying depth and so spaced as to draw upon several water-bearing sandstones, and also upon the joint cracks and other fissures that cut across the rocks. As the average dip is about one foot vertically downward for each four feet horizontal, such water as percolates down the sandstone layers has probably entered them within a distance of about four times the depth of the well; while the water that comes to the well through the joint cracks, because of the prevailing high angle of these cracks, has probably come chiefly from a less distance away, though part of it may have worked along the cracks from greater distances. Where a well field has shown signs of an overdraft upon the ground storage we have a clue to the capacity of the rocks involved. One such instructive case is that at the State Asylum near Trenton. The high yields of three of these wells are given above. While there are ten wells in the well field, they have used only six or less on the average, and during the six years from 1916 to 1922 were getting nearly half a million gallons per day. From data on record it appears that whereas in 1917 the static water level in the three wells described above was around 9 feet, in 1922 it was around 100 feet, and in some new wells it was also around 100 feet. The yield also had fallen off, being only about 485,000 gallons per day for six wells in 1922, as against 730,000 gallons per day for three wells in 1917. In view of these facts it was concluded that the draft on the ground water in this field had greatly exceeded the annual increment from the rainfall for several years and that large inroads had been made upon the ground storage. Judging from this case, it would appear that the capacity of a well field in the Stockton sandstones, of this size, 600 feet square, and probably drawing upon an area estimated to extend between 1500 to 2000 feet in all directions and to contain about 320 acres, without exceeding the annual increment due to the rainfall, is less than 500,000 gallons per day. Perhaps it should be added that the period between 1917 and 1922 is known to have been one of a deficient rainfall, so that the capacity in a time of normal rainfall may be somewhat greater than the figure indicated.

The Brunswick Shales and Sandstones.—By far the larger part of the Piedmont Plain is underlain by the reddish shales and sandstones which together are shown on our geologic maps as the Brunswick subdivision of the Triassic sedimentary rocks. In the southern part shales predominate over sandstones and in many places constitute practically the only rock; but north of the neighborhood of the Raritan River sandstones become more abundant and in places constitute a large part of the sections as revealed in outcrops and well borings. In view of this distribution, the Brunswick area, north of the Raritan, may be considered one of the regions where the underlying rocks are favorable for more ground water supplies than elsewhere. However, the sandstones occur too irregularly to permit of mapping separately the areas where they are relatively abundant. Consequently it is impossible to ascertain by a study of the geologic map where the more favorable localities will be found, as we could do in the case of the Stockton sandstones. There are some places where the wells that have been put down have proven to be large yielders. Among these favored localities are East Bound Brook, Netherwood, South Plainfield, Baltusrol, Springfield, South Orange, East Paterson, Midland Park, Mahwah and Harrison. In these and similar cases, such logs as are available indicate that sandstones usually constitute the water-bearing rocks, even though shales may form a large part of the materials penetrated. So far we are unable to predict favorable places of the type described. For this reason it is highly important to obtain good data in regard to local wells, and use it in the light of the known geology of the region, in working out the ground water problem for any particular locality.

As in the case of the Stockton sandstones, these Brunswick sandstones and shales are cut by numerous joint cracks and other fissures which are usually at a high angle. The dip of the beds is prevailingly toward the northwest, with a tendency near the southern and northern ends of the Watchung Mountains to swing around so as to be toward the mountains. These structural features being so similar to those of the Stockton beds, the circulation of the ground water and the difficulties in the recognition of definite water horizons are also similar. Where the wells penetrate shales, the joint cracks are probably the chief sources of the supply, and in the case of the sandstones these cracks probably frequently add to the amount of water the wells yield. The distribution of these cracks is quite irregular. At times they are closely spaced and wells that happen to strike zones of this type are apt to be relatively large yielders. It is probable that the wells giving the largest yields are those where a combination of favorable factors exist, such as a porous textured rock between impervious layers with a closely spaced joint zone, or a fissured fault zone, or even an intersection of one or more such groups of openings.

The average yield of over 600 wells utilizing the Brunswick beds was over 80 gallons per minute. The great majority of the wells were less than 300 feet deep and most of the large yields were from wells of 300 feet or less in depth. Only 11 wells over 450 feet deep are found among the 100 wells reporting a yield of 150 gallons per minute or more, while of the score of wells yielding 500 gallons or more, three-fourths were from 200 to 300 feet deep. The capacity of favorable well fields in the Brunswick beds appears to be fully equal to or even greater than those in the Stockton beds; but, as already indicated, these favorable areas cannot be predicted in advance, except in so far as exceptionally successful wells may be taken as indications of generally favorable conditions in the rocks.

The Glacial Deposits.—The glacial deposits from a discontinuous mantle over the northern part of the State down to and somewhat beyond the terminal moraine, which, as is well shown on our geologic map, crosses the State from Belvidere *via* Hackettstown, Dover, Morristown, Plainfield and Metuchen to Perth Amboy. Not all portions of the glaciated area are favorable for large supplies of ground water. With but few exceptions it is only where the glacial deposits are more or less stratified that large supplies may be expected. Many of the favorable areas are shown on our geologic map as "stratified drift." The gravelly and sandy deposits formed by the streams that issued from the ice are the most important. They occur close to the southern edge of the terminal moraine. These areas have already proven their favorable character by affording large supplies at Plainfield, Netherwood and elsewhere. One well at Netherwood yielded 750 gallons per minute from these stratified glacial deposits. North of the terminal moraine there are also to be found occasional areas where the drift is of the stratified type. Such areas should be regarded as of potential value as water horizons. Because of the fact that these areas of stratified drift are so irregularly distributed and vary so much in shape and size, it is impracticable to give any worthwhile estimate of their capacity for yielding ground water supplies.

Some deposits not mapped as "stratified drift" have, on investigation, proven to be irregularly stratified. Among these are some which appear to comprise gravel beds along ancient stream courses, that have been covered by lake deposits or ordinary glacial drift. The most remarkable case of this kind is that located in the neighborhood of the outlet of glacial Lake Passaic, near the Short Hills gap through the Watchung Mountains. When the geologists decided that the Passaic once flowed through the Short Hills gap instead of, as at present, by way of Paterson, it was inferred that water-bearing gravels might be found near bedrock in the vicinity of the ancient outlet. Test wells proved the inference sound, and since that time numerous wells have been drilled which have afforded large supplies of ground water. Among these are the successful wells at Short Hills and Springfield, and also many along Canoe Brook and at Chatham and Madison. Several wells in these ancient gravels have yielded 1000 gallons per minute. One well at Madison, when drilled, gave a natural flow, several feet above the surface, of 400 gallons per minute.

Of about 130 wells utilizing the glacial deposits and in connection with which the yield has been reported, about 80 gave yields of 50 gallons or more per minute, and most of these are believed to draw upon deposits of a stratified character. Nearly all of the large yields are from wells of from 50 to 100 feet in depth.

IMPORTANT WATER HORIZONS IN SOUTHERN NEW JERSEY

General Statement

It is generally known that all that portion of New Jersey lying south and southeast of the Delaware River below Trenton and a northeast-southwest line from Trenton *via* Monmouth Junction to Carteret on the Arthur Kill constitutes a Coastal Plain built up of various layers of unconsolidated sand, gravel, clay and greensand marl. Aside from some thin superficial deposits of comparatively recent geologic age (Quarternary), the strata forming the Coastal Plain belong either to the Tertiary period of Genozoic time or the upper Cretaceous period of Mesozoic time. Of the twelve formations into which the Cretaceous beds of New Jersey have been divided only a few are important as water horizons. These are the Magothy-Raritan (taken together), the Englishtown, the Mount Laurel-Wenonah (taken together) and the Vincentown. Of the four formations into which the Tertiary beds have been divided only two, the Kirkwood and the Cohansey, are important as water horizons. All of these Cretaceous and Tertiary beds dip gently southeastward toward the sea, the oldest (Raritan) at about 50 feet per mile and the youngest (Cohansey) at about 10 feet per mile. Starting from the seashore and traveling to the northwest we would reach the western limits of the wide area forming the outcrop of the Cohansey as we approached Yorktown, Pitman, Clementon and Prospertown. Continuing northwestward we would then cross in order the narrow belts constituting the outcropping edges of the various older formations (as shown on our geologic map), namely: *Kirkwood,* Manasquan marl, *Vincentown* sand, Hornerstown marl, Tinton loam, Red Bank sand, Navesink marl, *Mount Laurel* sand, *Wenonah* sand, Marshalltown clay-marl, *Englishtown* sand, Woodbury clay, Merchantville clay, *Magothy* formation and *Raritan* formation. A well just drilled at Lavalette, on the coast, northeast of Toms River, passed through various formations from the *Cohansey* to a water-bearing sand in the upper part of the Raritan which they struck at 1551 feet. These facts will give a general idea of the character and arrangement of the Coastal Plain beds.

The Magothy-Raritan Water Horizons

Both the Magothy and the Raritan formations are formed of alternating layers of sand and clay. The two formations have been separated at only a few points and are therefore mapped as a unit on our geologic map. Study of numerous exposures and many logs of wells has demonstrated that the sand and clay layers in these formations are extremely variable in thickness and in distribution both vertically and laterally along the strike and down the dip. This is probably because both sand layers and clay layers are in the form of lenses of various sizes and shapes.

While quite a number of sand beds in the Magothy-Raritan are known to be water-bearing, and locally constitute important water horizons, because of the irregularity in structure described above they cannot as a rule be correlated, or traced across country, any great distance. Nevertheless, it is seldom the case that a well passes through clay covering beds into sand layers in the Magothy-Raritan without striking water in quantities above the average. For this reason the combined formation may well be considered as a single great water horizon whose catchment area is practically equivalent to the outcrop as shown on our geologic map. (Southwest of Trenton the outcrop of the Magothy-Raritan formations extends along and beneath the Delaware River.)

The evidence indicates that the Magothy-Raritan formations were laid down upon an irregular surface. The thickness is therefore variable, ranging from 150 to 200 feet at the outcrop but increasing down the dip, as shown by well borings, to over 500 feet. The great majority of the wells utilizing these formations are located within the outcrop and obtain water at less than 150 feet below sea level. The remaining wells utilizing these beds usually lie within eight or ten miles from the outcrop and are less than 500 feet deep. A few wells at and near Asbury Park having depths of from 900 to 1160 feet and one at Lavalette having a depth of 1551 feet extend the zone of utilization in that part of the State to over 30 miles from the outcrop. The average dip of the Magothy-Raritan beds is about 50 feet per mile to the southeast, with a tendency to veer to the south-southeast in northeastern Monmouth county.

The water-bearing capacity of the Magothy-Raritan formations is considerable. The evidence at hand indicates that, considered as a single water horizon, it is one of the most important in the State. Over 600 wells are utilizing these formations as a source of supply. In most cases the yield is not reported. Of the older wells, sixty-three, in connection with which individual yields were reported, indicate that the yield varies greatly, ranging from 10 gallons per minute to over 500 gallons per minute. Of these sixty-three, four gave 10 or less; seventeen gave from 10 to 50; twelve from 50 to 100; twenty-four from 100 to 150; two from 150 to 250; two from 250 to 300; two from 400 to 500 gallons per minute. Several wells in recent years have given over 1000 gallons per minute.

One area in which the Magothy-Raritan is of especial importance is a belt about ten miles wide running in a northeast-southwest direction along the Delaware from Trenton to Penns Grove. Within this belt the Magothy-Raritan horizon is the chief one utilized; and it is also true that there are more wells utilizing these formations within this belt than there are in any area of equal size in the State. There are probably between 300 and 400 such wells in the belt. As indicative of the greatest possible yields from this horizon in this area we have the reports of six large diameter (24-inch) wells at or near Camden that gave 935, 1000, 1010, 1070, 1100 and 1100 gallons per minute. One of those giving 1100 gallons (well No. 4 for the Camden Water Department) had a specific capacity of 36.6 gallons per minute per foot of drawdown; the static level being 48 feet and the pumping level 78 feet. Mr. Thompson in his Memorandum, has furnished valuable data regarding the amount of water obtained from these formations in the Camden neighborhood.

Another area where the Magothy-Raritan is of especial importance is within a belt about twenty miles wide extending in a northwest-southeast direction from near Perth Amboy to Lavalette, including Sandy Hook and Jamesburg. Within the northwestern part of this area the Magothy-Raritan is the chief horizon utilized; and despite the great depth at which it lies, it is assuming ever increasing importance to the southeast along the beaches, where the higher horizons have in places failed to give adequate supplies. In this area some of the clay beds in the Magothy-Raritan attain a considerable thickness (as much as 60 feet at the outcrop), and such beds naturally have a larger areal extent and constitute effective impervious covers for the water-bearing sands beneath them over a wider area than is usually the case in these formations. In these exceptional cases certain water horizons have been traced or correlated for distances greater than the average. One important locality in this area is Runyon, where the well field of the Perth Amboy Water Department is located. One of the first wells drilled in this field, put down in 1900, 212 feet deep, gave the remarkable yield of 500 gallons natural flow at 16 feet above the surface. This was from the deeper water-bearing sand, which lies beneath the thick "Woodbridge clay" member of the Raritan formation. One deep well at Asbury Park, 8 inches in diameter at the bottom and 1162 feet deep, gave 1000 gallons per minute. Another well drilled in 1924 at Whitesville, near Asbury Park, 981 feet deep, is reported to have yielded 1000 gallons per minute. These maximum yields indicate that the capacity of the Magothy-Raritan horizon in this northeastern area is not notably different from that in the southwestern area and that it does not decrease much down the dip for at least as much as twenty miles. Mr. Thompson has furnished more definite quantitative data regarding the yield of the wells at Runyon, Asbury Park and elsewhere in this northeastern area.

The Englishtown Water Horizon

The Englishtown sand is the next important water-bearing formation above the Magothy-Raritan, from which it is separated by two clay formations whose aggregate thickness is 100 feet or more. The outcrop of the Englishtown, and therefore its catchment area, as shown on our geologic map, extends from Port Monmouth on Sandy Hook Bay, where it is about three miles wide, southwest to near Swedesboro, Salem county, where it diminishes to zero. It is thickest at the northeast (100 feet or more) and thins out southwestward to less than 20 feet in Salem county. The average dip of the formation is about 38 feet per mile toward the southeast.

The Englishtown sand is an important water horizon in north eastern Monmouth county. Most of the wells utilizing the horizon are located in this region, within twenty miles from the outcrop and chiefly along the seashore. The majority of them obtain water at 100 to 150 feet below sea level, though quite a number have had to go to greater depths, up to 900 feet. Another area in which the Englishtown has proven to be an important aquifer is a short narrow belt from near Mount Holly southwestward to near Marlton.

The capacity of the Englishtown is indicated by the fact that, of sixty wells utilizing it and in connection with which the yield on pumping was reported, seven gave less than 20 gallons per minute, three a yield from 20 to 49 gallons, twenty-six a yield from 50 to 99 gallons, twelve a yield of from 100 to 199 gallons, five a yield of from 200 to 299 gallons, and seven a yield of 300 gallons and over per minute. The yield in the last seven cases was 300 (3), 333, 350, 575 and 624 gallons. The 624 yield was at Spring Lake, being from a well with a 6-inch screen at 640 to 705 feet, the static level being 12 feet and the pumping level 72 feet during ten hours' pumping.

The Mount Laurel-Wenonah Water Horizon

The Mount Laurel-Wenonah sands are taken together and shown as a unit on our geologic map and constitute the next higher water horizon above the Englishtown sand. The outcrop and catchment area as indicated on the geologic map is from one to three miles wide and extends from Atlantic Highlands, near Raritan Bay, southwest to the Delaware River near Salem. Considered as a single sand bed, the Mount Laurel-Wenonah is separated from the Englishtown sand by a relatively impervious clay marl bed (the Marshalltown) which varies from 20 to 40 feet thick. The combined thickness of the Mount Laurel-Wenonah at their outcrop increases from 40 feet at the northeast to 80 or 100 feet in the southwest. The average dip is about 40 feet per mile toward the southeast.

The Mount Laurel-Wenonah sand bed is particularly important as a water horizon in a long narrow belt extending from near Pemberton to Salem and within six or seven miles of the outcrop. Most of the wells utilizing the horizon are in this belt. Another important area is in Monmouth county between Lakewood and Seabright, especially along the shore. The distribution of the wells utilizing the Mount Laurel-Wenonah is in a general way the reverse of that of the Englishtown, which is probably due to the fact that while the latter is thicker in the northeast and therefore more productive, the former is thicker in the southwest and so more productive there.

Marlton has over twenty-five wells drawing water from this horizon, most of them being less than 125 feet deep. Six wells for Woodstown obtained 60 gallons per minute per well at 140 feet from this horizon. Of fifty-one wells utilizing this horizon, in connection with which the yield on pumping is reported, two gave 20 gallons or less, twenty-six gave from 20 to 49 gallons, four gave from 50 to 99 gallons, two gave from 100 to 199 gallons, and one yielded over 200 gallons per minute. In general, the facts of record appear to indicate that the Mount Laurel-Wenonah is a smaller yielder than the Englishtown. The quality of the water, particularly as to iron content, plays its part in determining which horizon will be used where both can be penetrated. At some places, as for example at Brown's Mills, wells have struck more irony water in the Englishtown than in the Mount Laurel-Wenonah, and have been finished off so as to utilize the higher horizon. At other places, as for example at Camp Dix, the Mount Laurel-Wenonah has proven to be more irony than the Englishtown. However there are more places where the Mount Laurel-Wenonah has been reported as the water of better quality than is the case with the Englishtown.

The Vincentown Water Horizon

The Vincentown sand is the uppermost of the cretaceous water horizons. It is of less importance than any of the other and needs have but brief treatment here. While the outcrop, as shown on our geologic map, extends in a more or less discontinuous zone from Long Branch to Reedy Island in the lower Delaware River, it has been overlapped and covered at many places by the Kirkwood and other later formations. However, as the Kirkwood usually is a permeable sand bed, the effective catchment area of the Vincentown water horizon may be thought of as a continuous area averaging about two miles in width extending from Long Branch to Reedy Island. The wells utilizing the Vincentown are nearly all located within one to four miles to the southeast of the catchment area. Along its outcrop the Vincentown consists of alternating layers of a highly calcareous sand and a marly sand. Because of its calcareous character, often an indurated sand constituting an impure limestone, water from this formation is apt to be hard. The character of the formation changes down the dip to a marly clay that is relatively impervious; for which reason it is not likely to be a productive water horizon at a greater distance than five miles from the catchment area.

The wells utilizing the horizon are distributed somewhat evenly along the line from Marlton southwest to Quinton and are most abundant in the vicinity of Clementon, Camden county. Only a few wells are reported to draw on the Vincentown in the northeastern part of the Coastal Plain.

The wells drawing from the Vincentown rarely go to depths greater than 50 feet below sea level; but as the elevation of the surface varies considerably, the actual depth at places is as much as 200 feet or more. The data regarding yield in connection with this horizon is too meagre to justify any general conclusions. There are probably forty or fifty wells utilizing the Vincentown. Four of these reported yields on pumping of from 10 to 72 gallons per minute; while one reported a yield of 200, and another one of 300 gallons per minute. At Clementon, in 1923, four wells were together obtaining as much as 300,000 gallons per day, presumably from the Vincentown, as a depth of from 165 to 175 feet. The best of these wells, 8 inches in diameter, overflowed naturally about 40 gallons per minute and pumped 200 gallons per minute.

The Kirkwood Water Horizon

The Kirkwood formation is one of the most important water-bearing formations in the State, ranking along with the Magothy-Raritan. It is preëminently the water horizon along the beaches from Point Pleasant to Cape May and is also important inland south of the Mullica River. The outcrop and consequently the catchment area of the formation is relatively wide, being, as will appear from our geologic map, from ten to fifteen miles wide in Monmouth county, narrowing southwestward to about three miles in Gloucester county and widening again to ten miles along the Delaware River in Salem county. The effective catchment area is even wider than the outcrop owing to the fact that at many places the overlying beds, especially the Cohansey, are sands that permit the water to pass at once into the Kirkwood. The average dip of the Kirkwood beds is about 20 feet per mile in a southeast direction; though the deeper beds, because of a marked thickening of the formation down the dip, is better taken at 25 feet per mile. The thickness of the Kirkwood is 100 feet or more along the outcrop. Down the dip at Wildwood the portion of the section assigned to the Kirkwood is about 700 feet.

As in the case of the Magothy-Raritan water horizon, the wells utilizing the Kirkwood draw from several water-bearing sands. Where these beds are thick and lie beneath thick clay beds they can be correlated in wells a considerable distance apart; otherwise it is not always possible to correlate the water-bearing sands in even neighboring wells at the same locality.

The principal water-bearing strata are one or more coarse beds of sand at or near the base of the formation. Near the outcrop the basal Kirkwood sands are usually thin; but down the dip toward the coast the basal sands are quite thick, sometimes as much as 80 feet in thickness. For this reason the beaches are in the strategic position to utilize the Kirkwood where the thickness of the chief water-bearing strata is at a maximum and therefore most productive. This is probably the chief reason why we find the great majority of wells utilizing the Kirkwood located along the coast. The coarse sands at the base of the Kirkwood along the coast probably persist inland at least as far as Millville and Winslow. We cannot assert with positiveness that exactly the same basal beds persist to the outcrop; if not, their catchment area must lie within the outcrop of the Cohansey formation and the water that flows along them must first have percolated down through Cohansey sands. These coarse basal beds are probably water-bearing wherever they occur, so if all possible localities in the interior were prospected, the water obtained from the Kirkwood in the interior would no doubt exceed that obtainable along the coast.

Of 128 wells utilizing the Kirkwood water horizon, fifty reported the yield on pumping, of which seven gave less than 50 gallons per minute, eight gave from 50 to 99 gallons, sixteen gave from 100 to 199 gallons, eight gave from 200 to 299, and eleven gave a yield of 300 or more. The eight largest yields were three of 400 gallons, two of 450 gallons, one of 864 gallons, two of 1000 gallons and one of 1500 gallons. Mr. Thompson has given more definite quantitative data in regard to the Atlantic City region. There the principal water horizon utilized is the thick coarse sand extending from about 750 to about 850 feet and lying beneath thick clay beds that are also in the Kirkwood formation. This great water-bearing sand has a dip of about 23 feet per mile and probably comes up against the overlying Cohansey sands somewhere in the zone between Winslow and the outcrop of the Kirkwood.

The Cohansey Water Horizon

The Cohansey sand overlies the Kirkwood and, except for patches or discontinuous areas of Quarternary deposits, constitutes the uppermost formation in the stratigraphic series of the Coastal Plain. While it is of some importance as a water horizon in places, it is less so than the Kirkwood or most of the Cretaceous horizons already discussed. The Cohansey appears at or near the surface throughout the whole broad region lying to the southeast of the Kirkwood outcrop. Except at the relatively few localities where it is covered by Quarternary clays or where the outcropping Cohansey layers themselves may be clays, the whole broad region mapped as Cohansey acts as its catchment area. Like the Kirkwood, the Cohansey consists principally of sand, but lenticular masses of clay occur in it at a number of places, as for example near Toms River, Whitings and Woodmansie. The thickness of the Cohansey formation varies greatly with the topography, probably ranging up to 100 feet or more in the western portion and thickening to nearly 300 feet along the southern part of the coast. The average dip of the Cohansey is about eight or nine feet per mile in a southeast or south-southeast direction.

In the distribution of the wells utilizing the Cohansey water horizon a striking contrast to the Kirkwood is presented. The Kirkwood, as we have seen, is chiefly utilized along the beaches, whereas the Cohansey is chiefly utilized inland. This difference is due in part to the fact that the Cohansey has frequently proven to yield brackish water along the beaches, while even the same water-bearing sands have given fresh water inland.

One area where experience has shown that the Cohansey is especially valuable as a water horizon is a belt lying along the mainland back of the salt marshes, from Island Heights to Somers Point, and including Barnegat and Absecon and Pleasantville. The important group of wells forming a part of the public supply for Atlantic City is at Absecon. This group (except from a deep test well recently drilled) draws from two different water-bearing sands in the Cohansey, one at a depth of 100 feet and the other at a depth of 200 feet. About 1903 one 10-inch well to the upper horizon delivered 250 gallons per minute while one 8-inch and one 6-inch well to the deeper horizon together yielded about 480 gallons. In 1904 ten 10-inch wells and one 4-inch well, nearly all of which utilized the upper horizon, together yielded 3,500,000 gallons per day. The yield from the fifteen wells (to both horizons) in use in 1910, measured over a wier, was 4,000,000 gallons daily.

These 100-foot and 200-foot sands at Absecon probably outcrop about twelve and twenty miles to the northwest respectively. As the clay beds above the upper horizon are not very thick, and being in the Quarternary are not likely to be very extensive, it is probable that much of the water in that horizon enters the Cohansey much nearer the well field than the twelve-mile distance based on the dip. On the other hand the 38-foot clay bed between the two horizons, revealed in the well sections, is more likely to persist up the dip approximately as far as the twenty-mile distance indicated above. Another area in which the Cohansey is of especial importance is a belt about fifteen miles wide running northeast and southwest from Bridgeton and Cedarville to Williamstown and Hammonton and taking in Millville and Vineland. Within this area the towns named obtain considerable water from this horizon.

Of 156 wells utilizing the Cohansey, the yield on pumping was reported in forty-six cases. Of these, seventeen reported a yield of less than 50 gallons per minute, four a yield of from 50 to 99 gallons, thirteen a yield of from 100 to 199 gallons, eight a yield of from 200 to 299 gallons, and three a yield of 300 gallons or more per minute. The four largest yields were 250 (Absecon), 300 (Clayton), 350 (Anglesea), and 520 (Absecon).

Table No. 1

WATER SUPPLY SYSTEMS IN NEW JERSEY PRODUCING 500,000 GALLONS PER DAY OR OVER

(Systems purchasing water from other sources not included)

Water Works (1)	Ownership (2)	Source of Supply (3)	Resident Population Served at Retail (Thousands) (4)	Output 1924 (M.G.D.) (5)
Atlantic City Water Works	Municipal	Surface and ground	50.0	11.239
Atlantic County Water Company	Private	“	2.0	0.517
Asbury Park Water Works	Municipal	Ground	6.0	1.097
Boonton Water Works	“	Surface and ground	5.4	0.681
Bordentown Water Works	“	Ground	4.4	0.570
Bound Brook Water Company	Private	Surface and ground	7.0	0.692
Bridgeton Water Works	Municipal	Surface	17.0	2.549
Burlington Water Works	“	“	10.0	1.077
Butler Water Company	Private	“	5.4	0.869°
Camden Water Works	Municipal	Ground	108.0	16.139
Cape May City Water Works	“	“	2.9	0.980
Commonwealth Water Company	Private	“	69.5	3.923*°
Dover Water Works	Municipal	Surface and ground	10.0	0.647
East Orange Water Works	“	Ground	60.5	3.557
Elizabethtown Water Company, Consolidated	Private	Surface and ground	135.6	11.262*°
Essex County Institutions	Public	Ground	3.3	0.612*
Essex Fells Boro Water Works	Municipal	“	10.8	0.526
Garfield Water Works	“	“	23.3	0.932*
Gloucester Water Works	“	“	15.8	1.864
Hackensack Water Company	Private	Surface	335.0	26.342°
Jersey City Water Works	Municipal	“	340.0	60.321*°
Lakewood Water Company	Private	Ground	6.0	0.689
Lopatcong Water Company	“	Surface	2.0	1.420
Madison Water Works	Municipal	Ground	..	0.512
Merchantville Water Company	Private	“	34.0	2.125
Middlesex Water Company	“	Surface and ground	27.3	6.092°
Millville Water Company	“	“	10.5	1.887
Millville Water Works	Municipal	Ground	4.5	1.380

(1)	(2)	(3)	(4)	(5)
Morristown Water Works	Municipal	Surface and ground	17.5	1.016
Moorestown Township Water Works	Municipal	Ground	5.5	0.508
Newark Water Works	"	Surface	446.0	50.241*°
Newton Water Works	"	"	5.0	0.787
New Brunswick Water Works	"	"	44.8	6.362
New Jersey State Hospital, Morris Plains	Public	"	3.8	0.587
New Jersey Water Service Company	Private	Surface and ground	20.7	0.877
Ocean City Water Company	"	Ground	2.5	0.653
Orange Water Works	Municipal	Surface	33.0	2.265
Passaic Consolidated Water Company	Private	"	163.0	49.538*°
Perth Amboy Water Works	Municipal	Ground	45.0	7.677*
Peoples Water Company	Private	Surface and ground	10.0	2.061
Plainfield-Union Water Company	"	Ground	77.8	7.162*
Princeton Water Company	"	"	8.0	0.758
Rahway Water Works	Municipal	Surface	12.0	3.595°
Red Bank Boro Water Works	"	Ground	10.0	0.644
Ridgewood Village Water Works	"	"	12.0	0.858°
Riverton and Palmyra Water Company	Private	"	7.8	0.674
Salem City Water Works	Municipal	Surface and ground	7.0	1.492
Short Hills Water Company	Private	Ground	2.2	1.088°
South Amboy Water Works	Municipal	"	8.0	1.001
South Orange Water Works	"	"	9.5	0.779
Somerville Water Company	Private	Surface	11.3	1.831
Spring Lake Water Works	Municipal	Ground	1.2	0.523
Stockton Water Company	Private	"	22.5	2.151
Tintern Manor Water Company	"	Surface	61.3	4.357
Trenton Water Works	Municipal	"	135.0	16.449
Ventnor Water Works	"	Ground	5.0	1.007
Vineland Boro Water Works	"	"	10.0	1.046
Washington Water Company	Private	Surface	3.3	0.555
Warren Manufacturing Company, Milford	"	Ground	.25	0.590
Wildwood Water Works	Municipal	"	8.1	0.883°
Woodbury Water Works	"	"	7.0	0.906°

°Part of this amount delivered to other systems (see Table No. 11).
*Additional water received from other systems (see Table No. 11).

Table No. 1

Table No. 2

EXISTING WATER SUPPLIES IN NEW JERSEY SUPPLYING 500,000 GALLONS OR OVER PER DAY

(Classified by Sources)

Watershed (1)	Company or Municipality (2)	Total Output from Source in 1924 (M.G.D.) (3)	Total Drainage Area Above Intake (Sq. Miles) (4)	Safe Yield as Now Developed (M.G.D.) (5)
	SURFACE WATER SOURCES			
Hackensack River	Hackensack Water Co.	26.342	115	40.0
Elizabeth River	*Elizabethtown Water Co., Cons	2.463	18	2.5
Rahway River	*Middlesex Water Co	3.995	20	3.0
	Orange	2.265	5	2.5
	Rahway	3.995	41	4.0
		10.255		9.5
Passaic River:				
Rockaway River	*Boonton	0.569	1.7	0.8
"	*Dover	0.111	0.67	0.1
"	Jersey City	60.321	121	60.0
Stone House Creek—Asphawa Brook	Butler Water Co	0.869	7	2.0
Small tributaries	*Morristown	0.714	..	0.7
Whippany River tributary	N. J. State Hospital, Morris Plains	0.587	..	0.75
Pequannock River	Newark	50.241	64	57.0
Main stream—Little Falls	Passaic Cons. Water Co	49.538	773	56.0
		162.950		177.35
Raritan River:				
Middle Brook	*Bound Brook Water Co	.666	17	1.0
Lawrence Brook	New Brunswick	6.362	45	5.5
Main stream	Somerville Water Co	1.831	473	3.0
		8.859		9.5
Pohatcong River	Washington Water Co	.555	2.4	0.5
Wallkill River	Newton	.787	3.5	2.6
Delaware River:				
Cohansey River	Bridgeton	2.549	46	3.0
Maurice River	*Millville Water Co	830	218	3.0

Table No. 2

Watershed (1)	or Municipality (2)	(M.G.D.) (3)	(Sq. Miles) (4)	(M.G.D.) (5)
Delaware River (Continued):				
Cooper's Creek	*New Jersey Water Service Co	.359	..	0.4
Lopatcong Creek and Merrill Brook	Lopatcong Water Co	1.420	3.2	1.0
Alloway Creek and Deep Run Creek	*Salem City	.910	10	2.0
Main stream	Trenton	16.449	6,916	20.0
"	Burlington	1.077	7,240	7.35
		23.911		37.0
Atlantic Coast Basin:				
Absecon Creek	*Atlantic City	6.474	18.4	6.5
Patcong Creek	*Atlantic County Water Co	0.494	19	1.8
Jumping Brook	*Monmouth County Water Co	0.767	6.1	1.0
Swimming Brook, White Pond Creek	Tintern Manor Water Co	4.357	4.8	15.0
		12.092		24.3
	UNDERGROUND SOURCES, WELLS OR SPRINGS			
	*Atlantic City	4.765	..	11.5
	*Atlantic County Water Co	0.023	..	1.0
	Asbury Park	1.097	..	4.0
	Bordentown	0.570	..	.6
	*Boonton	0.112	..	.1
	*Bound Brook Water Co	0.026	..	1.5
	Camden	16.139	..	30.0
	Cape May	0.980	..	2.0
	Commonwealth Water Co	4.827	..	7.5
	*Dover	0.536	..	0.7
	East Orange	3.557	..	7.0
	*Elizabethtown Water Co., Cons	8.799	..	9.0
	Essex County Institutions	0.612	..	0.6
	Essex Fells Boro	0.526	..	1.0
	Garfield	0.932	..	1.0
	Carry forward	43.501		77.5

*Part of supply from surface and part from underground sources.

Table 2—Continued

Watershed (1)	(UNDERGROUND SOURCES, WELLS OR SPRINGS) Company or Municipality (2)	Total Output from Source in 1924 (M.G.D.) (3)	Total Drainage Area Above Intake (Sq. Miles) (4)	Safe Yield as Now Developed (M.G.D.) (5)
	Brought forward	43.501	..	77.5
	Gloucester	1.864	..	3.0
	Lakewood Water Co	0.689	..	2.0
	Madison	0.512	..	1.5
	Merchantville Water Co	2.125	..	2.5
	*Millville Water Co	1.048	..	1.0
	Millville	1.389	..	1.5
	*Monmouth County Water Co	0.602	..	2.0
	*Morristown	0.302	..	0.5
	*Morristown Township	0.508	..	0.6
	*Middlesex Water Co	2.097	..	6.7
	*New Jersey Water Service Co	0.518	..	0.6
	Ocean City Water Co	0.653	..	5.0
	Perth Amboy	7.677	..	14.0
	*Peoples Water Co	1.753	..	5.7
	Plainfield Union Water Co	7.162	..	7.0
	Princeton Water Co	0.758	..	.8
	Red Bank Boro	0.644	..	1.0
	Ridgewood	0.858	..	1.5
	Riverton and Palmyra Water Co	0.674	..	2.5
	*Salem City	0.582	..	1.0
	Short Hills Water Co	1.088	..	2.0
	South Amboy	1.001	..	1.0
	South Orange	0.779	..	1.7
	Spring Lake	0.523	..	1.0
	Stockton Water Co	2.151	..	4.0
	Ventnor	1.007	..	2.7
	Vineland Boro	1.046	..	1.2
	Warren Manufacturing Co., Milford	0.590	..	0.6
	Wildwood	0.883	..	2.5
	Woodbury	0.906	..	1.0

Table No. 3

EFFECTIVE DRAINAGE AREAS OF WATERSHEDS WITHIN THE STATE OF NEW JERSEY

Watershed (1)	Square Miles (2)	Square Miles (3)
HACKENSACK		115.0
PASSAIC:		
Ramapo River	147.0	
Wanaque	94.0	
Pequannock	64.0	
Rockaway	119.0	
Upper Passaic (above Little Falls)	349.0	773.0
RARITAN:		
Lower Raritan Branches	29.0	
North Branch	191.6	
South Branch	276.5	
Millstone River	285.7	
Lawrence Brook	45.0	
South River	52.0	879.8
WALLKILL:		
Pochuck	101.0	
Wallkill	132.0	233.0
DELAWARE RIVER BASIN:		
Flat Brook	62.8	
Paulins Kill	125.0	
Pequest River	147.1	
Pohatcong Creek	8.0	
Musconetcong River	122.5	
Assanpink Creek	17.0	
Crosswicks Creek	139.2	
Blacks Creek	22.0	
Assiscunk Creek	40.0	
Rancocas Creek	248.0	
Pensauken Creek	24.0	
Coopers Creek	11.7	
Big Timber Creek	23.0	
Mantua Creek	13.0	
Raccoon Creek	0.	
Oldmans Creek	10.0	
Salem Creek	22.6	
Alloways Creek	21.9	
Cohansey Creek	45.8	
Maurice River	218.4	1,322.0
Carry forward		3,322.8

Table No. 3—Continued

EFFECTIVE DRAINAGE AREAS OF WATERSHEDS WITHIN THE STATE OF NEW JERSEY

Watershed (1)	Square Miles (2)	Square Miles (3)
Brought forward		3,322.8
ATLANTIC COAST BASIN:		
Elizabeth River	17.0	
Rahway River	41.0	
Navesink	0.	
Manasquan	64.7	
Metedeconk	72.7	
Toms River	163.8	
Cedar Creek	55.8	
Forked River	14.7	
Mill Creek	19.7	
Westecunk Creek	21.0	
Tuckerton Creek	11.9	
Mullica River	402.0	
Great Egg Harbor River	215.8	
Absecon Creek	12.0	
Patcong Creek	19.0	
Tuckahoe River	60.2	1,191.3
Total		4,514.1

Table No. 4

AVAILABLE WATER RESOURCES FOR SOUTHERN METROPOLITAN DISTRICT AND REST OF STATE

Watershed (1)	Ultimate Available Capacity (Million Gallons Daily) (2)	
ATLANTIC COAST BASIN AVAILABLE FOR DISTRICT:		
Maurice River	125	
Great Egg Harbor River	144	
Mullica River	147	
Wading River	119	535
DELAWARE RIVER AND TRIBUTARIES (LOWER BASIN):		
Available by allotment Tri-State Compact	800	
Deduct watersheds in Delaware River Basin included in developments for Northern Metropolitan District	400	
	400	
Ground water	60	460
Total for Southern Metropolitan District		995
AVAILABLE FOR REST OF STATE:		
Atlantic Coast Basin	340	
Delaware River Basin	60	
Ground water	70	
Total for rest of State		470

Tables No. 3 and No. 4

Table No. 5

1924 WATER SUPPLY STATISTICS

(Classified by Districts and Counties)

County (1)	Upland Area (Sq. Miles) (2)	Net Assessed Valuation (Thousands) (3)	Population (Thousands) (4)	Population Density Per Sq. Mi. (5)	Number of Services (6)	Population Served (Thousands) (7)	Per Cent. of Population Served (8)	Consumption (M.G.D.) (9)	Gallons Per Capita (10)	Daily Gallons per Consumer (11)	Per Cent. of Services Metered (12)
Northern Metropolitan District											
Bergen	224	$ 277,500	245.0	1,090	50,168	242.0	98.8	12.128	49.5	50.2	91.0
Essex	120	1,035,200	714.0	5,950	106,619	712.8	99.9	63.529	89.0	89.2	93.0
Hudson	25	973,900	667.0	27,100	76,606	656.8	98.5	98.528	147.5	150.0	70.0
Middlesex	299	151,800	185.0	620	25,237	154.7	83.7	20.491	110.7	132.5	81.0
Passaic	196	339,200	283.0	1,440	37,996	186.3	65.8	27.795	98.3	149.0	93.0
Union	96	308,900	234.0	2,440	43,318	227.1	97.0	26.113	111.5	115.0	79.0
Adjacent communities	30	26,400	31.5	1,050	4,288	21.0	66.7	2.859	91.0	136.0	27.7
Total	990	$3,112,900	2,359.5	2,382	344,232	2,200.7	93.3	251.443	106.3	114.1	84.2
Southern Metropolitan District											
Burlington	800	$ 55,500	87.0	110	14,723	65.2	74.9	4.827	55.5	74.0	32.0
Camden	217	233,300	232.0	1,070	49,011	224.4	96.8	24.461	105.4	109.0	31.0
Gloucester	313	50,600	52.0	170	8,381	31.0	59.6	2.192	42.2	70.5	64.0
Mercer	226	221,400	171.0	760	33,438	151.2	88.5	18.112	105.8	119.6	31.0
Total	1,556	$ 560,800	542.0	348	105,553	471.8	87.0	49.592	91.6	105.1	33.8
Rest of State											
Atlantic	480	$ 254,700	90.0	190	17,930	80.5	89.4	13.745	152.7	171.0	75.0
Cape May	173	59,700	20.0	120	11,602	16.9	84.7	3.109	155.4	183.5	71.0
Cumberland	418	46,200	62.0	150	10,269	43.8	70.7	7.218	116.3	164.7	20.0
Hunterdon	437	25,400	32.0	70	3,301	15.9	49.8	2.012	62.8	126.2	2.9
Monmouth	470	153,500	108.0	230	30,973	86.7	80.5	11.140	103.5	129.0	67.0
Morris	457	75,900	80.0	175	11,284	55.3	69.2	4.582	57.0	83.0	67.2
Ocean	563	30,600	23.0	40	5,917	16.9	73.5	1.970	85.7	116.5	29.0
Salem	294	33,000	40.0	130	3,184	15.2	38.0	2.781	69.5	183.0	30.0
Somerset	293	26,500	26.5	90	963	6.6	24.9	0.379	14.0	58.0	71.0
Sussex	529	28,200	24.0	40	2,932	12.6	52.7	1.520	63.3	120.0	2.4
Warren	362	38,600	46.0	130	6,063	21.3	46.3	4.951	107.5	233.0	4.8
Total	4,476	$ 772,300	551.5	123	104,418	371.7	67.4	53.407	96.8	144.0	54.3
Total for State	7,022	$4,446,000	3,453.0	491	554,203	3,044.2	88.2	354.442	102.5	116.4	69.0

Table No. 6

DISTRIBUTION OF WATER IN NEW JERSEY IN 1924

County (1)	Safe Yield of Sources as Now Developed (M.G.D.) (2)	Total Average Daily Consumption (M.G.D.) (3)	Classified According to — Ownership — Municipal (M.G.D.) (4)	Private (M.G.D.) (5)	Source of Supply — Ground Water (M.G.D.) (6)	Surface Water (M.G.D.) (7)	Classified According to Size of Plant — 152 Plants 0 to 0.25 Million Gals. Daily (8)	57 Plants 0.25 to 1 Million Gals. Daily (9)	23 Plants 1 to 5 Million Gals. Daily (10)	8 Plants 5 to 20 Million Gals. Daily (11)	4 Plants Over 20 Millions Gals. Daily (12)
Northern Metropolitan District											
Bergen	44.320	12.128	3.913	8.215	3.075	9.053	.587	2.488	....	....	9.053
Essex	20.845	63.529	56.736	6.793	9.493	54.036	.003	2.168	9.840	....	51.518
Hudson	60.230	98.528	59.619	38.909	.230	98.298	.230	....	....	....	98.298
Middlesex	34.560	20.491	15.543	4.948	12.220	8.271	.358	.316	1.001	18.816	....
Passaic	115.615	27.795	.918	26.877	.672	27.123	.357	.741	....	....	26.697
Union	21.100	26.113	4.472	21.641	17.092	9.021	.017	....	5.493	19.727	.876
Adjacent communities	6.100	2.859	....	2.859	.018	2.841	.005	1.012	1.830	.012	....
Total	302.770	251.443	141.201	110.242	42.800	208.643	1.557	6.725	18.164	38.555	186.442
Southern Metropolitan District											
Burlington	15.010	4.827	2.493	2.334	2.452	2.375	1.164	2.586	1.077	....	....
Camden	43.250	24.461	18.759	5.702	24.102	.359	.609	1.573	6.140	16.139	....
Gloucester	3.360	2.192	1.625	.567	2.192	....	.997	1.195	....	....	....
Mercer	22.165	18.112	17.297	.815	1.663	16.449	.156	1.507	....	16.449	....
Total	83.785	49.592	40.174	9.418	30.409	19.183	2.926	6.861	7.217	32.588	....
Rest of State											
Atlantic	28.300	13.745	13.228	.517	6.777	6.968	.292	1.207	1.007	11.239	....
Cape May	14.200	3.109	2.276	.833	3.109	....	.593	2.516	....	....	....
Cumberland	10.200	7.218	5.331	1.887	3.830	3.388	.347	....	6.871	....	....
Hunterdon	2.970	2.012	.424	1.588	.821	1.191	.495	1.517	....	....	....
Monmouth	33.850	11.140	4.706	6.434	5.988	5.152	1.242	3.075	6.823	....	....
Morris	7.884	4.582	4.090	.492	2.498	2.084	.747	2.819	1.016	....	....
Ocean	6.650	1.970	.785	1.185	1.852	.118	.936	1.034	....	....	....
Salem	5.850	2.781	1.857	.924	1.395	1.386	.136	1.153	1.492	....	....
Somerset	.315	.379	.214	.265	.010	.369	.379	....	....	....	....
Sussex	6.360	1.520	1.332	.188	.038	1.482	.357	1.163	....	....	....
Warren	8.502	4.951	.377	4.574	1.902	3.049	.247	1.223	3.481	....	....
Total	125.081	53.407	34.620	18.787	28.220	25.187	5.771	15.707	20.690	11.239	....
Total for State	511.636	354.442	215.995	138.447	101.429	253.013	10.254	29.293	46.071	82.382	186.442

PRESENT (1924) AND ESTIMATED FUTURE POPULATION SERVED

(Classified by Districts and Counties)

County (1)	Estimated Population Served (in Thousands) 1924 (2)	1930 (3)	1940 (4)	1950 (5)	1960 (6)	1970 (7)	1980 (8)	Estimated Total Population 1924 (9)	1980 (10)	Per Cent of Total Population Served 1924 (11)	1980 (12)
Northern Metropolitan District											
Bergen	242.0	292	392	502	625	747	881	245.0	892	98.8	98.8
Essex	712.8	806	992	1184	1395	1599	1820	714.0	1824	99.8	99.8
Hudson	656.8	713	820	924	1033	1127	1229	667.0	1248	98.5	98.5
Middlesex	154.7	185	243	306	378	450	531	185.0	590	83.6	90.0
Passaic	186.3	218	275	339	414	492	582	283.0	746	65.8	78.0
Union	227.1	276	388	529	710	916	1165	234.0	1200	97.1	97.1
Adjacent communities	21.0	25	32	39	46	53	60	31.5	87	66.7	69.0
Total	2200.7	2515	3142	3823	4601	5384	6268	2359.5	6587	93.3	95.2
Southern Metropolitan District											
Burlington	65.2	71	83	98	108	122	134	87.0	166	75.0	81.0
Camden	224.4	284	327	382	422	472	510	232.0	528	96.7	96.7
Gloucester	31.0	35	42	49	57	66	77	52.0	107	59.7	72.0
Mercer	151.2	168	196	235	262	298	326	171.0	347	88.4	94.0
Total	471.8	558	648	764	849	958	1047	542.0	1148	86.9	91.0
Rest of State											
Atlantic	80.5	87	102	118	135	153	172	90.0	181	89.4	95.0
Cape May	16.9	18	21	24	27	30	33	20.0	37	84.6	90.0
Cumberland	43.8	45	48	50	52	54	57	62.0	75	70.6	76.0
Hunterdon	15.9	16	17	17	17	18	18	32.0	32	49.8	56.0
Monmouth	86.7	89	93	99	105	112	120	108.0	140	80.2	86.0
Morris	55.3	59	63	77	81	94	105	80.0	127	69.2	82.7
Ocean	16.9	17	17	18	19	20	20	23.0	26	73.4	79.0
Salem	15.2	17	21	25	30	35	41	40.0	94	38.0	44.0
Somerset	6.6	7	10	13	16	19	21	26.5	51	24.9	41.2
Sussex	12.6	13	13	13	14	14	14	24.0	24	52.7	59.0
Warren	21.3	22	24	25	27	29	30	46.0	58	46.2	52.0
Total	371.7	390	429	479	523	578	631	551.5	845	67.3	74.7
Total for State	3044.2	3463	4219	5066	5973	6920	7946	3453.0	8580	88.2	92.6

Table No. 7

Table No. 8

PRESENT (1924) AND ESTIMATED FUTURE WATER CONSUMPTION

(Classified by Districts and Counties)

County (1)	1924 M.G.D. (2)	1930 M.G.D. (3)	1940 M.G.D. (4)	1950 M.G.D. (5)	1960 M.G.D. (6)	1970 M.G.D. (7)	1980 M.G.D. (8)	Consumption Gallons Daily Per Consumer 1924 (9)	1980 (10)
NORTHERN METROPOLITAN DISTRICT									
Bergen	12.128	16.352	25.872	38.152	53.750	71.712	93.386	50.0	106.0
Essex	63.529	76.570	104.160	136.160	174.375	215.865	263.900	89.2	145.0
Hudson	98.528	111.228	136.120	162.624	192.138	220.892	253.174	150.0	206.0
Middlesex	20.491	25.530	35.964	48.348	63.304	80.100	99.828	132.5	188.0
Passaic	27.795	33.790	45.375	59.325	76.590	95.940	119.310	149.0	205.0
Union	26.113	33.396	50.828	74.589	107.210	147.476	199.215	115.0	171.0
Adjacent communities	2.859	3.500	4.700	6.000	7.400	8.900	10.500	136.0	175.0
Total	251.443	300.366	403.019	525.198	674.767	840.885	1039.313	114.1	165.8
SOUTHERN METROPOLITAN DISTRICT									
Burlington	4.827	5.680	7.470	9.800	11.880	14.640	17.420	74.0	130.0
Camden	24.461	32.660	40.875	51.570	61.190	73.160	84.150	109.0	165.0
Gloucester	2.192	2.660	3.612	4.704	6.042	7.656	9.702	70.5	126.0
Mercer	18.112	21.168	26.656	34.310	40.872	49.468	57.376	119.6	176.0
Total	49.592	62.168	78.613	100.384	119.984	144.924	168.648	105.1	161.1
REST OF STATE									
Atlantic	13.745	15.399	19.074	23.246	27.945	33.201	39.044	171.0	227.0
Cape May	3.109	3.420	4.200	5.040	5.940	6.900	7.920	183.5	240.0
Cumberland	7.218	7.695	8.688	9.550	10.452	11.394	12.597	164.7	221.0
Hunterdon	2.012	2.112	2.414	2.584	2.754	3.096	3.276	126.2	182.0
Monmouth	11.140	12.015	13.485	15.345	17.325	19.600	22.200	129.0	185.0
Morris	4.582	5.300	6.300	8.500	9.700	12.200	14.700	83.0	140.0
Ocean	1.970	2.091	2.261	2.574	2.907	3.260	3.460	116.5	173.0
Salem	2.781	3.213	4.179	5.225	6.570	8.015	9.799	183.0	239.0
Somerset	0.379	0.420	0.750	1.070	2.000	2.760	3.360	58.0	160.0
Sussex	1.520	1.638	1.768	1.898	2.184	2.324	2.464	120.0	176.0
Warren	4.951	5.258	5.976	6.475	7.263	8.091	8.670	233.0	289.0
Total	53.407	58.561	69.095	81.507	95.040	110.841	127.490	144.0	202.0

Table No. 9

DISTRIBUTION OF CONSUMPTION OF WATER

(By Sections of the Northern Metropolitan District)

Purveyor (1)	Consumption (M.G.D.) (2)	Total Consumption (M.G.D.) (3)
NORTHERN SECTION		
Garfield, City		1.018
Hackensack Water Co	25.900	
Bogota Water Co	.050	25.950
Bogota Water Co		.100
Hawthorne Boro		.468
Lodi, Boro		.444
Park Ridge, Boro		.160
Ramsey, Boro		.148
Ridgewood, Village	.818	
Hohokus, Boro	.040	.858
Wallington, Boro		.254
Miscellaneous small supplies		.179
Total for Northern Section		29.579
CENTRAL SECTION		
Butler Water Co	.508	
Pompton Lakes, Boro	.110	
Glen Ridge, Boro	.251	.869
Commonwealth Water Co		4.731
East Orange, City		3.557
Essex Fells, Boro	.074	
Caldwell, Boro	.267	
North Caldwell, Boro	.017	
Roseland, Boro	.016	
Verona, Boro	.134	
West Caldwell, Boro	.018	.526
Haledon, Boro		.153
Hackensack Water Co.:		
Hoboken, City		.392
Jersey City	52.266	
Hoboken, City	7.300	
Clifton, City (Allwood Section)	.004	
Lyndhurst, Township	.825	
North Arlington, Boro	.192	60.587
Carry forward		70.815

Table No. 9—Continued

DISTRIBUTION OF CONSUMPTION OF WATER

(By Sections of the Northern Metropolitan District)

Purveyor (1)		Consumption (M.G.D.) (2)	Total Consumption (M.G.D.) (3)
Brought forward			70.815
CENTRAL SECTION—(Continued)			
Newark, City		44.730	
Belleville, Town		1.420	
Bloomfield (through Passaic Consolidated Water Co.)		.796	
Glen Ridge, Boro		.119	
Kearny, Town		.089	
Montclair, Town, et al		1.945	49.099
Orange, City			2.265
Passaic Consolidated Water Co.:			
Retail—Paterson, Passaic, Clifton and Prospect Park		25.923	
Bayonne, City		14.834	
Bloomfield, Town		1.562	
Clifton, City (municipal system)		.095	
New Jersey Suburban Water Co.	.393		
East Newark, Boro	.388		
Harrison, Town	1.931		
Kearny, Town	3.097	5.809	
Little Falls Water Co		.187	
Montclair, Town, et al		.356	
Nutley, Town		.602	
Totowa, Boro		.083	49.451
Short Hills Water Co			.168
South Orange, City			.779
Miscellaneous supplies			1.190
Total for Central Section			173.767

Table No. 9—Continued

DISTRIBUTION OF CONSUMPTION OF WATER

(By Sections of the Northern Metropolitan District)

Purveyor (1)	Consumption (M.G.D.) (2)	Total Consumption (M.G.D.) (3)
SOUTHERN SECTION		
Bound Brook Water Co.	....	.692
Elizabethtown Water Co. Consolidated	....	15.691
Middlesex Water Co.	....	3.804
Middletown, Boro	....	.113
New Brunswick, City	....	6.362
Perth Amboy, City	....	7.662
Plainfield-Union Water Co.	....	7.452
Rahway, City	....	3.072
Somerville Water Co.	....	1.831
South Amboy, City	....	1.001
South River, Boro	....	.291
Miscellaneous small supplies	....	.126
Total for Southern Section	....	48.097
SUMMARY		
Total in Northern Section	29.579	11.8%
Total in Central Section	173.767	69.1%
Total in Southern Section	48.097	19.1%
Total in District (1924)	251.443	100.0%
ESTIMATES FOR 1980		
Total in Northern Section	180.	17.5%
Total in Central Section	550.	53.5%
Total in Southern Section	300.	29.0%
Total in District (1980)	1030.	100.0%

Table No. 10

YIELD OF PRINCIPAL WATER SOURCES IN NORTHERN METROPOLITAN DISTRICT AS NOW DEVELOPED

Watershed (1)		Capacity Million Gallons Daily (2)
HACKENSACK		40.0
PASSAIC:		
Little Falls	50.5	
Below Little Falls	5.5	
Minor branches	1.9	
Pequannock	57.0	
Rockaway	60.0	174.9
ELIZABETH		2.5
RAHWAY		9.5
RARITAN:		
Lawrence Brook	5.5	
Main stream	3.0	
Middle Brook	1.0	9.5
GROUND WATER:		
Bergen County	5.8	
Essex County	18.3	
Hudson County	0.2	
Middlesex County	26.1	
Passaic County	0.7	
Union County	14.6	65.7
Total for District		302.1

Table No 10

Table No. 11—Continued

INTERCHANGE OF WATER BY PURVEYORS IN NORTHERN METROPOLITAN DISTRICT

Total Yearly Interchange (1924) Expressed on Average Daily Basis

Purveyor (1)	Source of Supply (2)	Total Average Output (M.G.D.) (3)	Received from Other Systems (M.G.D.) (4)	Delivered to Other Systems (M.G.D.) (5)	Water Consumed (M.G.D.) (6)	Systems from Which Water is Received See Col. (4) (7)	Systems to Which Water is Delivered See Col. (5) (8)
Montclair, Town	Passaic River	....	.349	.037	....	Passaic Cons. Water Co.	Essex County Institutions
	Pequannock River	....	1.945	.012	....	City of Newark	Little Falls Water Co.
			....	.031	....	....	Passaic Cons. Water Co. acct. Bloomfield
			2.294	.080	....		
Middlesex Water Co.	Rahway River	3.995	....	2.086	....	....	Elizabethtown Water Co. Cons.
	Wells	2.097	....	.217	....	....	Plainfield-Union Water Co.
		6.092	.015	....	....	....	Perth Amboy, City
				2.303	3.804		
Newark City	Pequannock River	50.241	.015	1.420	....	Passaic Cons. Water Co.	Belleville, Town
				.796	....	....	Bloomfield, Town
				.876	....	....	Elizabethtown Water Co., Cons.
				.119	....	....	Glen Ridge, Boro
				.001	....	....	Irvington, Town
				.089	....	....	Kearny, Town
				1.945	....	....	Montclair, Town
				.280	....	....	Passaic Cons. Water Co.
				5.526	44.730		
N. J. Suburban Water Co.	Passaic River	....	5.809	.388	....	Passaic Cons. Water Co.	East Newark, Boro
				1.931	....	....	Harrison, Town
				3.097	....	....	Kearny, Town
				5.416	.393		
Passaic Cons. Water Co.	Passaic River	49.538	.031	.349	....	Montclair for Bloomfield	Montclair, Town
			.796	.015	....	Newark for Bloomfield	Newark for Montclair
			.280	.007	....	Newark for general use	Essex County Institutions
			1.107	15.100	....	....	Bayonne, City
				.095	....	....	Clifton, City
				5.809	....	....	N. J. Suburban Water Co.
				2.389	....	....	Bloomfield, Town
				.086	....	....	Garfield, City
				.602	....	....	Nutley, Town
				.187	....	....	Little Falls Water Co.
				.083	....	....	Totowa, Boro
				24.329	25.923		
Perth Amboy, City	Wells	7.677	....	.015	7.662	Middlesex Water Co.	
Plainfield-Union Water Co.	Wells	7.162	.073	....	....	Elizabethtown W.Co.Cons.	
			.217	....	....	Middlesex Water Co.	
			.290	....	7.452		
Pompton Lakes, Boro	Passaic River	....	.110	.008	....	Butler Water Co.	Riverdale, Boro
	Tributaries	....	....	.012	....	....	Wanaque, Boro
				.020	.090		
Rahway, City	Rahway River	3.595		.523	3.072		Elizabethtown Water Co. Cons.
Ridgewood, Village	Wells	.858		.040	.818		Hohokus, Boro
Short Hills Water Co.	Wells	1.088	....	.918	....	....	Elizabethtown Water Co. Cons.
				.002	....	....	Commonwealth Water Co.
				.920	.168		

Table No. 11

INTERCHANGE OF WATER BY PURVEYORS IN NORTHERN METROPOLITAN DISTRICT

TOTAL YEARLY INTERCHANGE (1924) EXPRESSED ON AVERAGE DAILY BASIS

Purveyor (1)	Source of Supply (2)	Total Average Output (M.G.D.) (3)	Received from Other Systems (M.G.D.) (4)	Delivered to Other Systems (M.G.D.) (5)	Water Consumed (M.G.D.) (6)	Systems from Which Water is Received See Col. (4) (7)	Systems to Which Water is Delivered See Col. (5) (8)
Bayonne, City	Passaic River	....	15.100	.266	14.834	Passaic Cons. Water Co.	City of Jersey City
Bloomfield, Town	Passaic River	....	1.562	....	....	Passaic Cons. Water Co.	
	"	....	.031	....	....	Montclair, Town	
	Pequannock River	....	.796	....	....	City of Newark	
			2.389	....	2.389		
Butler Water Co.	Passaic	.869	....	.251	....	....	Glen Ridge, Boro
	Tributaries	....	....	.110	....	....	Pompton Lakes, Boro
				.361	.508		
Commonwealth Water Co.	Wells	4.827	....	.099	....	....	Elizabethtown Water Co. Cons.
		....	.001	....	....	City of Newark	
		....	.002	....	....	Short Hills Water Co.	
			.003	....	4.731		
Elizabethtown Water Co., Cons.	Elizabeth River	11.262	....	.073	....	....	Plainfield-Union Water Co.
	Wells	....	.876	....	....	City of Newark	
		....	.099	....	....	Commonwealth Water Co.	
		....	.523	....	....	City of Rahway	
		....	.918	....	....	Short Hills Water Co.	
		....	2.086	....	....	Middlesex Water Co.	
			4.502	....	15.691		
Essex Fells, Boro	Wells	.526					
				.267	....	....	Caldwell, Boro
				.017	....	....	North Caldwell, Boro
				.016	....	....	Roseland, Boro
				.134	....	....	Verona, Boro
				.018	....	....	West Caldwell, Boro
				.452	.074		
Glen Ridge, Boro	Passaic River	....	.251	....	....	Butler Water Co.	
	Pequannock River	....	.119	....	....	City of Newark	
			.370				
Hackensack Water Co.	Hackensack River	26.342	....	.050	....	....	Bogota Water Co.
				.392	....	....	City of Hoboken
				.442	25.900		
Hoboken, City	Hackensack River	....	.392	....	....	....	Hackensack Water Co.
	Rockaway River	....	7.300	....	....	....	City of Jersey City
			7.692	....	7.692		
Jersey City	Rockaway River	60.321	.266	....	....	Bayonne, City	
				.004	....	....	Clifton, City
				7.300	....	....	Hoboken, City
				.825	....	....	Lyndhurst, Township
				.192	....	....	North Arlington, Boro
				8.321	52.266		
Kearny, Town	Passaic River	....	3.097	....	....	Passaic Cons. Water Co.	
	Pequannock River	....	.089	....	....	City of Newark	
			3.186	....	3.186		
Little Falls Water Co.	Passaic River	....	.187	....	....	Passaic Cons. Water Co.	
			.012	....	....	Town of Montclair	
			.199	....	.199		

Table No. 12

ESTIMATED ULTIMATE DEVELOPMENT OF SOURCES OF SUPPLY FOR THE NORTHERN METROPOLITAN DISTRICT

Watershed (1)		Available Capacity Million Gallons Daily (2)
HACKENSACK RIVER	...	84.0
PASSAIC RIVER:		
Rockaway River	100	
Pequannock River	57	
Wanaque River	100	
Ramapo River	116	
Remainder of watershed	260	633.0
ELIZABETH RIVER	...	2.5
RAHWAY RIVER	...	9.5
RARITAN RIVER:		
North and South Branches	414	
Millstone	150	
Lawrence and South Brook	35	
Green Brook	7	
Stony Brook	5	
Middle Brook	17	628.0
WALLKILL RIVER	...	230.0
GROUND WATER	...	60.0
		1,647.0
DELAWARE RIVER TRIBUTARIES:		
Musconetcong River	110	
Pohatcong Creek	7	
Pequest Creek	104	
Beaver Brook	29	
Paulins Kill	112	
Flat Brook	57	419.0
DELAWARE RIVER:		
Depending upon ultimate settlement of Tri-State Compact	425 to	700.0
Total	2,491 to	2,766.0

Table No. 12

Table No. 13

ESTIMATED COST OF PIECEMEAL DEVELOPMENT OF 160 M.G.D. ADDITIONAL SUPPLY IN CONJUNCTION WITH POOLED PRESENT SOURCES

Elements of First Cost (1)	Year of Completion (2)	Estimated Construction Cost including 25% Miscellaneous Construction Expenditures (3)	Present Worth at 5% (4)
60″ transmission mains to facilitate pooling of water.	1927	$ 2,300,000	$ 2,300,000
48″ transmission mains to facilitate pooling of water.	1930	4,145,000	3,580,617
20 M.G.D. diversion from Ramapo to Woodcliffe reservoir, including additional pumping station and filtration plant capacity at New Milford..	1940	5,129,000	2,720,011
40 M.G.D. development on Raritan (pumped and filtered). Delivery to Elizabeth.............	1940	9,359,000	4,963,265
60 M.G.D. additional development on Raritan (pumped and filtered). Delivery to Elizabeth..	1945	11,715,000	4,867,817
40 M.G.D. additional development on Rockaway River watershed of Jersey City..............	1950	4,068,000	1,324,430
Reinforcement of Jersey City aqueduct.......	1950	1,650,000	537,194
Total additional *160 M.G.D.* good through *1953*.....		$38,366,000	$20,293,334

Year of Operation (5)	Million Gallons Per Year from New Sources: Total (6)	Pumped (7)	Filtered (8)	Annual Costs: Interest and Sinking Fund at 5% (9)	Cost of Pumping at $8.25 (10)	Cost of Filtration at $6.75 (11)	Total (12)	Total Cost per M.G. (13)	Present Worth of Annual Costs at 5% (14)
1928	$....	$....	$....	$115,000	$....	$....	$115,000	$....	$115,000
1929	....	....	....	115,000	....	....	115,000	....	109,524
1930	....	....	....	115,000	....	....	115,000	....	104,308
1931	....	....	....	322,250	....	....	322,250	....	278,372
1932	....	....	....	322,250	....	....	322,250	....	265,115
1933	....	....	....	322,250	....	....	322,250	....	252,493
1934	....	....	....	322,250	....	....	322,250	....	240,469
1935	....	....	....	322,250	....	....	322,250	....	229,017
1936	....	....	....	322,250	....	....	322,250	....	218,112
1937	....	....	....	322,250	....	....	322,250	....	207,726
1938	....	....	....	322,250	....	....	322,250	....	197,832
1939	....	....	....	322,250	....	....	322,250	....	188,413
1940	....	....	....	322,250	....	....	322,250	....	179,442
1941	4,635	4,635	4,635	1,046,650	38,239	31,286	1,116,175	241	591,930
1942	9,270	9,270	9,270	1,046,650	76,478	62,572	1,185,700	128	598,861
1943	13,905	13,905	13,905	1,046,650	114,716	93,859	1,255,225	90	603,788
1944	18,540	18,540	18,540	1,046,650	152,955	125,145	1,324,750	71	606,881
1945	23,175	23,175	23,175	1,046,650	191,194	156,431	1,394,275	60	608,322
1946	27,810	27,810	27,810	1,632,400	229,432	187,718	2,049,550	74	851,629
1947	32,450	32,450	32,450	1,632,400	267,712	219,038	2,119,150	65	838,611
1948	37,085	37,085	37,085	1,632,400	305,951	250,324	2,188,675	59	824,890
1949	41,720	41,720	41,720	1,632,400	344,190	281,610	2,258,200	54	810,558
1950	46,355	46,355	46,355	1,632,400	382,429	312,896	2,327,725	50	795,733
1951	50,990	46,355	46,355	1,918,300	382,429	312,896	2,613,625	51	850,918
1952	55,625	46,355	46,355	1,918,300	382,429	312,896	2,613,625	47	810,407
1953	60,260	46,355	46,355	1,918,300	382,429	312,896	2,613,625	43	771,803

Sum of annual costs, 1928-1953.................................. $28,627,800

Present worth of annual costs.................................. $12,150,154

Average annual cost, 1941-1953.................................. $ 1,927,646

Average cost per million gallons, 1941-1953....................... $59

Table No. 14

ESTIMATED COST OF LONG HILL DEVELOPMENT TO YIELD 168 M.G.D. ADDITIONAL SUPPLY IN CONJUNCTION WITH POOLED PRESENT RESOURCES

Elements of First Cost (1)	Year of Completion (2)	Estimated Construction Cost including 25% Miscellaneous Construction Expenditures (3)	Present Worth 5% (4)
60″ transmission mains to facilitate pooling of water	1927	$ 2,300,000	$ 2,300,000
48″ transmission mains to facilitate pooling of water	1930	4,145,000	3,580,617
42″ M.G.D. development at Long Hill as estimated by Mr. Sherrerd	1940	16,000,000	8,485,120
168 M.G.D. transmission conduits of same size, location and cost as estimated by Mr. Sherrerd for his first Chimney Rock development......	1940	14,085,000	7,469,557
42 M.G.D. filtration plant as per Mr. Sherrerd's revision of Hazen's estimated cost............	1940	1,260,000	668,203
67 M.G.D. additional development at Long Hill as estimated by Mr. Sherrerd..............	1943	15,660,000	7,174,003
67 M.G.D. additional filter plant capacity as per Mr. Sherrerd's revision of Hazen's estimated cost..	1943	2,010,000	920,801
59 M.G.D. additional development at Long Hill as estimated by Mr. Sherrerd..............	1949	10,670,000	3,647,540
59 M.G.D. additional filter plant capacity as per Mr. Sherrerd's revision of Hazen's estimated cost..	1949	1,770,000	605,074
Total additional *168 M.G.D.* good through *1953*....		$67,900,000	$34,850,915

Year of Operation (5)	Million Gallons Per Year from New Sources: Total (6)	Pumped (7)	Filtered (8)	Annual Costs: Interest and Sinking Fund at 5% (9)	Cost of Pumping at $8.25 (10)	Cost of Filtration at $6.75 (11)	Total (12)	Total Cost per M.G. (13)	Present Worth of Annual Costs at 5% (14)
1928	$....	....	$....	$ 115,000	....	$....	$ 115,000	$....	$ 115,000
1929	....	....	....	115,000	....	....	115,000	....	109,524
1930	....	....	....	115,000	....	....	115,000	....	104,308
1931	....	....	....	322,250	....	....	322,250	....	278,372
1932	....	....	....	322,250	....	....	322,250	....	265,115
1933	....	....	....	322,250	....	....	322,250	....	252,493
1934	....	....	....	322,250	....	....	322,250	....	240,469
1935	....	....	....	322,250	....	....	322,250	....	229,017
1936	....	....	....	322,250	....	....	322,250	....	218,112
1937	....	....	....	322,250	....	....	322,250	....	207,726
1938	....	....	....	322,250	....	....	322,250	....	197,832
1939	....	....	....	322,250	....	....	322,250	....	188,413
1940	....	....	....	322,250	....	....	322,250	....	179,442
1941	4,635	....	4,635	1,889,500	....	31,286	1,920,786	414	1,018,631
1942	9,270	....	9,270	1,889,500	....	62,572	1,952,072	211	985,933
1943	13,905	....	13,905	1,889,500	....	93,859	1,983,359	143	954,035
1944	18,540	....	18,540	2,773,000	....	125,145	2,898,145	156	1,327,669
1945	23,175	....	23,175	2,773,000	....	156,431	2,929,431	126	1,278,111
1946	27,810	....	27,810	2,773,000	....	187,718	2,960,718	106	1,230,237
1947	32,450	....	32,450	2,773,000	....	219,034	2,992,038	92	1,184,039
1948	37,085	....	37,085	2,773,000	....	250,328	3,023,324	82	1,139,461
1949	41,720	....	41,720	2,773,000	....	281,610	3,054,610	73	1,096,422
1950	46,355	....	46,355	3,395,000	....	312,896	3,707,896	80	1,267,544
1951	50,990	....	50,990	3,395,000	....	344,182	3,739,182	73	1,217,365
1952	55,625	....	55,625	3,395,000	....	375,469	3,770,469	68	1,169,109
1953	60,260	....	60,260	3,395,000	....	406,755	3,801,755	63	1,122,658

Sum of annual costs, 1928-1953.................................. $42,301,285

Present worth of annual costs.................................. $17,577,037

Average annual cost, 1941-1953.................................. $ 2,979,522

Average cost per million gallons, 1941-1953........................ $92

Table No 14

Table No. 15

ESTIMATED COST OF CHIMNEY ROCK DEVELOPMENT TO YIELD 158 M.G.D. ADDITIONAL SUPPLY IN CONJUNCTION WITH POOLED PRESENT RESOURCES

Elements of First Cost (1)	Year of Completion (2)	Estimated Construction Cost including 25% Miscellaneous Construction Expenditures (3)	Present Worth at 5% (4)
50″ transmission mains to facilitate pooling of water.	1927	$ 2,300,000	$ 2,300,000
18″ transmission mains to facilitate pooling of water.	1930	4,145,000	3,580,617
58 M.G.D. development at Chimney Rock as estimated by Mr. Sherrerd....................	1940	31,715,000	16,819,099
58 M.G.D. transmission conduits as estimated by Mr. Sherrerd............................	1940	14,085,000	7,469,557
2 M.G.D. filtration plant added to Mr. Sherrerd's estimated cost of first development ($30,000 per M.G. capacity, *including* miscellaneous construction expenditures)..................	1940	1,260,000	668,203
7 M.G.D. additional filter plant capacity...........	1943	2,010,000	920,801
9 M.G.D. additional filter plant capacity.........	1949	1,470,000	502,520
otal additional *158 M.G.D.* good through *1953*.....		$56,985,000	$32,260,797

Year of Operation (5)	Million Gallons Per Year from New Sources: Total (6)	Pumped (7)	Filtered (8)	Annual Costs: Interest and Sinking Fund at 5% (9)	Cost of Pumping at $8.25 (10)	Cost of Filtration at $6.75 (11)	Total (12)	Total Cost per M.G. (13)	Present Worth of Annual Costs at 5% (14)
1928	$....	....	$....	$ 115,000	....	$....	$ 115,000	$....	$ 115,000
1929	....	....	....	115,000	....	....	115,000	....	109,524
1930	....	....	....	115,000	....	....	115,000	....	104,308
1931	....	....	....	322,250	....	....	322,250	....	278,372
1932	....	....	....	322,250	....	....	322,250	....	265,115
1933	....	....	....	322,250	....	....	322,250	....	252,493
1934	....	....	....	322,250	....	....	322,250	....	240,469
1935	....	....	....	322,250	....	....	322,250	....	229,017
1936	....	....	....	322,250	....	....	322,250	....	218,112
1937	....	....	....	322,250	....	....	322,250	....	207,726
1938	....	....	....	322,250	....	....	322,250	....	197,832
1939	....	....	....	322,250	....	....	322,250	....	188,413
1940	....	....	....	322,250	....	....	322,250	....	179,442
1941	4,635	....	4,635	2,675,250	....	31,286	2,706,536	384	1,435,330
1942	9,270	....	9,270	2,675,250	....	62,572	2,737,822	295	1,382,792
1943	13,905	....	13,905	2,675,250	....	93,859	2,769,109	199	1,331,997
1944	18,540	....	18,540	2,775,750	....	125,145	2,900,895	156	1,328,921
1945	23,175	....	23,175	2,775,750	....	156,431	2,932,181	127	1,279,311
1946	27,810	....	27,810	2,775,750	....	187,718	2,963,468	107	1,231,380
1947	32,450	....	32,450	2,775,750	....	219,038	2,994,788	92	1,135,127
1948	37,085	....	37,085	2,775,750	....	250,324	3,026,074	82	1,140,497
1949	41,720	....	41,720	2,775,750	....	281,610	3,057,360	73	1,097,409
1950	46,355	....	46,355	2,849,250	....	312,896	3,162,146	68	1,080,980
1951	50,990	....	50,990	2,849,250	....	344,182	3,193,432	63	1,039,686
1952	55,825	....	55,625	2,849,250	....	375,469	3,224,719	58	999,689
1953	60,260	....	60,260	2,849,250	....	406,755	3,256,005	54	961,498

Sum of annual costs, 1928-1953..................................	$42,492,035		
Present worth of annual costs..................................			$18,080,640
Average annual cost, 1941-1953..................................	$ 2,994,195		
Average cost per million gallons, 1941-1953........................		$92	

Table No. 16

COST PER MILLION GALLONS OF DELIVERING WATER FROM VARIOUS SOURCES FOR DISTRIBUTION AT CENTRAL POINTS IN THE NORTHERN, CENTRAL AND SOUTHERN SECTIONS OF THE NORTHERN METROPOLITAN DISTRICT

WHEN THE QUANTITY TAKEN IS 20 MILLION GALLONS DAILY

Water from Rockaway River treated and delivered to distribution at Jersey City	$26
Water from Raritan River filtered, pumped and delivered to distribution at Elizabeth	49
Diversion from Ramapo River at Suffern to Woodcliff reservoir on Pascack Creek, a tributary of the Hackensack, filtered and pumped at New Milford	50
Water from the Wanaque at Belleville, transmitted to New Durham and there pumped for distribution in the Northern Section:	
Based on total utilized yield of 100 M.G.D.	68
" " " " " " 74 "	82
Water from Ramapo River at Oakland, pumped, filtered and delivered to distribution at Hackensack	114
Water from the Wanaque, filtered and delivered to distribution, Paterson to Belleville	184
First development at Long Hill, filtered and delivered to distribution at Elizabeth	217
First development at Chimney Rock, filtered and delivered to distribution at Elizabeth	325

WHEN THE QUANTITY TAKEN IS 40 MILLION GALLONS DAILY

Water from Rockaway River, treated and delivered to distribution at Jersey City	$21
Water from Raritan River, filtered, pumped and delivered to distribution at Elizabeth	47
Water from Ramapo River at Oakland, pumped, filtered and delivered to distribution at Hackensack	68

Table No. 16—Continued

(40 Million Gallons Daily—Continued)

Water from Wanaque supply at Belleville, transmitted to New Durham and there pumped for distribution in the Northern Section:	
Based on total utilized yield of 100 M.G.D.	$65
" " " " " " 74 "	79
Water from the Wanaque, filtered and delivered to distribution, Paterson to Belleville	98
First development at Long Hill, filtered and delivered to distribution at Elizabeth	114
First development at Chimney Rock, filtered and delivered to distribution at Elizabeth	168

When the Quantity Taken is 80 Million Gallons Daily

Water from Ramapo River at Suffern (20 M.G.D.), additional development on Rockaway River (40 M.G.D.), and development on Raritan River (20 M.G.D.), delivered to distribution	$35
Water from Ramapo at Suffern (20 M.G.D.), additional development on Rockaway River (20 M.G.D.), and development on Raritan River (40 M.G.D.), delivered to distribution	43
Water from Raritan River, filtered, pumped and delivered to distribution at Elizabeth	45
Water from the Wanaque, filtered and delivered to distribution, Paterson to Belleville, based on 100 M.G.D. yield	54
First development at Chimney Rock, filtered and delivered to distribution at Elizabeth	89
First and second development at Long Hill, filtered and delivered to distribution at Elizabeth	89

When the Quantity Taken is 160 Million Gallons Daily

Water from Ramapo River at Suffern (20 M.G.D.), additional development on Rockaway River (40 M.G.D.), and development on Raritan River (100 M.G.D.), delivered to distribution	$39
First development at Chimney Rock, filtered and delivered to distribution at Elizabeth	50
First, second and third developments at Long Hill, filtered and delivered to distribution at Elizabeth	59

Table No. 17

COMPARATIVE ALLOWANCES FOR RESERVOIRS, COLLECTING TUNNELS AND DELAWARE RIVER PUMPING STATION

Step in Development (1)	Mr. Hazen Long Hill including 20% Overhead (2)	Mr. Sherrerd Long Hill including 25% Overhead (3)	Mr. Sherrerd Chimney Rock including 25% Overhead (4)
Mr. Sherrerd's first step	$16,045,000	$16,000,000	
	12,402,000	15,660,000	$31,715,000
Mr. Hazen's first three steps	7,085,000	10,670,000	
Mr. Sherrerd's second step Mr. Hazen's fourth step	10,939,000	15,700,000	15,215,000
Mr. Sherrerd's third step Mr. Hazen's fifth step	8,263,000	11,520,000	25,780,000
Mr. Sherrerd's fourth step Mr. Hazen's sixth step	9,981,000	12,035,000	30,285,000
Mr. Sherrerd's fifth step	5,750,000	7,620,000	
Mr. Hazen's seventh and eighth steps	2,862,000	2,190,000	36,870,000
Total	$75,327,000	$91,395,000	$139,865,000

Table No. 18

COMPARATIVE ALLOWANCES FOR TRANSMISSION CONDUITS AND TUNNELS

Step in Development (1)	Mr. Hazen Long Hill including 20% Overhead (2)	Mr. Sherrerd Long Hill including 25% Overhead (3)	Mr. Sherrerd Chimney Rock including 25% Overhead (4)
Mr. Sherrerd's first step	$6,234,000	$7,713,000	
Mr. Hazen's first three steps	......	......	$14,085,000
	27,538,000	33,480,000	
Mr. Sherrerd's second step Mr. Hazen's fourth step	......	......	8,950,000
Mr. Sherrerd's third step Mr. Hazen's fifth step	......	......	12,300,000
Mr. Sherrerd's fourth step Mr. Hazen's sixth step	......	......	13,950,000
Mr. Sherrerd's fifth step	......	......	11,300,000
Mr. Hazen's seventh and eighth steps	......	......	
Total	$33,772,000	$41,193,000	$60,585,000

Table No. 19

COMPARATIVE ALLOWANCES FOR FILTRATION PLANTS

Step in Development (1)	Mr. Hazen Long Hill including 20% Overhead (2)	Mr. Sherrerd Long Hill including 25% Overhead (3)	Mr. Sherrerd Chimney Rock including 25% Overhead (4)
Mr. Sherrerd's first step .	$1,176,000	$1,260,000	
Mr. Hazen's first three steps .	3,000,000	2,010,000	0
.	1,560,000	1,770,000	
Mr. Sherrerd's second step.....	3,900,000	3,960,000	$8,400,000
Mr. Hazen's fourth step.......			
Mr. Sherrerd's third step......	3,240,000	3,510,000	4,410,000
Mr. Hazen's fifth step.........			
Mr. Sherrerd's fourth step.....	4,116,000	4,230,000	3,750,000
Mr. Hazen's sixth step........			
Mr. Sherrerd's fifth step	1,680,000		
Mr. Hazen's seventh and	......	5,760,000	5,850,000
eighth steps	3,800,000		
Total....................	$22,472,000	$22,500,000	$22,410,000

Table No. 20

YEARS OF DEFERMENT OF 2D, 3D, 4TH AND 5TH STEPS FOLLOWING COMPLETION OF THE FIRST STEP

Safe yield available existing sources as now developed, 297 M.G.D.
Safe yield of Wanaque development, 100 M.G.D.

Long Hill Development

Step (1)	Capacity of Successive New Developments (M.G.D.) (2)	Total Developed Safe Yield After Completing Wanaque (M.G.D.) (3)	Year in Which Required (Completion Date from Forecast) (4)	Years of Deferment after Completion of Initial Step (5)
1	168	565	1940	..
2	132	697	1953	13
3	117	814	1962	22
4	141	955	1969	29
5	192	1147	1976	36
	Total, 750			

Chimney Rock Development

Step (1)	Capacity of Successive New Developments (M.G.D.) (2)	Total Developed Safe Yield After Completing Wanaque (M.G.D.) (3)	Year in Which Required (Completion Date from Forecast) (4)	Years of Deferment after Completion of Initial Step (5)
1	158	555	1940	..
2	123	678	1952	12
3	147	825	1960	20
4	124	949	1969	29
5	198	1147	1976	36
	Total, 750			

Tables No. 19 and No. 20

Table No. 21

COMPARISON OF COSTS—LONG HILL AND CHIMNEY ROCK PROJECTS

Using Sherrerd's Costs for Both Projects and Sherrerd's Filtration and Transmission Systems

		LONG HILL PROJECT			CHIMNEY ROCK PROJECT		
Step in Development (1)	Elements of Construction (2)	Years of Deferment After 1st Development (3)	Actual Capital Outlay Required (4)	Present Worth of Capital Expenditures @ 5% (5)	Years of Deferment After 1st Development (6)	Actual Capital Outlay Required (7)	Present Worth of Capital Expenditures @ 5% (8)
First Development 168-158 M.G.D.	Reservoirs and collecting aqueducts	..	$42,330,000	......	..	$31,715,000	
	Filtration plants	..	......	......	..	......	
	Transmission system	..	14,085,000	......	..	14,085,000	
	Total	0	$56,715,000	$56,715,000	0	$45,800,000	$45,800,000
Second Development 132-123 M.G.D.	Reservoirs and collecting aqueducts	..	$15,700,000	......	..	$15,215,000	
	Filtration plants	..	8,400,000	......	..	8,400,000	
	Transmission system	..	8,950,000	......	..	8,950,000	
	Total	13	$33,050,000	$17,517,000	12	$32,565,000	$18,139,000
Third Development 117-147 M.G.D.	Reservoirs and collecting aqueducts	..	$11,520,000	......	..	$25,780,000	
	Filtration plants	..	4,410,000	......	..	4,410,000	
	Transmission system	..	12,300,000	......	..	12,300,000	
	Total	22	$28,230,000	$9,655,000	20	$42,490,000	$16,826,000
Fourth Development 141-124 M.G.D.	Reservoirs and collecting aqueducts	..	$12,035,000	......	..	$30,285,000	
	Filtration plants	..	3,750,000	......	..	3,750,000	
	Transmission system	..	13,950,000	......	..	13,950,000	
	Total	29	$29,735,000	$7,404,000	29	$47,985,000	$11,948,000
Fifth Development 192-198 M.G.D.	Reservoirs and collecting aqueducts	..	$9,810,000	......	..	$36,870,000	
	Filtration plants	..	5,850,000	......	..	5,850,000	
	Transmission system	..	11,300,000	......	..	11,300,000	
	Total	36	$26,960,000	$4,664,000	36	$54,020,000	$9,345,000
All Developments 750 M.G.D.	All items	..	$174,390,000	$95,955,000	..	$222,860,000	$102,058,000

Table No. 22

NORTH JERSEY DISTRICT WATER SUPPLY COMMISSION

COMPARATIVE ESTIMATES OF COST OF LONG HILL SYSTEM, PROPOSED BY MR. ALLEN HAZEN, AND CHIMNEY ROCK SYSTEM, AS PROPOSED BY N. J. D. W. S. C.

Each system to supply ultimately a total of 750 M.G.D.

It is assumed that the 2d Development will be required 16 years after the 1st Development
" " 3d " " 28 " "
" " 4th " " 42 " "
" " 5th " " 55 " "

The figures given for "Present Value" indicate the amounts of money which would be required to be placed at interest at 4½% at the time of completion of the 1st Development, to provide for the construction of the later developments, as required by the above assumptions.

Development (1)	Long Hill Estimate by Mr. Hazen (2)	Long Hill Present Value (3)	Long Hill *Estimate by N.J.D.W.S.C. (4)	Long Hill *Present Value (5)	Chimney Rock Estimate by N.J.D.W.S.C. (6)	Chimney Rock Present Value (7)
1st Development	$75,040,000	$75,040,000	$88,563,000	$88,563,000	$45,800,000	$45,800,000
2d Development	14,839,000	7,320,000	19,660,000	9,680,000	32,565,000	15,950,000
3d Development	11,503,000	3,340,000	15,030,000	4,360,000	42,490,000	12,300,000
4th Development	14,097,000	2,230,000	16,265,000	2,570,000	47,985,000	7,580,000
5th Development	14,092,000	1,240,000	15,570,000	1,370,000	54,020,000	4,750,000
Total	$129,571,000	$89,170,000	$155,088,000	$106,543,000	$222,860,000	$86,380,000

	1st (M.G.D.)	2d (M.G.D.)	3d (M.G.D.)	4th (M.G.D.)	5th (M.G.D.)
Approximate yield of the developments are	165	125	135	130	195

*Estimated on the same basis of unit prices as for Chimney Rock system for comparison.

Table No. 23

NORTH JERSEY DISTRICT WATER SUPPLY COMMISSION

Long Hill System

As Proposed by Mr. Allen Hazen
Estimates of Cost by Mr. Hazen and N. J. D. W. S. C.

	Estimate by Mr. Hazen	Estimate by N.J.D.W.S.C.
1st Development (Hazen's first three steps)		
Long Hill reservoir	$16,045,000	$16,000,000
Southern loop to Newark with filters	7,410,000	8,973,000
Filters for N. Branch and Black River	3,000,000	2,010,000
Reservoir and tunnel	12,402,000	15,660,000
Pressure tunnel to Newark and Jersey City	27,538,000	33,480,000
Filters for South Branch	1,560,000	1,770,000
Reservoir and tunnel	7,085,000	10,670,000
168 M.G.D. =	$75,040,000	$88,563,000
2d Development (Hazen's fourth step)		
Filters for Musconetcong	$3,900,000	$3,960,000
Reservoirs and tunnel	10,939,000	15,700,000
132 M.G.D. =	$14,839,000	$19,660,000
3d Development (Hazen's fifth step)		
Filters for Pequest	$3,240,000	$ 3,510,000
Reservoir and tunnel	8,263,000	11,520,000
117 M.G.D. =	$11,503,000	$15,030,000
4th Development (Hazen's sixth step)		
Filters for Beaver Brook and Paulins Kill	$4,116,000	$ 4,230,000
Reservoirs and tunnels	9,981,000	12,035,000
141 M.G.D. =	$14,097,000	$16,265,000
5th Development (Hazen's 7th and 8th steps)		
Filters for Flat Brook and Delaware	$5,480,000	$5,760,000
Reservoir and tunnel	5,750,000	7,620,000
Tunnel and pumps	2,862,000	2,190,000
192 M.G.D. =	$14,092,000	$15,570,000

Table No. 24

NORTH JERSEY DISTRICT WATER SUPPLY COMMISSION

CHIMNEY ROCK—PROJECT A. FIRST DEVELOPMENT

ESTIMATE OF COST

Spruce Run, intake structures and real estate		$120,000
Two small brooks, intake structures and real estate		150,000
South Branch, " " " " "		300,000
Rockaway Creek, " " " " "		150,000
Black River, " " " " "		250,000
North Branch " " " " "		200,000
Chimney Rock Reservoir to Elevation 304—(Available capacity 48 B.G.)		
Main dams, including stream control	$5,500,000	
Gate houses and control works	125,000	
Small dams	100,000	
Clearing and grubbing	325,000	
Removal of cemeteries	15,000	
Relocation of highways	300,000	
Sanitary protection	30,000	
Fencing reservoir	70,000	
Forestration	65,000	

Engineering and contingencies, [illegible]%						[illegible]	
Real estate						3,000,000	11,160,000
Water rights						......	1,300,000
Aqueducts:							
Spruce Run to Brook,	1.4	mile cut-and-cover,	40	M.G.D.,	d. 5′6″	......	185,000
Brook to South Branch,	1.5	" "	55	"	d. 6′2″	......	225,000
"	1.0	" tunnel	55	"	d. 8′0″	......	370,000
South Branch to Rockaway Creek,	4.0	" "	270	"	d. 12′0″	......	3,380,000
Rockaway Creek to Sutton,	6.0	" cut-and-cover,	310	"	d. 12′0″	......	2,380,000
Sutton to Pluckemin,	6.5	" steel pipes	415	"	d. 10′2″	......	6,740,000
Pluckemin to Chimney Rock,	2.0	" cut-and-cover,	485	"	d. 14′0″	......	895,000
Black River to Sutton,	3.2	" "	105	"	d. 7′0″	......	630,000
North Branch to Pluckemin,	8.0	" "	70	"	d. 6′8″	......	1,480,000
Chimney Rock to Elizabeth,	14.0	" "	200	"	d. 10′0″	......	3,845,000
"	8.0	" steel pipe,	200	"	d. 11′6″	......	5,240,000
Aqueduct real estate						......	1,500,000
Aerater						......	300,000
158 M.G.D. = $260,000						......	$40,800,000
Extensions in metropolitan area						......	5,000,000
Total						......	$45,800,000

Table No. 24

Table No. 25

NORTH JERSEY DISTRICT WATER SUPPLY COMMISSION

Musconetcong—Second Development

Estimate of Cost

Musconetcong Reservoir to Elevation 450—(Available capacity 37 B.G.)		
Main dam, including stream control	$2,990,000	
Gate house and control works	120,000	
Clearing and grubbing	550,000	
Relocation of highways	640,000	
Relocation of railroads	420,000	
Sanitary protection	10,000	
Fencing reservoir	95,000	
Forestration	10,000	
	$4,835,000	
Engineering and contingencies, 25%	1,210,000	
Real estate	3,140,000	
Water rights	2,730,000	$11,915,000
Aqueducts and Right-of-Way:		
Musconetcong to South Branch, 5.0 miles tunnel, 125 M.G.D., d. 9′0″	......	3,300,000
Chimney Rock to Elizabeth, 14.0 miles cut-and-cover, 155 M.G.D., d. 9′6″	......	4,100,000
Chimney Rock to Elizabeth, 8.0 miles steel pipe, 155 M.G.D., d. 10′0″	......	4,850,000
Filtration for 1st and 2d developments	......	8,400,000
123 M.G.D. = $265,000	......	$32,565,000

Table No. 26

NORTH JERSEY DISTRICT WATER SUPPLY COMMISSION

Pequest and Beaver Brook—3rd Development

Estimate of Cost

Pequest and Beaver Brook Reservoirs to Elevation 445—(Available capacity 57 B.G.)		
Main dams, including stream control	$2,355,000	
Gate houses and control works	195,000	
Clearing and grubbing	995,000	
Removal of cemeteries	40,000	
Relocation of highways	1,690,000	
Relocation of railroads	2,310,000	
Sanitary protection	15,000	
Fencing reservoir	125,000	
Forestration	20,000	
	$7,745,000	
Engineering and contingencies, 25%	1,935,000	
Real estate	2,100,000	
Water rights	500,000	$12,280,000
Aqueduct and Right-of-Way:		
Beaver Brook to Pequest, 3½ miles cut-and-cover, 70 M.G.D., d. 8′0″		700,000
Pequest to Musconetcong, 8 miles tunnel, 150 M.G.D., d. 9′6″		5,900,000
Musconetcong to South Branch, 5 miles tunnel, 150 M.G.D., d. 9′6″		3,700,000
South Branch to Rockaway Creek, 4 miles tunnel, 80 M.G.D., d. 8′0″		2,250,000
Rockaway Creek to Sutton, 6 miles cut-and-cover, 50 M.G.D., d. 6′0″		950,000
Chimney Rock to Elizabeth, 14 miles cut-and-cover, 190 M.G.D., d. 9′6″		4,100,000
Chimney Rock to Elizabeth, 8 miles steel pipe, 190 M.G.D., d. 11′6″		5,700,000
Filtration for 3d development		4,410,000
Extension to Newark		2,500,000
147 M.G.D. = $290,000		$42,490,000

Table No. 26

Table No. 27

NORTH JERSEY DISTRICT WATER SUPPLY COMMISSION

Paulins Kill—4th Development—Estimate of Cost

Paulins Kill Reservoir to Elevation 475—(Available capacity 37.5 B.G.)		
Main dam, including stream control	$1,695,000	
Gate house and control works	130,000	
Clearing and grubbing	670,000	
Removal of cemeteries	40,000	
Relocation of highways	185,000	
Relocation of railroads	1,210,000	
Sanitary protection	10,000	
Fencing reservoir	80,000	
Forestration	10,000	
	$4,030,000	
Engineering and contingencies, 25%	1,005,000	
Real estate	1,500,000	
Water rights	1,000,000	$7,535,000
Aqueducts and Right-of-Way:		
Paulins Kill to Beaver Brook, 4 miles cut-and-cover, 125 M.G.D., d. 8′6″		1,050,000
Paulins Kill to Beaver Brook, 6½ miles tunnel, 125 M.G.D., d. 9′0″		4,300,000
Beaver Brook to Pequest, 3½ miles cut-and-cover, 125 M.G.D., d. 8′6″		950,000
Pequest to Musconetcong, 8 miles tunnel, 125 M.G.D., d. 9′0″		5,300,000
Musconetcong to South Branch, 5 miles tunnel, 125 M.D.G., d. 9′0″		3,300,000
South Branch to Rockaway Creek, 4 miles cut-and-cover, 125 M.G.D., d. 9′0″		2,650,000
Rockaway Creek to Sutton, 6 miles cut-and-cover, 125 M.G.D., d. 8′6″		1,600,000
Sutton to Pluckemin, 6½ miles steel pipe, 90 M.G.D., d. 8′6″		3,250,000
Pluckemin to Chimney Rock, 2 miles cut-and-cover, 50 M.G.D., d. 6′0″		350,000
Chimney Rock to Elizabeth, 14 miles cut-and-cover, 155 M.G.D., d. 9′0″		4,100,000
Chimney Rock to Elizabeth, 8 miles steel pipe, 155 M.G.D., d. 10′0″		4,850,000
Filtration for 4th development		3,750,000
Extension to Jersey City		5,000,000
124 M.G.D.=$385,000		$47,985,000

Table No. 28

NORTH JERSEY DISTRICT WATER SUPPLY COMMISSION

FLAT BROOK AND DELAWARE—5TH DEVELOPMENT—ESTIMATE OF COST

Flat Brook Reservoir to Elevation 455—(Available capacity 19.5 B.G.)		
Main dam, including stream control	$1,890,000	
Gate house and control works	100,000	
Clearing and grubbing	230,000	
Relocation of highways	145,000	
Sanitary protection	5,000	
Fencing reservoir	15,000	
Forestration	10,000	
	$2,395,000	
Engineering and contingencies, 25%	600,000	
Real estate	675,000	$3,670,000
Pumping station, capacity 200 M.G.D., 200′ lift		1,600,000
Aqueducts and Right-of-Way:		
Flat Brook to Paulins Kill, 7 miles cut-and-cover, 65 M.G.D., d. 6′6″		1,300,000
Flat Brook to Paulins Kill, 4 miles tunnel, 65 M.G.D., d. 8′0″		2,200,000
Paulins Kill to Beaver Brook, 1½ miles cut-and-cover, 65 M.G.D., d. 6′6″		300,000
Paulins Kill to Beaver Brook, 6½ miles tunnel, 65 M.G.D., d. 8′0″		3,600,000
Pumping Station to Beaver Brook, 3 miles steel pipe, 200 M. G. D., d. 10′0″		1,850,000
Beaver Brook to Pequest, 3½ miles cut-and-cover, 200 M.G.D., d. 10′0″		1,100,000
Pequest to Musconetcong, 8 miles tunnel, 200 M.G.D., d. 10′6″		6,500,000
Musconetcong to South Branch, 5 miles tunnel, 200 M.G.D., d. 10′6″		4,100,000
South Branch to Rockaway Creek, 4 miles tunnel, 200 M.G.D., d. 10′6″		3,300,000
Rockaway Creek to Sutton, 6 miles cut-and-cover, 200 M.G.D., d. 10′0″		1,900,000
Sutton to Pluckemin, 6½ miles steel pipe, 200 M.G.D., d. 11′6″		4,800,000
Pluckemin to Chimney Rock, 2 miles cut-and-cover, 200 M.G.D., d. 10′0″		650,000
Chimney Rock to Elizabeth, 14 miles cut-and-cover, 250 M.G.D., d. 11′0″		5,200,000
Chimney Rock to Elizabeth, 8 miles steel pipe, 250 M.G.D., d. 12′0″		6,100,000
Filtration for 5th development		5,850,000
198 M.G.D. =$275,000		$54,020,000

Table No. 28