GEOLOGICAL SURVEY OF NEW JERSEY

ANNUAL REPORT

OF THE

STATE GEOLOGIST

For the Year 1909

TRENTON, N. J.
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1910

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HIS EXCELLENCY J. FRANKLIN FORT, Governor and *ex officio* President of the Board, ... Trenton.

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DAVID E. TITSWORTH,	Plainfield,	1911
GEORGE G. TENNANT,	Jersey City,	1911
HARRISON VAN DUYNE,	Newark,	1912
CHARLES L. PACK,	Lakewood,	1913
JOHN C. SMOCK,	Trenton,	1913
ALFRED A. WOODHULL,	Princeton,	1914
FRANK VANDERPOEL,	Orange,	1914

Congressional Districts.

I.	FREDERIC R. BRACE,	Blackwood,	1911
II.	P. KENNEDY REEVES,	Bridgeton,	1912
III.	HENRY S. WASHINGTON,	Locust,	1914
IV.	WASHINGTON A. ROEBLING,	Trenton,	1913
V.	FREDERICK A. CANFIELD,	Dover,	1910
VI.	GEORGE W. WHEELER,	Hackensack,	1911
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IX.	JOSEPH D. BEDLE,	Jersey City,	1913
X.	AARON S. BALDWIN,	Hoboken,	1910

State Geologist,

HENRY B. KÜMMEL.

TRENTON, N. J., January 22d, 1910.

To His Excellency John Franklin Fort, Governor of the State of New Jersey, and ex officio President of the Board of Managers of the Geological Survey:

SIR—I have the honor to submit my Administrative Report, summarizing the work of the Geological Survey of New Jersey for the year 1909. In accordance with long-established custom, several papers of scientific and economic value will accompany and form a part of the Annual Report of the State Geologist.

I recommend that advance copies of the Administrative Report be printed for the use of the Legislature, and that the printing of the whole report be deferred until the other papers can be completed.

Yours respectfully,

HENRY B. KÜMMEL,

State Geologist.

Administrative Report.

Administration, Organization, Publication, Distribution, Library.—Topography.—Hydrography.—Geology, Building Stones, Iron Ores, Paleobotany, Raritan Folio, Soil Surveys.—Chemistry.—Co-operation with the U. S. Geological Survey.

Administrative Report.

HENRY B. KÜMMEL, STATE GEOLOGIST.

The work of the Geological Survey for the year ending October 31st, 1909, is briefly summarized in the following Administrative Report. The special reports give in detail the results of scientific investigations.

ADMINISTRATION.

Organization.—In April the following appointments to the Board of Managers were made by the Governor for the terms expiring April 1st, 1914:

Henry S. Washington, Locust; Third Congressional District.

Edward H. Dutcher, East Orange; Eighth Congressional District.

Frank Vanderpoel, Orange; Member-at-Large.

Alfred A. Woodhull, Princeton; reappointment; Member-at-Large.

During the year the following persons were engaged upon work for the Survey, most of them upon a per diem basis:

Henry B. Kümmel, State Geologist.
R. B. Gage, Chemist.
Laura Lee, Clerk and Stenographer.
Howard M. Poland, Assistant in charge of collection of well data.
John S. Clark, General Assistant.
E. B. Sterling, Jr., General Assistant.

R. D. Salisbury, Geologist.
Stuart Weller, Paleontologist.
W. S. Bayley, Geologist.
J. Volney Lewis, Geologist.
A. C. Spencer, Geologist.
E. W. Berry, Paleobotanist.
Irving L. Owen, Assistant on Soil Survey.
Tunis Denise, Assistant on Soil Survey.
W. B. Duryee, Jr., Assistant on Soil Survey.

C. C. Vermeule, Topographer and Consulting Engineer.
George E. Jenkins, Engineer.
P. D. Staats, Topographer.
D. C. Stagg, Draughtsman.
Robert A. Lufburrow, Draughtsman.
F. E. Mott, Draughtsman.

John Baumann, Janitor at Laboratory.

Publications.—The Administrative Report of the State Geologist for 1908 was published in January and laid before the Legislature. The complete Annual Report for 1908 was, however, delayed until the report on Building Stones, by Dr. Lewis, could be finished, and the mineral statistics for the calendar year collected. The report was published in September, and contained the following papers:

Administrative Report.

Part I.—Further Notes on the Changes at Manasquan Inlet, by Henry B. Kümmel.

Part II.—The Mine Hill and Sterling Hill Zinc Deposits of Sussex County, New Jersey, by Arthur C. Spencer.

Part III.—Building Stones of New Jersey, by J. Volney Lewis.

Part IV.—Notes on the Mineral Industry, with Mineral Statistics, by Henry B. Kümmel.

Revised editions of Atlas Sheet 26 and of the Newark sheet were issued in the early part of the year.

The publication of geologic folios in co-operation with the United States Geological Survey was continued. The Franklin Furnace Folio, the Philadelphia Folio, and the Trenton Folio were issued in the order named and placed on sale at prices which cover merely the cost of paper and postage.

The FRANKLIN FURNACE QUADRANGLE embraces the district centering about Franklin Furnace, and lies mainly in Sussex County, but includes a small part of Morris County on the southeast. It is bounded by the parallels 41° and 41° 15′ north latitude, and meridians 74° 30′ and 74° 45′ west longitude, and embraces a territory approximately 17 miles from north to south, and 13 miles from east to west, with an area of about 225 square miles. The folio comprises a topographic map on a scale of about an inch to the mile, with contour interval of 20 feet; a geologic map on the same scale showing the surface formations, which are principally of glacial origin; a geologic map showing the distribution of the various underlying rock formations, which comprise chiefly pre-Cambrian granite and gneiss, pre-Cambrian white crystalline limestone, Cambrian and post-Cambrian limestone, slate, sandstone and shale; a geological structure map showing by cross-sections the underground position of the various geologic formations; and special topographic and geologic maps of the region immediately around Franklin Furnace. This region is of especial importance, owing to the rich deposits of zinc ore there mined, as well as the white limestone quarried at numerous points. The descriptive text which accompanies the maps, and is bound with them, discusses the geography, descriptive geology, geologic structure, geologic history, and economic geology of the region. Under the descriptive geology the various rock formations, the occurrence of which is shown upon the geologic maps, are described in detail, and brief mention is made of the many well-defined mineral species which are known from Franklin Furnace, Sterling Hill and vicinity. Under this heading there is also given a full description of that interesting episode in geologic history known as the "ice age," when the northern part of New Jersey was covered with a great sheet of ice like that which rests upon most of Greenland to-day.

The relation of the rocks to each other is discussed in the paragraphs relating to geologic structure, and under the caption "Geologic History," the successive steps in the geologic development of this region from the earliest times in the earth's history to the close of the glacial period are pointed out.

The most important economic deposits of the region are zinc ore, iron ore, and white limestone. The occurrence of the iron and zinc ores is described in detail, and by numerous diagrams, maps and cross-sections the relations of these deposits to the inclosing rocks are plainly shown.

The authors of the folio are A. C. Spencer, H. B. Kümmel, J. E. Wolff, R. D. Salisbury and Charles Palache.

The PHILADELPHIA FOLIO describes a district lying in Pennsylvania, New Jersey and Delaware between 39° 45′ and 40° 15′ north latitude, and 75° and 75° 30′ west longitude. It covers a quarter of a square degree, or about 915 square miles, and is about 34½ miles from north to south, and 26½ miles from east to west. This territory is four times as large as that of the Franklin Furnace folio, and, since the maps are on the same scale, it contains 4 topographic atlas sheets, 4 geologic sheets, 2 geologic structure sheets, and 1 sheet of half-tone illustrations. In this respect it is a "double" folio.

The Philadelphia district comprises portions of the two provinces—the Appalachian and the Coastal—which characterize the Atlantic border region of the United States; hence the two parts of this region show strongly contrasted topographic and geologic features. Delaware River roughly divides these two provinces. The descriptive text accompanying the atlas sheets, and bound with them, describes in considerable detail the topography and geology of the region, taking up in order of age the various rock formations and their relations to each other. In the paragraphs relating to historic geology the various stages in the development of the region lying south and southeast of Camden will be of particular interest to New Jersey readers.

The mineral resources of this region are described in the paragraphs devoted to economic geology. Within the Coastal Plain area the principal mineral resources at present utilized are gravel, sand, clay and greensand marl. The location of these and their relative importance are fully discussed.

Under the head of "Water Resources" important facts are given regarding the flow of the various streams in the region, the location and depth of deep wells and the water supply of the various towns.

The authors of the folio are F. Bascom, W. B. Clark, N. H. Darton, H. B. Kümmel, R. D. Salisbury, B. L. Miller and G. N. Knapp.

The TRENTON FOLIO covers the region about Trenton and embraces portions of Pennsylvania and New Jersey. It lies between 40° and 40° 30′ north latitude and 74° 30′ and 75° west longitude, and covers an area of about 912 square miles, measuring 34½ miles from north to south and 26½ miles from east to west. It embraces a territory the same size as that described in the Philadelphia folio and four times that of the Franklin Furnace folio, but the maps are on a scale of about two miles per inch, instead of one mile per inch.

Like the Philadelphia folio, the Trenton folio describes portions of the Coastal Plain Province and the Appalachian Province of the Atlantic border region, and therefore the region presents in its northwestern and southeastern portions strongly contrasted geologic structures. The dividing line between the two provinces is approximately the line followed by the Pennsylvania Railroad between Philadelphia and New Brunswick.

The maps of the Trenton folio are a topographical sheet, contour interval twenty feet, scale approximately two miles to the inch; a geological sheet showing distribution of the various rock formations, of which thirty-one are recognized and differentiated on the map; a geologic structure sheet, which shows in strong contrast the almost horizontal strata of the Coastal Plain, the strongly crumpled belt of ancient rocks in the vicinity of Trenton, and the regularly northwestward dipping sandstones and shales of the red sandstone district.

The descriptive text, which is bound with the maps, is similar in its general arrangement to that of the Franklin Furnace and Philadelphia folios. Each of the various geologic formations is described, many local details as to their occurrence are given.

and the characteristic fossils by which those of the Coastal Plain can be identified are mentioned. A series of diagrams illustrate the profound fractures which traverse the red sandstone belt northwest of Trenton, and show how these faults have repeated the series and widened its outcrop.

The geologic formations included within this area range in age from some of the most ancient known to the most recent. Under the head of "Historical Geography" the successive stages in the geologic development of this region are set forth, and the enormous changes in the geography are made plain.

The region is not one of great mineral resources, the chief being building stone, road material, clay, sand and marl.

The water resources, both surface waters and underground waters, are described in considerable detail, and information given as to the water supply of the various towns within the region.

The authors of the folio are F. Bascom, N. H. Darton, H. B. Kümmel, W. B. Clark, B. L. Miller and R. D. Salisbury.

All of these folios were prepared in co-operation with the United States Geological Survey. The field work and preparation of the text was done partly by one organization, partly by the other; the engraving and printing was done by the United States Survey, a special State edition being printed for the use of this department.

The folios are distributed only by sale, at a price which barely covers the cost of paper and mailing. The price of the Franklin Furnace and Trenton folios is twenty-five cents each per copy, postage fifteen cents extra. The Philadelphia folio, being a double folio, is sold for fifty cents per copy, postage fifteen cents extra. Where a number of folios are ordered at a time they can usually be sent cheaper by express, charges collect.

Distribution.—The distribution of the Survey publications is through the office of the State Geologist. Maps are sold at a uniform price of twenty-five cents per sheet, while the reports are generally distributed free, except that the payment of postage in the case of some volumes is required. When the supply of any report is reduced to 200 copies it is withdrawn from free distribution and, by order of the Board of Managers, the remaining copies are sold at cost. The editions of the following reports have been so reduced, and they can now be obtained only by purchase at the price mentioned:

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Annual Report for 1883, ... Price, $0 50
" " " 1892, ... " 1 55
" " " 1903, ... " 40
Paleontology, Vol. I—Brashiopoda and Lamellibranchista of the Raritan Clays and Greensand Marls of New Jersey. To non-residents of New Jersey, $1.50. charges prepaid.
" " II—Grasteropoda and Cephalopoda of the Raritan Clays and Greensand Marls of New Jersey. To non-residents of New Jersey, $1.40, charges prepaid.
" " III—Paleozoic Paleontology, ... Price, $1 00
" " IV—Cretaceous Paleontology, ... " 2 70

Vol. II, Part 1—Mineralogy, Botany. Bound, price, $1.50; unbound, postage 25 cents.
" IV—Report on the Physical Geography of New Jersey. Unbound, price, $1.00; bound, price, $1.35; photo-relief map, $1.50 extra.

The sale of maps by the Survey during the past three years is as follows:

	Sheets sold.		
	1907	*1908*	*1909*
Maps on scale of 1 inch per mile,	1127	1637	1435
Maps on scale of 2½ inches per mile,	2160	1718	2205
Geologic folios,	....	41	246
	3287	3396	3886

The above figures show an increase in the total sales during the past three years, but the figures are still nearly 700 copies short of the sales in 1906.

The reports of the Survey have been distributed as follows:

SURVEY REPORTS DISTRIBUTED IN 1908 AND 1909.

	1908.	1909.
Annual Report for 1908,		3,174 copies.
" " " 1907,	3,044 copies.	160 "
" " " 1906,	122 "	74 "
" " " 1905,	92 "	96 "
" " " 1904,	34 "	48 "
" " " 1903,	33 "	33 "
" " " 1902,	32 "	44 "
" " " 1901,	27 "	36 "
" Reports between 1883-1900,	419 "	457 "
Final Reports, Vol. II,	50 "	55 "
" " Vol. III,	55 "	71 "
" " Vol. IV,	44 "	52 "
" " Vol. V,	78 "	63 "
" " Vol. VI,	72 "	85 "
Other Reports,	1,423 "	157 "
Total Reports,	5,525 "	4,605 "

Library.—The accessions to the library were 47 bound volumes, 101 unbound volumes, 41 pamphlets, 145 maps and 6 atlases. Most of these were received by exchange, but some standard works of reference needed in investigations by members of the Survey were purchased.

TOPOGRAPHIC WORK.

Mr. C. C. Vermeule has continued in charge of all topographic work done by the Survey, and in this work he has employed several of his assistants for various periods.

Field work.—Some field work was done in preparing a new edition of Atlas Sheet No. 22, but a complete revision of this region was not made.

In connection with the Report on Iron Ores a sketch map of the mines at Mount Hope and vicinity was made by Mr. Staats.

Office work.—The office work comprised preparing for the engraver a portion of Sheet 29 (the greater part of this sheet having been made ready the previous year), Sheet 22, Sheet 23, and in reading the proof of the Newark sheet and No. 29. The changes on Sheet 29 were so extensive as to make necessary the engraving of new copper plates, and reading of these proofs required long and careful attention.

HYDROGRAPHIC WORK.

Underground waters.—During the past year the collection of well records has been in charge of Howard M. Poland. The work has been done in co-operation with the United States Geological Survey, which has furnished the necessary record books, bags for the collection of samples and post office franks, so that correspondence and materials collected could be transmitted through the mails without expense to the State Survey.

At present 43 well-drillers have agreed to furnish data. Circular letters are sent to these at frequent intervals, and each driller is supplied with cards on which he may advise the Survey when and where new wells are to be drilled. In these cases a log book, in which the driller may keep a record, is sent for each well, and, where it is desirable to procure samples of materials, bags are provided. In many instances, particularly in the hard rock formations of north New Jersey, where there is very little change in material in any well, and where samples have already been obtained, they are not preserved. During the year 172 new records and 42 sets of samples have been received.

The log books, when returned, are attached to cards giving the location of the well, name of the owner and driller, the date, the depth, a filing number and other pertinent data. These are filed according to locality. Each record receives also a number. Samples from the boring, if any, are preserved in small glass vials bearing a label giving the corresponding number, the locality and depth of the sample. The position of each well is also marked upon a set of maps, by which it is possible at a glance to see the distribution of these records throughout the State.

In initiating this work it has been found necessary to have personal interviews with most of the drillers in order to enlist their co-operation and to secure their continued assistance.

Mr. Poland has also spent considerable time in re-arranging the earlier well records so that they will correspond with the system now in use. These records are all filed alphabetically according to location. Colored clips variously placed on the top of the cards indicate also the geologic horizons from which the water is obtained.

The records as preserved are open to inspection by members both of the United States Geological Survey and the State Survey, and all inquiries regarding the occurrence of underground waters are answered as fully as the data in hand permits.

Surface supplies.—The Annual Report of the State Geologist for 1905 contained a report by Mr. C. C. Vermeule, Consulting Engineer of the Survey, entitled "Lake Passaic Considered as a Storage Reservoir." That investigation was made and the report prepared in response to numerous inquiries for more information regarding the suggestion put forth in an earlier report (Annual Report of the State Geologist for 1903) that the extreme floods upon Passaic River and its tributaries might be controlled by the construction of large storage reservoirs. The authorization of this investigation by the State Geologist and the publication of the report as a part of his Annual Report did not, of necessity, commit the Board of Managers of the Survey either collectively or individually to the advocacy of this project. It was not the purpose of the report to urge the adoption of this plan, but, as was stated in the report at that time, its aim was solely "to lay the facts before the people of the State in order that they may judge for themselves of the wisdom and utility of such an improvement."

About the same time another plan for an extensive reservoir to be located at Mountain View was urged, first by the Passaic Valley Flood Commission and afterwards by the State Water-Supply Commission. Later an attempt was made to secure necessary legislation to permit the initiation of the latter project, but owing to the opposition which developed the bill was withdrawn. In view of these facts the Board of Managers of the Survey, in May, 1909, directed the State Geologist to have made an examination of the possible reservoir sites on the upper Passaic and its tributaries above Little Falls and Mountain View for the purpose of determining the possibilities of a gradual development of the water-supply of northern New Jersey by the construction of a number of smaller reservoirs as the needs of the district may demand. Because of his intimate knowledge of the water-supply problem, Mr. C. C. Vermeule was requested to make this examination and prepare a report. This has been done and Mr. Vermeule's paper will be included in the Annual Report of the State Geologist for 1909.

In presenting this statement of another method of solving the problem of an adequate supply of potable water which will soon confront the people of northern New Jersey, it must be understood that the Geological Survey does not appear as the advocate of any plan, but is concerned only with setting forth the physical possibilities, with a fair and impartial statement of the advantages and disadvantages involved. The questions concerned in the gradual development of the watershed by the construction of several smaller reservoirs are therefore presented, not with the view that this is necessarily a better method of meeting the situation than either of the plans previously proposed, but merely as a statement of a third method of solving the problem in order that the people of the State may have all available data before them before committing themselves to any policy.

Persons interested should read Mr. Vermeule's complete report, but it may be advisable to refer briefly here to certain facts there developed at greater length.

It must always be borne in mind that no additional development of the Passaic watershed (or of any watershed) and further diversion of water can be carried out under State, municipal or corporate control without taking into consideration all riparian rights below the point of diversion. As Mr. Vermeule points out there are transportation companies, water-power companies and water-supply companies which, in various ways, have acquired rights along Passaic River. None of these rights have been questioned, save the rights of certain water companies to divert water from the Passaic. This right is now the subject of litigation, and even if the final decision be wholly against these companies the undisputed rights of the other riparian owners, both corporate and individual, will remain. Therefore, no plan of water conservation, reservoir construction and diversion can be carried out without providing for the acquisition of such rights, either by purchase or condemnation, for such sum as their value may finally be determined to be. If they are taken they must be paid for; they cannot be arbitrarily obliterated.

Continued investigation indicates that there are greater supplies of ground water in the glacial drift and in the coarser sandstones interstratified in the Triassic shales north of the latitude of Newark than has heretofore been supposed. These waters afford potential supplies available particularly for the smaller suburban communities.

It is possible to construct a series of moderate-sized reservoirs on the tributaries of the Passaic which taken together will conserve a very considerable proportion of the total available supply of this watershed. Two of these located on the Wanaque and Ramapo, respectively, are discussed in some detail in Mr. Vermeule's report. These two reservoirs are estimated to supply about 169,000,000 gallons daily.

The chief advantage in the construction of several small reservoirs is that by the gradual development of the watershed a very large initial investment, with the resulting interest charges, is avoided, and provision for a supply is made as the demand increases.

The smaller reservoirs are more likely to be located in the mountainous sections, where land is of less value. Both of the proposed large reservoirs at Little Falls and at Mountain View involve the relocation of either the Jersey City or Newark pipe lines and extensive changes in the location of important railroads. This very considerable outlay is entirely saved by smaller reservoirs. The chief disadvantage may lie in the fact that it may not be possible by the small reservoirs ultimately to conserve for use so large a percentage of the total run-off of the watershed as by a single large reservoir located further down stream.

The question of an adequate and economical development of the water resources is so great, and contains so many diverse factors, that it needs to be examined from all points of view, and every possible means of solution thoroughly tested. No project involving the expenditure of millions of dollars should be initiated until its pre-eminence as the best had been thoroughly established.

GEOLOGIC WORK.

Building stones.—The report on building stones was completed by Prof. J. Volney Lewis early in the year, and was included in the Annual Report for 1908.

Iron-ore report.—The report on iron ores, by Dr. W. S. Bayley, was completed during the year, and the State Printing Board was requested to authorize its publication. At the close of the year no action had been taken upon this request. In view of the valuable information contained in this report, the demand for it on the part of those interested in the mining industry, and the expense already incurred in the preparation of the manuscript, it is to be hoped that its early publication may be provided for.

Paleobotanic work.—Early in the year Mr. E. W. Berry submitted his report upon the fossil plants of the Raritan clays—the result of investigations which have been in progress for a number of years. In preparing this report Mr. Berry had not only the material which he had collected himself, but large collections made in years past for the U. S. National Museum, as well as much of the material used by Prof. Newberry and preserved in the museum of the New York Botanical Garden.

It is hoped to publish Mr. Berry's report as one of the accompanying special papers. While it is highly technical in its details, yet his conclusions as to the age and botanical relations of the plant remains preserved in the clay beds at Woodbridge and South Amboy will doubtless be of interest to many persons. It is significant of the great lapses of time dealt with by geologists that the plants preserved in these beds antedate all of the higher animals, and were the contemporaries of the huge and uncouth reptiles—the Dinosaurs, Mososaurs, etc., which have long since disappeared, and yet these clay beds are youthful when compared with the much greater age of many of the formations of North Jersey.

The Raritan folio.—The preparation of geologic maps and a portion of the text of the Raritan geologic folio has occupied much of my own time. In this connection some field work was found necessary, and some interesting structural features were made out in the extensive excavations along the new line of the Delaware, Lackawanna and Western Railroad in Warren and Sussex counties.

Soil surveys.—Arrangements have been made between the United States Bureau of Soils, the State Agricultural Experiment Station of New Jersey and the State Geological Survey for a detailed agricultural and soil survey. The U. S. Bureau of Soils detailed a field man, and has paid his salary and field expenses. The State Survey has carried on in its laboratory considerable chemical work incident to the analyses of the soils, and has contributed toward the salaries and expenses of some of the field men. The State Experiment Station has contributed an equal amount. Beginning July 1st, four men were in the field, two on soil work proper and two on the agricultural surveys. Work was commenced in Sussex County in the region included in the Franklin Furnace folio, and up to the close of the year 200 square miles had been studied in detail.

The objects of the soil survey are three-fold: 1. To differentiate and map the various types of soils and to make mechanical analyses of average samples of each type. This would furnish the necessary data concerning the methods of tillage, the green-manuring crops and the rotations best adapted to each particular soil.

2. To determine chemical composition of the various soil types. The physical survey and tests are supplemented by a chemical survey. Average samples of each type of soil are to be analyzed to determine their content of available and total plant food. The data thus accumulated will furnish information as to permanent systems of agriculture suitable for each soil and as to the kinds and amounts of fertilizers required.

3. To acquire accurate information as to present farming methods. The physical and chemical survey is accompanied by an agricultural survey, in the progress of which detailed information will be gathered concerning prevailing methods of tillage, fertilization and crop rotation. Information is also to be collected in reference to the seeds, varieties, yields, methods and time of planting, animals, machinery, markets, transportation, etc.

During the past season much of the work was of a preliminary nature and proceeded slowly. It was necessary to establish, by careful study and comparison, the various soil types which ocurred and which should best be recognized. An effort was made to lay broad foundations rather than to cover much territory. While it is too early, yet, to make a detailed statement of the results obtained, inasmuch as at the close of the year some of the men were still in the field, nevertheless it may be said that a close relationship has been established between the soil types and the geology. The region chosen for beginning the work was one showing marked geologic and topographic differences. Topographically it comprised portions of the Highlands, of the broad upland Kittatinny valley and of the narrow ridge of Kittatinny Mountain. The Highlands are underlain by various types of gneiss; Kittatinny valley mainly by the Kittatinny (blue) limestone and Martinsburg (Hudson River) shale and slate; while Kittatinny Mountain is composed of hard quartzite and conglomerate (Shawangunk conglomerate). The entire region has been glaciated. A sheet of till of variable thickness covers the hills, while kames, terraces, deltas and gravel plains occupy many of the valleys, with swamps and low clayey flood plains along many rivers. The soil survey has established the fact that a definite series of soil types characterizes each of the chief rock formations. That is, each of the chief rock formations has certain soil types which are peculiar to it. Certain soil types occur upon the shale areas and not upon the limestone or geniss, and *vice versa*. The underlying rock has entered largely into the composition of these soils and determined their character.

But this is not all. Certain other types are more widespread, occurring indiscriminately upon several rock formations, and showing a striking independence of the underlying rock. The clayey soils along the flood plains of the streams, the peaty soils in the swamps and meadows, the soils on the plains of glacial sand and gravel and those of the kames and coarse gravel terraces, formed of materials which have been transported considerable distances, are, in the region studied, largely indifferent to the underlying rock formations. They possess characteristics typical of their manner of origin, and in so far as these conditions continued uniform the resulting soils are the same, even over areas of diverse geologic formations.

It is proposed to continue the soil survey during the coming year along the same general lines.

CHEMICAL WORK.

Mr. R. B. Gage has continued in charge of the chemical laboratory. During the early part of the year, from November, 1908, to March, 1909, his time was largely occupied in rock analyses which were being made for the report on building stones. During this time fourteen complete silicate rock analyses, two limestone and two water analyses were made in duplicate.

In February the Geological Survey was requested by the State Road Commissioner to assist in preparing specifications covering the use of heavy residual oils in constructing macadam roads. It was found that there was little or no literature on the subject, and that of those who had considered the subject no two agreed. The details of the matter were placed by me in charge of Mr. Gage, who spent considerable time in visiting various oil companies and securing what information could be had from different experts.

The Survey was also requested by the Road Commissioner to examine and test every carload of oil before its use upon the roads, to insure that it conformed to the specifications. This necessitated enlarging the laboratory by securing new apparatus and fitting up an extra work room. Much of Mr. Gage's time during March and April was consumed in this preliminary work.

From May 1 to the end of the year samples of oil were received at frequent intervals and tested, 58 analyses having been made. This work has consumed a great deal more time than that required merely by the analyses. The oil is shipped in tank cars. Although it is extremely thick and viscous when cold, yet during transportation some segregation takes place so that the bottom layers have a higher specific gravity than the top. Consequently, a sample of oil taken from the top of the car was found not to represent fairly the entire car. This made it necessary to design a sampler by which an average sample of oil from the car could quickly be taken. The various road supervisors had each to be instructed how to sample the car.

In addition to this work, Mr. Gage has carried on experiments with various oils with a view to suggesting modifications in next year's specifications, so that a more satisfactory grade of oil will be obtained. He has also inspected the various roads under construction in which oil was used, and kept himself informed of the results obtained with oil of different grades.

In addition to the oil work, he has been occupied in analyses of the soils collected in the course of the soil survey. Forty-six complete analyses were made, some in duplicate, the following determinations being made on each sample: insoluble residue, soluble silica, alumina, ferric oxide, lime, magnesia, soluble alkalies of sodium and potassium, soluble phosphorus, sulphur, manganese oxide (Mn_3O_4), loss on ignition, total potash, and total phosphorus.

Considerable experimental work has been done in connection with these soil analyses with a view of devising reliable methods and eliminating sources of error which frequently cause different chemists working on the same sample to obtain diverse results.

Since May 1 Mr. Gage has had the assistance in the laboratory of Fred H. Baumann, who has made most of the oil determinations, and whose salary has been paid by the State Road Department. That department also defrayed many of the other expenses incident to the oil work.

CO-OPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY.

Several phases of the co-operative work with the U. S. Geological Survey have already been alluded to. The most important is that by which the geological folios are prepared and published. As already stated, three of these folios were issued during the past year, and the preparation of manuscript for others was continued.

The co-operative work in the collection of well data has proved satisfactory and will be continued during the coming year.

The joint collection of mineral statistics, agreement concerning which was contained in the last Annual Report, was found to have many advantageous features. The State Survey was enabled to get returns in several lines in which it had not previously attempted to collect statistics, and, owing to the ability of the State Geologist and his assistants personally to interview delinquents, the returns were more complete than in previous years. It threw considerable detailed work upon this office, a considerable portion of which had to be done by the State Geologist personally.

A recent act of Congress, providing for the taking of the 13th Census, directs that a census of the manufacturers and mines and quarries of the United States shall be taken by the Director of the Census in the year 1910. This legislation made it incumbent upon the United States Geological Survey and the Bureau of the Census to co-operate in order that the duplication of work might be eliminated, and the continuity and uniformity of statistics of the U. S. Geological Survey might be uninterrupted. The plan agreed upon places the collection of the data in the hands of the special census agents. Under these circumstances the plan of co-operation pursued last year between the U. S. Survey and the State Survey cannot be carried out. Arrangements have been made, however, by which the Federal Survey will furnish to the State Survey the totals for New Jersey covering each subject as fast as the compilation is completed. It will be possible, therefore, to continue the complete record of our mineral production which was presented in the 1908 Report, although all the returns may not be received in time to be included in the report of this year.

PART I.

Report upon the Development of the Passaic Watershed by Small Storage Reservoirs.

By C. C. VERMEULE.

3 GEOL

TRENTON, N. J., February 1st, 1910.

To the Board of Managers of the Geological Survey:

GENTLEMEN—I have the honor to submit the following report made in accordance with the instructions contained in the resolution adopted by you on May 4th, 1909:

> "*Resolved*, That the State Geologist be requested to make, to the extent that funds not otherwise appropriated will permit, an investigation and report on the available sites for storage reservoirs on the upper Passaic and its tributaries above the proposed Mountain View and Little Falls sites."

In carrying out your wishes it seemed best to refer the matter to Mr. C. C. Vermeule, Consulting Engineer of the Survey, whose long study of and great familiarity with the water resources of the State had made him exceptionally well qualified to undertake this investigation and prepare this report.

Yours respectfully,

HENRY B. KÜMMEL,
State Geologist.

EAST ORANGE, N. J., January 24th, 1910.

To Henry B. Kümmel, State Geologist, Trenton, N. J.:

SIR—I submit herewith a report upon "The Development of the Passaic Watershed by Small Storage Reservoirs," as requested by you.

Yours truly,

C. C. VERMEULE,
Consulting Engineer.

Report upon the Development of the Passaic Watershed by Small Storage Reservoirs.

BY C. C. VERMEULE.

In the annual report for 1905 I presented the possibilities for control of floods and development of the potable water supply of Passaic River by means of a large storage reservoir created by a dam located on the main stream at Little Falls. At about the same time the Passaic River Flood District Commission proposed to create a reservoir on Pompton Plains, by means of a dam on the northerly branch of the Passaic, at Mountain View. The leading data as to these two propositions are given in the following table:

	Mountain View Reservoir.	*Little Falls Reservoir.*
Catchment area controlled (square miles), ...	375	773
Catchment area, exclusive of that controlled by Jersey City and Newark, ...	311	589
Surface area of reservoirs (acres), ...	11,200	32,922
Low water area (acres), ...	......	27,850
Area laid bare by maximum draft on reservoir (acres), ...	11,200	5,072
Area laid bare for flood control (acres), ...	2,700	2,722
Estimated cost of reservoir, ...	$7,437,624	$6,994,242
If dam foundations are carried to rock, we estimate additional cost approximately, ...	1,000,000	....
Total cost if carried to rock, ...	$8,437,624	$6,994,242
Total yield in million gallons daily, ...	254	306

The estimate for Mountain View dam, as given by the Flood Commission, makes no provision for carrying foundations or cut-off wall to rock. Since the depth of more or less pervious material overlying the rock is nearly 100 feet, I do not consider any plan safe which does not make such provision. As the cost of this work will be at best problematical, I have not attempted a close estimate, but have added $1,000,000 which I consider a reasonable approximate estimate.

Neither plan includes the cost of riparian rights on the stream below, which must be secured. The validity of the rights of the large water-power companies and of the Morris Canal and Banking Company, has not been seriously questioned, and recent decisions make it clear that all riparian rights, even those of owners abutting upon the stream who are making no use of the waters for power, must be acquired and paid for. I pointed out in my report for 1905 that an agreement with these interests would be necessary and I believed might be feasible. It now appears to me that no such agreement is ever likely to be reached, and that the cost of acquiring these rights must be provided for, if either of these reservoirs is to be built. A reasonable estimate of the value of riparian rights affected is, in my judgment, not less than $7,000,000. Even this takes no account of the value of the rights and the plant of water companies which now obtain their supply from Passaic River. The rights of these companies are being tested in the courts and no accurate estimate of their value is at present possible. Enough appears from the above considerations to make it reasonably clear that the total cost of carrying out either of the above projects will probably range from $15,000,000 to $20,000,000. The above considerations must be kept in mind if an intelligent comparison is to be made of the method of development which is considered in the present report.

I have been instructed to report upon a scheme of development by means of small reservoirs upon the tributaries of the Passaic, which may be constructed gradually from time to time as required, and which call for no such costly and extensive undertaking as is involved in the construction of either of the foregoing great reservoirs in the central valley. I shall endeavor, therefore, to set out what may be done to this end, bearing in mind that although the construction cost may be greater, this may be more than offset by the possibilities of gradual construction in such manner that the improvement shall at no time be too far in advance of the demand, and with the consequent saving in interest and maintenance charges. Such a plan may make it feasible for different municipalities to continue to develop their own supplies under the general direction of the State, but without making necessary any important change in legislation or in methods of financing.

PROBABLE FUTURE REQUIREMENTS.

It is practically impossible to determine the relative economy of the various methods of developing the Passaic until there has been determined, at least approximately, the probable amount of water which will be required in the future from this source, together with the date at which it will be required. This cannot be determined without forecasting the future demand or without considering how much of this demand will probably be met from other sources of supply. I attempted a forecast of this nature for the Metropolitan district in the report for 1905, but since that report was written the report of the Potable Water Commission has made further data available; and furthermore, several very important changes have been taking place in the sources and methods of supply which have an important bearing upon this question.

As to the amount of water required, the Report of the Potable Water Commission for 1905 showed that in that year the cities of the State as a whole consumed 202,287,600 gallons daily, being substantially at the rate of 117 gallons per capita. Going over these figures with some care, there is indisputable evidence that there is some exaggeration in the reported amount of water consumed in many of the cities and towns. It should be borne in mind that many water-works have no accurate means of measuring the total consumption of water, other than pump displacement, which may overrate the actual consumption as much as 50 per cent., or in the case of gravity supplies there may be nothing but a rough estimate, even less reliable than pump displacement; consequently, although the statistics are the best available, it is by no means certain that the average consumption at the present time exceeds 100 gallons per capita. Surely this is more than ample as an average for the whole State. There are undoubtedly manufacturing cities in the State in which a larger amount than this is legitimately used, but there are many other municipalities which do not actually use in excess of 60 gallons per capita. In 1882 the average per capita use was 83 gallons daily. In 1894, 97 gallons, and in 1905, 117 gallons daily, showing a steady increase in the per capita use. However, the restriction of waste has now become a settled policy with most of our cities and is beginning to have its effect. Another noticeable factor is the introduction of a separate supply for manufacturing purposes in some of our large manufacturing cities. For such purposes, water of inferior quality is found sufficient. The same policy of separate supply is being generally applied for fire service in many large cities. These tendencies are toward the reduction of the demand for potable water of high quality.

TOTAL WATER SUPPLY OF THE STATE.

Taking the State as a whole, the Report on Water Supply,[1] of 1894, and the Report of the Potable Water Commission indicate clearly that the total supply either from driven wells or from streams will average about 666,000 gallons daily for each square mile of upland. Applying this factor to the entire upland area of the State, it will be found that the total available water supply amounts to about 5,000,000,000 gallons each 24 hours. It is true that all of this is not equally good in quality, but improved methods of purification now in practical use have rendered a much larger part of this supply available for public water supply than was believed to be possible when the Report on Water Supply of 1894 was written. Furthermore the Report of the Potable Water Commission gives a reliable list (page 33 et seq.) of "streams or portions of the streams, which, by reason of elevation, character of the watershed, or absence of serious contamination, seem available as sources of a water supply." Eliminating from this list the branches of streams in cases where the

[1] Geological Survey of New Jersey, Vol. III., Report on Water Supply, 1894.

whole stream is elsewhere included, we find that these stream-waters of peculiar excellence exhibit a total yield of over 2,100,000,000 gallons daily. It is to be noted that this does not include well water of which it is certainly possible to develop sufficient to make the total available supply of waters of peculiar excellence in the State at least 2,500,000,000 gallons daily, still leaving an equal amount of additional water which may be applied to manufacturing, fire protection, sewer flushing, street cleaning, etc., if needed. It, therefore, becomes apparent that if it is conceded that 100 gallons daily per capita is an ample allowance, there is sufficient water in the State to supply at least 25,000,000 inhabitants with water of peculiar excellence, and by applying methods of purification we could ultimately supply 50,000,000 people without going beyond the boundaries of the State. It must be considered impossible that the population of this State will ever reach any such figures, which would reduce the entire State to the condition of a solidly built city. Therefore, it may be safely assumed that the State is not dependent upon Passaic River alone and that the entire available water supply is far in excess of any probable future requirements. It will be observed that the total available supply is nearly twenty-five times the amount of water consumed in 1905. During the past the population of the State has doubled each twenty-five years, and if this rate should continue, the population might be expected to reach 4,000,000 in 1935 and 8,000,000 in 1960, but the natural laws which operate to check undue increase in population are already known to be in operation to a marked extent, and it must be assumed that the rate of increase in the future will be much less than in the past. In any case in making up a forecast of this nature, which from necessity is more or less conjectural, it is unwise to attempt to provide for more than fifty years in the future.

AVAILABLE SUPPLY FOR METROPOLITAN DISTRICT.

Taking the Metropolitan district alone, I find, as already noted, that the consumption of water in 1905 was 137,000,000 gallons daily. It it is assumed that this consumption will increase in the future at the same rate that the population of this district has increased during the past, namely, 40% each ten years, I find that by 1935 we shall need 397,000,000 gallons daily, and by 1955, 778,000,000 gallons daily. Here again, 778,000,000 gallons daily would be sufficient for a population of nearly 8,000,000 people at the rate of 100 gallons per capita, which is far more than the Metropolitan district is likely to contain, being in fact as much as our previous estimate for the entire population of the State fifty years hence. However, even were this liberal amount needed, it will be found that sources of supply immediately adjacent to the Metropolitan district are capable of furnishing 1,222,000,000 gallons each 24 hours.

INCREASED USE OF GROUND WATER.

A matter which has an important bearing upon the supply available for this district is the rapid increase in the development and use of ground waters. The story is told in the following table compiled from the Annual Report of the State Geologist for 1882, the Report on Water Supply for 1894, and the Report of the Potable Water Commission for 1905:

DAILY CONSUMPTION OF POTABLE WATER BY SOURCES AT CERTAIN PERIODS.

All quantities in gallons.

	1882.	*1894.*	*1905.*
Lakes and Streams,	48,028,406	93,762,061	140,755,000
Wells,	895,000	6,578,300	42,302,600
Combined Sources,	....	7,500,000	19,230,000
Total,	48,923,406	107,840,361	202,287,600

The water given in the above table, as taken from combined sources, I find, after careful examination, to be very nearly equally divided between well water and stream water. Allotting one-half to each, I find that of the total supply in use in the State, the relative percentages of surface water and ground water are as follows:

PERCENTAGE OF TOTAL SUPPLY.

Source.	*1882. Per cent.*	*1894. Per cent.*	*1905. Per cent.*
Lakes and Streams,	98.2	90.4	74.4
Wells,	1.8	9.6	25.6

This shows clearly the increasing popularity of well water, the development of which for municipal supply began at about 1880 and which rose from nothing at that time to over 25% of the total supply twenty-five years later.

A further analysis shows that a very important part of this ground water has been developed within or immediately adjacent to the Metropolitan district. Of this Metropolitan supply of well water, 4,000,000 gallons come from just south of Raritan River, in which vicinity a large additional supply may be developed. Within an area of about 100 square miles, mostly in Union County and east of the Orange Mountains, there is in use for municipal supply 12,500,000 gallons daily of ground water, and there also exists within the same territory at least 3,000,000 gallons daily already developed and in reserve. In the district north of Union County, to the New York State line, and east of the Orange Mountains, only 750,000 gallons daily are taken from wells for municipal supply, but over 7,000,000 gallons daily have been developed and are in reserve. This does not include a very large amount which has been developed for private industrial plants, some of which use several million gallons daily. Recent experience has demonstrated that unquestionably a large amount of well water may be developed in this region, both from the overlying glacial sand and gravel and from the red sandstone rock beneath.

A large amount of ground water exists also in the Passaic Valley wast of the Orange Mountains. From this region, ground water is already in use to the extent of 6,750,000 gallons, and there is a reserve supply estimated at 4,500,000 gallons daily in addition, so that present development in the valley amounts to not less than 11,250,000 gallons daily. The larger part of this water is pumped across the Orange (Watchung) Mountains into the Metropolitan district, and a general survey of the possibilities seems to indicate that from 40,000,000 to 50,000,000 gallons daily may readily be obtained from wells in this valley.

These ground-water supplies are peculiarly adapted to the smaller cities and towns, for the reason that it is not usually possible to develop in one locality more than 5,000,000 gallons daily. Of course, this can be increased by additional units spread sufficiently far apart to avoid interference, but these ground-water supplies are peculiarly popular in suburban towns, and are not likely to be adopted by the large cities. In making up my estimate of sources from which the Metropolitan district is likely to be supplied, I have estimated the driven-well supply to be gradually increased until it reaches a total of 100,000,000 gallons daily in 1955. This figure is probably much too conservative, but is purposely taken low enough in order to estimate the maximum which may be needed from Passaic River.

Other New Sources.—Another important new source of supply for the Metropolitan district is Raritan River. Preparations are already being made to develop a supply of 20,000,000 gallons daily from this source, and with this start the Raritan should appear as a very useful factor in the future supply of the Metropolitan district, relieving to an important extent the drafts upon the Passaic. The supply from the Raritan is capable of development to a total of 500,000,000 gallons each 24 hours. This water is capable of being made entirely satisfactory for a public water-supply through proper handling and methods of treatment.

Still another source, conveniently situated for gravity delivery to the Metropolitan district, is Musconetcong River. It is capable of being developed to supply 90,000,000 gallons each 24 hours.

DEMAND AND SUPPLY OF METROPOLITAN DISTRICT BY SECTIONS.

In order to make intelligible the points from which will come the greatest probable demand for water in the Metropolitan district, I have grouped the cities within this district according to the source from which they are at present supplied with water, and in the following table have shown how much water each of these groups used in 1905, and have estimated how much they will require up to 1955. It must be borne in mind that this table is made up to show to what extent each group of cities will exceed the capacity of its present source of supply. The capacity of Hackensack River is taken conservatively for this purpose at 45,000,000 gallons daily, although it is entirely practicable to develop this supply to about 65,000,000 gallons daily. I have some doubts, however, whether this ultimate development will actually be made, consequently the lower figure is adopted. The capacity of the Passaic at Little Falls is estimated upon the data given later in this report, and is the total practical development of the Passaic by means of reservoirs on the branches, exclusive of the 140,000,000 gallons daily estimated as the combined capacity of the present Newark and Jersey City watersheds; or, in other words, the total practicable development of the Passaic is taken at 487,000,000 gallons daily without the large reservoirs in the central valley.

PRESENT AND ESTIMATED MAXIMUM FUTURE CONSUMPTION OF MUNICIPALITIES IN THE METROPOLITAN DISTRICT, GROUPED ACCORDING TO PRESENT SOURCES OF SUPPLY.

Quantities in million gallons daily.

Communities now supplied from:	*1905*	*1915*	*1925*	*1935*	*1945*	*1955*	*Total Capacity of Source.*
Pequannock River (Newark),	35	49	69	96	134	188	50
Rockaway River (Jersey City),	35	49	69	96	134	188	90
Hackensack River,	20	39	55	77	107	150	45
Local Streams,	6	8	12	16	23	32	3
Passaic at Little Falls,	23	31	43	60	85	118	347
Driven Wells,	21	27	37	52	73	102	100
Total,	140	203	265	397	556	778	635

FEASIBLE AND PROBABLE DRAUGHT UPON PRESENT AND OTHER NEARBY SOURCES OF SUPPLY TO MEET THE ABOVE DEMAND.

	1905	*1915*	*1925*	*1935*	*1945*	*1955*	*Ultimate.*
Pequannock River,	50	50	50	50	50	50	50
Rockaway River,	50	50	69	90	90	90	90
Hackensack River,	25	39	45	45	45	45	45
Local Streams,	6	0	0	0	0	0	0

	1905	*1915*	*1925*	*1935*	*1945*	*1955*	*Ultimate.*
Driven Wells, ...	28	30	37	52	73	100	100
Raritan River, ...	...	20	39	55	77	185	500
Passaic at or above Little Falls,	40	40	40	105	221	307	347
Musconetcong River, ...	0	0	0	0	0	0	90
Total, ...	199	229	280	397	556	778	1,222

The second table is printed immediately under the first to admit of ready comparison. In this table I have endeavored to estimate the feasible and probable draught upon sources immediately adjacent to and available for the supply of the Metropolitan district. It will be noted by comparing the two tables, that the capacity of the Newark works will be reached about 1915 and of the Jersey City Water Works about 1934 and that after those dates these cities will require additional supplies either from the further development of the Passaic watershed or from other sources. The cities now supplied from Hackensack River will require an additional supply about 1924, if we assume that the Hackensack will not be developed beyond 45,000,000 gallons daily. The cities now supplied from local stream sources, I have assumed, will find it necessary to find other sources by 1915. The cities at present supplied from driven wells are likely to continue to be supplied from that source with the amount of water at present developed and some additional water, but most of their future increased demand will probably come from Raritan River or Musconetcong River, but on the other hand, it must be assumed that the development of well water will steadily increase and that most of this increase will be in the northern part of the Metropolitan district and will in part make up for the deficiency of the Hackensack and Passaic. The tables are also made up on the assumption that the amount of water drawn from the stream at Little Falls, without storage, will be limited to 40,000,000 gallons daily, leaving about 40,000,000 gallons to run down the stream to preserve sanitary conditions during the extreme dry season, and of course a very much larger amount during most of the year.

A comparison will show that, assuming the recent rapid rate of growth to continue, the cities at present supplied from the Passaic at Little Falls will, according to the first table, require

118,000,000 gallons daily in 1955. In the same year the additional supply required by Newark will amount to 138,000,000 gallons and that required by Jersey City to 98,000,000 gallons. The total additional supply required, therefore, by cities now supplied from the Passaic watershed will amount to 354,000,000 gallons daily in 1955. My later studies will show that I estimate that without the great reservoirs in the central valley the Passaic may be depended upon to yield 298,000,000 gallons daily of this amount, leaving 56,000,000 gallons daily to be taken from the Raritan or from driven wells, or a part from each source. The additional requirements of the cities now supplied from Hackensack River are estimated at 105,000,000 gallons in 1955 which will probably also be made up in part from the Raritan and in part from driven wells.

The assumptions in the table all appear to be founded upon sound reasoning, to the effect that all of the sources now in use will continue to be used and developed from time to time as additional water is required, excepting only the small local stream supplies which may be more profitably abandoned. Upon this assumption, it will be noted that the Passaic at Little Falls, without storage reservoirs, and with the draught limited to 40,000,000 gallons daily, will furnish all of the water needed from that water shed until about 1925, after which time storage must be ready to be drawn upon, and that the entire amount of storage on the Passaic will not be needed until after 1935, or twenty-five years in the future.

The second table also shows in the last column the ultimate capacity of the several sources immediately adjacent to the Metropolitan district, amounting to 1,222,000,000 gallons daily. This is sufficient for 12,000,000 inhabitants and this does not take account of Walkill River and the Delaware. Delaware River above Phillipsburg will alone furnish 600,000,000 gallons daily without storage, and is capable of development to yield a total of 3,250,000,000 gallons each 24 hours. This water is of excellent quality, but of course does not belong entirely to the State of New Jersey. However, the yield is sufficient to take care of all possible future requirements of all of the cities likely to need the supply both in New Jersey and eastern Pennsylvania.

The above makes it clear that Passaic River is not at all likely to be called upon to supply the entire requirements of the Metropolitan district. There is nothing in the plan hereinafter outlined for the development of the Passaic which makes impossible the construction of the Little Falls reservoir in order to utilize an additional supply from the 311 square miles of catchment not controlled by the reservoirs on the head-waters and for flood control. The necessity of such a reservoir for potable water supply will, however, be postponed practically fifty years.

SUFFICIENCY OF RESERVOIRS ON HEADWATERS OF PASSAIC.

A brief consideration of the possibilities in the Passaic watershed will be sufficient to indicate that improvement of the individual branches of the stream by means of separate reservoirs may readily accomplish all that is required so far as the development of the potable water supply is concerned, and substantially all that was intended to be accomplished by the construction of the large reservoirs referred to. The following is a general estimate of the ultimate capacity of the several branches upon which good reservoir sites exist:

	Million gallons daily.	*Total storage needed, million gallons.*
Ramapo River,	128	26,400
Wanaque,	88	18,150
Pequannock,	68	11,220
Rockaway,	96	19,800
	380	75,570

Add to this for small branches available for local supply about 20,000,000 gallons and it will be seen that at least 400,000,000 gallons daily may be obtained by taking the branches separately in a gradual process of development without making any use of the remaining 300 square miles in the central valley and on the Whippany.

Flood Control.—It is true that this method of development does not make direct provision for flood control. Undoubtedly the development and use of such a system of reservoirs for potable water supply will very considerably diminish the probability of great floods, such as have occurred in the past, yet the possibility of occasional floods will remain. Still it is evident that expenditures for flood control must be borne by the very property which is now subject to damage, and that if the sum expended for the control of floods shall be so large as to cause an annual burden greater than the annual average damage from floods a serious economic error will have been committed. Much attention was attracted to the flood question by the unusual recurrence of three great floods in 1896, 1902 and 1903, that is within a period of eight years. But there had been no previous experience similar to this for over a century, and at the present time the alarm which they occasioned has largely subsided. However, if the future shall determine that the construction of reservoirs for flood control is necessary or desirable, there is nothing in the present proposed scheme for smaller reservoirs on the head waters which will prevent future construction of such reservoirs for flood control, and I shall later in the report give some attention to the effect upon floods of the proposed system of reservoirs on the head waters and the possibilities of further reducing them by other reservoirs in the central valley. I shall first further consider the development of reservoirs for potable water supply upon the several branches.

STORAGE ON RAMAPO RIVER.

The total watershed of Ramapo River includes 160.7 square miles, of which 112.4 square miles lie in the State of New York. The New York portion of the watershed is amply supplied with lakes, ponds and small reservoir sites, but since these lie entirely without the jurisdiction of the State of New Jersey, it may not be easy for either the State, or the municipalities of the State, to utilize them. However, they will be briefly referred to in order to make the record complete.

A site exists on the Mahwah where a reservoir may be formed by a dam just north of the village of Suffern, raising the water to an elevation of 350 feet above mean tide, which will afford a reservoir capacity of 6,906,000,000 gallons. This reservoir has only 19.5 square miles of catchment, so that the storage is too large for the watershed, although it may be utilized by leading the main river into the Mahwah basin from a diverting dam near Sloatesburg.

The next possible location is higher up on the Mahwah opposite Mechanicsville, where a reservoir raising the water to 390 feet elevation will store 1,265,000,000 gallons, which is just sufficient for its watershed of 10.15 square miles.

A third location which is somewhat difficult to utilize owing to the presence of the main line of the Erie Railroad is at Ramapo, where a dam raising the water to 350 feet elevation, would store 3,485,000,000 gallons. Sites other than these on the main stream have become practically impossible, owing to enhanced value of the property, the location of the Erie Railroad and other difficulties.

On Stony Brook a good location exists where a rather expensive dam about one-half a mile from the Ramapo, raising the water to 460 feet elevation, would store 2,806,000,000 gallons.

Round Pond near Monroe may be easily improved to store 88,000,000 gallons. Mombasha Lake was originally a storage reservoir for the Southfield works, and may be readily improved to store 400,000,000 gallons.

Another site on Mombasha Creek at Southfield works may be improved to store 590,000,000 gallons. A site on Indian Kill, near the road from Southfield to Sterling Lake, will afford 567,000,000 gallons storage.

Tuxedo Lake has a capacity of 475,000,000 gallons and is an admirable storage reservoir, but owing to the high class development in that vicinity and the great value of property, it cannot well be considered really available. The same may be said of several other sites upon the watershed which are physically adapted to become good reservoirs of moderate capacity.

Taking only the lower reservoir on the Mahwah, since both would not be needed, the above list makes up a total capacity of 14,841,000,000 gallons, which would be sufficient to afford a total suply from the Ramapo of 86,000,000 gallons each 24 hours.

As indicated above these sites lie without the jurisdiction of New Jersey.

Upper Ramapo Reservoir.—I shall next consider feasible storage reservoir sites on the Ramapo lying wholly within the State of New Jersey. The first of these may be formed by a dam across the valley at the head of Pompton Lake, raising the water to an elevation of 267 feet above mean sea level. This flow line would carry the water to the State line near Suffern. The area of water surface would be 2,049 acres, and the capacity of the reservoir 14,618,000,000 gallons, which would afford a continuous supply from the Ramapo of 82,700,000 gallons each 24 hours. The low-water level would be at elevation 220, which is the same as the high-water level of the proposed Mountain View reservoir, and is 50 feet higher than the low-water level of that reservoir. The dam would raise the water 57 feet, and would have an over-all length of 2,600 feet. The quantities involved in the construction of the dam and its cost are given in detail in the appendix, which shows the total cost to be $1,118,638, if foundations are not carried to rock. Generally the dam is very similar in volume and height to the proposed Mountain View dam, with high-water elevation at 220. The cost of this dam was estimated at $1,062,225.

A careful inventory of the buildings has been made, and the total comes to $496,150. The value of the land may be estimated at $500,000. The improvement would involve comparatively little highway construction, but would require the relocation of four miles of the New York, Susquehanna and Western Railroad and the building of one important bridge. We estimate approximately for the railroad work $378,179, and for relocation of highways, $136,964, making the total cost of this reservoir $2,949,273.

The exact depth to rock, however, has not been ascertained, but it is positively known to be over 50 feet, and, taking into account the geological history of the valley, it is reasonable to assume that the depth to rock is about the same as was determined by the borings at the site of the proposed Mountain View dam, or practically 100 feet. It was assumed in the case of the Mountain View dam that it would not be necessary to carry the foundations to rock, and the above estimate makes the same assumption in case of the proposed Ramapo reservoir. Nevertheless, the writer is of the opinion that this assumption is not a safe one for either case, and that provision should be made at least for a cut-off wall to rock, the cost of which may be roughly taken at $1,000,000 additional. This would make the relative cost of the two reservoirs with cut-off wall to rock as follows:

Mountain View reservoir, ...	$8,437,624
Upper Ramapo reservoir, ...	3,949,273

My estimates above for land and buildings, however, are upon a basis of about $500 per acre, whereas the estimates for the Mountain View reservoir are on a basis of about $200 per acre. An inspection of the district makes it clear that my estimates in this respect are on a much more liberal basis for the Ramapo reservoir. However, the above estimates are sufficient to clearly indicate that the development of Ramapo River to the extent of 82,700,000 gallons daily is entirely practicable with the single reservoir proposed. If it should prove practicable to construct later the reservoirs previously indicated lying within the State of New York, the river could be further developed to supply ultimately 128,000,000 gallons each 24 hours.

Lower Ramapo Reservoir.—Attention has also been given to the practicability of development on a larger scale on the Ramapo, and it has been found by our recent surveys and investigations, that if a dam should be raised at the present location of the Pompton Steel Works dam to a flow-line elevation of 267 feet, together with a dam running northward from the trap hill west of Pompton Lake to the south end of Ramapo Mountain, a storage capacity of 24,888,000,000 gallons would be secured. This I have designated the "Lower Ramapo Reservoir," and its estimated cost and other data concerning it will be found in the appendix. Its superficial area will be 2,935 acres, its depth at the dam 57 feet, and it will cost $5,607,640. Its cost per million gallons of capacity will be $225, against $270 for the Upper Ramapo reservoir previously considered. It will yield a continuous supply of 120,000,000 gallons daily, against 82,700,000 gallons daily for the Upper Ramapo reservoir. It is cheaper than the upper reservoir both per unit of capacity and per million gallons yield, although it requires a larger original outlay.

Pompton Lake.—Other less expensive methods of development of the Ramapo are possible. Pompton Lake, if raised 10 feet, will afford 1,000,000,000 gallons storage, and a site exists just east of the Pompton Steel Works dam, on a small branch of the Ramapo, where a reservoir may be created with a flow-line elevation of 280, a low-water elevation of 250, a superficial area of 162 acres, and a storage capacity of 1,000,000,000 gallons. The water from Pompton Lake would have to be pumped into this lateral reservoir, but the sanitary advantages of a large storage reservoir not directly connected with the main stream, together with the increased head available for delivery, would fully compensate for the cost of pumping. The lift would range from 40 to 70 feet. Pompton Lake and this lateral reservoir together would afford a total storage of 2,000,000,000 gallons, and with the natural flow of the river a continuous supply of 36,000,000 gallons daily. The cost of these reservoirs would not exceed $600,000, and the supply would be a valuable one for a large municipality, being capable of expansion by the construction of either of the large reservoirs previously described.

Point View Reservoir.—An additional storage reservoir might be constructed east of Point View and about two miles southeast of Pompton Steel Works. The capacity of this reservoir would be 5,400,000,000 gallons. The flow-line elevation would be 400 feet, and the low-water elevation 360 feet. This reservoir, being 190 feet above Ramapo River at Pompton Lake, would have to be filled by pumping, and might be used for a high-service supply to accompany the reservoirs previously mentioned or for an independent supply with increased pressure. Taken alone, it would maintain the supply from the Ramapo at about 50,000,000 gallons daily. Used with the reservoirs previously mentioned, each of 1,000,000,000 gallons capacity, it would furnish 58,000,000 gallons daily, and this supply could be later increased by the construction of either of the two large reservoirs on the Ramapo first mentioned.

Riparian Rights.—Whichever of the foregoing methods of making use of the Ramapo might be determined upon, the cost of the riparian rights to be acquired would be eventually the same. I have, on page 26, estimated the total value of these rights, not including the rights of water companies engaged in furnishing water to municipalities, at about $7,000,000. In my judgment, this is a sufficiently reliable estimate to make it helpful to include with the foregoing estimates an estimate of the proportional part of these damages which must be paid for the diversion of either of the branches of the Passaic. My estimate for damages due to the diversion of the Ramapo upon this basis would be $1,920,000 if the storage is used to supply works at Little Falls, but about $500,000 more if the diversion is at Pompton Lakes.

STORAGE ON WANAQUE RIVER.

The total catchment area of Wanaque River measures 109.6 square miles, and if supplied with storage amounting to 18,150,000,000 gallons this is sufficient to furnish 88,000,000 gallons daily. It must be borne in mind, however, that the water from 28 square miles tributary to Greenwood Lake is stored in Greenwood Lake and used by the Morris Canal. The water from the lake is drawn off and flows down through the river to the canal feeder at Pompton Plains. Greenwood Lake affords ample storage for its watershed and this leaves 82 square miles to be provided with storage. This area, exclusive of Greenwood Lake, would require 13,530,000,000 gallons of storage capacity and will supply 66,000,000 gallons daily.

Lower Wanaque Reservoir.—The State Water Commission of 1884 gave consideration to a storage reservoir in Wanaque Valley to be created by dams situated about one mile above Pompton Junction. I have investigated this site and estimated its cost. It will require two dams, one of which consists of an earthen embankment with concrete core wall across the west side of the valley and having a length of 1,480 feet, and the other a masonry or concrete spillway dam across the river, having a length of about 470 feet. The elevation of flow-line of this reservoir would be 270 feet, and its low-water elevation 220 feet. The area of water surface would be 3,041 acres and the storage capacity 25,817,000,000 gallons. The catchment area tributary to the reservoir would be 108 square miles. The storage capacity is greater than would be required strictly for storage purposes, but the flow-line elevation is the best, giving the best depth of water and steepest shore lines, and the additional storage would greatly increase the purity of the supply, yielding a water of excellent quality. In case this reservoir should be used for storage for works located at Little Falls, then the entire storage capacity above given could be effectively used to maintain the flow of the stream between this point and Little Falls.

This reservoir, which, for convenience, I designate the Lower Wanaque reservoir, would make it necessary to acquire and remove the works of the Dupont Powder Company and the Wanaque River Paper Company, together with a considerable number of residences, etc., in the village of Midvale. My estimate of the cost of the reservoir is given in the appendix and includes among other items, lands $745,500, buildings, $1,-683,438 and a total cost, including all engineering work, of $4,524,121. The cost per million gallon of storage capacity is $160, which is moderate. The reservoir, if drawn upon direct. will supply, exclusive of Greenwood Lake, 65,600,000 gallons daily, and including Greenwood Lake it will supply 86,400,000 gallons daily.

Midvale Reservoir.—An excellent site exists, on the Wanaque, for a much less expensive reservoir than the foregoing, which, for convenience, I designate the Midvale reservoir, the main dam for which would be located at the works of the Wanaque River Paper Company, near Midvale. During 1909, applications for this reservoir site and supply were filed with the State Water Supply Commission, by both Newark and Paterson. By means of a low auxiliary embankment located upon Posts Brook about one mile west of Greenwood Lake Railroad and another just south across the outlet of Mud Pond Brook, there can be made tributary to this reservoir a catchment of 97 square miles. The best flow-line elevation appears to be 280 feet and the low-water level will be 240 feet. The area of water surface will be 1,612 acres and it will have a capacity of 12,950,000,000 gallons. Exclusive of Greenwood Lake it will supply 55,200,000 gallons daily and including Greenwood Lake, 77,600,000 gallons daily. It will require the removal of the mills of the Wanaque River Paper Company, but taken as a whole, the cost of land and improvements is very much less than the Lower Wanaque reservoir. Our estimate of cost is given in detail in the appendix and shows for land $300,000, and for buildings, etc., $500,440, with a total cost for the reservoir of $1,678,601. This is a cost per million gallons of storage capacity of $129, which is very low and in fact the lowest of any of the reservoirs feasible upon the Ramapo or Wanaque. Possibly for this reason there has been competition to obtain the site. While it is true that the cost per million gallons of storage capacity is very low, nevertheless, the cost in proportion to the daily supply available is greater than for that plan herein proposed, which provides for the development of the Ramapo by raising the dam at Pompton Lake and building an auxiliary reservoir immediately to the eastward. It will be recalled that that plan provided 36,000,000 gallons daily at an estimated outlay for reservoirs of only $600,000, whereas the Midvale reservoir supplies 55,200,000 gallons daily at an outlay of $1,678,601. The Ramapo development has the further advantage of being four miles nearer to either of the cities which filed the applications referred to. The Ramapo development is also cheaper, even including Greenwood Lake in the Wanaque plan for the reason that that lake cannot well be included without compensating the Morris Canal and Banking Company, and, indeed, it must be evident that the Midvale reservoir can scarcely be used at all without reaching an agreement with the Morris Canal and Banking Company, owing to the fact that the water from Greenwood Lake must pass through this reservoir. However, the peculiar advantages of either source of supply are sufficient to make either available to the competing cities without very marked discrepancies in cost, or the relative excellence of the two.

Other Reservoir Sites.—Greenwood Lake has already been referred to in the foregoing. It is a reservoir for the Morris Canal and has a catchment area of 28 square miles, the area of its water surface being 1920 acres. Its storage capacity is

10,000,000,000 gallons. Taken alone, it will supply 22,000,000 gallons each 24 hours.

There are other available storage sites on the Wanaque which, however, have only a minor importance for the reason that the watershed could not well be developed sufficiently without the construction of either the Lower Wanaque or Midvale reservoirs, and if either of these should be constructed, additional reservoirs are unnecessary. However, they may be mentioned as mere possibilities in order to complete the record. A dam just below the State line would flood Eagle valley, the reservoir lying mostly in the State of New York. Its high-water elevation would be 500 feet and if drawn down to 430 feet, the storage would be 4,829,000,000 gallons. The area of its water surface would be 377 acres. The dam would be about 1360 feet long at the top, and 110 feet high.

Sterling Lake could also be utilized for storage. It has a catchment of 4.6 square miles and the area of its water surface is 301 acres.

A site also exists on West Brook about one mile above its junction with the Wanaque, where a reservoir might be created with a flow-line elevation of 380 feet and a low-water elevation of 320 feet, a superficial area of 397 acres and a storage capacity of 3,804,000,000 gallons. The length of the dam would be about 1500 feet and its height 114 feet. The tributary catchment area is 12.5 square miles.

The water rights on the Wanaque, other than those included in the cost of the reservoirs estimated upon and not including Greenwood Lake or any rights of the water companies supplying municipalities, may be valued approximately at $1,300,000. This is upon the basis of $7,000,000 for all rights below Passaic Falls as previously estimated. The interference with the flow from Greenwood Lake raises, perhaps, the question of acquiring this important right from the Morris Canal and Banking Company. If it becomes necessary to acquire these rights, a large amount must be added to our estimate.

PEQUANNOCK RIVER.

Pequannock River is already developed for the supply of Newark by means of a dam at Macopin intake and several large storage reservoirs above. Only 40 square miles of the 63.7 square miles of catchment above the intake is supplied with storage, leaving 23.7 square miles immediately above the intake not so supplied, except for the storage capacity provided at Cedar Grove reservoir, along the pipe line to Newark near the Great Notch and about 15 miles from the intake. However, since the capacity of the two pipe lines is over 60,000,000 gallons daily, the amount of water which spills over at the intake and which might be utilized by further storage is not of great importance, although a large storage reservoir near the intake might materially improve the quality of the supply and somewhat reduce the waste. The capacity of these works, however, may be safely taken at 50,000,000 gallons each 24 hours. About 10 square miles of the Pequannock catchment, between the Macopin intake and the village of Butler, is not at present utilized. This water may be led into either Lower Wanaque or the Midvale reservoir and will add 8,000,000 gallons daily to the supply of either of these reservoirs.

ROCKAWAY RIVER.

Rockaway River is developed by means of a dam at Lower Boonton to supply Jersey City. As now developed, the capacity of the works is 50,000,000 gallons each 24 hours. The catchment area is 120 square miles. By the addition of about 13,000,000,000 gallons of storage capacity, the supply may be increased to 90,000,000 gallons daily. This will be sufficient to provide all the water needed by Jersey City for nearly twenty-five years in the future. There are a number of good sites for storage reservoirs on Rockaway River, such as Dixon's Pond, Beach Glen and Lower Longwood and the entire 90,000,000 gallons daily may readily be developed.

SUPPLY FROM PASSAIC RIVER AT LITTLE FALLS.

The entire catchment area of Passaic River above Little Falls measures 773 square miles. The foregoing existing and proposed developments include of this the following:

Lower Ramapo Reservoir, ...	160	square	miles
Lower Wanaque Reservoir, ...	108	"	"
Lower Pequannock, ...	10	"	"
Pequannock, above Newark intake, ...	64	"	"
Rockaway, above Jersey City intake, ...	120	"	"
Making a total of, ...	462	"	"

This leaves undeveloped 311 square miles of catchment in the central Passaic Valley and upon the Whippany and Upper Passaic watersheds. Comparatively little of this territory can be used for separate developments, although a small amount of water can be obtained for local use from the headwaters of the Passaic above Van Doren's mills near Bernardsville, where at an elevation of about 300 feet a supply of 6,000,000 gallons daily may be obtained. There are a few other opportunities for local supplies on the branches of the Whippany. Assuming that the entire 311 square miles shall remain unprovided with storage, it will yield a dry-season flow during the dryest months amounting to about 38,000,000 gallons each 24 hours; but ordinarily, during all but three months in the year, the discharge will amount to at least 75,000,000 gallons each 24 hours. Therefore, if the future development of the Passaic shall be by means of the Lower Ramapo and Lower Wanaque reservoirs, with intakes at said reservoirs, the water being led thence to the point of use by gravity, we shall have an available supply of 214,000,000 gallons each 24 hours; the water above referred to from the 311 square miles not provided with storage being allowed to waste at Little Falls, or being pumped at that point for city supply. The low-water elevation of each of the reservoirs above referred to is 220 feet, while the elevation at the dam at Little Falls is 158 feet, the intervening distance being about 10 miles. The fall, therefore, is about 6 feet per mile, and all of this would be used up in friction in case the supply should be delivered by pipes. If it should be delivered by masonry conduits or tunnels, probably the effective level of delivery from the reservoirs direct would be about 30 feet higher than the level of the river at Little Falls, but the expense of aqueducts of this kind would be so large as to offset fully the economic advantage of 30 feet increased head. Consequently, economically it will be found fully as advantageous to use the above reservoirs to supplement the ordinary dry-season flow of the stream at Little Falls and to pump and filter the whole supply at that point as to draw directly from the reservoirs.

If the supply should be delivered direct from the reservoirs, it would be possible to furnish 214,000,000 gallons each 24 hours. It must be borne in mind that in this case at least 38,000,000 gallons would flow down the stream unused if pumping at Little Falls should be discontinued; but, on the other hand, if the whole supply should be utilized at Little Falls, then of the 336,000,000 gallons daily available, 38,000,000 gallons could be allowed to run down the stream at all times, and 298,000,000 gallons would remain available for a potable water supply, against 214,000,000 gallons obtainable in case the water should be diverted directly from the reservoirs. Since this method of development would mean the saving of 10 miles of conduit, it becomes evident that a larger supply could be obtained at a smaller outlay, and consequently it would appear to be more economical, even if storage reservoirs should be built, to continue to pump and filter the water at Little Falls. The same considerations apply quite as forcibly to the Mountain View reservoir, for the reason that the low-water level of that reservoir is 50 feet lower than that of the proposed Lower Ramapo and Wanaque reservoirs.

We may assume that filtration will shortly become necessary, wherever may be the point of intake, consequently in this respect there will be comparatively no difference in the cost of the two methods. Neither are the comparative advantages of these two methods of developments affected sensibly by the fact that the water-works of the East Jersey Water Company are now located at Little Falls, for the reason that whatever rights exist in this company, or any other water companies upon the stream, will be affected in practically the same manner by the diversion of

Ramapo and Wanaque rivers direct as by the diversion at Little Falls.

SUMMARY OF POSSIBLE METHODS.

To summarize, I will, therefore, re-state the several possible plans which may be used for the gradual development of Passaic River to provide for future requirements.

1. We may develop Ramapo River by raising the Pompton Lake dam ten feet and building a reservoir on the branch immediately east, creating 2,000,000,000 gallons storage, with a yield of 36,000,000 gallons daily. The cost of the reservoirs we estimate at $600,000, and the cost of water rights at $1,920,000.

2. We may build a reservoir at Point View, at a low-water elevation of 360 feet, which will afford a supply, with Ramapo River, of a capacity of 50,000,000 gallons daily, at a cost for storage of $1,350,000, and the cost for water rights, $1,920,000.

3. We may develop the Ramapo by means of the Upper Ramapo reservoir, to a capacity of 82,700,100 gallons daily, at a cost for storage of $3,949,273, and a cost for water rights of $2,420,000. The low-water level of this reservoir is 220 feet.

4. We may develop Ramapo River by means of the Lower Ramapo reservoir to a capacity of 120,000,000 gallons daily, at a cost for storage of $5,607,640, and a cost for water rights of $2,420,000. It should be noted that the total supply of the Ramapo cannot be increased beyond 128,000,000 gallons daily, and that with the Lower Ramapo reservoir other storage reservoirs would not be needed, although the Point View reservoir might be advantageously combined with it for a high-service supply.

5. Wanaque River may be developed by means of the Lower Wanaque reservoir to yield 65,600,000 gallons daily, exclusive of Greenwood Lake, or 86,400,000 gallons daily, including Greenwood Lake at a cost for storage of $4,524,121, and a cost for water rights not including Greenwood Lake of $1,300,000.

To the above may be added at comparatively small cost 8,000,000 gallons daily by diverting into the reservoir lower Pequanock River.

6. We may develop Wanaque River by building the Midvale reservoir to furnish, exclusive of Greenwood Lake 55,-200,000 gallons daily and including Greenwood Lake 77,600,000 gallons daily at a cost for storage of $1,678,601, and a cost for water rights, not including Greenwood Lake, of $1,300,000. To the above may be added 8,000,000 gallons daily by diverting the lower Pequannock into the reservoir.

It should be noted that the Lower Wanaque reservoir is sufficient to develop the entire yield of Wanaque River, and if this built no other reservoirs are needed unless the supply is used at Little Falls, in which case more storage will be valuable.

The Lower Ramapo reservoir and the Lower Wanaque reservoir, together with the lower Pequannock, will yield a total supply of 214,000,000 gallons daily. If the Point View reservoir is added, the supply will be increased to 222,000,000 gallons daily. The available supply from Mountain View reservoir was estimated to be 254,000,000 gallons daily. Practically the same amount could be utilized by means of the Ramapo and Wanaque reservoirs with an intake on Pompton River at Mountain View. The construction cost of this development might be a little greater than the Mountain View reservoir, although any difference might disappear in actual construction, owing to the fact that our estimates are on a more liberal basis than the estimates for the Mountain View reservoir. However, assuming the estimates to be of equal accuracy, the difference would be much more than offset by the saving in interest due to more gradual outlay with the construction of the smaller reservoirs. By means of the Midvale reservoir, together with the smaller reservoirs proposed in paragraphs 1 and 2, a supply of 100,000,000 gallons daily would be developed from the Ramapo and Wanaque at a comparatively small cost, and these reservoirs would be sufficient to provide the water needed for at least twenty-five years in the future.

In addition to the above possibilities, or as another method of utilizing the same reservoirs, works may be established or acquired at Little Falls to pump and filter the water and the foregoing reservoirs may be used to supplement the yield of the stream at that point. If so used, the supply may be maintained at 336,000,000 gallons, or if it should be found desirable to allow 38,000,000 gallons daily to flow down the stream, the remaining 298,000,000 gallons may be utilized for city supply, in which case the total cost for storage is $10,423,394, and a cost for water rights is $5,700,000, but in this latter case the cost of both storage and water rights may be distributed over a period of thirty-five years, so that although the construction cost might be equal to the cost of the large storage reservoirs at Little Falls or Mountain View, the saving in interest, depreciation and operation would make the actual cost thirty-five years hence very much less, as will be more definitely ascertained from our estimates of comparative cost given below.

COMPARATIVE ESTIMATES OF COST.

For the purpose of determining the relative economy of the several methods of development, I have assumed three of the above methods, namely:

A. The construction of Mountain View reservoir, with intake at Mountain View.

B. The use of the water by pumping and filtering the supply at Little Falls up to a limit of 40,000,000 gallons daily without storage, leaving about an equal amount to flow down the stream during the dryest month, with the addition from time to time of storage reservoirs on the head waters as may be required by the increased demand. The first to be constructed, on the basis of our previous estimates of the amount of water required from the Passaic, will be the Lower Wanaque reservoir, which will be needed in 1925, and at the same date the damages for diverting the Wanaque River must be paid. The next reservoir, namely, the Lower Ramapo reservoir, will be needed in 1940, at which time damages for diverting the Ramapo River must be paid.

C. The third method of development assumed is by separate municipal action, such as has already been indicated by the applications of Newark and Paterson to the State Water Supply Commission. We have pointed out already the possibilities for beginning development on the Ramapo at a moderate expense, and since the complications as to Morris Canal rights are much less on the Ramapo than on the Wanaque, while the former stream is also more convenient to the City of Paterson, it has seemed sufficient to assume, for the purposes of this comparison, that the Wanaque will be developed by the City of Newark, and added to in accordance with the future requirements of that city; and that the Ramapo will be developed and added to from time to time for the supply of any other municipalities which may require the water, additions being made at such a rate as to furnish the whole amount of water which we have previously estimated will be required to be taken from the Passaic watersheds for the use of the Metropolitan district, less 40,000,000 gallons daily which we have assumed will continue to be taken from Passaic River at Little Falls.

Carrying out this plan on the Wanaque, the Midvale reservoir must be built in 1912, and at the same time it will be necessary to acquire the right to use Greenwood Lake. Also all other damages for diversion must be paid. No further works will be needed by Newark until 1940, at which time the water may be led into this reservoir from the lower Pequannock watershed. On the Ramapo I have assumed that Point View reservoir will be constructed in 1912 and the right acquired to divert 50,000,000 gallons daily, and that in 1935 the Lower Ramapo reservoir will be constructed and additional damages paid for diversion. This latter plan of development is so elastic as to readily admit of independent municipal action, while the first and second plans could only be carried out by the construction of storage reservoirs for the joint account of the several municipalities to be supplied.

Upon the above basis of development, the following table shows the capacity of the several works, together with the estimated total demand to be supplied from Passaic River at various periods up to 1950. It will be seen that the supply is at all times in excess of the demand in case the plan of taking out a supply at Little Falls should be adopted, and is practically equal to the demand to 1950 by the other two plans.

TABLE SHOWING CAPACITY OF THE SEVERAL PLANS OF DEVELOPMENT AND THE ESTIMATED DEMAND.

All quantities in million gallons daily.

Separate Municipal Development—Plan C.	*1925*	*1935*	*1945*	*1950*
Wanaque—Additional Newark Supply,	77	77	85	85
Ramapo—Other Municipalities,	50	128	128	128
Little Falls,	40	40	40	40
Total for Plan C,	167	245	253	253
Mountain View Reservoir, Plan A,	254	254	254	254
Headwaters storage, supply taken out at Little Falls, Plan B,	171	171	298	298
Estimated total demand,	40	105	221	265

Damages for Diversion.—I have heretofore estimated the damages to riparian rights including Morris Canal rights, which would grow out of the total diversion of Passaic River, at $7,000,000. This, as previously stated, does not take into account the rights of any existing water companies engaged in furnishing public water supply. These damages are so important a factor in the problem and are so differently affected by the different methods of development that the relative economy of the several plans of development cannot well be determined without making at least an approximate estimate of the damages for each plan.

I do not consider it expedient to be too explicit as to these estimates in a report of this nature, but the effect of each development upon riparian rights has been carefully considered and in general it may be stated that I have estimated damages for the total diversion of Pompton River, including the Ramapo, Wanaque and lower Pequannock to the amount of $5,500,000. For the diversion of Wanaque River, including interference with the draught from Greenwood Lake to the Morris Canal, the estimate is $2,820,000, and the damages for constructing storage works on the Ramapo, allowing the water to flow down to Little Falls, are estimated at $1,920,000. While the damages for diverting the Ramapo by means of an intake at Pompton Lake are estimated for 50,000,000 gallons daily at $1,700,000, with

$980,000 additional for total diversion. The diversion of the first 40,000,000 gallons at Little Falls is estimated to carry damages to the extent of $960,000. It is believed that these figures are proportionately correct and that they are sufficiently close to admit of a fair judgment as to the comparative economy of the several methods of development.

As to the rights of existing water companies, it is assumed that whatever may be the value of these they will affect all plans similarly.

Annual Charges.—We have estimated that the annual charges for all plans will be at the same rate, namely, interest 4 per cent., depreciation, maintenance and operation 2 per cent, making in all 6 per cent. annually. This is charged up in our estimate, *but is not compounded, being computed only upon the estimated outlay for construction and damages.* These charges also have an important bearing upon the relative economy of the several plans. It will be noted in the foregoing table, showing the capacity of the works and the estimated demand, that the Mountain View reservoir develops a supply much in excess of the demand during the first twenty-five years of the period, and calls for a correspondingly large outlay, so that the annual charges count up heavily against this plan as compared with the other plans which provide for a gradual development, more nearly proportioned to the demand.

The following tables give the result of the estimates:

COMPARATIVE ESTIMATES OF COST OF STORAGE AND RIPARIAN RIGHTS.

Date.		*Mountain View Reservoir. Plan A.*	*Headwaters storage, supply taken out at Little Falls. Plan B.*
1912	Cost of Mountain View Reservoir, ...	$8,437,625	....
1912	Damages for diversion of Pompton River, ...	5,500,000	....
1912	Damages for diversion of 40,000,000 gallons daily at Little Falls, ...	....	$960,000
1912 25	Interest and other charges, ...	10,871,347	748,800
1925	Total cost, ...	$24,808,972	$1,708,800

1925	Lower Wanaque Reservoir,	....	$4,524,121
1925	Damages for diverting Wanaque River,	....	2,820,000
1925-40	Interest and other charges,	$12,543,863	7,473,709
1940	Total cost,	$37,352,835	$16,526,630
1940	Lower Ramapo Reservoir,	....	5,607,640
1940	Damages for diverting Ramapo River,	....	1,920,060
1940-50	Interest and other charges,	8,362,575	9,499,057
1950	Total cost,	$45,715,410	$33,553,327

SEPARATE MUNICIPAL DEVELOPMENT FROM RESERVOIRS ON HEADWATERS, PLAN C.

Cost of Storage and Riparian Rights.

Additional Works for Newark:

1912	Midvale Reservoir,	$1,678,601
	Damage for diversion,	2,820,000
1912-25	Interest and other charges,	3,508,909
1925	Total cost,	$8,007,510
1925-40	Interest and other charges,	4,048,741
1940	Total cost,	$12,056,251
	Lower Pequannock Works,	200,000
1940-50	Interest and other charges,	2,819,161
1950	Total cost,	$15,075,412

Additional Works for other Municipalities:

1912	Point View Reservoir,	$1,350,000
	Damages for diversion of 50,000,000 gallons daily,	1,700,000
1912-25	Interest and other charges,	2,379,000
1925	Total cost,	$5,429,000
1925-40	Interest and other charges,	2,745,000
1935	Lower Ramapo Reservoir,	5,607,640
	Additional damages for diversion,	980,000
1935-40	Interest, etc., on additions,	1,976,292
1940	Total cost,	$16,737,932
1940-50	Interest and other charges,	5,782,584
1950	Total cost,	$22,520,516

SUMMARY OF TOTAL COSTS, SHOWING RELATIVE ECONOMY OF SEVERAL PLANS.

	1925	*1940*	*1950*
Newark additional works, ...	$8,007,510	$12,056,251	$15,075,412
Other municipal works, ...	5,429,000	14,959,269	22,520,516
Municipal development on headwaters, total, Plan C, ...	$13,436,510	$27,015,520	$37,595,928
Mountain View Reservoir, Plan A,	24,808,972	37,352,835	45,715,410
Headwaters storage, supply taken out at Little Falls, Plan B, ...	1,708,800	16,526,630	33,553,327

The above estimates show a startling economic advantage in favor of taking the supply at Little Falls and developing storage on headwaters from time to time as needed. It should be remembered that we have included only the cost of storage and riparian rights. It is impossible to estimate intelligently the cost of conduits and pumping stations, and it is not believed that any differences growing out of these costs will materially affect the result in any case, but as between the Mountain View reservoir and the headwaters storage with the supply taken out at Little Falls (Plan B), there will be no difference whatever for the reason that the supplies are taken from practically the same point at nearly the same elevation. It is believed that pumping and filtration would cost practically the same in either case. In the plan for separate municipal development (C) there will be some additional conduit against which will be an offset for a somewhat higher level of delivery. In the case of the Ramapo and Point View reservoirs, the cost of pumping from Pompton Lake to Point View reservoir should not be charged to the collection works, as it will be of great advantage in reducing the cost of conduits and distribution.

The income from any works which may be constructed will depend upon the amount of water required during any given period. It is assumed for the purposes of this report that this income, therefore, will be equal in all cases and that consequently the relative economy of the several methods of development will be measured by the cost of construction, damages for diversion, interest and maintenance up to any given date.

The striking advantage of the plan (B) which contemplates the diversion of the supply at Little Falls with storage reservoirs on the headwaters, grows out of the fact that the necessary supply can be obtained at Little Falls until 1925 without the construction of any storage reservoirs whatever, and also in some measure to the fact that the use of storage to supplement the flow of the river at Little Falls produces a considerably larger total supply than can be obtained if the intake is located immediately at the reservoir.

It will be noted that up to 1925 plan B (diversion at Little Falls) is cheaper than the Mountain View reservoir by about $23,-000,000, due largely to the saving in interest and maintenance charges. Plan C, which provides for separate municipal development of the headwaters, is also cheaper by about $11,400,000.

The construction of storage reservoirs upon the Ramapo and Wanaque, together with those already constructed by Newark on the Pequannock and by Jersey City on the Rockaway, effects a large measure of flood control incidentally. Indeed they may be expected to modify so largely the flood discharge on the lower Passaic as to very much diminish the prospective damages from floods in the future. Estimates which have been made of the damage done by floods have unquestionably been excessive. No data are at hand which enable us to make a correct estimate of such damage, but it may be confidently asserted that since the excess of $23,000,000 in cost of the above plans up to 1925 represents about $1,500,000 annually, it is far in excess of the average damage from floods during any period of fifty years in the past. Taking the entire period up to 1940, or about thirty years, the excess cost of the Mountain View reservoir over the Little Falls plan is $20,800,000, or nearly $700,000 annually, which is also very largely in excess of the average annual loss from floods. It does not appear, therefore, that the increased cost of the Mountain View plan can be readily justified by any probable advantage in the control of floods which this reservoir can offer over the plan for separate reservoirs on the headwaters.

Comparing the plan for separate municipal development with the Mountain View plan, it will be seen that the former also costs very much less throughout, and about $8,000,000 less even in 1950. The saving in cost during the earlier years of the period is especially important, owing to the fact that, according to my estimates, by 1950 there will have been provided enough water for over 7,000,000 people, and if the population of the Metropolitan district shall have reached these figures at that time, it will certainly experience no financial difficulty in going to Delaware River or more remote sources for a supply.

Our analysis of the supply and probable future demand has already shown clearly that Jersey City is in a position to provide for its own future requirements simply by adding to its present works on Rockaway River up to about 1934, and if it exercises strict economy in the use of water, probably for a much longer period; therefore, that city has no immediate water problem to face. Newark, on the other hand, is in almost immediate need of a further supply, and on the average, throughout the period under consideration, the future needs of that city will amount to about half the total amount required in the Metropolitan district over and above existing sources of supply. Therefore, it seems fair to assume that in case there shall be any common development in lieu of independent municipal action, Newark will have to bear practically one-half of the total expense. My estimates, however, show that the cost to Newark, if that city shall independently develop Wanaque River, will be less than one-half the cost of the Mountain View development, to the extent of nearly $4,500,000 in 1925, $6,600,000 in 1940, and $7,800,000 in 1950. Roughly, therefore, these sums represent the saving to the City of Newark from independent municipal action rather than sharing in a general system of water supply to be drawn from Mountain View reservoir. Leaving aside estimates of total requirements and total use, present and future, in the Metropolitan district taken as a whole, there is at present no other important city or group of cities within the district which has not already provided itself with water sufficient for a considerable period in the future, and the important questions before most of these municipalities is not sufficiency of the sources of supply, but the relative economy and advantage of municipally owned as compared with privately owned water-works. Even if this question shall be decided in favor of municipally owned water-works, it would seem likely to be solved by acquiring existing works and sources already in use rather than by the development of entirely new sources of supply. It is important that these two phases of the water-supply problem should not be confused, and if such confusion is avoided, the problem of the future supply of the Metropolitan district becomes much simpler than it has sometimes appeared to be. For this reason the foregoing report has dealt exclusively with the physical and engineering features of the problem without reference to any question of ownership of the supply.

CONCLUSION.

To summarize, concisely, the conclusions of this report, it may be said that my investigations this year demonstrate that from an engineering standpoint development of Passaic River for the purpose of furnishing the Metropolitan district with all the water likely to be required from the Passaic watershed until 1950 is entirely feasible by means of the construction of storage reservoirs upon the headwaters in lieu of the construction of either of the large reservoirs in the central valley which have been heretofore proposed.

Owing to the recent very successful use of filtration and other means of purification, together with the rapid increase in the development of well water, it is most reasonable to assume that practically all of the sources of water supply now in use in the Metropolitan district will continue to be used and will be further developed to the practical limit of their capacity.

The introduction of a very important and valuable supply from Raritan River is already begun and will lessen to an important extent the amount of water required from the Passaic. It must also be kept in mind that a gravity supply of 90,000,000 gallons daily is available from Musconetcong River to reduce further the demands upon the Passaic.

The total available supply in the whole State, being sufficient for 50,000,000 inhabitants, must be considered far more than it is probable that the State will ever require, while the supply conveniently at hand for use in that portion of the State which we have designated the Metropolitan district is more than double what can possibly be needed for use in that district, upon the most liberal estimates, up to 1950, and is sufficient for 12,000,000 inhabitants, which is far more than this section of the State is ever likely to contain. When this population shall have reached even half of this number, it must be assumed that its financial resources will be such as to render it a simple matter to draw upon the Delaware at or above Phillipsburg, which stream is capable of being developed to supply over 30,000,000 inhabitants. There is consequently no reasonable ground for anxiety as to the future water supply either of the State as a whole, or of the Metropolitan district, nor is it reasonable to assume that the entire additional supply of the Metropolitan district must be taken from the Passaic River.

Finally our estimates demonstrate that by far the most economical method of development of the Passaic is by means of reservoirs on the headwaters, to be used to supplement and maintain a supply to be pumped and filtered at Little Falls, but that independent municipal action may easily be applied, under State regulation and control, to the future development of the Passaic by means of independent works drawing from various points upon the headwaters and from Little Falls and will prove much more economical than a common supply from Mountain View reservoir. Such independent municipal action does not involve any change in the present policy of the State, which has already provided the means of regulation and control, and does not call for any new or unusual method of financing or administration, and for these reasons it has appeared important to suggest in this report a practical method of utilizing the resources of the Passaic watershed in this manner.

Appendix.

UPPER RAMAPO RESERVOIR.

DATA AND ESTIMATE OF COST.

Location of Dam at Head of Pompton Lake:

Catchment area,	154	square miles.
Flow line elevation,	267	feet.
Height of spillway above river,	57	"
Length of dam on flow line,	2,600	"
Area of water surface, at 267 feet elevation,	2,049	acres.
Area at 260 feet elevation,	1,584	"
" " 240 " "	747	"
" " 220 " "	264	"

Capacity between elevations 267 feet and 220 feet=14,618,000,000 gallons.

Land to be purchased, 2,500 acres, @ $200 per acre, exclusive of buildings,		$500,000
Inventory of buildings on site:		
Stone or Brick residences,	$47,240	
Frame residences and school houses,	253,044	
Factories—Stone or Brick,	23,925	
" —Frame,	4,614	
Stone barns and outbuildings,	14,670	
Frame barns and outbuildings,	145,208	
Sheds and miscellaneous structures,	7,450	
Total for buildings,		496,151
Estimate for Dam (not carried to rock):		
36,663 cu. yds. concrete, @ $6.50,	$238,309	
1,408,893 cu. yds. rolled embankment, @ 35c.,	493,113	
50,711 sq. yds. slope paving, @ $2,	101,422	
30,980 cu. yds. Soil stripping, @ 30c.,	9,294	
122,000 cu. yds. rock excavation, @ $2,	244,000	
Gate house, gates and machinery,	32,500	
Total for dam,		1,118,638

Change of New York, Susquehanna and Western Railroad, 3.25 miles:

Rock excavation 54,600 cu. yds., @ $1.50, ...	$81,900	
Earth excavation 188,500 cu. yds., @ 25c., ...	47,125	
2,250,000 lbs. steel bridge, @ 4½c., ...	101,250	
9,988 cu. yds. masonry, @ $8, ...	79,904	
7 miles single track (90 lbs. rail), @ $9,000, ...	63,000	
Small culverts, ...	5,000	
Total for changing railroad, ...		$378,179

Change of Highways:

4 miles of new road, @ $8,000, ...	$32,000	
4 " " " " @ $12,000, ...	48,000	

Crossing of Reservoir:

30,668 cu. yds. embankment, @ 30c., ...	9,200	
300,000 lbs. steel bridge, @ 4½c., ...	13,500	
9,600 ft. B.M. lumber, @ $40, ...	384	
4,235 cu. yds. Masonry, @ $8, ...	33,880	
		136,964
Clearing and Grubbing 2,049 acres, @ $25, ...		51,225
Engineering and Contingencies 10%, ...		268,116
Total Cost of Reservoir, ...		$2,949,273

If a cut-off trench is carried to rock at dam, add approximately $1,000,000, making total, ... $3,949,273

Cost per million gallons storage capacity, $270.

Daily supply without other storage, 82,700,000 gallons.

LOWER RAMAPO RESERVOIR.

DATA AND ESTIMATE OF COST.

Spillway Dam at Pompton Steel Works, Auxiliary Dam across valley north:

Catchment area, ...	160 square miles.
Flow line elevation, ...	267 feet.
Height of spilway above river, ...	57 "
Length of Dam on flow line:	
Spillway, ...	1,180 feet.
Side embankment, ...	3,780 "
Total, ...	4,960 feet.

Area of water surface, elevation 267 feet, ...	2,935 acres.
Area at 260 feet elevation, ...	2,386 "
Area at 240 " "	1,444 "
Area at 220 " "	655 "

Capacity between elevations 267 feet and 220 feet—24,888,000,000 gallons.

Land to be purchased—2,500 acres @ $200 exclusive of buildings,	$500,000	
1000 acres @ $500 exclusive of buildings,	500,000	
		$1,000,000
Buildings,		600,100
Spillway Dam:		
51,856 cu. yds. concrete @ $6,	$311,136	
Rock excavation 39,000 cu. yds. @ $1.50,	58,500	
Gate house and machinery,	27,500	
		397,136
Embankment with Core Wall:		
51,683 cu. yds. concrete @ $6.50,	$335,940	
1,961,530 cu. yds. rolled embankment @ .35c.,	686,535	
76,839 sq. yds. slope paving @ $2,	153,678	
44,921 cu. yds. soil stripping @ 30c.,	13,476	
		1,189,629
Change of New York, Susquehanna and Western Railroad:		
42,770 cu. yds. rock excavation @ $1.50,	$64,155	
427,560 cu. yds. earth excavation @ 35c.,	149,646	
600 feet tunnel @ $100,	60,000	
4,580,000 lbs. steel bridges @ 4½c.,	206,100	
22,548 cu. yds. bridge masonry @ $8,	180,384	
8.4 miles track (90 lbs. rail) @ $9,000,	75,600	
		735,885
Change of Highways:		
4 miles new road @ $8,000,	$32,000	
8½ miles new road @ $12,000,	102,000	
Reservoir Crossing near Darlington:		
30,668 cu. yds. embankment @ 30c.,	9,200	
300,000 lbs. steel bridge @ 4½c.,	13,500	
9,600 ft. B. M. lumber @ $40,	384	
4,235 cu. yds. masonry @ $8,	33,880	
		190,964
Clearing and Grubbing 3,000 acres @ $25,		75,000
Engineering and Contingencies 10%,		418 876
Total Cost of Reservoir,		$4,607,640
If a cut-off trench is carried to rock at embankment, add approximately $1,000,000, making total cost,		$5,607,640

Cost per million gallons storage capacity, $225.
Daily supply without other storage, 120,000,000 gallons.

LOWER WANAQUE RESERVOIR.

DATA AND ESTIMATE OF COST.

Location of Dams one mile above Pompton Junction:

Catchment area,	108 square miles.	
Flow line elevation,	270 feet.	
Height of spillway above river,	60 "	
Length of Dam on flow line:		
Spillway Dam,		470 feet.
Side embankment,		1,480 "
Total,		1,950 feet.

Area of water surface, elevation 270 feet,	3,041 acres.
Area at elevation 260 feet,	2,565 "
" " " 240 "	1,299 "
" " " 220 "	327 "

Capacity between elevations 270 feet and 220 feet = 25,817,000,000 gallons.

Land to be purchased (exclusive of buildings)—		
1,612 acres @ $150,	$241,800	
2,013 acres @ $250,	503,250	
		$745,050
Buildings:		
Frame residences, schools, churches,	$1,302,128	
Masonry residences, churches, etc.,	66,080	
Barns and outbuildings,	119,935	
Factory buildings,	113,594	
Miscellaneous structures,	81,700	
		1,683,437
Spillway dam:		
26,636 cu. yds. concrete @ $6,	$159,816	
Earth excavation 2,350 cu yds. @ $1,	2,350	
Rock excavation 45,000 cu yds. @ $2,	90,000	
Gate house, etc.,	32,500	
		284,666
Main Embankment:		
10,566 cu. yds. excavation @ $1,	$10,566	
18,425 cu. yds. concrete @ $7,	128,975	
695,223 cu. yds. embankment @ 35c.,	243,328	
26,114 sq. yds. slope paving @ $2,	52,228	
2,617 cu. yds. drainage culvert and filling @ $8,	20,936	
		456,033
West Embankment:		
4,820 cu. yds. excavation @ $1,	$4,220	
890 cu. yds. concrete @ $7,	6,230	
22,518 cu. yds. embankment @ 35c.,	7,881	
		18,331

Relocation of New York & Greenwood Lake Railroad, 8 miles,..	$280,000
Relocation of highways, 12.75 miles @ $9,000,	114,750
Clearing and grubbing 3,041 acres @ $25,	76,025
Engineering, legal expenses, etc., 10%,	365,829
Total for Reservoir,	$4,024,121
If core wall of embankment is carried to rock, add approximately	500,000
Making total for reservoir,	$4,524,121

Cost per million gallons storage capacity, $160.
Daily supply exclusive of Greenwood Lake, 65,600,000 gallons.
Daily supply inclusive of Greenwood Lake, 86,400,000 gallons.

MIDVALE RESERVOIR.

DATA AND ESTIMATE OF COST.

Catchment area, 97 square miles.
Flow line elevation, 280 feet.
Height of spillway above river, 70 feet.
Length of dam on flow line:

Spillway Dam,	820 feet.
Post brook embankment,	590 "
South embankment,	310 "
Small embankments,	970 "
Total,	2,690 "

Area of water surface at elevation 280 feet,	1,612 acres.
" " " " " " 260 "	1,010 "
" " " " " " 240 "	343 "

Capacity between elevations, 280 feet and 220 feet = 12,950,000,000 gallons.

Land to be purchased, exclusive of buildings, 2,000 acres @ $150,		$300,000
Buildings, etc.:		
Frame residences,	$162,400	
Masonry residences,	18,000	
Barns and outbuildings,	38,600	
Factories,	101,440	
Water rights,	180,000	
		500,440
Dams:		
Spillway Dam:		
12,500 cu yds. earth excavation @ $1,	$12,500	
35,000 cu. yds. rock excavation @ $2,	70,000	
23,517 cu. yds. concrete @ $6,	141,102	
Gate house, etc.,	32,500	
		256,102

Posts Brook Embankment:		
14,000 cu. yds. excavation @ $1,	$14,000	
3,810 cu. yds. concrete @ $7,	26,670	
124,857 cu. yds. embankment @ 35c.,	43,700	
6,662 sq. yds. slope paving @ $2,	13,324	
		$97,694
Four small dikes:		
20,900 cu. yds. excavation @ $1,	$20,950	
6,053 cu. yds. concrete @ $7,	42,371	
166,983 cu. yds. embankment @ 35c.,	58,444	
11,500 sq. yds. slope paving @ $2,	23,000	
		144,765
Relocation of New York and Greenwood Lake Railroad, 2 miles,		70,000
New Highways—8 miles @ $9,000,		72,000
Clearing and Grubbing 1,700 acres @ $50,		85,000
Engineering, legal expenses, etc., 10%,		152,600
Total Cost of Reservoir,		$1,678,601

Cost per million gallons storage capacity, $129.
Daily supply exclusive of Greenwood Lake, 55,200,000 gallons.
Daily supply inclusive of Greenwood Lake, 77,600,000 gallons.

WATER SUPPLY OF METROPOLITAN DISTRICT.

CLASSIFIED BY SOURCES.

Place.	*Population in 1905.*	*Daily Consumption Gals., 1905.*
Pequannock River.		
Belleville,	7,632	170,000
Newark,	283,289	35,000,000
Total Pequannock River,	290,921	35,170,000
Rockaway River.		
Jersey City,	232,699	35,500,000
Hackensack River.		
Bergenfields,	1,095	
Carlstadt,	3,100	
Cliffside Park,	2,128	
Cresskill,	505	
Closter,	1,272	
Delford,	841	
Demarest,	480	
Dumont,	914	
East Rutherford,	3,165	

Place.	*Population in 1905.*	*Daily Consumption Gals., 1905.*
Englewood City,	7,922	
Englewood Cliffs,	266	
Edgewater,	1,392	
Etna,	681	
Fairview,	1,693	
Fort Lee,	3,433	
Hasbrouck Heights,	1,650	
Hackensack,	11,098	
Leonia,	1,041	
Little Ferry,	1,776	
Palisades Township,	911	
Maywood,	687	
Ridgefield,	745	
Rutherford,	5,218	
Tenafly,	2,142	
Westwood,	1,044	
Woodridge,	721	
North Bergen,	11,300	
Guttenberg,	4,563	
Hoboken,	65,468	
West Hoboken,	29,082	
Secaucus,	3,191	
Union,	17,500	
West New York,	7,196	
Total Hackensack River,	194,220	20,000,000
Local Streams.		
Orange,	26,101	3,000,000
Bound Brook,	3,389	500,000
Rahway,	8,649	2,000,000
Wallington,	2,475	50,000
Total Local Streams,	40,614	5,550,000
Driven Wells.		
Garfield,	5,092	150,000
East Orange,	25,175	2,389,000
Bogota,	522	30,000
Glen Rock,	778	5,000
Haworth,	400	3,000
Lodi,	2,793	200,000
Ridgewood,	3,980	200,000
Irvington,	7,180	
South Orange, Village and Township,	4,932	1,000,000 (Irvington, South Orange, Milburn)
Milburn,	3,182	
Dunellen,	1,517	30,000

Place.	Population in 1905.	Daily Consumption Gals., 1905.
Metuchen,		
South Plainfield,		
Woodbridge,		
Carteret,	12,128	1,200,000
Sewaren,		
Chrome,		
Port Reading,		
North Plainfield,	5,616	1,677,446
Plainfield,	18,468	
Cranford,	3,600	
Fanwood Borough,	445	
Fanwood Township,	1,341	
Garwood,	564	1,416,186
Roselle,	2,142	
Roselle Park,	2,236	
Westfield,	5,265	
Elizabeth,	60,509	
Linden,	403	8,000,000
Union,	2,614	
Springfield,	1,123	50,000
Perth Amboy,	25,895	4,000,000
Summit,	6,845	1,000,000
Total Driven Wells,	204,745	21,350,632
Passaic River at Little Falls		
Bloomfield,	11,668	690,000
Glen Ridge,	2,362	108,000
Nutley,	4,556	100,000
Bayonne,	42,262	4,250,000
Harrison,	12,823	800,000
Kearney,	13,601	700,000
East Newark,	2,828	280,000
Little Falls,	3,079	20,000
Passaic,	37,837	4,500,000
Paterson,	111,529	10,500,000
Prospect Park,	1,911	170,000
Montclair,	16,436	1,250,000
Total Passaic River at Little Falls,	260,892	23,368,000

PART II.

Records of Wells in New Jersey 1905-1909.

BY HENRY B. KÜMMEL AND HOWARD M. POLAND.

Records of Wells in New Jersey, 1905-1909.

BY HENRY B. KÜMMEL AND HOWARD M. POLAND.

The following records of deep wells have been collected by the Survey since 1904, chiefly in the last two years, and supplement the records published in many of the Annual Reports previous to 1904. They are arranged according to the geological formations from which the water is obtained, beginning with the oldest.

WELLS IN THE PRE-CAMBRIAN ROCKS.

With the exception of a small area of Pre-Cambrian rocks at and near Trenton, these strata occur only in the northern portion of the State and form the mountainous belt known as the Highlands. These rocks are for the most part hard, dense, crystalline gneisses of various types. They are relatively impervious, and except where traversed by cracks or joints contain but little water. Locally cracks and joints traverse them by which ground-water may descend to considerable depths. The deep iron mines at Mount Hope, Wharton, Oxford and other points afford some data as to the amount of water in these rocks. Several of these mines are 1,000 feet or more in depth, but in none of them is the amount of water so large as to be greatly troublesome, although pumping is of course necessary in all. When the great extent of some of these underground workings is considered, the comparatively small amount of ground-water in the gneiss, except in an occasional open seam or crushed zone, is very marked.

The average depth of 12 wells drilled in these rocks near Bernardsville is 320 feet, and the average yield is 15 gallons per minute. One well only 86 feet deep is reported to yield 100 gallons per minute, while two 621 feet deep produced 3½ and 8 gallons each, and two others about 700 feet deep were practically dry. As the result of experience in this and other States[1] it has been found to be rarely advisable to drill deeper than 250 feet in gneiss in search of water. Joints and cracks are most numerous near the surface and become less numerous and closer with depth, so that if sufficient water is not found within the first 250 feet in these rocks it is usually better to drill again in another locality.

Since the water obtained is usually that contained in the joints and crevices intersected by the boring, and since these are irregularly distributed, a slight change in location may result in finding water where a former effort was a failure. In general, the chances of success are much better where the rock is traversed by numerous joints than where it is massive.

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[1] U. S. Geological Survey, Water Supply and Irrigation Paper No. 232, pp. 93-94.

WELLS IN PRE-CAMBRIAN FORMATIONS.

Location.	Owner.	Driller.	Total depth.	Depth to principal water source.	Height from surface to which water rises.	Water lowered by pumping.	Flows gallons per minute.	Pumps gallons per minute.	Elevation above sea level.	Diameter in inches.	Remarks.	Feet.
Bernardsville,	S. S. Childs,	Stothoff Bros.,	75	....	....	....	....	....	....	....	Gneiss.	
Bernardsville,	J. E. Hulchizer,	Stothoff Bros.,	190	....	....	....	....	....	....	....	Sand, gravel and clay,	0—60
											Decomposed rock,	60—105
											Gneiss,	105—190
Bernardsville,	Col. A. R. Kuser,	Stothoff Bros.,	190	186	10	12	....	120	....	6	Sand and gravel,	0—28
											Decomposed granite and gneiss,	28—76
											Granite and gneiss,	76—186
											Decomposed granite,	186—190
Bernardsville,	Geo. B. Post,	Stothoff Bros.,	158	148	13	52	....	75	....	6	Sand, gravel, decomposed rock,	0—58
											Granite and gneiss,	58—130
											Decomposed rock,	130—158
Bernardsville,	J. A. Roebling,	Stothoff Bros.,	678	535	55	295	....	31	....	6	Discharged 820 pounds of powder.	
Bernardsville,	G. C. Smith,	Stothoff Bros.,	157	....	....	....	....	....	....	....	Yellow clay and gravel,	0—40
											Crystalline rock,	40—157
Bernardsville,	Water Company,	Stothoff Bros.,	700+	....	....	....	....	0	355	8	Well located near creek.	
											Trap rock,	0—330
											Fault breccia containing much calcite,	330—445
											Gneiss,	445—700+
											No water. Well crosses faults between the Triassic and Pre-Cambrian rocks.	
Trenton,	E. L. Kerns,	Geo. Ridpath,	170	....	....	....	....	0	60	....	Gneiss; had to pour in water in order to work bucket,	0—170
Trenton,	Strauss Roller Mill,	Geo. Ridpath,	400	....	50	100	....	25	50	6	Gneiss; too much iron for use in boiler.	

WELLS IN THE PALEOZOIC FORMATIONS.

The Paleozoic formations consist chiefly of limestone, shale and sandstone with lesser amounts of conglomerate. They occur mainly northwest of the Highlands in Warren and Sussex counties, but appear also in some valleys intersecting the Highlands. Comparatively few deep wells have been drilled in these formations. Large amounts of water are not usually found, but most wells of moderate depth can be relied upon to furnish sufficient for residences and farm use.

Three wells have been reported:

Martin's Creek.—Seitz Brewing Co., owner; Stothoff Bros., driller; total depth was 140 feet, 1–60 feet, sand and gravel; 60–100 feet, siliceous limestone; 100–140 feet, limy shale and sandstone. The amount of water obtained was not reported.

Quarryville.—Jefferson Dunn, owner; H. E. Estes, driller. Elevation, 900 feet. Well was drilled 80 feet partly through shale and sandstone. Water was obtained chiefly at a depth of 40 feet, rose to within 10 feet of the surface, and was lowered to 40 feet by pumping at the rate of 4 gallons per minute. The water was reported to be hard and to contain a little iron.

Quarryville.—At the creamery of Horton & Lewis, a well was drilled by H. E. Estes to a depth of 300 feet. At 80 feet a supply of 5 gallons per minute was obtained and at 240 feet a larger amount. The water rose to within 8 feet of the surface and was lowered 76 feet by five hours steady pumping, the yield being 30 gallons per minute. The drilling disclosed 10 feet of soil and decomposed rock, 45 feet slate, 245 feet flagstone, total 300 feet, all in the Martinsville (Hudson River) formation.

WELLS IN THE TRIASSIC FORMATION.

The rocks of the Triassic formation cross the State from northeast to southwest. They lie southeast of the Highlands and northwest of a line from Trenton to Woodbridge. The sedimentary members consist chiefly of reddish-brown shales and sandstones with some coarse conglomerates and some very fine, dense argillites. The crystalline members consist of thick sheets of basalt and diabase, commonly known as trap rock. These sheets are intercalated between the beds of the sedimentary members and slant parallel to them or nearly so. The general slant or dip of both sedimentary and crystalline rocks is towards the northwest at angles which usually do not exceed 15 degrees.

There is little chance of finding large supplies of water in the trap rock, which is practically impervious except where traversed by crevices and joints. In this respect it is like the gneiss of the Highlands. Several wells 600 to 1,000 feet deep have been drilled in this rock and no water found. The trap sheets vary from 200 to upwards of 1,000 feet in thickness. Sometimes moderate supplies have been obtained by drilling through the trap into the more porous shales and sandstones below, but in general it is better not to attempt to obtain water in the trap rock. If the attempt must be made, it is rarely wise to continue drilling to depths greater than 250 or 300 feet. If sufficient water has not been found within that depth, another boring in a different locality may be more successful. In spite, however, of the generally unfavorable conditions, a few wells in trap have been successful, and at Caldwell a flowing well has been obtained in this formation (p. 79).

The sedimentary members vary considerably in the amount of water they contain. The hard, dense, dark-colored argillites which occur in several belts in the western portion of the State are relatively dry. The same is true, but to a less extent, of the softer red shales. Some water is carried in the cracks, joints and bedding planes which separate these layers, and still more is found in more or less porous sandstones which are intercalated with the shales. These porous sandstones, which grade locally into coarse, more or less open-textured conglomerates, become more abundant in the northern and eastern sections, and are capable of supplying large amounts of water.

Owing to the relatively steep dip—13 to 15 degrees, or, roughly, 1,000 to 1,300 feet per mile—any given water-bearing stratum quickly reaches such a depth as to render it impracticable to utilize it over wide areas, and, owing to the lack of regularity in the alternation of coarse and fine beds, predictions as to the occurrence of water horizons can be made only to a very limited extent. Experience, however, has demonstrated that moderate amounts of water can usually be obtained without difficulty from any well in the sedimentary beds within 400 or 500 feet at the most and in most cases at much less depths.

Caldwell.—Two flowing wells have been obtained west of Caldwell. One drilled for M. S. Crane and located 1½ miles west of Caldwell, is 240 feet deep, and flowed 8 gallons per minute one foot above the surface. On lowering the surface 6 feet the flow was increased to 16 gallons per minute. The boring penetrated 70 feet of glacial drift, the balance being in red shale and sandstone. Water was struck at 225 feet. The other well, drilled for S. Francisco, has a depth of 208 feet, diameter of 6 inches, and flows 3 gallons per minute 4 feet above the surface. Both wells are located on the low ground west of the second Watchung Mountain, the strata dipping from the mountain towards the well sites.

Midland Park.—Three wells of the Bergen Water Co., along the creek northwest of Godwin avenue, yielded 1,500 to 2,400 gallons per minute on a 12-hour pumping test, the water level being lowered 4 feet. After heavy rains the wells flow freely from two to four days at one foot above the surface, but the normal level is a little below the surface. The wells are spaced 125 feet apart, and penetrated 25 feet of glacial drift and 210 feet of red sandstone, total depth, 235 feet.

Trenton.—Three new wells at the State Hospital for the Insane, at an elevation of 135 feet, and spaced 100 feet apart, on a 24-hour pumping test in a dry season, yielded 301 gallons per minute. These wells are 305, 307 and 588 feet deep, respectively, the water rising to the surface in the first two and to 65 feet in the third. It was lowered to 100 feet during the pumping test. The drilling showed 30 feet of gravel and clay at the surface, the balance being red shale.

Other wells in this vicinity drilled in the red shale to average depths of 500 feet yield 20 to 30 gallons per minute, and are generally affected by drought. These conditions prevail particularly along the river bluff as far north as Titusville.

Data regarding other wells in the Triassic formations are given in the table below.

WELLS IN TRIASSIC STRATA.

LOCATION.	OWNER.	DRILLER.	Total depth.	Depth to principal water bed.	Depth to which water rises.	Depth to which water is lowered by pumping.	Flows gallons per minute.	Pumps gallons per minute.	Elevation above sea level.	Diameter in inches.	REMARKS.	Feet.
Colonia,	C. D. Freeman,	F. T. Cladek,	153		36			25	150		Red shale.	
Colonia (½ mi. N.W.)	J. W. Nevitte,	F. T. Cladek,	190	180	27			12		6	Mantle rock,	0—20
											Red shale,	20—190
Cranford, 1¼ mi. N.W.	Henry Deyan,	F. T. Cladek,	121		17			14		6	Red sand and clay,	0—54
											Red sandstone,	54—121
Cranford,	H. Dryer,	F. T. Cladek,	140					25			Sand and gravel,	0—40
											Red sandstone,	40—140
Creskill,	John Bedowe,	F. T. Cladek,	67	60	18			21		4½	Red shale.	
Elizabeth,		H. E. Estes,	180					50			Sand,	0—20
											Muck and soft clay,	20—30
											Red shale,	30—67
Far Hills,	J. V. Ludlow,	J. C. Dorland,	114½					6			Red shale.	
Frankfort,	M. J. Wortz,	J. C. Dorland,	109½					15			Red shale.	
Garwood (1 mi. E.),	E. L. Masset,	F. T. Cladek,	82	82	30			25		6	Sand and boulders,	0—28
											Red sandstone,	28—82
Haskill,	Lafflin, Rand & Co.,	T. B. Harper,	100					0		6	Red shale.	
Lawrenceville,	Morris Hall,	C. P. Bainbridge,	126½	120	18	4		60	110	10—8	Sand and gravel,	0—23
											Shale,	23—126½
Lawrenceville,	Alfred Gaskill,	C. P. Bainbridge,	127	125	30	10		60	160	6	Sand and decomposed rock,	0—10
											Shale,	10—127
Linden,	Rosehill Cemetery,	F. T. Cladek,	209	204	15	17		15		6	Red sandstone.	
Linden,	Walter Luchen,	F. T. Cladek,	63					30			Sand and gravel,	0—20
											Red sandstone,	20—63
Little Ferry,	Feucht, Wanger & Co.,		352								2′ sand, 90′ clay, 248′ sandstone, 12′ conglomerate; water bearing.	
Moore's Station,	James Ealy,	C. P. Bainbridge,	170	168				10			Mantle rock,	0—4
											Shale,	4—170
Morristown,	J. W. Castles,	Artesian Well and Supply Co.,	565					50			Sand and gravel,	0—8
											Red sandstone,	8—565
Morristown,	C. B. Mitchell,	Artesian Well and Supply Co.,	600					30			Sand and gravel,	0—15
											Red sandstone,	15—600

WELLS IN TRIASSIC STRATA (CONTINUED).

LOCATION.	OWNER.	DRILLER.	Total depth.	Depth to principal water bed.	Depth to which water rises.	Depth to which water is lowered by pumping.	Flows gallons per minute.	Pumps gallons per minute.	Elevation above sea level.	Diameter in inches.	REMARKS.	Feet.
Newark,	Standard Heating Co.,	H. E. Estes,	400	....	....	....	....	22	....	6	Sand and gravel,	0—20
											Red sandstone,	20—400
New Vernon,	....	Stothoff Bros.,	123	....	....	....	....	20	....	......	Red sandstone.	
North Branch,	Wm. Cawley & Co.,	J. C. Dorland,	117	....	....	....	....	8	....	......	Red shale.	
North Branch,	H. J. Stelson,	J. C. Dorland,	96½	....	....	....	....	8	....	......	Red shale.	
Orange,	McKinley School,	F. T. Cladek,	182	....	....	....	....	20	....	......	Sand and gravel,	0—37
											Red sandstone,	37—182
Passaic,	A. Wirksman,	McTammeny Co.,	250	....	30	12	....	15	....	8		
Passaic,	....	....	363	250	23	....	....	153	....	......	Sand and gravel,	0- 98
											Red sandstone,	98- 363
Paterson,	Lafflin & Rand Co.	T. B. Harper,	128	40	....	....	....	....	....	8	Sand and gravel,	0- 20
											Trap rock,	20- 128
Princeton,	Water Co.,	T. B. Harper,	450	....	34	....	....	100	....	8-6	Sand, gravel and clay,	0- -20
											Red sandstone,	20—450
Princeton Junction,	Hotel,	C. P. Bainbridge,	70	....	....	....	....	5	80	6	Sand and clay,	0—35
											Red sandstone,	35- 70
Rahway,	John Bedon,	F. T. Cladek,	67	....	....	....	....	21	....	......	Sand and clay,	0- 30
											Red sandstone,	30- 67
Rahway,	Dr. Cladek,	F. T. Cladek,	45	....	....	....	....	[illegible]	....	......	Sand and clay,	0- 30
											Red sandstone,	30- 45
Rahway,	Wm. Mershon,	F. T. Cladek,	101	....	....	....	....	15	....	......	Sand and clay,	0- 50
											Red sandstone,	50- 101
Rahway,	Newton Moore,	F. T. Cladek,	76	....	....	....	....	10	25	......	Sand and clay,	0- 38
											Red sandstone,	38- 76
Rahway,	Dennis Ryan,	F. T. Cladek,	84	51	20	....	....	5	18	5	Sand and gravel,	0- 30
											Black muck,	30- 34
											Red sandstone,	34- 84
Rahway,	Miss Jane Ayress,	F. T. Cladek,	62	55	30	....	....	30	21	5	Sand and yellow gravel,	0- 40
											Red sandstone,	40- 62
Rahway,	Henry Lamphere,	F. T. Cladek,	67	57	8	....	....	4	[illegible]	5	Blasted 30 pounds of powder at bottom; was not successful.	
Rahway,	Geo. Van Sickle,	F. T. Cladek,	70	60	18	12	....	8	23	5	Old sand pit filled in,	0- 25
											Coarse sand, yellow,	25—32
											Red shale,	32- 70

LOCATION.	OWNER.	DRILLER.	Total depth.	Depth to principal water bed.	Depth to which water rises.	Depth to which water is lowered by pumping.	Flows gallons per minute.	Pumps gallons per minute.	Elevation above sea level.	Diameter in inches.	REMARKS.	Feet.
Rahway,	Geo. Robson,	F. T. Cladek,	57	57	18	....	....	12	25	5	Sand, clay and gravel,	0—36
											Red shale,	36—57
Rahway,	Fred. Morch,	F. T. Cladek,	77	77	19	....	....	20	24	5	Sand and hard pan,	0—27
											Red shale,	27—77
Rahway (2 mi. N.W.),	John Willick,	F. T. Cladek,	90	80	20	....	....	25	....	6	Sand and gravel,	0—20
											Red shale,	20—90
Raritan,	Mr. Brown,	J. C. Dorland,	141	....	....	....	....	10	....	....	Red sandstone.	
Roselle,	Fenton Keenan,	F. T. Cladek,	55	55	18	....	....	10	....	5	Red sand and gravel,	0—22
											Red shale,	22—55
Scudder's Falls,	Mr. Swayze,	Stothoff Bros.,	190	190	25	....	....	2	130	....	Drilled entirely in hard black shale.	
Somerset,	A. M. Maddock,	C. P. Bainbridge,	263	23	20	....	....	2	80	6	Red shale,	0—80
											Hard blue shale,	80—263
Somerville,	W. W. Wyckoff,	J. C. Dorland,	72½	....	....	....	....	12	....	....	Red shale.	
Somerville,	G. W. Potts,	Stothoff Bros.,	303	....	120	....	....	30	....	....	Red shale.	
Titusville,	L. I. Scudder,	C. P. Bainbridge,	145	96	50	....	....	20	75	....	Alternating red and blue shale.	
Titusville,	Edward Anderson,	C. P. Bainbridge,	90	....	....	....	....	20	70	6	Sand and gravel,	0—40
											Red shale,	40—90
Wash'gton's Crossing,	A. C. Cooley,	Stothoff Bros.,	121	90	20	....	....	20	170	6	Red shale,	0—85
											Argillite,	85—121
Wash'gton's Crossing,	Harry Morgan,	T. S. Moore,	100	100	20	....	....	10	100	6	Mantle rock,	0—20
											Red shale (hard),	20—100
Westfield,	Water Co.,	F. T. Cladek,	100	98	20	....	....	15	....	5	Glacial drift,	0—39
											Red shale,	39—100
Westfield,	Chas. Peifer,	F. T. Cladek,	96	90	33	....	....	18	....	5	Glacial drift,	0—50
											Clay (red),	50—96
Westfield,	B. E. Ball,	F. T. Cladek,	119	108	33	....	....	20	....	4½	Sand, clay and gravel,	0—50
											Red sandstone,	50—119
Edgewater,	Ford, Bacon & Davis,	H. E. Estes,	255	97	6	....	....	10	....	8—10	Gravel and broken rock,	0—9
											Red sandstone,	9—255
Great Notch,	Wright & Lindsey,	....	300	....	....	....	....	45	....	....	Slight brackish taste to water. Drilled in trap rock.	
Lambertville,	Rubber Co.,	....	1005	....	....	....	....	10	90	10	Unsuccessful; drilled entirely in trap rock.	
Caldwell,	W. H. & R. S. Francisco,	Stothoff Bros.,	300	209	....	....	3	....	....	6	Drilled in trap rock and water rose 4 feet above surface.	

WELLS IN THE CRETACEOUS FORMATIONS.

The Cretaceous formations[1] comprise beds of gravel, sand, clay and greensand marl (glauconite). These appear at the surface, except where covered by thin beds of gravel and sand of much later (Pleistocene) age, in a belt extending from Atlantic Highlands to Delaware River south of Trenton and thence southwestward through Salem County. The northwestern boundary of this belt is fairly regular, and coincides approximately with a straight line drawn from Woodbridge to Trenton. The southeastern boundary is extremely irregular, and lies from 10 to 30 miles from the former. The Cretaceous strata are nearly horizontal, with low dips to the southeast of from 45 to 25 feet per mile. Southeast of their zone of outcrop they are overlapped by strata of Tertiary age, but at many points wells have been drilled through these later strata to some one of the Cretaceous water-bearing horizons beneath.

Since the Cretaceous strata dip gently southeast the lowest and oldest members outcrop farthest to the northwest, while successively higher and younger beds appear at the surface to the southeast. Several of the Cretaceous formations are water-bearing and afford ample supplies of water. These are beginning with the oldest, the Raritan-Magothy formations, the Englishtown sands, the Mt. Laurel-Wenonah sands, the Redbank sand, and the Vincentown sand. These porous, water-bearing strata are each overlain by other formations, which are relatively impervious, and which contain little or no water.

The Raritan-Magothy Water Horizons.—The Raritan and Magothy formations contain beds of gravel, sand and clay somewhat irregularly interbedded, so that while several water horizons are known to exist in these formations they are to a degree local and cannot be correlated over wide areas. Usually no difficulty is experienced in obtaining water from one or more horizons in these formations, but experience has shown that wells not

[1] These formations have been described at length in many of the previous reports of the Survey, notably the Trenton and Philadelphia folios of the Geologic Atlas of New Jersey, the Report on Clays, Vol. VI, Report on Paleontology, Vol. IV.

far distant may find water at markedly different levels within these formations.

The Englishtown Water Horizon.—The Englishtown sand is the second of the water-bearing strata of the Cretaceous. It is separated from the Magothy-Raritan beds by two clay formations, the Woodbury and Merchantville, the aggregate thickness of which is about 100 feet, although this varies somewhat along the line of outcrop and increases in the direction of the dip. The Englishtown is a sand formation with lenses of clay. It is thickest at the northeast in Monmouth County (100 feet or more) and apparently disappears or thins to less than 20 feet in Salem County. It is overlain by the Marshalltown clay-marl bed, which is relatively impervious. Many wells in Monmouth County, particularly along the shore, draw from the Englishtown, but its importance as a water carrier decreases towards the southwest. In the earlier reports it was referred to both as the Cropwell water horizon and as the Columbus sand. The term "Englishtown" has, however, superseded both the other names.

The Mount Laurel-Wenonah Water Horizon.—The Mount Laurel and Wenonah sand beds form the third Cretaceous water horizon. Although these formations may be separated from each other on slight lithological and more marked faunal grounds, from the present point of view they form a single sand stratum, some portion of which is usually water bearing. The Marshalltown marl and clay bed, averaging 20 to 40 feet thick, underlies the Wenonah sand and separates it from the Englishtown sand below. The Mount Laurel sand is overlain by the Navesink marl, a relatively impervious bed, having a thickness of 35 to 40 feet. The Mount Laurel-Wenonah sand bed is particularly important as a water horizon in the regions between Pemberton and Salem and between Lakewood and Seabright. Its thickness at its outcrop increases from about 40 feet at the northeast to 80 or 100 feet in the southwest. In some of the older reports it is referred to as the Marlton water horizon, from the large number of wells drawing water from it in the vicinity of Marlton.

The Vincentown Water Horizon.—The Navesink marl, Redbank sand, Hornerstown marl, which successively overlie the Mount Laurel-Wenonah sands, are not in general important water-bearing strata. The little water obtainable from the two marl beds is nearly always highly charged with iron and unpleasant to the taste. In some portions of Monmouth County the Redbank sand is a good water carrier, but it thins out rapidly to the southwest, so that the area within which it can be utilized is limited.

The Vincentown sand overlies the Hornerstown marl, and is the fourth of the important Cretaceous water horizons. In Monmouth County it outcrops as a coarse, yellowish or greenish quartz sand in the region west of Long Branch, but farther south it becomes more calcareous, and in the southern counties is often referred to as the limesand formation. As revealed in wells southeast of the line of outcrop it is in some places quite clayey. It is the Lindenwold water horizon of earlier reports.

WELLS IN THE CRETACEOUS FORMATIONS.

MAGOTHY—RARITAN WATER HORIZONS.

Location.	Owner.	Driller.	Total depth.	Depth to principal water bed.	Depth to which water rises.	Depth to which water is lowered by pumping.	Flows gallons per minute.	Pumps gallons per minute.	Elevation above sea level.	Diameter in inches.	Remarks.	Feet.
Amboy,	Wm. McCabe,	W. R. Osborne,	51							4	White clay,	0—20
											Red clay,	20—35
											Yellow sand,	35—51
Amboy,	Geo. Seaman,	W. R. Osborne,	75	60						4	Yellow sand,	0—20
											Clay,	20—60
											Yellow and white sand,	60—75
Amboy,	R. N. & H. Valentine,	W. R. Osborne,	55	40						4	Clay,	0—40
											Sand,	40—55
Bordentown,	Ice Co.,	Geo. Ridpath,	140	130	30			50	60	8	Water found in bed of white sand and gravel overlying clay.	
*Bordentown,	Bordentown Brick Co.'s Clay Pit,		243								Black clay,	0—12
											White sand,	12—36
											Clays,	36—80
											White sand,	80—95
											Bluish sand (compact),	95—235
											Gravel (water bearing),	235—243
Bordentown, 2 mi. S.E.	J. L. Kuser,		282		75			12		8		
Camden,	Atlas Cereal Co.,		125	100	12			50		8	Fine sand,	0—60
											Clay,	60—100
											Coarse sand and gravel,	100—125
Camden,	Y. M. C. A.,	Geo. Ridpath,	125½	115	10	0		100		6		
Camden,	J. L. Wilkins,	W. C. Barr,	121								Soil and gravel,	0—5
											Red sand,	5—25
											Alternating clay and sand,	25—115
											Coarse sand and gravel,	115—121
Clarksville,	School House,	C. P. Bainbridge,	113	90					108	4	Gravel and clay,	15—20
											Clay,	20—80
											Sandy clay,	80—90
											Rock (Trias?),	90—113
Cliffwood,	Cliffwood Brick Co.,	J. V. Conover,	165					75	10			
*Fort Hancock,	U. S. Government,	T. B. Harper,	365					60				
*Fort Hancock,	U. S. Government,	T. B. Harper,	754									

* See notes at end of tables.

WELLS IN THE CRETACEOUS FORMATIONS—CONTINUED.

LOCATION.	OWNER.	DRILLER.	Total depth.	Depth to principal water bed.	Depth to which water rises.	Depth to which water is lowered by pumping.	Flows gallons per minute.	Pumps gallons per minute.	Elevation above sea level.	Diameter in inches.	REMARKS.	Feet.
*Haddonfield,	Water Co.,	T. B. Harper,	218		36			100	40			
*Jamesburg,	Boys' Home,	Geo. Ridpath,	650		485			100		8		
Merchantville,	J. S. Collins,		65	65	18	2		15		4½		
Moorestown,	D. C. Kalbach Bros.,	A. G. Dunphey,	99	99	50			15		3½		
Oaklyn,	W. J. & S. S. R. R.,	W. C. Barr,	114								Sand and gravel,	0- 8
											Blue clay,	8- 46
											Marly clay and sandy,	46- 86
											Lignitic sand,	86- 100
											Chocolate clay,	100- 101½
											Coarse sand and gravel (water bearing),	101½ -114
Old Bridge,	P. A. Water Co.,	Geo. Kisner,	88	22	20			100		6—4	Yellow sand and gravel,	0—26
											White sand,	26—38
											Yellow and white sand,	38—86
											Clay,	86—88
Perth Amboy,	Barber Asphalt Co.,	W. R. Osborne,	50	45				25		6	Clay,	0—45
											Greenish sand,	45—50
Perth Amboy,	Martin Oertel,	F. T. Cladek,	144	130	55			12		6	Well drilled at No. 19 Goodwin St.	
*Perth Amboy,	R. H. Chemical Co.,	Stothoff Bros.,	142									
Robbinsville,	Jos. Delatush,	C. P. Bainbridge,	100	90	2	60		30		6	Yellow gravel and clay,	0—30
											Black clay,	30—90
											Fine white sand,	90—100
Roebling,	J. A. Roebling Co.,	T. B. Harper,	500	230	2+	0	10		15	8	Beds above rock cased in as water was too irony. No water in the rock.	
											Sand, gravel and clay,	0—249
											Gneiss,	249—500
*Sandy Hook,	Newburg Dredging Co.,	Matthews Bros.,	427	387	0		18	65	3	3	See notes.	
Sewell,	G. B. Knoff,		345	329	80	4		40		4½—3	Section not given.	
Swedesboro,	Woolwich Water Co.,		133	120			5	70				
*Trenton,	A. R. Kuser,		264					250	30		Three wells combined pump 250 gallons.	
Woodbury,	Wm. Goldy,		75	50	12					6	Well was drilled on Red Bank Ave.	
Yardville,	Odd Fellows' Home,	C. P. Bainbridge,	295	235		0		100	60		Water horizon, coarse sand, 60 feet in depth.	

* See notes at end of tables.

WELLS IN THE CRETACEOUS FORMATIONS—CONTINUED.

Location.	Owner.	Driller.	Total depth.	Depth to principal water bed.	Depth to which water rises.	Depth to which water is lowered by pumping.	Flows gallons per minute.	Pumps gallons per minute.	Elevation above sea level.	Diameter in inches.	Remarks.	
ENGLISHTOWN WATER HORIZON.												
*Brown's Mills,	Mr. Reilley,	Ridpath & Potter,	430	....	....	....	48	225	70–80	6	See notes.	
*Hillsdale,	Daniel Tailer,	Matthews Bros.,	225	210	....	....	....	10	200+	3	1 mile east of Bradwell station.	
Jobstown,	J. D. Black,	J. V. Conover,	250	....	....	....	....	18	110	....		
*Jobstown,	Jos. J. White,	T. B. Harper,	170	152	15	....	....	40	80	....	On road from Jobstown to Juliustown.	
*Marlboro, 2mi. N.W.,	J. B. Conover,	Matthews Bros.,	154	....	....	....	....	10	....	3	Water contained much iron.	*Feet.*
New Egypt,	....	Geo. Pfeiffer,	238	218	25+	0	90	....	25	8	Marl and shells,	0—112
											Sand,	112—120
											Marl,	120—218
											Dark quartz sand,	218—238
Sharptown,	Wm. Richman,	J. B. Rulon & Co.,	180	175	5	13	....	100	18	8	No section given.	
*Wichatunk Station,	Wm. Shepherd,	Matthews Bros.,	208	....	....	....	....	10	....	3	Well located 2 miles west.	
Woodbury,	Sanitarium,	J. A. Tubbs,	41	25	8	....	....	100	10	6	No section given.	
MOUNT LAUREL—WENONAH WATER HORIZON.												
Hornerstown,	Chas. Higgins,	F. Hope,	75	73	....	....	3	....	20	3½	No section.	
Jefferson,	David Owen,	....	135	120	75	....	....	30	....	4	Gravel,	0—10
											Sand,	10—70
											Marl,	70—120
											Coarse sand (water bearing),	120—135
Jobstown,	Barclay White,	W. C. Barr,	70	....	....	....	....	25	....	....	Water is very irony.	
Kirkwood,	Phila. Real Estate Co.,	Geo. Ridpath,	100	....	0	....	60	....	70–80	8		
VINCENTOWN WATER HORIZON.												
*Deal,	C. L. Despard,	J. V. Conover,	158	....	....	....	10	75	20	6		
Gibbsboro,	W. H. Nicholson,	H. B. Dunphy,	82	44	19	....	....	10	....	6	Greenish sand,	0—19
											Quick sand (yellow),	19—55
											Black clay and marl,	55—76
											Pepper and salt sand,	76—82
											(Water bearing).	
Woodstown,	C. F. Moore,	....	90	75	....	10	....	15	....	....	No section.	

* See notes at end of tables.

Notes on Wells Drawing from the Cretaceous Formations.

Bordentown.—The strata shown in the well section at the Bordentown Brick Company's clay-pit are correlated as follows: Merchantville clay, 0–12 feet; Magothy-Raritan formations, 12–243 feet. The water contains considerable iron.

Fort Hancock–Sandy Hook.—In 1905 a well was drilled for the U. S. Government at Fort Hancock, Sandy Hook, by T. B. Harper to a depth of 365 feet. The water rises 7 feet above low tide, and after long pumping at the rate of 60 gallons per minute it falls to 6 feet below tide. A sample taken after 50 hours of pumping on analysis is reported to have shown

	Parts in 10,000
Solids,	105
Chlorine,	19
Organic matter,	26
Iron,	21

Mr. J. H. Pearson has reported a deeper well at the same post, known as deep well No. 2, which obtained "much water" at 724–754 feet, the geologic section being as follows:

Well at Fort Hancock.

Strata.	*Depth. Feet.*	
Beach sand and fine gravel,	0– 80 ft.	Recent.
Compact gray sand,	80–120 "	
Blue clay,	120–160 "	Woodbury and Merchantville formations.
Sand, clay with marl (?),	160–200 "	
Blue clay,	200–260 "	
Fine, light-gray sand,	260–395 "	
Blue clay,	395–400 "	Magothy-Raritan formations.
Fine white sand,	400–500 "	
Blue clay,	715–724 "	
White clay,	500–503 "	
Sand and gravel,	503–560 "	
Blue clay,	560–674 "	
Coarse sand,	674–694 "	
Sand,	694–711 "	
White sand—*water*,	711–715 "	
Blue clay,	715–724 "	
Coarse white sand—*much water*,	724–754 "	

The beds below 260 feet in this well and 240 feet in the preceding well are clearly referable to the Magothy-Raritan formations, while the overlying clay beds up to 120 feet are referable to the Merchantville and probably to at least a portion of the Woodbury formations.

Haddonfield.—Data regarding this well were furnished by Dr. J. R. Stevenson, of Haddonfield, and the contractor, George Pfeiffer, of Camden. The well is located just east of the junction of the Marlton & Medford Railroad with the West Jersey Railroad.

Well Section at Haddonfield.

Strata.	*Depth. Feet.*		
Marsh mud,	0— 2	Recent and Pleistocene.	
Sand and gravel,	2— 12		
Micaceous sand, Marly clays,	12—146	Englishtown sand. Woodbury clay. Merchantville clay.	Cretaceous.
Light-colored clay,	146—169	Magothy-Raritan formations.	
White sand and gravel,	169—218		
Clay at	218		

The Englishtown sand outcrops in the side of the ravine and the basal part apparently was found in the well section. The top of the Woodbury clay is here about 18 feet above tide level.

Analysis of the water (furnished by Dr. Stevenson) showed:

	Parts per Million.
Total solids,	135.
Volatile "	25.
Fixed "	110.
Nitrogen as Free Ammonia,	.182
" " Albuminoid Ammonia,	.098
" " Nitrites,	0.0
" " Nitrates,	0.0
Chlorine,	6.
Alkalinity,	82.5
Hardness,	85.5
Iron,	.12

Jamesburg.—Two attempts have been made to obtain an adequate and pure supply of artesian water at the State Home for Boys at Jamesburg. Neither has been wholly successful, either in point of quantity or quality. From the first well the water contained so much iron as to be unsuitable for laundry or boiler purposes. The first attempt was described in the earlier Annual Reports.[1]. The second attempt was made in 1908, the location being about 100 feet from the first well, and the boring being carried to a depth of 650 feet. The underlying gneiss rock was struck at a depth of 503 feet or about 400 feet below sea level. Water was found at 485–503 feet in a coarse sand and fine gravel immediately above the gneiss rock, and yielded on testing 100 gallons per minute, but contained too much fine black material (lignite?) to be satisfactory. No water of any amount was found in the rock.

The section penetrated was as follows:

Well at Jamesburg.

Strata.	*Feet.*	
Black clay,	0 – 38	Woodbury (?) and Merchantville clays.
Coarse mixed sand,	30 – 40	
Sand rock,	40 – 40½	
Marly sand,	40½– 52½	
Sand rock	52½– 54	
Black clay,	54 – 85	Magothy-Raritan.
Gray, micaceous sand, lignite,	85 – 119	
Fine sand and clay,	119 – 250	
Black clay,	250 – 309	
Fine micaceous sand,	309 – 313	
Fine gravel (water bearing),	313 – 485	
Coarse white sand (*water*),	485 – 503	
Rock,	503 – 650	Gneiss.

Perth Amboy.—The section of the R. H. Chemical Company's well at Perth Amboy was as follows:

Strata.	*Depth. Feet.*	
Red clay and sand,	0– 25	Pleistocene.
Coarse yellow sand and gravel,	25– 40	Cretaceous. (Raritan)
Brown sand,	40– 45	
Yellow sand and gravel,	45– 55	
Coarse brown gravel,	55– 60	
Clay—dark,	60– 70	
White clay,	70–105	
Light sand and gravel,	105–142	

[1] Annual Reports 1879, 1880, 1882, 1885.

Sandy Hook.—A 3-inch well drilled for the Newburg Dredging Company near Spermaceti Cove, Sandy Hook, at an elevation of 3 feet above tide flowed 18 gallons per minute and yielded on pumping 65 gallons. The geological section with probable correlation is as follows:

Strata.	*Feet.*		
Sand,	0– 60	Recent	
Blue clay,	60– 68	Marshalltown	Cretaceous.
Sand with lignite, *water bearing,*	68–118		
Gravel,	118–121		
Blue clay,	121–131		
Sand with lignite—*brackish water,*	131–280	Englishtown	
Gravel,	280–288		
Rock layer,	288–292	Woodbury and Merchantville	
Marl (Marly clay?),	292–347		
Dark sand,	347–359		
Rock,	359–368		
White sand—*water bearing,*	368–378		
Very hard marl (marly clay?),	378–387		
White sand, with lignite—*water bearing,*	387–427	Magothy	

The top of the Magothy formation at 387 feet accords fairly well with its occurrence at 240 or 260 feet in the Fort Hancock wells, which lie 2½ miles farther north, and also with its occurrence at Highland Beach, 1½ miles south at 510 feet.

Trenton.—There seems to be no published record of the three wells at the Hygeia Ice Plant, drilled in 1892, on the bluff overlooking Delaware River near Riverview Cemetery, at an elevation of 30 feet. Their depths were 85, 90 and 264 feet respectively. These wells showed the following section:

Strata.	*Depth. Feet.*	
Sand and gravel,	0– 45	Pleistocene.
Coarse, yellowish sand, sharp and clay coated,	45– 65	Cretaceous. (Raritan)
White sand and gravel—clay coated,	65– 90	
White clay,	90–264	

Water occurred in the coarse sand and gravel above the white clay. The three wells yielded 250 gallons per minute.

Browns Mills.—Samples taken every 10 feet were obtained from this well through the co-operation of the drillers.

Strata.	*Depth. Feet.*	
Sand and gravel,	0– 10	Pleistocene.
Brown sandy clay,	10– 60	Kirkwood.
Greenish clay, containing some marl, rarely a pebble, and lignite,	60–140	Shark River.
Greensand marl,	140–220	Manasquan to Navesink marl.
Fine gray sand, with some marl at top and bottom, slightly micaceous,	220–330	Mount Laurel-Wenonah.
Coarse yellow sand, shells, clay pellets and very micaceous dark sand,	330–350	
Black sandy clay,	350–370	Marshalltown.
Very fine, greenish-black micaceous sand, somewhat glauconitic,	370–390	
Fine gray, quartz sand,	380–400	Englishtown.
Fine quartz sand, some glauconite (marl),	400–420	
Coarse quartz sand—*water bearing,*	420–430	

The above correlation is not free from difficulty, but it seems the best that can be made in the absence of further data.

Hillsdale, Monmouth County.—The reported section was as follows:

Strata.	*Feet.*	*Formations.*
Sand,	0– 65	Redbank.
Marl,	65– 91	Navesink.
Sand, with some marl,	91–100	Mount Laurel-Wenonah.
Clay,	100–109	
Sand,	109–135	
Clay and gravel,	135–140	
Black clay,	140–172	Marshalltown.
Sand,	172–190	Englishtown.
White sand, with some hard, white clay,	190–210	
Coarse sand, *water bearing,*	210–225	

The supply is drawn from the Englishtown sand, the top of which is about 25–30 feet above sea level.

Jobstown.—The section of this well was not given in detail, but the Navesink marl and the underlying Mount Laurel-Wenonah sand was found from 0 to 120 feet, the Marshalltown clay from 120–152 and the Englishtown sand at 152–170 feet.

Marlboro.—The section of the J. B. Conover well was as follows:

Strata.	*Feet.*	*Formations.*
Soil,	0– 2	
Sand,	2– 30	Wenonah.
Marl and marly clay,	30– 50	Marshalltown.
Sand,	50–100	Englishtown.
Clay,	100–130	
Sand—*water bearing,*	130–154	

Wickatunk.—This well on the Marlboro Squab Farm is not far from the one above. Its section is as follows:

Strata.	*Feet.*	*Formations.*
Sand,	0– 63	Wenonah.
Marl and marly clay,	63– 97	Marshalltown.
Alternating beds sand and clay from 4–15 feet thick,	97–195	Englishtown.
Coarse sand—*water bearing,*	195–208	

Deal.—The section at Deal was as follows:

Strata.	*Feet.*	*Formations.*
Clay and gravel,	0– 10	Pleistocene.
Marl,	10– 80	Shark River and Manasquan marl.
Fine sand,	80–130	Vincentown sand.
Coarse sand,	130–158	

WELLS IN THE MIOCENE FORMATIONS.

In New Jersey two subdivisions of the Tertiary system have been made, called the Kirkwood and Cohansey formations, respectively. The Kirkwood is the older, and is certainly of Miocene age; the Cohansey is unconformable upon the Kirkwood, and may be late Miocene. Both formations afford good supplies of water at many points.

The Kirkwood formation appears at the surface in a belt of variable width from Asbury Park and the head of Barnegat Bay to the shores of Delaware Bay. At the northeast it is principally a fine quartz sand, usually somewhat micaceous. Black lignitic clays are abundant at or near the base, and some yellow, clayey layers occur at other horizons. Locally thin beds of coarse sand or fine gravel occur immediately at the base. In Salem County a fine, loose, somewhat glauconitic sand occurs near the base, above which there are several feet of very soft, micaceous sand and clay, with a soapy talc-like feeling; it is snow white where pure, but is not uncommonly stained with iron. Above this sand there is an 80 to 90-foot bed of clay, chocolate to drab and locally black in color. Above the clay there is a bed of brown clay and fine clayey gray sand containing great numbers of shells, the so-called Shiloh marl exposed in openings along the headwaters of Stowe Creek and its tributaries. Not only does the Kirkwood vary lithologically along its outcrop, but from borings it is known to change materially down the dip and to increase greatly in thickness. It is an important water-bearing formation along the coast from Sea Girt to Cape May, and it is also utilized by a few wells in the interior. Owing to its complicated lithologic character and local variations, wells draw from several horizons, which cannot always be correlated in neighboring wells.

The Kirkwood formation overlies unconformably the Cretaceous beds, frequently resting upon the Hornerstown marl and Vincentown sand, but also overlapping both younger or older beds.

The Cohansey formation overlies the Kirkwood, appearing at the surface southeast of it, and except for discontinuous areas of Pleistocene gravels, forming the surface over a wide area of the Coastal Plain. The Cohansey is primarily a sand formation, but it contains some gravel and locally considerable beds of clay. The sand is predominantly coarser than that of the Kirkwood, and the grains are in places so coated with clay that when moist it readily compacts; other beds are so clean that they are extensively dug for glass sand. This formation overlies the Kirkwood with a slight unconformity, its base declining to the southeast at about 11 feet per mile, being about 390 feet below sea level at Atlantic City.

Along the beaches wells in the Cohansey formation are frequently brackish, particularly after long pumping, even though fresh when first drilled, but in the interior this formation has yielded good water. Experience apparently demonstrates that the best results with the Cohansey as a water horizon are reached in localities one to ten miles back from the salt marshes.

WELLS IN THE MIOCENE FORMATIONS.

Location.	Owner.	Driller.	Total depth.	Depth to principal water bed.	Height to which water rises.	Water is lowered from surface.	Flows gallons per minute.	Pumps gallons per minute.	Elevation above sea level	Diameter in inches.	Remarks.
Anglesea,	Water Co.,	Geo. Ridpath,	350	350	10	60	....	125	....	8—6	No section received.
*Barnegat City,	J. W. Haddock,	J. V. Conover,	440	370	....	....	20	80	5	......	
*Barnegat,	Water Co.,	J. V. Conover,	155	100	....	....	150	....	30	8—6	
*Fortescue,	Mr. Bradford,	....	306	302	3½	2	....	60	5	4	
*Ocean City,	Dickson, Campbell Co.,	T. B. Harper,	805	....	....	17	50	30	10	......	
*Absecon,	A. C. Water Co.,	T. B. Harper,	190	136	....	....	50	520	6	6	
Sea Isle City,	Water Co.,	J. V. Conover,	138	130	....	....	....	200	....	......	Well draws from coarse sand at depth of 130 feet.
*Stone Harbor,	S. J. Realty Co.,	T. B. Harper,	860	820	7+	24	28	126	....	8—3	Well utilizes two horizons.
Wildwood,	Water Co.,	Geo. Ridpath,	340	....	....	....	....	50	....	......	No section given.
Woodbine,	Water Co.,	Geo. Ridpath,	158	145	....	....	....	200	....	......	Utilizes two horizons; the first was struck at a depth of 75 feet.

* See notes at end of the table.

Notes on Wells in the Miocene.

Barnegat.—The reported section of the Water Company's well at Barnegat is as follows:

Section of Barnegat Well.

Strata.	*Depth.*	
Quartz sand,	0– 40	feet
Gravel—*water bearing,*	40– 50	"
Coarse quartz sand,	50– 60	"
Sand with finely broken shells,	60– 80	"
Clay and fine gravel,	80–120	"
Gray sandy clay,	120–130	"
Fine quartz sand,	130–135	"
Sand and fine gravel,	135–149	"
Gravel (1/8 to 3/8 inch diam.) *water,*	149–155	"

The elevation being 30 feet, the water horizon lies about 120–125 feet below sea level probably in the Cohansey formation. The well flows 150 gallons per minute.

Barnegat City.—A well drilled for J. W. Haddock along the beach at an elevation of 5 feet, gave the following section:

Section at Barnegat City.

Strata.	*Depth.*	
Sand,	0– 40	feet
Gray sand—grains clay coated,	40– 60	"
Gravel (coarse to very fine),	60–130	"
Fine sand slightly micaceous,	130–150	"
Hard clay containing small pebbles, diatomaceous,	150–310	"
Coarse gray sand,	310–330	"
Coarser sand,	330–350	"
Clay containing lignite,	350–365	"
Coarse quartz sand—*water,*	365–405	"
Very fine micaceous sand,	405–440	"

The beds below 150 feet and perhaps below 130 feet are referable to the Kirkwood. The water-bearing stratum from 365 to 405 feet, from which a flow of 20 gallons per minute was obtained, is tentatively regarded as the equivalent of the 720-foot Atlantic City horizon.

Fortescue.—The record of this well was obtained from Mr. S. P. Foster, of Elmer. It is located on the beach of Delaware bay, the section being as follows:

Section at Fortesque.

Strata.	*Depth.*		*Formations.*
Beach sand,	0– 18	feet.	Recent.
Marsh mud,	18– 38	"	
Quicksand,	38–200	"	Cohansey and Kirkwood.
Sand and shell beds,	200–250	"	
Clay,	250–300	"	
Shell bed,	300–302	"	
Greenish sand and gravel—water,	302–306	"	

Ocean City.—At Ocean City a well was drilled for The Dickson-Campbell Co. at West End ave. and 12th street to a depth of 805 feet, which flowed 50 gallons per minute.

Section at Ocean City.

Strata.	*Depth.*		*Formations.*
Sand,	0–180	feet.	Recent.
Gray clay,	180–190	"	Cohansey.
Gray sand,	190–235	"	
Fine sand,	235–260	"	
Alternating layers gravel, sand and clay,	260–285	"	
Blue clay,	285–330	"	Kirkwood.
Sand,	330–385	"	
Blue clay,	385–490	"	
Find sand with shell,	490–515	"	
Coarse sand,	515–575	"	
Black sandy clay—shells,	575–750	"	
Fine gravel—*water*,	750–800	"	
Sand and clay,	800–805	"	

This section was not reported in so great detail as that in the Annual Report for 1896, and as reported the resemblance in the two sections does not seem to be close. In both, however, water was struck at essentially the same depth, 746 and 750 feet, the horizon being correlated with the great 800-foot horizon at Atlantic City.

Absecon.—A well at the Absecon Pumping Station known as No. 2, sunk in 1904, yields under air lift 750,000 gallons per day[1]. Its depth is 201 feet, the water being drawn from a coarse

[1] Information from Mr. E. E. Lampher, Engineer of the Atlantic City Water Department.

sand between 156–206 feet, a lower horizon than that utilized by the other wells. The detailed section is as follows:

Section at Absecon.

Strata.	*Depth.*		*Formations.*
Black mud,	0– 5	feet	Recent and Pleistocene.
White sand,	5– 13	"	
Blue clay,	13– 23	"	
Clay and sand,	23– 30	"	
White sand,	30– 73	"	Cohansey.
Yellowish sand,	73– 90	"	
Coarse sand and gravel (*water*),	90–100	"	
Fine sand and gravel (*water*),	100–116	"	
Blue sandy clay,	116–131	"	
Hard yellow clay,	131–146	"	
Dark brown sand—some coarse (*water*),	146–201	"	

The dark-colored sand reached at 146 feet (140 feet below tide) has a thickness of 112 feet or more, as shown by a test boring put down in 1903[1] and corresponds to a somewhat thicker sand bed (185–190 feet) reached at Atlantic City at about 190 feet below tide. Both water-bearing horizons are referred to the Cohansey formation, the top of which is tentatively placed at about 30 feet.

Stone Harbor.—A well drilled by Thos. B. Harper one-half a mile southwest of the Post Office at Stone Harbor for the South Jersey Realty Company penetrated 860 feet. It flowed 28 gallons per minute 7 feet above the surface, and on a 48-hour pumping test the water was lowered about 24 feet, the yield being 126 gallons per minute. The well was finished with a 3-inch strainer from 820 to 860 feet.

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[1] Annual Report for 1904, p. 263.

Section at Stone Harbor.

Strata.	*Depth.*		*Formations.*
Sand, gravel, some clay,	0– 60	ft.	Recent and Pleistocene.
Sand, slight color changes white to brown,	60–385	"	Cohansey.
Sandy clay,	385–410	"	Kirkwood.
Chocolate-colored clay,	410–440	"	
Sandy clay,	440–495	"	
Stiff black clay,	495–520	"	
Clay containing shells,	520–545	"	
Clay with coarse quartz grains and shells,	545–620	"	
Rock layers 5 in. and 24 in. at 553 and 565 feet.			
Fine sand, shells (scant supply water at 710),	645–745	"	
Sand and clay, shells,	745–795.	"	
Rock layer 18 inches at 797 feet.			
Coarse sand (*water*),	795–860	"	
Rock layer 37 inches at 825 feet.			

The Cohansey-Kirkwood contact seems best put at 385 feet. At Avalon to the northeast it may be either at 300 or 385 feet, while at Wildwood it is apparently at 328 feet. The water horizon, 795 to 860 feet, does not correspond to the 800-foot Atlantic City horizon, which occurs at Avalon at 875–925 feet, and at Wildwood at 887–931. It is better referred to the 720-foot horizon at Atlantic City.

WELLS IN PLEISTOCENE AND RECENT FORMATIONS.

In the northern part of New Jersey the Pleistocene formations comprise the various deposits made by glacier ice and the waters resulting from their melting. They include stony clay (till), gravel, sand and locally laminated clay, and vary in thickness from nothing up to 250 feet or more. The gravel and sand deposits occur more commonly in the valleys, while the till predominates on slopes and hilltops. These two types of deposits are frequently interbedded in all possible relationships. Till may underlie or cover beds of sand and gravel or may occur between them. So, too, beds of sand or gravel may occur between layers of till. The till varies considerably in texture and permeability, but it is less porous than the sand and gravel. The latter, particularly where they underlie beds of till in valleys or on lower slopes, frequently carry large amounts of water and some striking examples of flowing wells have been obtained under these conditions. Large supplies of water from wells in till alone are much less common.

In the central and southern portions of the State the Pleistocene formations are beds of yellowish gravel and sand rarely exceeding 30 or 40 feet in thickness, although in Cape May County and in other counties along the shore they may exceed that amount. Locally these formations may yield some water, but most wells, except shallow dug wells, go to underlying formations.

Along the beaches shallow wells draw from sands and gravels of recent age, but these supplies are uncertain and readily subject to pollution, as the water is essentially a surface supply.

WELLS IN THE PLEISTOCENE FORMATIONS.

LOCATION.	OWNER.	DRILLER.	Total depth.	Depth to principal water bed.	Height to which water rises.	Water is lowered.	Flows gallons per minute.	Pumps gallons per minute.	Elevation above sea level.	Diameter in inches.	REMARKS.
Camden,	Wm. Weldey,	W. C. Barr,	34	....	....	....	....	8	....	......	Water not particularly good; used in stable.
Cranford,	Miss Donaldson,	F. T. Cladek,	71	....	....	....	3	50	....	5	*Feet.* Glacial sand, 0—70; Red shale, 70—71
Cranford,	Wm. Meyers,	....	60	59	22	....	....	15	....	6	Glacial sand and gravel.

Trenton, May 24, 1910.

PART III.

Notes on the Mineral Industry.

BY HENRY B. KÜMMEL.

Notes on the Mineral Industry for 1909.

BY HENRY B. KÜMMEL.

The plan of collecting the mineral statistics in co-operation with the U. S. Geological Survey tried last year was not pursued this year. It was found that the National census would make necessary a combination of effort between the Census Bureau and the U. S. Geological Survey, and would delay the collection and compilation of data. It did not seem advisable for the State Survey to duplicate this work, and, therefore, the collection of data was restricted to the iron, zinc, copper, Portland cement and crystalline limestone products, of which the State Survey has obtained returns for a considerable period. Through the courtesy of the U. S. Geological Survey it is possible also to present at this time data regarding the production of sand and gravel for 1909.

IRON MINING.

During 1909 the iron-mining industry in New Jersey recovered very largely from the general depression and stagnation which had prevailed during the preceding year. Fewer mines were reported active, but the production at those which were worked was in most cases considerably in excess of that for 1908. The following mines have been reported as having been active during all or a portion of the year: Ahles, Shoemaker, Washington, Mount Hope group, Richard, Hude, Hurd (at Wharton), Hoff, Wharton, Orchard and Peters. With the exception of the Ahles mine, the product of which is a soft, manganiferous ore, and a lesser amount of limonite from the Shoemaker, all the ore mined was magnetite, the total production being 539,779 long tons. This is an increase of 107,213 tons over that of 1908, but is less than the maximum of 558,137 tons in 1907. The reports show that at the close of the year 101,478 tons remained on the dumps, which is 13,740 tons less than at the close of 1908, so that the consumption was slightly in excess of the amount mined.

The amount of metallic iron in the ore varied considerably, the lowest reported being a few thousand tons of 45 per cent. ore, while the best was about 100,000 tons carrying 59 per cent. The average per cent. of metallic iron in all the ore mined was reported to be 56.00 per cent.

Any endeavor to obtain the actual gross commercial value of the ore at the mines is attended with difficulty. About 90 per cent. or more of the ore mined was sent to furnaces controlled by the companies which own the mines and was not sold in the market. Under these conditions the value of the ore at the mine is largely a matter of bookkeeping, each company having its own practice as to the value at which the ore is charged. The highest figures reported were $4 per ton, the lowest $2.75. In both cases the ore contained 58 per cent. metallic iron or better. The reported value is $1,690,496, an increase of $433,418 over that of 1908. The average value per ton was $3.13 as against $2.94 in 1908, an increase of 19 cents per ton.

The average value per ton as reported is slightly less than the actual selling price of some of the ore having nearly the average content of metallic iron, so that $1,690,494 is probably a little under rather than over the true commercial value.

With increasing depth and extent of underground workings the mines become more expensive to operate through greater cost for pumping, hauling, hoisting, etc. This tendency has been met in many mines by more efficient machinery and more economical methods, so that mining costs in our best equipped mines are to-day probably no higher than they were 20 or 30 years ago, although the mines are much deeper. Whether the maximum of efficiency and economical working has yet been attained, or whether as greater depths are reached increased costs from this cause can be met by further economy, has yet to be demonstrated.

Many mines in the State have been abandoned, for the time being at least, because under present conditions of costs and ore values they could not be profitably worked. Owing to varying conditions, it is hardly possible to compare working costs in two mines, or to give figures which are of more than very general application.

The following percentages based on the actual experience of one company in 1909 are, in a general way, indicative of the mining costs in well-equipped and well-managed New Jersey magnetite mines:

Table of Costs of Mining.

	Percentage of cost.
Labor at mines,	63.8
Superintendence and other overhead charges,	01.6
Coal, including freight on the same,	17.9
Timber, including freight on the same,	2.1
Powder, fuse, oils, candles and all other supplies,	13.5
Incidental expenses, taxes, accidents, etc.,	1.1
Total cost represented by	100.0

Iron Ore Mined Since 1870.

Previously reported,	17,918,508	tons.
Mined in 1909,	539,779	"

ZINC MINES.

Mr. R. M. Catlin, superintendent of the New Jersey Zinc Company mine at Franklin Furnace, reports that the total ore produced was 428,303 tons, of which 72,858 tons were taken from the open cut. This is an increase of 71,846 tons over 1908. Operations were carried on in 40 different stopes, and about 700,000 feet of timber were placed.

The Palmer shaft, commenced in 1906, was continued full size to the 1,150-foot level, or 1,445 feet on the incline. Much of the shaft has been very heavily timbered, while the four tracks of 70-lb. steel rails have been laid on concrete piers. The permanent shaft headgear and equipment have been completed, and two new

22x48-inch duplex, direct-acting, double drum, Allis-Chalmers Corliss hoisting engines have been installed.

Three electrically driven centrifugal pumps have been installed on the 1,050-foot level. Two smaller centrifugal pumps will be installed in a station just below the lowest level (1,150 feet) to raise to the main 1,050-foot pump such water as originates below that level. Two additional small electric centrifugal pumps will also be placed in the foot wall just below the 300-foot level to take care of surface water drained through the open cut.

Two 3-phase, 1,500 Kw., 480 volt, turbo generators, which will furnish electric power for the operation of the pumps and electric tramways, have been installed, and it is expected the electric haulage in the 300-foot, 759-foot, 950-foot and 1,150-foot levels by 6-ton electric locomotives will be in operation, and that ore will be hoisted by the new equipment by February, 1910.

Zinc Ore Mined Since 1880.

Previously reported, ...	3,737,047 tons.
Mined in 1909, ...	428,303 "

COPPER.

During 1909 some mining of copper ore was done at both the Pahaquarry Copper Mine in Warren County and at the Alpha Copper Mine (American Copper Mine) north of Somerville. At the former mine the work was chiefly of an experimental nature, some changes in the equipment of the mill being found necessary. These included the installation of a pumping station to furnish a water supply for the mill, an ore dryer, flotation system, and the electrifying of the plant.

As indicated in a previous report, the copper at the Pahaquarry mine occurs as the gray sulphide *chalcocite* impregnating a hard, gray quartzite of Silurian age, which outcrops on the flank of Kittatinny Mountain several hundred feet above Delaware River. Much of the chalcocite is so minutely disseminated that its presence is indistinguishable to the naked eye, owing to its close resemblance in color to the rock. It occurs also in thin seams sometimes along the bedding or joint planes, sometimes within the mass of the rock. Less frequently the fractured surface of the quartzite shows dark-gray areas several inches or even a foot in diameter, where the chalcocite has partially replaced the rock. All available data point to the existence of a considerable body of low-grade ore, the value of which depends entirely upon the cost at which it can be milled and concentrated. Inasmuch as the proposed treatment involves untried methods, the work is in the nature of an experiment, which, in view of the large investment made, it is to be hoped will prove successful.

At the Somerville mine, controlled by the Alpha Copper Company, work continued without much interruption until late in December, when the mine was shut down. Many improvements were installed during the year, including a new hoisting engine, larger cars, new dump, and additional Wilfley tables. Considerable ore was mined, concentrated and smelted, and some copper ingots were sold. During the winter the mine was kept pumped out, and a small force of men employed in perfecting improvements. It was reported that operations would be renewed early in the spring.

PORTLAND CEMENT.

The mills of the Alpha Portland Cement Company, the Vulcanite Portland Cement Company, and the Edison Portland Cement Company were all in operation during 1909 for varying periods. All the mills were shut down, or ran at only part capacity, for considerable portions of the year. The total production amounted to 4,044,623 barrels, as against 3,208,446 barrels for 1908, a gain of 836,177 barrels, or 26 per cent. over the previous year. In every case the production was far short of the reported capacity, ranging from 52 per cent. to 68 per cent., with an average of 61 per cent. for the entire State.

The total selling value for 1909 in bulk at the mills was $2,656,108, as against $2,420,868 for 1908, an increase of $235,240, or 9.7 per cent. The gain in amount of cement was 26 per cent., while in value it was less than 10 per cent. During 1908 the average selling price in bulk was 75 cents per barrel, whereas in 1909 it was only 65.6 cents.

In the three plants reporting, the number of kilns in operation were as follows: eighteen 60-foot kilns, six 100-foot, eight 125-foot and ten 150-foot kilns. These figures show an increase in the number of 125-foot kilns, a decrease in the 60-foot kilns and a decrease in the total number, with an increase in the total capacity.

The above figures afford no encouragement for the promotion of new cement plants. On the contrary, they only emphasize what was said in this connection a year ago, that the present capacity of the mills of this State and of the industry as a whole is far in excess of the present consumption, and is more than able to take care of any probable increase in the near future. It may be well to note also that a large cement company in a neighboring State, which was widely boomed two or three years ago as a gilt-edged proposition, and whose stocks and bonds were sold more or less extensively in New Jersey, passed into the hands of receivers before the plant was fairly in operation.

WHITE LIMESTONE.

No attempt has been made this year to collect complete statistics covering the quarrying of limestone, but the following facts regarding the production of the white crystalline limestone are put on record. Eight firms or corporations report the production of white limestone, most of these being located at McAfee, Hamburg and Franklin Furnace. The total amount quarried was reported to be 580,400 gross towns. Of this amount about 332,617 tons were used for flux, 194,127 tons in the manufacture of Portland cement, and the balance, 53,656 tons, in the manufacture of lime and for purposes not specified. The average value of the limestone sold for flux or cement was 52 cents per gross ton, while the approximate value of the manufactured lime was $4.56 per short ton.

One quarry, which was a small producer in 1908, did not report, but so far as could be learned the importance of this quarry as a producer had not increased, and no serious error in the above figures can have resulted from the failure to include this company. The increase in the production of white limestone as compared to 1908 was 48,077 tons.

SAND AND GRAVEL.[1]

The accompanying table shows the production of sand and gravel in New Jersey during 1909 and the value as compared with 1908:

Production of Sand and Gravel in 1909 and 1908.

Kinds.	1909. Amount short tons.	Value.	Value per ton.	1908. Value.
Glass sand,	85,696	$62,830	.73	$46,379
Molding sand,	499,291	310,910	.62	....
Building sand,	1,343,958	290,056	.22	274,418
Fire sand,	66,023	65,142	1.00	60,667
Engine sand,	33,269	10,131	.30	16,437
Furnace sand,	5,768	2,911	.50	3,474
Other sands,[2]	162,013	74,718	.46	42,923
Gravel,	494,696	117,675	.23	60,373
Total sand and gravel,	2,690,714	$935,373	.35	$712,178

From the above table it will be seen that there was an increased production in 1909 over 1908 in all grades of sand except engine sand and furnace sand, and that the total value for 1909 exceeded that of 1908 by $223,195. The figures are, however, still short of those reached in 1907, when the total value was given by the U. S. Geological Survey as $1,045,259.

The figures showing the average value per ton at the pit are instructive. Fire sand was worth a fraction of a cent over $1.00 per ton, with glass sand next in value at 73 cents, while building sand was worth only 22 cents and gravel 23½ cents per ton.

In connection with the low price of glass sand as compared to prices paid for it at the quarries in Pennsylvania, where it brings $1.25, it may be well to allude to the investigations made a few

[1] Statistics collected by the U. S. Geological Survey.

[2] Includes sand for stone polishing, glass grinding, filling by railroads, brick and pottery molding, filtration, etc.

years ago by the New Jersey State Survey regarding the constitution of glass sands.[1] The New Jersey glass sand contains more iron than the Pennsylvania sand, and hence brings a lower price. In the report referred to it was pointed out that the iron is present in certain iron-bearing minerals—magnetite, ilmenite, etc., which are more or less magnetic, and which it is possible to eliminate either by sieving or by magnetic separation. When this is done the New Jersey glass sands are as pure chemically as the best of the Pennsylvania sands, and should command as high a price. Inasmuch as the Pennsylvania sand costs between $2 and $3 per ton at the glass factories in south Jersey, the difference in cost would seem to be large enough to warrant some treatment of the New Jersey sand to eliminate the iron.

Burlington County is the chief producer of sand and gravel, its product being valued at $322,040, with Middlesex ($180,841), and Cumberland ($180,559), second and third respectively. Then come Cape May, Morris, Monmouth and Warren in the order named, with productions ranging from about $50,000 to $25,000 each, while all the other counties produced less than $10,000 each, except Hudson, Essex, Hunterdon and Mercer, which were not reported as producers.

Cumberland County led in the value of glass and molding sand, Middlesex in fire sand and engine sand; Burlington in building sand and in gravel; Camden in furnace sand and Cape May in "other sands."

May 24, 1910.

[1] Ann. Report State Geol. of N. J., 1906, p. 77 et seq.

PUBLICATIONS.

The Annual Reports of the State Geologist are printed by order of the Legislature as a part of the legislative documents. They are distributed by the State Geologist to libraries and public institutions, and, so far as possible, to any who may be interested in the subjects of which they treat.

It is the wish of the Board of Managers to fill out, so far as possible, incomplete sets of the publications of the Survey in public libraries, and librarians are urged to correspond with the State Geologist concerning this matter.

Six volumes of the Final Report series have been issued. Volume I., published in 1888, has been very scarce for several years, but all the valuable tables were reprinted in an appendix of Volume IV., of which a few copies still remain, although the supply of this volume is so far reduced that indiscriminate requests cannot be granted.

The appended list makes brief mention of all the publications of the present Survey since its inception in 1864, with a statement of the editions now out of print. The reports of the Survey are distributed without further expense than that of transportation. Single reports can usually be sent more cheaply by *mail* than otherwise, and requests should be accompanied by the proper postage as indicated in the list. Otherwise they are sent *express collect. When the stock on hand of any report is reduced to 200 copies, the remaining volumes are withdrawn from free distribution and are sold at cost price.*

The maps are distributed only by sale, at a price, 25 cents per sheet, to cover cost of paper, printing and transportation. In order to secure prompt attention, requests for both reports and maps should be addressed simply "State Geologist," Trenton, N. J.

CATALOGUE OF PUBLICATIONS.

GEOLOGY OF NEW JERSEY. Newark, 1868, 8vo., xxiv+899 pp. Out of print.

PORTFOLIO OF MAPS accompanying the same, as follows:

1. Azoic and paleozoic formations, including the iron-ore and limestone districts; colored. Scale, 2 miles to an inch.

2. Triassic formation, including the red sandstone and trap-rocks of Central New Jersey; colored. Scale, 2 miles to an inch.

3. Cretaceous formation, including the greensand-marl beds; colored. Scale, 2 miles to an inch.

4. Tertiary and recent formations of Southern New Jersey; colored. Scale, 2 miles to an inch.

5. Map of a group of iron mines in Morris County; printed in two colors. Scale, 3 inches to 1 mile.

6. Map of the Ringwood iron mines; printed in two colors. Scale, 8 inches to 1 mile.

7. Map of Oxford Furnace iron-ore veins; colored. Scale, 8 inches to 1 mile.

8. Map of the zinc mines, Sussex County; colored. Scale, 8 inches to 1 mile.

A few copies can be distributed at $2.00 per set.

REPORT ON THE CLAY DEPOSITS of Woodbridge, South Amboy and other places in New Jersey, together with their uses for firebrick, pottery, &c. Trenton, 1878, 8vo., viii+381 pp., with map. Out of print.

A PRELIMINARY CATALOGUE of the Flora of New Jersey, compiled by N. L. Britton, Ph.D. New Brunswick, 1881, 8vo., xi+233 pp. Out of print.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. I. Topography. Magnetism. Climate. Trenton, 1888, 8vo., xi+439 pp. Out of print.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part I. Mineralogy. Botany. Trenton, 1889, 8vo., x+642 pp. Unbound copies, postage, 25 cents. Bound copies, $1.50.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part II. Zoology. Trenton, 1890, 8vo., x+824 pp. (Postage, 30 cents.)

REPORT ON WATER-SUPPLY. Vol. III. of the Final Reports of the State Geologist. Trenton, 1894, 8vo., xvi+352 and 96 pp. (Postage, 21 cents.)

REPORT ON THE PHYSICAL GEOGRAPHY of New Jersey. Vol. IV. of the Final Reports of the State Geologist. Trenton, 1898, 8vo., xvi+170+200 pp. Unbound copies, $1.00; cloth bound, $1.35, with photo-relief map of State, $2.85. Map separate, $1.50.

REPORT ON THE GLACIAL GEOLOGY of New Jersey. Vol. V. of the Final Reports of the State Geologist. Trenton, 1902, 8vo., xxvii+802 pp. (Sent by express, 35 cents if prepaid, or charges collect.)

REPORTS ON CLAYS AND CLAY INDUSTRY of New Jersey. Vol. VI. of the Final Reports of the State Geologist. Trenton, 1904, 8vo., xxviii+548 pp. (Sent by express, 30 cents if prepaid, or charges collect.)

BRACHIOPODA AND LAMELLIBANCHIATA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1886, quarto, pp. 338, plates XXXV. and Map. (Paleontology, Vol. I.) (To residents of New Jersey, by express, charges collect; to non-residents, $1.50, charges prepaid.)

GASTEROPODA AND CEPHALOPODA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1892, quarto, pp. 402, Plates L. (Paleontology, Vol.

II.) (To residents of New Jersey, by express, charges collect; to non-residents, $1.40, charges prepaid.)

PALEOZOIC PALEONTOLOGY. Trenton, 1903, 8vo., xii+462 pp., Plates LIII. (Paleontology, Vol. III.) (Price, $1.00.)

CRETACEOUS PALEONTOLOGY. Trenton, 1907, 8vo., ix+1106 pp., Plates CXI. (Paleontology, Vol. IV.) (Price, $2.70.)

ATLAS OF NEW JERSEY. The complete work is made up of twenty sheets, each about 27 by 37 inches, including margin. Seventeen sheets are on a scale of 1 inch per mile and three on a scale of 5 miles per inch. It is the purpose of the Survey gradually to replace Sheets 1-17 by a new series of maps, upon the same scale, but somewhat differently arranged so as not to overlap. The new sheets will be numbered from 21-37, and will be subject to extensive revision before publication. These sheets will each cover the same territory as eight of the large maps, on a scale of 2,000 feet per inch. Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 15, 16 and 17 have already been replaced as explained below.

No. 10. Vicinity of Salem from Swedesboro and Bridgeton westward to the Delaware.

No. 14. Vicinity of Bridgeton, from Allowaystown and Vineland southward to the Delaware Bay shore.

No. *19. New Jersey Relief Map.* Scale, 5 miles to the inch. Hypsometric.

No. 20. New Jersey Geological Map. Scale, 5 miles to the inch. (Out of print.)

No. 21. Northern Warren and Western Sussex counties. Replaces Sheet 1.

No. 22. Eastern Sussex and Western Passaic counties. Replaces Sheet 4.

No. 23. Northern Bergen and Eastern Passaic counties, to West Point, New York. Replaces northern part of Sheet 7.

No. 24. Southern Warren, Northern Hunterdon and Western Morris counties. Replaces Sheet 2.

No. 25. Morris and Somerset counties, from Lake Hopatcong to Somerville and New Brunswick. Replaces Sheet 6.

No. 26. Vicinity of Newark and Jersey City—Paterson to Perth Amboy. Replaces in part Sheet 7.

No. 27. Vicinity of Trenton—Raven Rock to Palmyra, with inset, Trenton to Princeton. Replaces Sheet 5.

No. 28. Trenton and Eastward—Trenton to Sayreville. Replaces Sheet 8.

No. 29. Monmouth Shore, with the interior from Ernston to Lakehurst. Replaces Sheet 9.

No. 31. Vicinity of Camden, to Mount Holly, Hammonton and Elmer. Replaces Sheet 11.

No. 32. Part of Burlington and Ocean counties, from Pemberton and Whitings to Egg Harbor City and Tuckerton. Replaces Sheet 12.

No. 33. Southern Ocean County—Tuckerton to Tom's River and Chadwicks. Replaces Sheet 13.

No. 35. Vicinity of Millville, from Newfield to Port Norris and Cape May Court House.

No. 36. Parts of Atlantic and Cape May counties—Egg Harbor City to Townsend's Inlet, with inset of New Inlet and Great Bay.

No. 37. Cape May—Cape May City to Ocean City and Mauricetown.

No. 38. New Jersey State Map. Scale, 5 miles to the inch. Shows all municipalities.

Other sheets of the new series, Nos. 21–37, will be printed from time to time, as the older sheets become out of print. All the maps are sold at the uniform price of twenty-five cents per sheet, either singly or in lots. Since the Survey cannot open small accounts, and the charge is merely nominal, remittance should be made with the order. Order by *number* of the State Geologist. Trenton, N. J.

TOPOGRAPHIC MAPS, NEW SERIES.

These maps are the result of recent revision of the earlier surveys, and contain practically all of the features of the one-inch scale maps, with much new material. They are published on a scale of 2,000 feet to an inch, and the sheets measure 26 by 34 inches. The Hackensack, Paterson, Boonton, Dover, Jersey City, Newark, Morristown, Chester, New York Bay, Elizabeth, Plainfield, Pluckemin, Amboy, New Brunswick, Somerville, Navesink, Long Branch, Shark River, Trenton, Camden, Mt. Holly, Woodbury, Taunton and Atlantic City sheets have been published and are now on sale. The price is twenty-five cents per sheet, *payable in advance*. Order by *name* any of the sheets above indicated as ready, of the State Geologist, Trenton, New Jersey.

GEOLOGIC ATLAS OF NEW JERSEY.

The State Geological Survey, in co-operation with the U. S. Geological Survey, is engaged in the publication of a Geologic Atlas of New Jersey. It will be issued in several parts, each part containing a complete discussion of the geography and geology for the region covered. Each volume will comprise (1) pages of descriptive text, (2) a topographic map, (3) geologic maps showing the distribution and structure of the various rock formations, the occurrence of all mineral deposits of economic importance, and (4) in some cases pages of half-tone illustrations. The following folios are now ready:

THE PASSAIC FOLIO, which covers the region from Morristown to Jersey City, and from Perth Amboy and New Brunswick to Pompton and Westwood, comprising 945 square miles; scale, 2 miles to an inch. It includes 27 pages of text, a topographic map, 3 geologic maps and a page of illustrations. Price, 25 cents; postage, 15 cents; if sent by express, charges collect.

THE FRANKLIN FOLIO covers the territory from Branchville and Newton, on the west, to Stockholm on the east, and from Andover and Petersburg, on the south, to Libertyville on the north, or 235 square miles; scale, 1 inch to a mile. In addition to the regular text and maps it includes a special study and description of the famous zinc deposits at Franklin Furnace, and of the white crystalline limestones. Price, 25 cents; postage, 15 cents extra; if sent by express, charges collect.

THE PHILADELPHIA FOLIO covers parts of New Jersey and Pennsylvania adjacent to Philadelphia. It is a double folio (scale, 1 inch per mile), having four topographic maps, four geologic maps, two maps showing, by means of cross sections, the geological structure and the relation of the various rock formations to each other below the surface, a page of illustrations and twenty-four pages of descriptive text. Price, 50 cents; postage, 15 cents extra; if sent by express, charges collect.

THE TRENTON FOLIO describes the region around Trenton as far as Stockton, Millstone, Hightstown, New Egypt, Mount Holly, Delanco and Newtown, Pa., an area of 911 square miles. It contains descriptive text and three maps (scale, 2 miles per inch). It is published in two forms, the folio size (21¾ by 18½ inches) and a pocket or octavo size (9¼ by 6 inches). In the latter the maps are on thin paper, are folded and in a pocket. This size is more convenient for field use than the folio size. Price, folio edition, 25 cents, postage 15 cents extra; pocket edition, 50 cents, postage 10 cents extra. If sent by express, charges collect.

Other folios will be prepared and issued from time to time until the entire State is covered.

Orders for these folios should be addressed to the State Geologist, Trenton, N. J., and *remittance must accompany the order.*

ANNUAL REPORTS.

REPORT OF PROFESSOR GEORGE H. COOK upon the Geological Survey of New Jersey and its progress during the year 1863. Trenton, 1864, 8vo., 13 pp. Out of print.

THE ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to his Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1864. Trenton, 1865, 8vo., 24 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to his Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1865. Trenton, 1866, 8vo., 12 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, on the Geological Survey of New Jersey, for the year 1866. Trenton, 1867, 8vo., 28 pp. Out of print.

REPORT OF THE STATE GEOLOGIST, Prof. Geo. H. Cook, for the year of 1867. Trenton, 1868, 8vo., 28 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1869. Trenton, 1870, 8vo., 57 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1870. New Brunswick, 1871, 8vo., 75 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1871. New Brunswick, 1872, 8vo., 46 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1872. Trenton, 1872, 8vo., 44 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1873. Trenton, 1874, 8vo., 128 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1874. Trenton, 1874, 8vo., 115 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1875. Trenton, 1875, 8vo., 41 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1876. Trenton, 1876, 8vo., 56 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1877. Trenton, 1877, 8vo., 55 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1878. Trenton, 1878, 8vo., 131 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1879. Trenton, 1879, 8vo., 199 pp., with maps. Out of print

ANNUAL REPORT of the State Geologist of New Jersey for 1880. Trenton, 1880, 8 vo., 220 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1881. Trenton, 1881, 8vo., 87+107+xiv. pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1882. Camden, 1882, 8vo., 191 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1883. Camden, 1883, 8vo., 188 pp. (Price, 50 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1884. Trenton, 1884, 8vo., 168 pp., with maps. (Postage, 8 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1885. Trenton, 1885, 8vo., 228 pp., with maps. (Postage, 9 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1886. Trenton, 1887, 8 vo., 254 pp., with maps. (Postage, 9 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1887. Trenton, 1887, 8vo., 45 pp., with maps. (Postage, 5 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1888. Camden, 1889, 8vo., 87 pp., with map. (Postage, 5 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1889. Camden, 1889, 8vo., 112 pp. (Postage, 6 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1890. Trenton, 1891, 8vo., 305 pp., with maps. (Postage, 10 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1891. Trenton, 1892, 8vo., xii+270 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1892. Trenton, 1893, 8vo., x+368 pp., with maps. (Price, $1.55.)

ANNUAL REPORT of the State Geologist of New Jersey for 1893. Trenton, 1894, 8vo., x+452 pp., with maps. (Postage, 18 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1894. Trenton, 1895, 8vo., x+304 pp., with geological map. (Postage, 11 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1895. Trenton, 1896, 8vo., xl+198 pp., with geological map. (Postage, 8 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1896. Trenton, 1897, 8vo., xxviii+377 pp., with map of Hackensack meadows. (Postage, 15 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1897. Trenton, 1898, 8vo., xl+368 pp. (Postage, 12 cents.)

ANNUAL REPORT of the State Geologist for 1898. Trenton, 1899, 8vo., xxxii+244 pp., with Appendix, 102 pp. (Postage, 14 cents.)

ANNUAL REPORT of the State Geologist for 1899 and REPORT ON FORESTS. Trenton, 1900, 2 vols., 8vo., Annual Report, xliii+192 pp. FORESTS, xvi+327 pp., with seven maps in a roll. (Postage, 8 and 22 cents.)

ANNUAL REPORT of the State Geologist for 1900. Trenton, 1901, 8vo., xl+231 pp. (Postage, 10 cents.)

ANNUAL REPORT of the State Geologist for 1901. Trenton, 1902, 8vo., xxviii+178 pp., with one map in pocket. (Postage, 10 cents.)

ANNUAL REPORT of the State Geologist for 1902. Trenton, 1903, 8vo., viii+155 pp. (Postage, 6 cents.)

ANNUAL REPORT of the State Geologist for 1903. Trenton, 1904, 8vo., xxxvi+132 pp., with two maps in pocket. (Price, 40 cents.)

ANNUAL REPORT of the State Geologist for 1904. Trenton, 1905, 8vo., x+317 pp. (Postage, 12 cents.)

ANNUAL REPORT of the State Geologist for 1905. Trenton, 1906, 8vo., x+338 pp., with three maps in a pocket. (Postage, 14 cents.)

ANNUAL REPORT of the State Geologist for 1906. Trenton, 1907, 8vo., vii+192 pp. (Postage, 10 cents.)

ANNUAL REPORT of the State Geologist for 1907. Trenton, 1908, 8vo., ix+192 pp. (Postage, 12 cents.)

ANNUAL REPORT of the State Geologist for 1908. Trenton, 1909, 8vo., xi+159 pp. (Postage, 8 cents.)

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C.C. VERMEULE, CONSULTING ENGINEER
MAP TO ACCOMPANY REPORT UPON THE DEVELOPMENT OF THE PASSAIC WATERSHED BY SMALL RESERVOIRS
1909
SCALE OF MILES
PORT JERVIS
MILFORD
MONROE
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SOUTHFIELDS
SUSSEX
BRANCHVILLE
FRANKLIN FURNACE
NEWTON
EDISON
BLAIRSTOWN
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PASSAIC WATERSHED
WANAQUE WATERSHED
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EAST ORANGE
KEARNEY
EAST NEWARK
HARRISON
SOUTH ORANGE
MORRISTOWN
MADISON
WASHINGTON
CHATHAM
SUMMIT
MILBURN
NEWARK
SUPPLIED FROM PEQUANNOCK RIVER
IRVINGTON
JERSEY CITY
SPRINGFIELD
JUNCTION
GLEN GARDNER
NEW PROVIDENCE
UNION
ELIZABETH
NEWARK BAY
BAYONNE
NEW YORK BAY
HIGH BRIDGE
WESTFIELD
CRANFORD
ROSELLE PARK
ROSELLE
GARWOOD
FANWOOD
ANNANDALE
CLINTON
NORTH PLAINFIELD
PLAINFIELD
LINDEN
RAHWAY
DUNELLEN
SUPPLIED FROM DRIVEN WELLS
CARTERET
SOMERVILLE
RARITAN
SOUTH PLAINFIELD
BOUND BROOK
WOODBRIDGE
SEWAREN
METUCHEN
RARITAN RIVER
PERTH AMBOY
FLEMINGTON
HIGHLAND PARK
NEW BRUNSWICK
LEGEND
Existing Reservoirs
Proposed Reservoirs
Driven Well Stations
Surface Water Stations
Territory Supplied From Driven Wells
Territory Supplied From Hackensack River
Territory Supplied From Passaic River
Territory Supplied From Pequannock River
Territory Supplied From Rahway River
Territory Supplied From Rockaway River