GEOLOGICAL SURVEY OF NEW JERSEY.

ANNUAL REPORT

OF THE

STATE GEOLOGIST,

FOR THE YEAR

1876.

TRENTON, N. J.:
JOHN L. MURPHY, STATE GAZETTE PRINTING HOUSE.
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With Compliments of

GEORGE H. COOK,

State Geologist,

New Brunswick, N. J.

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To His Excellency, Joseph D. Bedle, Governor of the State of New Jersey, and President of the Board of Managers of the State Geological Survey:

SIR—I have the honor herewith to submit my annual report on the operations of the Geological Survey for the year 1876.

With high respect, your obedient servant,

GEO. H. COOK,
State Geologist.

REPORT.

INTRODUCTION.

The Geological Survey of New Jersey has, from its first organization, had for its work a much wider field than belongs to the science of Geology. It has taken notice of our natural and indigenous products, mineral and vegetable, and, besides describing them, has pointed out their uses and economical applications. In this way, it has been an important agent in helping forward that extraordinary development of our population and wealth which has been going on for the past few years. Its work is still in the same direction, and while new objects of study and new uses for our products come up every year, it endeavors to select from them those which are of most pressing importance at the present time. The work of the Survey during the year 1876 has been as follows:

1. Exhibit of the Geological Survey of New Jersey at the Centennial.
2. Exhibit of New Jersey woods, soils and natural fertilizers in the New Jersey agricultural exhibit.
3. Arrangement of the Centennial collections for permanent exhibition in the Geological Rooms at the State House, Trenton.
4. Making surveys for topographical maps of upper and lower Passaic water-sheds.
5. Analyses, and examinations of water from all parts of the State.
6. Examinations and studies for the geology and chemistry of the fire and potters' clays.
7. Miscellaneous work in furnishing information in answer to inquiries regarding various natural products.

ASSISTANTS.

Prof. J. C. Smock, Assistant Geologist, has been engaged chiefly with the Centennial exhibits and catalogues, and with the geology and topography of the clay region.

Mr. E. H. Bogardus, Chemist, has been constantly occupied in analyzing waters, minerals, fertilizers and ores.

George W. Howell, Engineer, has been engaged for two months in surveying, leveling and describing ponds, streams and lines of elevation.

Wm. F. Gregory, Surveyor, was engaged for about six weeks in a topographical survey of the Rockaway and Pequannock valleys.

Wm. E. King, Engineer, was engaged for six weeks in levelling for the surveys on the Pequannock and Rockaway.

Wm. R. Whitehead and George McC. Taylor, students of engineering, surveyed and mapped Bear Swamp, near Trenton.

Messrs. E. A. Reiley and R. A. Meeker, students, have rendered valuable service in preparing and arranging specimens for the Centennial.

Fred. A. Canfield, M. E., has given special attention to the exhibition at the Centennial of our rarest and most beautiful minerals.

EXPENSES.

The expenses of the year have been kept considerably within the appropriation.

EXHIBIT OF THE GEOLOGICAL SURVEY AT THE CENTENNIAL.

The exhibit at the Centennial was made on the "allotted floor space, four spaces each, 14 feet by 8 feet, with passage on all sides, in the Main Exhibition Building, located," just north of Column T 70, near the southeast corner of the building. The specimens were arranged in eight cases, two on each space, standing with their backs together, and with high tablets between for the exhibition of the maps of the survey. The effort was made to show full and correct specimens of the results of the survey in all its departments.

A catalogue of the exhibit was prepared and printed, which gave name and short description of four hundred and twenty-six specimens from the various geological formations of the State; sixty-eight specimens of choice and beautiful minerals; thirty-six specimens of building stone, roofing slate, flag stone, limes, cements, &c.; two hundred and fifty-seven specimens of iron ore; twenty specimens of zinc ore; six specimens of copper ore; twenty-six specimens of potters' clays and glass sands; ten specimens of baryta, manganese, and other useful natural products; twenty-two specimens of iron and zinc from New Jersey ores; twenty or more specimens of fire-brick, pottery, alum, glass, &c., from State products; a collection of characteristic fossils from all the geological formations; twenty-four maps; a model of the zinc mine and vein at Franklin Furnace, and the publications of the Geological Survey, in an octavo volume. The preparation of this exhibit met the hearty approval of all, and it is to the active efforts and co-operation of the State officials that it owes its completeness. Hon. Lewis Perrine, Quarter-master General, and Samuel C. Brown, Esq., President New Jersey Centennial Commission, in particular, have given a great deal of time and labor to make this exhibition of State products creditable and pleasing. Valuable and unique specimens were loaned to the exhibition by Fred. A. Canfield, M. E., of Dover, N. J., by the New Jersey Zinc Company, by the Passaic Zinc Company, and by Rutgers College. Joseph F. Talson, of Jersey City, took great pains to make his collection of minerals, from Bergen Hill, perfect and handsome.

The following is the Centennial Commissioners' award for the exhibit:

"The United States Centennial Commission has examined the report of the Judges, and accepted the following reasons, and decreed an award in conformity therewith:

'GEOLOGICAL SURVEY OF NEW JERSEY.

'PROF. GEO. H. COOK, STATE GEOLOGIST.

'*Report*—Large, well selected and well arranged collections, showing (1) all the rocks of the various formations known in New Jersey, including the potters' clay and the green sand; (2) the ores of iron and zinc, and the products of their metallurgical treatment; (3) the building stones; (4) a fine collection of the rare crystalline minerals of the State; (5) plans illustrating the mode of occurrence of the magnetic iron ores, a model of the Franklin Furnace zinc mine, and the geological maps published by the State Survey; the whole giving a very complete and most instructive view of the scientific and economic geology of New Jersey.

'T. STERRY HUNT.

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MR. L. NICHOLSKY, Russia.
MR. NICHOLAS JOSSA, Russia.
PROF. DR. Th. KJERULF, Norway.'"

The exhibit was examined by thousands of visitors from all parts of the world; and we believe this public exhibition of our natural products and resources is, and will continue to be, both creditable and profitable.

At the close of the Centennial Exhibition, the specimens and cases were returned to Trenton, and are now arranged for permanent exhibition in the museum of the Geological Survey. The catalogue is to be printed in the report of the Centennial Commissioners to the Legislature of New Jersey.

AGRICULTURAL EXHIBIT.

The Geological Survey furnished specimens of soils, sub-soils, marls, and other natural fertilizers, and a collection of all the woods growing in New Jersey, for this collection, which was exhibited in Agricultural Hall, at E 17 and 18. It contained samples of one hundred and fourteen soils and sub-soils, representing the kinds found on the several geological formations, and from all parts of the State. Seventy-nine greensand marls, four calcareous marls, and seventeen fertilizers, as shells, lime, muck, &c.

These specimens were exhibited in glass bottles, enough of each being put in to show its characteristic appearance. They represent very fully the greensand marls and miocene marls in nearly all their more common forms, as found in the clay marls, in the lower, middle and upper marl beds, and in the miocene localities. The soils of the marl region were also well represented by good and fairly average specimens, showing all the varieties of soil found in that part of the State. From northern New Jersey we have a few good soils, typical of large areas of some of our best and most productive land.

These make the nucleus of a collection which will represent all the varieties of soil found within our limits, and they are all good specimens for chemical examinations and study.

Of the woods there were seventy-two species, brought from one hundred different localities, and each specimen was represented in three sections, one being cut crosswise, one lengthwise, and the third aslant. It is a fine collection of native woods.

At the close of the exhibition these specimens were returned to the museum of the Geological Survey at Trenton, for permanent exhibition, and are now arranged there. There are duplicates of many of the specimens, which can be exchanged or given to institutions of science and learning.

TRIGONOMETRICAL SURVEY OF THE STATE.

The work of triangulating the State, and determining the precise latitude of marked geographical points in different parts of the State, has been continued through the year. It is done by the United States Coast Survey, and at the expense of the general government, and at the same time it is done with the object of facilitating and making more complete the work of our Geological Survey.

There are now selected nine primary and three secondary stations, located in New Jersey, mostly on mountain peaks in the middle and northern part of the State, connecting with stations already determined in former coast survey work in the middle and southern part of the State, and extending into New York on the northeast, and into Pennsylvania on the southwest, to connect with similar surveys in progress in those States.

These stations are from ten to thirty miles apart, and the work of the past season has been very trying on account of the unusual prevalence of extreme heat and hazy weather. There have been weeks together in which the signals could not be seen at the distance of ten miles, and it was not uncommon, even when the air was clear, to find it so unsteady from hot and cold currents that observations could not be made. As each angle has to be measured at least seventy-two times, and the measurements must all agree within 5″ of each other or be rejected, it will readily be understood the work must go on very slowly. Its accuracy is such, however, as to pay for the labor bestowed. An inaccuracy of two inches on the length of a side eighteen miles long could probably be detected.

This work is needed now; we find immediate use for it in the construction of our topographic maps, which are to be used in locating lines for railroads, roads, lines of water supply, and drainage. And this coast survey work, in aid of ours, is looked upon with great satisfaction.

The triangulation map of the State is herewith submitted.

DRAINAGE.

The drainage of the Great Meadows on the Pequest, in Warren county, is still in progress. The outlet is finished, and a great number of stumps, logs, and other obstructions have been taken from the bed of the stream in the meadows. As soon as the outlet was opened, the bed of the stream began to lower as much as the outlet had been cut down, and the deepened channel continued to work its way up stream, and it has really worn backwards for a half mile or more in this way; and the bed of the stream has nearly the same slope that it had before, but several feet lower. The effect of this in draining the meadows is most gratifying; the ground is drying and becoming solid, so that cattle can pasture on it, and rich sweet grasses are taking the place of rushes and wild grass. It promises to be a perfect success. There is some delay just now by the damming of the stream to allow the dredge to float in clearing out a side ditch, but this will soon be removed, and the channel left open for the action of the winter and spring floods.

It is unfortunate that the work is delayed and its cost increased by prolonged and expensive litigation. This, it is hoped, will soon be settled, and the work of carrying out this great improvement be completed and made useful.

The drainage of the wet lands of the Passaic above Little Falls has not yet begun. There is difficulty in getting money in the present state of business in the country, but it is to be hoped some means will be devised for carrying it out and securing its great advantages.

The Bear Swamp, through which the Pennsylvania railroad passes on the line, about three miles east of Trenton, is an unsightly and discreditable piece of property. If it were drained so as to make it available for pasturage, meadow or cultivation, it would add to our agricultural wealth and remove an ugly blotch from one of the most conspicuous places in the State.

The swamp has been surveyed, and levels taken to find the most convenient place for drains. The map submitted to the Board shows the location of the swamp in its relation to Mount's and Whitehead's mills, and to the Assanpink and Mirey Run. Its area is seven hundred acres. There is nine feet fall in the Assanpink from the foot of Mount's dam to the water surface in Whitehead's mill pond, and the distance is one and five-sixths miles. The swamp along the railroad is also nine feet above Whitehead's pond. A good ditch, four feet wide and three feet deep, for a mile along the railroad through the swamp, and then a ditch, three feet deep and seven feet wide, running northwest from the railroad for a half mile to the Assanpink, would furnish a sufficient outlet for the water and soon dry the swamp. The Assanpink is tolerably clear, though some few obstructions from stumps, logs, brush and sand-bars, might have to be removed. The cost of these main ditches should not exceed two dollars an acre, and probably not half that sum.

WATER SUPPLY.

The subject of a supply of pure water for our large towns and cities has been alluded to in former reports. This year it has been further examined, and the results are herewith submitted. They are somewhat more specific and local than they would otherwise have been, on account of the circumstances under which they were collected. In the early part of the summer, a meeting was held in Newark to consider the question of water supply for the cities and towns in the counties of Hudson, Passaic, Essex, Union, and parts of Bergen and Middlesex. At this meeting the State Geologist, and others from outside the district, had been invited to be present and to take part in the proceedings. A committee was appointed, consisting of the mayors of Newark, Jersey City, Hoboken, Bayonne, Orange, Bloomfield and Montclair, who were instructed to collect more definite information upon the subject, and for that purpose to ask the Board of Managers of the State Geological Survey for their help. The application was made to Governor Bedle, President of the Board of Managers, and with his approval this work was done. The public importance of it will be appreciated when it is considered that the country interested in this investigation includes all that part of the State between the Hudson river and the First Mountain, and from a line north of Paterson and Hackensack to the Raritan river. With an area of four hundred and eight square miles, it has a population of four hundred and fifty-six thousand, and is increasing rapidly in inhabitants and in wealth, and from its location near the great commercial centre of our country, it must continue to attract a large share of the capital and industry of the State. An abundant supply of pure and wholesome water is indespensable to the proper development of the advantages of this favored district.

The present supply for Newark and Jersey City is drawn from the Passaic river near Belleville. This stream receives the sewage from Paterson, a city of near forty thousand inhabitants. The recent clearing of the channel above Newark, by the United States Government, has given more freedom to the tidal movement of the water, so that salt water from the bay and sewage from Newark may flow further up the stream than they formerly did. On account of these circumstances, there has been much doubt expressed as to whether this water was suitable and safe to be used for household purposes, and hence the inquiry.

In carrying out the investigation, we first submitted the various samples of water to analysis, as follows:

ANALYSES OF WATERS FROM VARIOUS PLACES—IMPURITIES IN 1,000,000 PARTS OF WATER.

	Solid Matter.		Ammonia.							
	Dried at 212° Fah.	Ash after burning.	Free.	Albuminoid.	Chlorine.	Sulphuric acid.	Lime.	Magnesia.	Source.	Date of collection.
1	271.70	208.78	0.133	0.215	91.52	17.658	21.204	13.385	Jersey City Pump Works, high water,	Aug. 31
2	111.54	77.22	0.100	0.190	10.01	8.338	21.201	9.266	" " low "	" "
3	223.08	171.60	0.109	0.325	70.07	6.867	20.025	17.503	" hydrant,	" 25
4	160.16	125.84	0.100	0.145	61.49	14.300	20.033	15.444	Newark Pump Works, high water,	" 31
5	100.10	74.36	0.118	0.195	4.29	7.840	20.033	8.752	" " low "	" "
6	128.70	108.68	0.020	0.180	25.02	6.860	20.020	12.355	" hydrant,	" 25
7		71.50	0.080	0.175	5.00	6.864	19.699	12.012	Passaic river at D. & L. R. R. bridge,	" 31
8	77.22	57.20	0.100	0.125	2.80	3.433	16.874	12.355	" " above Two Bridges,	July 20
9	72.20	50.05	0.133	0.115	2.90	9.810			" " at Hanover Bridge,	Aug. 16
10	145.86	102.96				4.905	20.821	11.880	" " above mouth of Rockaway,	July 20
11	85.80	78.65	0.093	0.120	2.20	9.809	17.875	12.260	Rockaway river below Dover,	Aug. 16
12	64.35		0.021	0.125	1.50	1.962	12.870	9.270	" " at Lower Longwood,	" "
13	45.00	35.03	0.080	0.215	1.71	3.924	11.211	7.202	Ramapo " Pompton furnace pond,	" 23
14	40.04	28.60	0.059	0.158	2.14	3.924	8.801	6.178	Ringwood " near Pompton,	" "
15	60.06	45.76	0.027	0.120	2.14	3.924	11.212	8.237	Pequannock " " "	" "
16	54.34	35.75	0.013	0.175	1.43	3.924	10.010	5.148	Morris Canal, head of Bloomfield Plane.	" 25
17	134.42	102.96	0.133	0.310	5.72	10.791	28.829	9.266	Hydrant at Elizabeth,	" 31
18	174.46	154.44	0.037	0.135	4.29	31.882	48.334	12.360	" " Rahway,	" "
19	77.22	57.20	0.027	0.235	6.44				" " Camden,	
20	27.50	14.30	0.000	0.158	1.30	3.924	3.703	2.703	" " New Brunswick,	
21			0.040	0.195	2.86	2.943	14.300	3.089	Mt. Holly Water Works (1),	
22	40.51	35.75	0.026	0.130	2.14	3.923	2.860	4.118	" " " (2),	
23	21.45		0.011	0.112	1.40	5.886	5.606	3.089	Hydrant at Hackettstown,	Aug. 16

The samples of water were collected in the dryest season of the year, when the flow of the streams is the smallest, and of course when impurities in water are least diluted. The results are given in millionth parts, as upon the whole most convenient. They may be turned into parts in a gallon by dividing them by 17.1. The quantities in any case are very small, the whole of the solid matters in a barrel of the most impure water analysed being less than an ounce.

The *first column* gives the weight of the dry matter left after evaporating one million parts of the water at a boiling heat.

The *second column* shows the weight of the ash or mineral matter left from burning the dry residue of the first column.

The *third column* gives the weight of the free ammonia in the water when it was first collected. This may come from the air or from matters decomposing in the water. A little is found in rain water, but any considerable quantity gives reasonable cause for suspicion of contamination. Corfield says if it amounts to one in a million of water, it must be condemned.

The *fourth column* gives the weight of albuminoid ammonia. This is the animal or vegetable substance in water which, in putrefying, finally forms free ammonia. It is in animal and vegetable substances, and in the filth from them; and in certain stages of their decay or putrefaction, is unwholesome and dangerous.

The *fifth column* gives the amount of chlorine. This is one of the elements of common salt. It is not in the least injurious, but it is not a constituent of pure water. It is always found in the excreta of animals, and its presence in water to much amount is a proof of contamination by sewage. A very little of it is to be found in our mountain streams, much more of it in the streams flowing through a cultivated country, and most in those upon which towns and cities are located.

The *sixth column* shows the amount of sulphuric acid. This is not particularly injurious, but it is of interest to those who use the water for making steam or for manufacturing purposes, and its amount, compared with that of the chlorine, helps to determine the origin of impurities in water, as will appear further on.

The *seventh column* gives the amount of lime. This is one of the chief constituents of hard water. It is not unwholesome in small quantities.

The *eighth column* contains the weight of the magnesia. In the quantities found in these waters, it is probably not unwholesome.

If the lime and magnesia together amount to forty parts or more in a million parts of water, it is called hard water; if less than forty, it is soft water.

The sulphate of lime forms a hard scale in boilers if present in much quantity.

It should be remarked, in regard to water analyses, that there is great difference of opinion as to their value. Formerly, the chief part of the chemical examination was to determine the kind and amount of mineral matter in the water, but longer experience has shown that this is of minor importance, both hard and soft waters being wholesome enough if they are otherwise pure. At the present time, the leading object of the chemist is to determine whether water is free from waste or decaying animal and vegetable substances, and in particular whether it is free from such as contain nitrogen and are capable of undergoing a kind of putrefactive decomposition. Such substances, in the course of their decomposition, yield different products, with more or less active properties, and finally yield ammonia, or nitric acid. Under the head of *albuminoid ammonia* it is intended to include those substances containing nitrogen, but which have not yet been decomposed so as to yield ammonia, or nitric acid. Wanklyn, an English chemist, has devised processes for determining free and albuminoid ammonia, which, in some conditions, are of astonishing nicety, and they have been very generally accepted and adopted by chemists. They have been used in preparing the results in the table of analyses here given. They are satisfactory for the free ammonia, but not for the albuminoid ammonia. In our trials upon water containing known quantities of urea in water, we could not get uniform results, nor detect more than a small part of the urea added. Urea is the important substance sought in the analyses, and it contains the elements which constitute albuminoid ammonia, but it is not accurately found; and there is nothing better at present.

Some points may however be made out from the analyses. From those of Jersey City and Newark waters, compared with those from farther up the Passaic, it is plain that the water supplied to those cities contains three or four times as much mineral matter as that from farther up stream. A comparison of the amounts of chlorine shows twenty or more times as much in the Jersey City and Newark waters as in those from the upper Passaic; but as the tide flows freely up from Newark Bay to a long distance above the water works pump-houses, it leaves it somewhat uncertain whether the impurity is sewage or salt water from the Bay.

For comparison, some of the constituents in one million parts of sea water and of urine are here given:

TABLE.

	Solid matter burned.	Chlorine.	Sulphuric acid.	Lime.	Magnesia.
Sea water......	35300.	19266.	2276.	671.	1475.
Urine......		4320.	1241.	224.	212.

The analysis of sea water is taken from Bischof's Chemical Geology. It is the average of analyses of nine specimens of water collected from as many different and remote places in the Atlantic and Pacific oceans. The different samples are remarkably like each other in composition and strength.

The analysis of urine is taken from Watts' Dictionary of Chemistry, and is probably a fair average, though different samples must of course vary widely with the food, mode of living, and health of individuals.

Now, by comparing the ratio of chlorine and sulphuric acid in No. 1 with the same in No. 7, the conclusion can safely be reached that the impurity is part salt water and part sewage, and that the waters 1–6, which are samples taken at high tide, low tide, and mixed in the reservoirs, are decidedly impure.

A comparison of 7 with 8—that is, of the water below Paterson and Dundee—with that above Little Falls, shows only a difference in the amount of chlorine, there being nearly twice as much in the former as in the latter, and it has undoubtedly been contaminated by sewage.

This conclusion can also be satisfactorily reached by testimony.

There is, at the present time, along the Passaic from Paterson to Belleville, and located on a surface of not more than twenty square miles, a population of very nearly fifty thousand—a population which has more than doubled within the last twenty years, and which has every prospect of continuing to increase for a long time to come. This population is largely engaged in manufactures, and the whole of the waste and filth from the factories, and all the sewage from houses, finds its way into the river. In addition to this the manufacturers' waste, and most of the sewage from Newark and Belleville, with a population of one hundred and twenty-six thousand, are emptied into the river; below the pumps, it is true, but the flood tide carries this polluted water up stream for a long distance, as far up as the pumps certainly, as the analyses show. This pollution of the water is, from the rapid increase of population, growing worse every year.

Water contaminated by filth and sewage, however offensive it may be, is not always, or even generally, poisonous. But it is never safe to be used for domestic purposes. In hot weather the organic matters in it decompose rapidly, producing new and unwholesome substances, which frequently are the causes of sickness and death. Diseases such as typhoid fever, cholera, &c., are conveyed in drinking water to an extraordinary extent, and exposure to air and oxidation destroys them very slowly. Even freezing does not always destroy organic poisons in water.

Every physician can cite cases in which well water, contaminated by soakage from privies and cess-pools, has been the active cause of sickness and death.

A few instances, to show the effects of water polluted by organic and rapidly decomposing substances, are selected from the mass of testimony that has been collected upon this subject.

In the transactions of the New Jersey State Medical Society for 1863, is a report by Dr. Thomas F. Cullen, of Camden, on the "Kensington Diarrhœa." He says:

"Persons only were affected with this disorder who drank of the water supplied by the works formerly owned by the district of Kensington, in the upper portion of the city of Philadelphia.

"The water supplying this reservoir is taken from the Delaware river, near where a creek and culvert empties into it, receiving the filth from numerous privies, sinks, culverts, &c., in a thickly settled and filthy manufacturing portion of the city. Of the residents so supplied with water very many were affected with diarrhœa, and many fatal cases occurred. The attention of the authorities of Philadelphia being called to this fact, this supply of water was cut off, and a supply from the Schuylkill substituted, during which time there was a subsidence of the disease—no new cases occurring and the majority of those sick recovering.

"On account of an accident to the Schuylkill works the Kensington works again opened, when a return of the disease followed.

"Many of the citizens of Camden are called by their business to that part of Philadelphia, where they remain all day, the mechanical nature of their business making large draughts of water necessary to their comfort. Among this class of our citizens we found many cases of the Kensington diarrhœa, the symptoms of which are diarrhœa, loss of appetite, great thirst, muscular debility; which symptoms, after continuing from a few days to a few weeks, become more severe, with a dry and cracked tongue, cool skin, contracted and leaden-hued, cramps in extremities and abdomen, discharges of a soap-suds character, or perfectly colorless, and very frequent. In fact, in a bad or neglected case all symptoms are present of Asiatic cholera, and the surprise to the practitioner, when called, is that the patients insist, in many instances, on their having been in nearly that condition for the past six, twelve, twenty-four or thirty-six hours, which in fact he cannot at first believe, and does not until he finds them remaining in the same state for twelve or twenty-four hours longer, in spite of vigorous treatment. * * * Some few fatal cases have occurred in Camden.

"It has been denied by some persons that this disease was the result of the water used, but patients of mine who have suffered from it have proved the falsity of the assertion by carrying their daily allowance of water with them for some time, during which time they maintained perfect health, but becoming careless again resorted to the supply there and were again attacked in the same way."

There was a very sudden and severe outbreak of typhoid fever at St. Mary's Hall, Burlington, in the beginning of the winter of 1874. The first case occurred on the 4th of December, and before the 20th of the month there were eighty cases. Sixty remained in the institution, and were all cured. Of the twenty who went away to their friends five died very soon, and two others after lingering for six months. The cause of the disorder was a polluted water supply.

A large well received its supply from the Delaware, and the water was pumped from this for the use of the establishment. Adjoining the well was a large cess-pool, lined with brick and cement, in which the cement had decayed, and allowed a leakage from the cess-pool to the well, by which the water was poisoned. As soon as the cause was known the proper remedies were applied, and the disease was stopped.

The disorder was entirely confined to the young ladies attending the school. Teachers and servants who drank tea and coffee only escaped the sickness altogether.

A similar case occurred at Lake Mahopac, in Putnam county, New York. This beautiful lake in the Highlands, five hundred feet above tide water, at head of Croton river, with abundance of pure water and fresh and invigorating air, is a popular place of summer resort. It is easy of access from New York, and large numbers of citizens go there during the hot weather. A favorite boarding house there was supplied with water from the lake, through an earthen pipe, which conducted it into a large brick cistern, and from that it was pumped to all parts of the building. The increased patronage of the house called for its enlargement. A steam engine was put in to drive the pump, and a new reservoir, connecting with the old one, to supply it with water. Still later, a larger engine and reservoir were constructed, and the old one fell into disuse, but its connections with the drinking-water cistern was not cut off. In the summer of 1871, some cases of typhoid fever, and more of diarrhœa and vomiting, occurred among the guests and occupants of the house. It was found that the disused reservoir received some of the kitchen slops, and that this accidental drainage had rendered it very filthy, and the water from this had flowed back and into the drinking water cistern, contaminating the whole water supply of the house. The reservoir was thoroughly cleansed and the trouble ceased, and being kept clean during the succeeding year the household was entirely exempt from sickness. In 1873 disease appeared again among the guests, but it was found that this originated from neglect to clean the reservoir, and on this being attended to the disorders ceased. In 1874 the proprietorship of the house was changed, and it was opened in the latter part of June with some five hundred guests and attendants. Several of the guests were attacked with disorders of the bowels before the end of the month. Extreme hot weather came on, the disorders became violent, and typhoid fever set in. Five persons died. The case was again investigated. The connection of the old reservoir, defiled with slops and drainage from the kitchen, was found to be still open to the cistern which supplied the house, and from thence the contamination and sickness came. The whole water arrangement was thoroughly cleansed at once, the old reservoir filled up, and the drainage safely provided for. The cause of sickness being removed, the place is now as healthy as ever.

The fact that cold weather, and even ice, does not always affect the organic impurities in water, or destroy their active properties, is well shown in a report from Dr. A. H. Nichols, of Rye Beach, N. H., published in the Sanitarian for August, 1876. At the beginning of the season of 1875 the guests at one of the hotels there were very generally affected by continued though mild digestive disorders. The attacks were characterized by "giddiness, nausea, vomiting, diarrhœa, and severe abdominal pain, accompanied by fever, loss of appetite, continued indigestion, and mental depression." It was soon found that sickness was confined to a single house. After much fruitless inquiry and investigation it was ascertained that the ice supply for this house was not obtained from the same source with the other houses there. It was cut from a flooded marsh, where the water was about two feet deep, and the water was supplied from a small saw-mill stream, which brought down and deposited in the pond large quantities of saw-dust. This was found to be rotting, offensive in smell, and to be contaminating all the water of the pond. The use of the ice was at once discontinued, and no more sickness occurred. It should be observed that the pond formerly had free opening to the sea, and the water was not stagnant, but had become so by the obstruction of the channel with stones and sand, which were driven in by storms.

An interesting case, illustrating the extreme difficulty of purifying water which has once been contaminated by the germs of disease, is given in the June number of the Journal of the London Chemical Society. It is in a paper by Dr. E. Frankland, "On some points in the analyses of potable waters." He says:

"The researches of Chauveau, Burdon, Sanderson, Klein, and others, scarcely leave room for doubt that the specific poisons of the so-called zymotic diseases consist of organized and living organic matter, and it is now certain that water is the medium through some, at least, of these diseases are propagated. It is evident, therefore, that an amount of exposure to oxydizing influences, which may resolve the dead organic matters present in water into innocuous mineral compounds, may, and probably will, fail to affect those constituents which are endowed with life. Indeed, instances are not wanting illustrative of the persistency of the typhoid and other similar poisons when they are diffused in water and then exposed to oxydizing influences. One of the most striking of these occurred at the village of Lausen, near Basel, Switzerland. It was investigated with much care and skill by Dr. A. Hägler, of Basel. In this healthy village, which had never within the memory of man been visited by epidemic typhoid, and in which even a single sporadic case had not occurred for many years, there broke out, in August, 1872, an epidemic which simultaneously attacked a large proportion of the inhabitants. About a mile south of Lausen, and separated from it by the mountain or ridge of the Stockhalden, which is probably an old moraine, from the glacial epoch, lies a small parallel valley, the Fürlerthal. In an isolated farm house, situated in this valley, a farmer, who had just returned from a long journey, was attacked by typhoid fever on the 10th of June. During the next two months three other cases occurred in the same house, viz.: a girl, who was attacked on the 10th of July, and the farmer's wife, and their son, who sickened in August. The inhabitants of Lausen were entirely ignorant of what had occurred at this solitary mountain farm, which was cut off from all communication with the rest of the world, when, on the 7th of August, ten of the villagers were suddenly struck down by typhoid fever, whilst during the next nine days the number of cases had already increased to fifty-seven, out of a population of seven hundred and eighty persons, living in ninety houses. In the first four weeks the number of cases reached one hundred (or above twelve per cent. of the population), and altogether, to the close of the epidemic at the end of October, one hundred and thirty, or seventeen per cent. of the population, were attacked, besides fourteen children who were infected at Lausen during their summer holidays, and became ill after their return to schools in other localities.

"The fever cases were pretty equally distributed throughout the entire village, but those houses, six in number, which were supplied from their own private wells, and not from the public fountains, were entirely exempt. This remarkable difference naturally led to a suspicion that the public water supply was connected with the cause of the epidemic, although the apparently immaculate source of this supply seemed to negative any such suspicion. The water came from a spring situated at the foot of the adjacent Stockhalden ridge. It was there received in a tank lined with brickwork, and carefully protected from pollution, nevertheless a careful investigation into the source of this spring placed beyond all doubt the origin of the infection. Ten years previously it had been proved that direct water communication, through the intervening mountain, existed between the spring and a brook in the Fürlerthal, flowing past the farmhouse in which the typhoid cases occurred. At that time there was spontaneously formed, by the giving way of the soil at a short distance below the farmhouse and close to the brook, a hole about eight feet deep and three feet in diameter, at the bottom of which a moderate stream of clear water was observed to be flowing. As an experiment, the whole of the brook water was now diverted into this hole, at the bottom of which it entirely disappeared, but in an hour or two the spring at Lausen, at that time nearly dry from a long drought, overflowed with an abundance of water, which was turbid at first, but afterwards clear, and this continued until the Fürler brook was again confined to its bed. It was, however, afterwards noticed that whenever the meadows below this hole were irrigated with the water from the Fürler brook, the volume of the Lausen water supply became greatly augmented a few hours afterwards. Now this irrigation, practised every year, was carried on in the summer of the epidemic from the middle to the end of July, the brook being polluted by the dejections of the typhoid patients, for it was in direct communication with the closets and dung heaps of the infected house, whilst all the chamber slops were emptied directly into it, and the dirty linen of the patients washed in it. Soon after the irrigation had begun, the water supplied to Lausen was at first turbid, acquired an unpleasant taste, and increased in volume. About three weeks after the commencement of the irrigation, the sudden explosion of typhoid fever in Lausen occurred.

"In his search after the cause of this outbreak, Dr. Hägler did not rest satisfied with the evidence just recorded, but supplemented it by the following ingenious and conclusive experiments: The hole in the Fürlerthal, already mentioned, was re-opened, and the brook again led into it; three hours later the fountains of Lausen delivered double their previous supply of water; eighteen cwts. of common salt, previously dissolved in water, were now poured into the hole and soon the water at Lausen exhibited a stronger chlorine reaction, gradually increasing until it became very strong, whilst the proportion of solid matter dissolved in the water augmented three-fold. The passage of the Fürlerthal water to the fountains of the fever-stricken village was thus established beyond doubt, but another interesting question here presented itself: Did the water find its way through the Stockhalden by a natural open conduit, or was it filtered through the porous material of the old moraine? To decide this point, two and a half tons of flour were first carefully and uniformly diffused in water, and then thrown into the hole, but neither an increase in the solid constituents, nor the slightest turbidity of the Lausen water was observed after this addition. Thus, the investigation of the typhoid epidemic at Lausen, showed:

"1. That the epidemic followed immediately after the use, for dietetic purposes, of water which had received the dejections of persons suffering from typhoid fever, and that it was confined to persons who drank the infected water.

"2. That the water still retains its infective properties after a filtration, which is efficient enough to remove very minute starch granules, but not sufficient at all times to prevent the passage of visible suspended matter in a still more minute state of division.

"3. That spring water which has been polluted with human excrements, before its descent into the earth, and which is subject to visible turbidity, is not always safe for domestic use.

"4. That water which is polluted with *normal*, as distinguished from *infected* excrementitious matters of human origin, may be used for dietetic purposes with impunity.

"Inasmuch, therefore, as no means are known of distinguishing between normal and infected excrements, and as excrementitious matters are liable to become infected constantly with typhoidal, and occasionally with cholera poison, it is not safe to consume water which is contaminated with human dejections. Further, as typhoidal poison is almost certainly organized and living, it is likely to resist oxidation much longer than the dead organic matters with which it is associated; and as this poison is not removed from water by natural filtration through nearly a mile of porous earth, it follows that the tracing of the previous history of potable water is of prime importance in water analysis."

This testimony is conclusive as to the dangerous character of water that has once been contaminated by poisonous sewage, and it is certain that the Passaic River, from Paterson downwards, is exposed to such contamination. Hence it becomes imperative that a supply of water for domestic uses should be obtained from other and less questionable sources.

A comparison of these waters of the lower Passaic with those above Paterson show a marked difference in favor of the latter. These are all pure enough for household use, and many of them are almost absolutely pure. The streams which form the upper Passaic come largely from a mountainous region which is rocky, rough and still in forest. Of the 750 square miles of drainage area for the upper Passaic, full 550 are in the region of granitic rocks, from which rain water runs off uncontaminated, and as pure as it fell. The remaining 200 square miles are in the region of red sandstone and trap-rocks, and the water dissolves out a little more mineral matter from the soils and rocks, but it is still soft and pure. The population on this area of 750 square miles is between 50,000 and 60,000, and not densely settled anywhere.

To ascertain if the conclusion that the upper Passaic water is pure and fit for all practical uses was a correct one, application was made to John Cooke, Esq., President of the Danforth Locomotive and Machine Company, of Paterson, for information as to the quality of the Passaic water above Paterson, in its household, steam and manufacturing uses. He says:

"In reply to your favor of the 4th inst., I beg leave to say:

"We use the Passaic water for all domestic purposes, and prefer it to any spring water we can get, except in a very dry time in the summer, when there is a slight taste of vegetable matter in it.

"We use it in the boilers at our works, it does not produce scale, seems perfectly free from anything that would produce it.

"It is used by all our dyers and bleachers, who speak in the highest terms of its quality, particularly the silk dyers.

"The Ivanhoe paper mill uses it for everything except the very finest paper, and in a dry time and in winter, when there is less surface water, can use it exclusively.

"You are at liberty to use this information as you deem best, and any further that I can give you will be given with pleasure.

"Yours truly,

"JOHN COOKE."

These particulars, from analysis and from testimony, are sufficient to prove the purity and excellence of the waters of the Passaic, above Paterson.

There are important points suggested by the analyses of the waters used at Elizabeth, Rahway, and Camden, as compared with the purer waters from Hackettstown, Mount Holly and New Brunswick. But the labor of the analyses made has been so great, and the time for making proper inquiries so limited, that conclusions must be deferred with the hope that favorable opportunities and more time may be given to this subject another year.

QUANTITY OF WATER TO BE COLLECTED.

The amount of water which can be collected from any portion of country is dependent on the rain-fall. Water is seen to collect in ponds, lakes, streams, springs and wells, but it all comes from the rain that falls on the districts that slope towards and drain into these natural or artificial receptacles. This drainage may be upon the surface, or it may be through earth, gravel or other open material beneath, but usually not far under the surface. A deficiency of rain-fall is soon seen in the diminished streams and reservoirs; and later the effect is seen in the failure of wells and springs. And the return of seasonable rains soon replenishes the exhausted sources of water supply.

It is to the rain-fall we must then look for data from which to ca-culate the amount that can be obtained from the *water-shed*, or drainage area of any district of country.

The annual rain-fall is nearly the same in all parts of New Jersey where records have been kept. The showers seem very unequal in different places, but in the aggregate for the year they furnish nearly the same quantity of rain at all the places of observation.

TABLE

Of the annual fall of rain and melted snow, in inches of depth, at various places in and on the borders of New Jersey; also, the greatest and least depths recorded:

PLACES.	Number of years.	Average amount Fall.	GREATEST.		LEAST.	
			Year.	Annual Fall.	Year.	Annual Fall.
Newark	33	46.06	1859	57.05	1856	34.07
Lake Hopatcong	23	42.55	1850	54.61	1866	30.06
New Brunswick	23	45.41	1873	59.95	1876	30.33
Trenton	11	46.49	1867	55.60	1870	38.20
Lambertville	22	44.25	1841	57.36	1856	32.32
New Germantown	7	44.33	1871	52.45	1872	39.75
Vineland	11	44.47	1873	54.94	1866	40.73
Greenwich	6	42.95	1868	47.63	1866	36.95
Philadelphia, Pa.	50	44.92	1867	61.18	1825	29.57
New York, N. Y.	36	45.60	1837	65.31	1836	27.57
Flatbush, L. I.	49	42.47	1859	58.92	1845	32.14

The observations and records for Newark are from 1843–76, and have been kept by Wm. A. Whitehead, Esq.

The Lake Hopatcong records were made by the late W. H. Talcott, C. E., and furnished from the Morris Canal Company's papers by the President, Joseph F. Randolph, Esq. They include the time from 1846–69.

The table of New Brunswick rain-fall was recorded at Rutgers College for 1854–67; by P. Vanderbilt Spader, Esq., for 1868–75, and at the College Farm for 1876.

The Trenton observations were made by E. R. Cook, Esq., and include the years from 1866–76.

The Lambertville observations were made by Lemuel H. Parsons, and have been taken from the American Almanac. They cover the period from 1838–59.

The New Germantown observations were recorded and sent by A. B. Noll, Esq. They cover the period from 1869–75.

The Vineland observations were taken and furnished by Dr. J. Ingram, and include the period from 1866–76.

The Greenwich observations were taken by Miss R. C. Sheppard from 1865–70, and were sent by her for this report.

The Philadelphia rain-fall is from the Pennsylvania Hospital reports, and includes the period from 1825–74.

The New York rain-fall is taken from Dr. Hough's New York Meteorology, second series. It covers the period from 1836–71. The observations from 1836–59 were taken at Fort Columbus, in New York Harbor, and the remainder at the Deaf and Dumb Asylum.

The Flatbush rain-fall is taken from the Brooklyn annual report of the Commissioners of City Works for 1874, and covers the period from 1836–74.

Detailed monthly and yearly registers of the rain-fall at Newark, near the mouth of the Passaic, and Lake Hopatcong, upon its head-waters:

TABLE OF RAIN-FALL AT NEWARK FOR THIRTY-FOUR YEARS,

As observed by WILLIAM A. WHITEHEAD, Esq., and by him prepared for this report.

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	TOTAL.
1843....					0.085	1.590	2.285	22.485	3.610	5.905	3.920	4.145	
1844....	4.985	1.640	4.785	0.390	3.550	2.560	5.820	2.080	2.970	5.515	2.040	3.875	40.210
1845....	3.370	4.210	3.765	1.275	2.155	3.400	2.175	4.800	2.455	2.255	2.875	3.735	36.470
1846....	5.125	4.150	3.415	3.265	8.745	2.175	4.730	4.105	0.550	2.815	8.745	3.745	51.575
1847....	4.655	6.075	4.145	0.850	3.155	6.250	3.305	2.890	11.300	3.460	2.840	5.910	54.835
1848....	1.825	1.815	2.395	1.335	5.985	6.005	2.065	0.955	2.195	4.965	2.720	4.520	36.780
1849....	0.640	2.690	4.855	0.910	4.235	1.090	2.365	8.085	1.600	6.930	2.180	4.470	40.050
1850....	5.010	3.055	4.175	3.030	7.435	3.535	7.420	4.725	4.405	1.725	1.520	5.110	51.145
1851....	2.010	4.500	3.967	6.090	3.930	1.105	6.435	1.520	0.625	3.660	4.610	1.930	40.382
1852....	2.920	2.205	4.805	5.215	2.675	1.720	2.535	4.165	1.740	2.170	5.845	7.545	43.540
1853....	3.090	5.220	3.145	3.015	4.675	3.655	3.250	11,225	5.030	5.080	3,670	1.285	52.340
1854....	1.790	5.020	0.980	11.365	4.170	2.100	3.580	1.125	3.960	2.440	4.310	2.635	43 475
1855....	4.030	3.466	1.895	2.470	2.365	4.525	4.470	4.160	2.250	5.260	2.890	6.500	44.261
1856....	3.370	1.250	2.000	2.570	4.315	3.120	1.410	5.700	2.665	1.400	2.790	3.485	34.075
1857....	3.830	1.580	1.990	7.155	6.030	5.345	5.080	4.015	3.810	3.955	0.870	5.785	49.365
1858....	3.405	2.495	1.010	3.852	4.995	4.650	2.995	4.210	1.410	3.010	4.785	4.260	41.077
1859....	6.055	3.800	6.885	5.305	2.250	3.945	4.025	6.265	6.985	2.550	3.785	5.200	57.050
1860....	2.320	2.710	1.225	2.510	5.000	1.815	2.720	6.235	5.650	2.835	6.715	3.420	43.155
1861....	4.465	1.885	4.915	4.920	5.190	2.600	1.120	3.970	3.260	2.865	6.425	1.990	43.605
1862....	5.415	3.695	3.995	3.215	3.045	6.605	3.020	3.005	2.125	4.265	4.455	1.850	44.690

TABLE OF RAIN-FALL—Continued.

1863....	4.270	4.250	5.250	5.835	4.490	1.045	5.955	4.975	1.300	3.445	2.610	4.575	48.000
1864....	1.730	0.825	3.145	3.670	5.280	1.855	2.675	3.210	4.680	2.675	3.950	4.760	38.455
1865....	4.090	4.570	4.890	3.340	5.730	3.485	6.735	3.935	3.210	4.685	3.300	4.385	52.355
1866....	1.740	5.070	1.820	2.820	4.400	2.505	1.840	5.345	5.470	3.970	2.090	2.910	39.980
1867....	1.610	5.640	4.395	2.575	6.550	9.745	3.755	10.615	1.235	4.620	1.945	2.045	54.730
1868....	3.275	1.620	2.170	5.255	6.925	5.895	8.535	4.755	8.955	1.250	4.375	3.845	56.855
1869....	3.420	5.055	4.670	1.150	4.670	5.845	3.690	1.555	2.540	6.820	3.085	5.435	47.935
1870....	4.725	4.265	4.555	7.000	1.995	3.125	6.965	3.095	2.795	4.750	2.460	2.185	47.915
1871....	3.035	3.045	4.990	3.685	3.950	7.105	4.140	5.310	1.990	6.026	3.990	2.175	49.441
1872....	1.845	1.775	3.880	3.745	3.075	4.270	8.940	6.625	3.240	3.110	4.175	3.785	48.465
1873....	5.820	3.885	2.760	5.835	3.755	1.715	6.615	7.765	3.550	3.740	4.670	2.470	52.580
1874....	5.670	3.168	2.135	8.715	2.755	3.580	4.230	2.785	9.050	2.435	2.860	2.810	50.193
1875....	3.310	2.400	3.820	3.135	1.595	2.325	5.985	10.215	1.930	2.870	4.360	2.610	44.565
1876....	1.200	5.355	10.000	3.305	3.045	1.585	3.060	2.450	7.505	1.260	4.040	2.515	40.320
Means....	33 years. 3.456	33 years. 3.403	33 years. 3.721	33 years. 3.903	34 years. 4.182	31 years. 3.585	31 years. 4.233	34 years. 5.846	34 years. 3.707	34 years. 3.668	31 years. 3.723	34 years. 3.672	34 years. 46.057
Greatest..	6.055	6.075	10.000	11.365	8.745	9.745	8.940	22.485	11.300	6.930	8.745	7.545	57.050
Least.....	0.640	0.825	0.980	0.390	0.085	1.090	1.120	0.955	0.550	1.250	0.870	1.285	34.075

* Very remarkable—perhaps unprecedented.

SEASONS.

	Spring Months.	Summer Months.	Autumn Months.	Winter Months.
Greatest quantity in any one year,	1854, 16.515	1843, 26.360	1847, 17.600	1852–3, 15.855
Least quantity in any one year,	1855, 6.710	1854, 6.805	1856, 6.865	1871–2, 5.795
Mean quantity,	11.806	13.664	11.098	

Table of inches of rain and melted snow observed at the outlet of Lake Hopatcong,* for each month from January, 1846, to December, 1869.

Taken from the rain-gauge and feed record books in the Morris Canal office, Jersey City, N. J., kept by Wm. H. Talcott, Engineer and Superintendent.

Furnished for this report by Joseph F. Randolph, Esq., President Morris Canal Company, and copied by L. B. Ward, C. E.

TABLE.

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	TOTAL.
1846.........	3.88	0.42	6.34	2.03	4.88	3.64	7.17	7.78	0.87	3.23	5.76	4.12	50.12
1847	4.26	5.84	4.18	0.25	2.76	3.94	5.35	2.59	10.84	3.50	1 61	7.30	52.42
1848...	2.02	1.44	2.49	1.95	5.90	4.04	3.14	0.50	2 02	3.89	4.88	6.09	38.36
1849.........	0.48	1.34	3.90	2.40	5.25	1.33	1.37	5.66	0.50	9.47	2.77	4.75	39.22
1850.........	3.67	4.66	3.56	3.37	6.56	1.81	7.91	5.75	7 58	2.68	1.96	5.10	54 61
1851...	0 82	4.71	2.27	6.59	4.37	1.36	3.85	1.38	1.49	4.41	3.31	3.00	37.56
1852.........	2.91	3.05	3.48	5.25	2.36	2.17	5.17	6.15	2.05	2.82	6.12	5.54	47 07
1853.........	1.75	4.01	2.86	3.84	6.01	4.06	5.72	5.21	2.85	6.13	4.42	1.68	48.54
1854.........	2.71	4.07	1.07	7.35	5.36	3.85	5.17	1.55	5.80	2.13	3.95	2.10	45.11
1855...	3.43	0.40	1.55	2.67	6.04	7.64	7.51	2.02	1.86	9.94	3 03	7.24	53.33
1856.........	1.45	0.52	0.82	2.74	4.14	4.02	0.90	8.55	6.03	1.42	1.97	5.10	37.66
1857.........	1 50	2.20	1.62	6.66	6.22	4.63	4.75	4.69	2.67	4.56	2.24	5.66	47.40
1858........	2.43	1.84	0.40	3.21	6.37	4.15	4.24	4.21	1.96	2.72	4.05	3.83	39.41
1859...	5.15	2.87	7.54	5.03	2.10	3 99	3.25	6.62	8.73	1.87	4.09	2.09	53.33
1860.........	2.12	2.78	0.91	2.17	4.56	2.07	2.79	6.37	2.79	2.04	6.37	1.90	36.87
1861...	2.32	1.33	3.66	6.10	3.03	1.72	2.01	3.68	5.05	1.65	4.64	0.75	35.94
1862.........	3.37	1 50	2.48	2.69	1.89	6.10	2.84	1.97	2.08	3.65	2.97	0.75	32.19
1863.........	2.62	2.90	3.64	2.90	2.52	0.93	3.91	3.07	2.11	3.90	2.66	3.55	34.71
1864.........	0.98	0.46	2.25	3.31	7.69	1.32	1.66	5.01	3 17	1.36	2.68	1.61	31.50
1865.........	2 42	1.99	4.23	3.51	5.17	3 62	5.26	2.03	1.63	3.16	2.24	3.11	38.37
1866.........	0.61	4.54	0.60	2.13	2.49	3.63	1.92	3.05	4.44	2.21	2.41	2.03	30.06
1867.........	0.63	1.92	1.88	3.11	6.91	7.29	3.53	10.70	0.35	2.98	1.68	0.60	41.58
1868.........	1.97	0.97	0.80	2 46	5.33	7.24	3.39	3.37	11.44	1.04	3.90	1.02	42.93
1869.........	3.43	2.78	4.41	1.51	4.29	3.37	2.10	1.58	7.12	9.82	8.46	4.03	52.90
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept	Oct.	Nov.	Dec.	
Average	2.372	2.439	2.790	3.468	4.675	3.659	3.954	4.312	3.976	3.774	3.674	3.456	42.55
Greatest	5.15	5.84	7.54	7.35	7.69	7.64	7.91	10.70	11.44	9.94	8.46	7.30	54 61
Least	0.48	0.40	0.40	0.25	1 89	0.93	0.90	0.50	0.35	1.04	1.61	0.60	30.06

SEASONS.

	Spring.	Summer.	Autumn.	Winter.
Average	10.932	11.926	11.424	8.260
Greatest	1859, 14.670	1846, 18.590	1869, 25.400	1847, 14.220
Least	1866, 5.220	1851, 6.590	1867, 5.010	1848, 3.540

* Lake Hopatcong has an elevation of 914 feet above the sea level, and is 50 miles inland.

From these registers, and their slight differences from each other, we may safely infer that the annual rain-fall over all parts of New Jersey is nearly the same, and it may be set down in figures at thirty inches. The lowest observed annual rain-fall is 27.5 inches.

The rain that falls upon the ground does not all run off in the streams. A considerable portion is evaporated from the surface of the earth and water, and some is taken up by vegetation. In hilly countries, and where there is much rock, more water runs off at once in the streams than in countries which are less hilly and with more gravel and earth on the surface; though in the latter case the streams are much more uniform in their flow.

In calculating for water supply, we can only depend upon the amount which falls in the driest years. On the Croton water-shed, it has been found that 60 per cent. of the rain-fall runs off in the streams. In most cases, however, only about 40 per cent. of the rain-fall escapes in the streams. For the purpose of our calculations, we shall assume that 12 inches of the annual rain-fall can be collected in streams and reservoirs, this being 40 per cent. of 30 inches, our minimum rain-fall, nearly.

That estimates based on the annual collection of a cubic foot of water from each square foot of surface are not too large, is proved by the experience of the Morris Canal Company with their reservoirs Lake Hopatcong and Greenwood Lake.

Lake Hopatcong, originally, covered 1,500 acres, and by raising it 10 feet it covered 2,800 acres. This gives an average of 2,150 acres, which is 3½ square miles. The whole drainage area for the lake is 27 square miles, which is 7 7-10 times the area of the lake. A rain-fall of 1 foot on the whole water-shed would only raise the lake 7 7-10 feet. But it is generally drawn down more than this below high water mark for the uses of the canal during the season of navigation, and yet the lake has sometimes been filled between December 1st and February 1st; generally, it is filled by the 1st of March, though in some cases it has not been filled till the middle of May. These times cover only half the year or less, and the inference is conclusive that more than a foot of rain-fall can be stored from this water-shed. The Stanhope mill has rights to the original water-power on the outlet, and an opening of 10x36 inches is kept for this use. A large draught is made upon the water of the lake for the mill, even during the time when it fills so rapidly. It is a common observation, that the lake rises about twice as much as the rain-fall in the two days following a rain.

Greenwood Lake has been raised, by a dam, 13 feet. Its drainage area is 32 square miles, and its surface is 4 square miles. It has never been largely drawn upon for the uses of the canal, seldom being lowered more than 2 feet; but it furnishes water-power to Hewitt Furnace, and there is a gate drawn constantly of 5x36 inches.

This draws out a large quantity. The lake is now down 7 feet, but is expected to be full before spring. The water has been known to rise 3 feet by a single storm; one of the rains this fall raised it 6 inches. It is sometimes raised so as to be 2 or 3 feet higher than the dam.

From an acre which is 43,560 square feet of surface, then 43,560 cubic feet or 326,700 gallons of water can be collected in a year. And from a square mile there can be collected 27,878,400 cubic feet or 209,088,000 gallons in a year, which is equivalent to a daily supply of nearly 900 gallons per acre or 572,844 gallons per square mile.

The water-shed of the Passaic and its branches, above Little Falls, is 750 square miles.

This drainage area of the Passaic is made up from that of its branches, which, for purposes of calculation, it may be well to set down separately.

The Ramapo* rises in Orange and Rockland counties, New York, and runs through Bergen county, N. J., with a drainage area of 108 square miles in the former State and 40 square miles in the latter, equal to.............. 148 sq. m.

The Ringwood* rises in Orange county, N. Y., and runs through Passaic county, N. J. It has a drainage area of 32 square miles in New York and 76 in New Jersey, equal to.. 108 sq. m.

The Pequannock* rises in Morris, Passaic and Sussex counties, in N. J., and is the boundary between the two first named. It has a drainage area of 28 square miles above Oak Hill, and in all of........................ 82 sq. m.

*The Ramapo, Ringwood and Pequannock Rivers unite at Pompton, and form Pompton River, which runs into the Passaic at Two Bridges.

The Rockaway River has its whole course in Morris county. Its drainage area above Baker's Forge is 30 square miles, the whole above Denville is 100 square miles, and its entire area above its mouth, near Pine Brook, where it joins the Passaic, is......................	165 sq. m.
The Whippany River, which rises near Morristown and runs into the Rockaway near its mouth, has a drainage area of..	59 sq. m.
The Passaic, which rises near Mendham, in Morris county, and retains its name throughout its course to Newark Bay, has a drainage area of 51 square miles above Millington, of 35 square miles in the valley southeast of Long Hill and above Page's dam at Chatham, and of 102 square miles between Chatham and Little Falls, including the area up to Pompton, being in all.	188 sq. m.
Total area of the Passaic water-shed..................	750 sq. m.

This area is capable of yielding a daily supply of 429,633,000 gallons of water if a depth of 12 inches of rain-fall can be collected, and the experience at Lake Hopatcong and Greenwood Lake proves that it can be done.

The Passaic water is used at the Falls in Paterson and at Dundee for driving machinery, for the water supply of Paterson and in part for the supply of the Morris canal. The quantity daily used for these purposes may be estimated in this way. On the upper raceway in Paterson there are 34 square feet of water leased. A square foot is the descriptive term for the water that can flow through a rectangular cast iron gate-way 6 inches high and 24 inches long, with its lower edge on a level with the monument in the bottom of the raceway. This water falls 22 feet, and is said to equal 17 horse power for each square foot. With the wheels now in use, it probably exerts a force of 16 horse power in driving machinery and loses 5 horse power in the friction and resistance of the water-wheel, or 21 horse power in all. A horse power is 33,000 pounds falling 1 foot in a minute, or 1,500 pounds falling 22 feet in the same time. To continue that power for 12 hours would require 720 times as much water, which is 1,080,000 pounds or 135,000 gallons; and the 714 horse power of the 34 square feet would use 96,390,000 gallons of water daily. The Dundee works only use over the same water which has already done duty in Paterson. The Paterson water works may consume for their water-wheels and their water supply 13,000,000 gallons a day, and the whole quantity needed daily may amount to 110,000,000 gallons. In the driest seasons of the year the quantity flowing in the stream is much less than this, probably not as much as 100,000,000 gallons a day. The Morris canal draws its supplies of water from Lake Hopatcong, which is in the water-shed of the Musconnetcong, and so of the Delaware river, and from Greenwood Lake, which is on the head waters of the Wynokie branch of Ringwood river. The latter holds back a part of the water which falls in the water-shed of the Passaic. It has a drainage area of 32 square miles. For this storage for the use of the canal there must be an allowance of 18,332,000 gallons.

The whole Passaic water-shed, then, may be depended on for supplying daily..........		429,633,000	gallons.
Deduct for Paterson water-power....	96,390,000		"
" " " water works...	13,000,000		"
" " Greenwood Lake.........	18,332,000		"
		127,722,000	"
And there remains..................................		301,911,000	"

Which now run to waste in freshets. A large part of this is capable of being collected in storage reservoirs and used for water supply, or for giving an enlarged and steady water-power.

It is not desirable to shorten the valuable, industrial and economic uses of the water as it is now applied. But the natural ponds in the mountains could easily be increased in capacity by damming, or by lowering their outlets, and putting in gates to regulate their discharge; and reservoirs could be made in the narrow and deep mountain valleys, sufficient to hold all the water needed for a long time to come, and in locations where the purity of the water would be beyond question.

The Passaic river, from Two Bridges up to Chatham, runs through a very flat country, and with but little fall. The channel is deep for the whole distance, but in times of heavy rain the river overflows its banks, and covers with water the flat lands on its borders. In summer, when the meadows are covered with standing grass or other vegetation, the freshets subside very slowly, and great damage is done to health and property. The overflow is caused by the slackness of the current of the river. The obstructions to the flow are:

1. A bar of earth and boulders across the stream just above the mouth of the Pompton, at Two Bridges.

2. A ledge or reef of trap-rock across the stream at the head of Little Falls, which is of about the same height with the bar at Two Bridges.

3. A strong stone dam built just below the reef, which is about a foot and a half higher than either the reef or the bar.

These effectually obstruct the free flow of water in the stream. The lowering of the obstructions seven feet is, from the depth of the channel above, feasible, and comparatively inexpensive; and when done would lower the water surface to almost the same extent. By this change the water could be kept within the banks of the stream after ordinary rains; and in times of heavy rain the overflow of water would soon drain off. The plan for this improvement has been matured, but its execution is delayed on account of the expense to be incurred before work can be begun. It is greatly needed for its sanitary and economical benefits, and it would improve the quality of the water in that portion of the Passaic.

Surveys of valleys have been made on the Rockaway, Pequannock, Ringwood and Ramapo this year, in which deep, capacious and unpolluted reservoirs can be made, which would hold a daily supply of more than 100,000,000 gallons. The rough maps of these surveys are drawn, but there is much more work to be done on them before they would be ready for public inspection.

The supply from natural ponds is least expensive, most quickly obtained, and with less change in the arrangements of property. To get more definite information regarding some of the ponds from which supplies could be drawn, George W. Howell, C. E., was instructed to examine a number of them and report the result, which he has done as follows:

"In accordance with your instructions I have made an examination of various lakes or ponds in Passaic, Morris and Sussex counties, especially with the view of ascertaining the extent of surface which is or may be flowed, the capacity for storage of water, and also their respective drainage areas, together with such other items of information as may be of service in defining their utility in supplying and storing water, a report whereof is hereto annexed.

For convenience of reference I have arranged the lakes in the order of their outlets, classifying together those respectively that flow (I) into the Ramapo River, (II) the Ringwood River, (III) the Pequannock River, and (IV) the Rockaway River.

I. THE RAMAPO RIVER.

1. *Franklin Lake* lies about three miles directly east of Pompton Furnace. It covers an area of 94 acres and drains about 1,000 acres, the drainage area being about equally divided between mountain slopes and gravelly farming land. There are numerous small ponds in the vicinity, some of them having no visible inlet or outlet, and all of them nearly, if not altogether, of the same level. Crooked Lake, a pond of inconsiderable depth, but some 30 or 40 acres in extent, is said to rise and fall with Franklin Lake, the residents of the vicinity maintaining that there is some subterranean connection between the two. About half a mile west of Crooked Lake is Crystal Spring, which discharges large volumes of water, supposed to be derived from the lakes, which, collectively, are known as "The Ponds." Singack Brook, rising in a ravine a little to the south of Franklin Lake, is supposed to have a similar origin. A few years ago one of the ponds was observed to rise to a much higher elevation than ordinary, and from no known cause, so much so, that it became necessary to change the location of a public road, which had been submerged. After remaining thus for a year or two, the pond subsided to its former level, which it has since retained.

The outlet of Franklin Lake, which is smaller than the inlet, runs for about 500 feet through a level meadow, when, with about 7 feet head, it drives a small water-wheel. The head has been obtained rather by lowering the tail-race than by a dam.

Lowering the surface of the lake 5 feet would diminish its size perhaps one-third.

Raising a dam of 5 feet at the outlet would overflow 75 to 80 acres more, the greater part of the addition being a cedar swamp at the head of the lake. Such a dam would be 300 feet long. A higher dam would be over 1,000 feet long, and it is quite doubtful whether the first mentioned rise of 5 feet in the surface could be maintained, owing to the porous, gravelly nature of the soil, and the probability that some connection exists between the various ponds in the locality.

2. *Rotten Pond* takes its drainage wholly from the mountains, and lies one and a half miles southeasterly from Wynokie. The original surface was about 80 acres, which has been reduced to 20 acres by lowering the outlet some 6 feet. Should the present surface be raised 10 feet by a dam 4 feet high, fully 100 acres would be covered. The drainage area is about 1,200 acres.

3. *Negro Pond,* a long narrow pond between the mountains, a little east of Shepherd's Pond, lies partly in New Jersey and partly in New York, about one-quarter of a mile east of the 19th milestone. It covers an area of about 100 acres, and drains about 900 acres, wholly mountainous. The ordinary surface can be lowered several feet without uncovering much land, and the dam can also be raised 4 or 5 feet, and would flow 25 to 30 acres more.

II. THE RINGWOOD RIVER.

1. *Mud Pond* lies one and one-half miles north of Bloomingdale, and has its outlet in a small stream, which crosses the Montclair and Greenwood Lake Railway near the first public road, north of Pompton Junction. Its area is 50 acres and drains 1,600 acres, chiefly mountainous. It is surrounded by a cranberry marsh and other low lands, which would be covered to the extent of 70 acres by raising the present surface 10 feet. The outlet has been lowered 4 feet through the rock. A dam 6 feet high would be 800 feet long. The present outlet runs through the marsh for 300 feet and then falls rapidly, and could be lowered without great expense.

2. *Tice's Pond* is a natural lake one mile east of Boardville. Its water surface is 40 acres, but before the outlet was lowered five feet, for a distance of several hundred feet, the area was nearly, or quite, 100 acres. An area of 125 acres would be covered by raising the original surface three to five feet. The dam required would be 400 feet long. The drainage area is about 800 acres; mountainous.

3. *Shepherd's Pond* has had its natural surface drawn down four feet. It covers about 90 acres, and, owing to its steep shores, but little more land would be covered by raising it 10 feet. A dam of

150 feet would be sufficient. The pond lies wholly in New Jersey, near the New York line, about half a mile west of Negro Pond, and drains 1,000 acres, chiefly of mountain forest land, but with a small area of rough clearing. The water is said to be of considerable depth.

The outlets of Shepherd's and Tice's Ponds unite near Boardville and enter the Ringwood River, along which, between Boardville and Wynokie, have been several large furnace and forge ponds, but whose dams have been more or less broken away.

4. *Greenwood Lake*, the head of Wynokie creek which flows into Ringwood River, has an area of a little more than 4 square miles, and has a water-shed of 32 square miles. It is used as storage for the Morris Canal. The surface of the lake is 13 feet above its original level.

III. THE PEQUANNOCK.

1. *Macopin Pond* or *Echo Lake* is situate two miles northeast of Newfoundland. Its area is 363 acres, and by raising the surface five feet an area of 412 acres can be obtained. The depth is 40 to 50 feet. The pond can now be drawn down four feet by means of a flume. The surface also can be raised five feet by a dam 250 feet long. A greater rise than five feet would flow a tract of several hundred acres, called the "Pine Hammock," lying at the head of the lake. The drainage of Macopin Pond is 1,700 acres. An additional drainage of 1,500 acres can easily be procured, at little expense, by turning a stream to the east into the pond. The drainage is divided between mountain forests and rough farm land, about in the proportion of one to two.

2. *Hank's Pond*, two miles north of Newfoundland, covers about 80 acres. It is a natural lake and has been lowered four feet, and can be still more drawn down by cutting a channel 500 feet long. The surface can also be raised above its original height by a dam 300 feet long, thus affording large available storage capacity. By raising the dam 120 acres would be flowed. The drainage area is four square miles, wholly mountainous.

3. *Cedar Pond*, one and one-half miles northeast of Hank's pond, draining entirely from mountain slopes, has had a natural surface of 125 to 140 acres, but has been reduced to about 96 acres by lowering

the outlet. Its vertical capacity is about 7 feet, and drains an area of about 800 acres.

4. *Buck Mountain Pond,* four miles north of Newfoundland, has an area of 75 acres, but can flow 120 acres by means of a dam 250 feet long, and can be used with 10 to 12 feet head. It drains two and one-half square miles of mountain slopes. The outlets of Hank's, Cedar and Buck Mountain Ponds unite and form Cedar Brook, which flows through Clinton, giving opportunities for artificial reservoirs on that stream.

5. *Dunker Pond* lies one and one-half miles north of Stockholm, and has a present surface of 25 acres. The outlet has been lowered through rock at considerable expense, thereby reclaiming a large tract of rich soil, similar in character to the Bog and Fly in Morris county. A dam 100 feet long and 10 feet high would make a lake two to two and one-half miles long and half a mile wide. The drainage area is about five square miles, principally rough and mountain lands.

6. *Canistear Pond* is an artificial pond three miles north of Dunker Pond, and covers, when full, 70 acres. By raising the dam 600 feet long and 5 feet higher 120 acres may be flowed, and 20 feet head may be obtained. Drainage area about 2,000 acres, one-third farming land and the remainder forest and mountain.

7. *Pine Hammock,* at the head of Canistear Brook, flows about 100 acres, and is an artificial pond used as storage for Canistear Pond. Drainage area probably two to three square miles.

8. *Timber Brook Pond,* which lies two miles southwest of Charlotteburg, has an area of 72 acres and can draw down five feet. Raising three feet higher, thus giving eight feet head, would flow 25 to 30 acres more. Raising the surface of the pond would make it necessary to lift several hundred feet of the track of the Green Pond Railroad, it being within two to three feet of the surface of the water. This pond has a drainage area of about 800 acres, one-half forest and one-half rough, poor farm land.

9. *Stickle's Pond,* lying about two miles east of Timber Brook Pond, has its outlet through Stone House Brook into the Pequannock River, at Bloomingdale. Its area is 101 acres and can be drawn 10 feet. A dam 5 feet higher than the present dam, and 800 feet long, would flow but little more land. The drainage is about 1,800 acres, wholly in forest and mountain.

IV. THE ROCKAWAY.

1. *Split Rock Pond,* five miles northwest of Boonton, has an area of 237 acres, and drains six and one-quarter square miles, almost wholly mountainous and forest. Twenty feet available head can be obtained by raising the dam two feet, the length of the dam being 200 feet.

2. *Durham Pond,* near the head of Split Rock Brook, and used as a storage for Split Rock Pond, covers an area of about 65 acres and drains about 1,000 acres, one-half woods and one-half rough farming land. The present dam is 900 to 1,000 feet long, and if raised would flow 30 to 40 acres more. The pond could be drawn down four feet.

3. *Green Pond* or *Green Lake,* a noted resort four miles southwest of Newfoundland, contains 560 acres and drains two and one-half to three square miles. It has great depth, no inlets and a small outlet.

4. *Denmark Pond,* on Burnt Meadow Brook, a tributary of Green Pond outlet, drains two and one-half to three square miles, and has an area of about 175 acres. It receives its waters from forest and rough farm land.

5. *Milde Forge Pond,* on Green Pond Brook, receives the waters of Green Pond and Denmark Pond, and contains about 70 acres.

6. *Dixon's Forge Pond,* on a tributary of the Rockaway River, about two miles south of Split Rock Pond, covers an area of 60 to 75 acres, and has a drainage area of one and one-half to two square miles, mostly rough land.

7. *Shongum Pond,* five miles northwest of Morristown, and at the head of Den Brook, drains two and one-half to three square miles of rough land, and embraces an area of 125 acres. Increasing the height of the dam five feet, thus giving ten feet head, would cover an area of 165 acres.

In addition to the above ponds, which are already in existence, a large number of artificial reservoirs can doubtless be constructed, affording valuable additional storage, and utilizing the rain-fall over a wide extent of mountain lands. A few of these are herewith given:

1. On the outlet of Mud Pond, one-quarter of a mile above the Montclair and Greenwood Lake Railway, a dam 250 feet long can

be erected, which, if 15 feet high, would flow 100 to 125 acres, and would receive the drainage of four to five square miles.

2. Along the Ringwood River, between Boardville and Wynokie, as has hereinbefore been mentioned, are several forge and furnace sites, the dams of which have been broken away, but which, by being rebuilt, would afford very large storage facilities.

3. One mile west of Hewitt Furnace, on a stream flowing easterly, a reservoir of 75 to 80 acres could be made by a dam 150 feet long and 15 feet high, and would drain about two square miles.

4. About three miles due west of Boardville is a tract of land which has been drained, at some expense, but which it is said could be converted into a reservoir of 140 or 150 acres with little difficulty. A large drainage of several square miles finds its outlet through the locality.

5. On the outlet to Stickle's Pond, a dam 15 feet high and 350 feet long, at the old forge site below the pond, would flow 80 to 100 acres, chiefly meadow, and would drain 1½ to 2 square miles, independent of the drainage of Stickle's Pond.

6. At Mount Pleasant, on Green Pond Brook, a reservoir of 800 acres, and capable of drawing 10 to 12 feet, may be constructed by means of a dam, at a moderate expense, and afford storage for the drainage of 12 to 15 square miles of mountain lands.

7. At Berkshire Valley a dam could be built across the Rockaway, by which a reservoir could be made, covering 1200 acres, 20 or 30 feet deep, and capable of storing the drainage of 30 square miles.

Annexed is a table showing the capacity and supply of the ponds here described, and the approximate cost of making them available by dam or otherwise.

TABLE.

NAME OF POND.	Area in acres.	Head or working depth, in feet.	Storage capacity in million gallons.	Drainage area in acres.	Minimum supply in million gallons.	Approximate cost of dam, &c.
Franklin Lake. . . .	94	5 + 0 = 5	161	1000	327	$750
Rotten Pond. . . .	20 to 100	6 + 4 = 10	294	1200	392	1500
Negro "	100	5 + 4 = 9	294	900	294	2000
Mud "	50 " 120	4 + 11 = 15	441	1600	523	6200
Tice's "	40 " 125	5 + 3 = 8	261	800	262	1175
Shepherd's Pond. . .	90	4 + 6 = 10	294	1000	327	1150
Greenwood Lake. . .						
Macopin Pond. . . .	362	4 + 5 = 9	1117	3200	1046	950
Hank's "	80 " 120	6 + 5 = 11	431	2500	817	1310
Cedar "	96 " 140	4 + 3 = 7	274	800	262	860
Buck Mountain Pond. .	75 " 120	0 + 12 = 12	353	1600	523	2600
Dunker " .	125 " 800	5 + 5 = 10	1960	3200	1046	1400
Canistear " .	70 " 120	15 + 5 = 20	588	2000	653	2100
Timber Brook. " .	72 " 100	5 + 3 = 8	196	800	262	3000
Stickle's " .	101	10 + 5 = 15	392	1800	589	2700
Split Rock " .	237	10 + 10 = 20	1307	4000	1308	1800
Durham " .	65 " 110	4 + 6 = 10	327	1200	392	4000
Green " .		0 + 3 = 3	551	1920	627	600
Denmark " .	175 " 300	5 + 3 = 8	462	1800	589	1000
Middle Forge " .	70 " 100	5 + 10 = 15	490	4000	1308	750
Dixon's " .	75	5 + 5 = 10	245	1200	392	1300
Shongum " .	125 " 165	5 + 5 = 10	473	1800	589	1200

The first column in the foregoing table shows the area of the reservoirs, both when drawn down and when filled. The second column, showing the available head, gives two numbers, the first of which shows the depth below the present surface to which the pond can be drawn, and the other gives the height above the present surface to which it can be raised, the sum of the two being the available vertical capacity.

The following table shows the approximate capacity of the artificial reservoirs which have been referred to:

TABLE.

LOCATION.	Area in acres.	Head or working depth.	Storage capacity in million gallons.	Drainage area in acres.	Minimum supply in million gallons.	Approximate cost of dams, &c.
Outlet of Mud Pond, . .	100 to 125	10	290	3,000	981	$800
On Ringwood River, .	570	20	3,650	55,680	18,200	22,200
Near Hewitt Furnace, .	75 " 80	10	245	1,300	425	600
West of Boardville, . .	100 " 150	10	320	1,000	327	1,000
Outlet of Stickle's Pond, .	80 " 100	8	261	3,000	981	500
Mount Pleasant, . . .	800	10	1,831	8,320	2,718	25,000
Pompton Furnace, . . .	292	6	573	94,720	31,000	5,000

Very large and capacious reservoirs can also be made in the valley of the Pequannock at Oak Hill, at Newfoundland, at Bloomingdale and at some other points, altogether sufficient to store the whole of the freshet waters of that stream.

A very large reservoir can also be made on the Ringwood at Wynokie, by raising the old Furnace dam; or still better, by erecting a dam where the stream crosses into the eastern valley, for which an estimate is put into the table.

The Furnace Pond on the Ramapo, at Pompton, now covers 275 acres, and averages probably as much as 20 feet in depth; can be raised 6 feet more, and thus be made to store the surplus water from 148 or more square miles on that stream.

The time devoted to this work has not been sufficient to collect more details than those given above. But there are many other ponds known, and many other promising locations for storage reservoirs, in high and sequestered localities.

PLANS FOR SUPPLYING WATER.

Any plans for water supply for this district should be on a comprehensive scale; arranged so as to admit of enlargement equal to any future need, and so carried out as to avoid unnecessary expense in anticipation of the future, or to construct any work that will need to be abandoned in after enlargements. There are now about 250,000 people supplied from the water pumped at Belleville, and in the heat of summer this year the daily consumption rose to nearly 25,000,000 gallons, which is 100 gallons for each inhabitant. It is not unlikely the person is now living who will see 1,000,000 inhabitants in this district. And the plan which is now adopted for water supply should be ample for the present, and capable of easy expansion to meet the wants of this coming people.

The plan of getting the Morris Canal water and its reservoirs, Lake Hopatcong and Greenwood Lake by purchase, has been frequently proposed. The water is unexceptionable in quality, sufficient in quantity with its present reservoirs to supply 35,000,000 gallons daily, and capable of having its supply enlarged indefinitely. The canal is 174 feet above mean tide at the head of Bloomfield Plane, which is only two or three miles from the water pipes of Jersey City and Newark, and it can be connected with the present water pipes, quickly and at moderate expense. It is objected that the canal is needed for its present uses; that it cannot be given up without great injury to many business and industrial interests and obligations; that it is questionable whether the open canal will answer for the conveyance of a winter supply of water, and if it should not, a pipe or conduit on its line would be long and expensive; and that the cost of the canal would be more than that of an adequate supply from some other source.

It has also been proposed to bring the water of the Rockaway from near Denville, mostly by natural channels, to near Morristown, and from there by conduit or pipe along the high ground back of Madison and Chatham, and across the Passaic valley, and then, by tunnel, to ground 300 feet high near Millburn, and from thence by pipes wherever needed. This would supply 60,000,000 gallons daily of good water, and with sufficient head for all present demands. The line, however, is long, expensive, and would divert some streams from their present courses.

This plan could be modified by taking the water at Morristown through the ridge to Loantaka Brook, and thence in the natural channels to Chatham, from which it could be taken at an elevation of about 200 feet through the mountain to near Millburn, and then distributed by pipes wherever needed. This is a feasible plan. It would bring in the water from 180 square miles of water-shed, and could supply 100,000,000 gallons of good water daily.

A plan proposed and carefully studied out by L. B. Ward, C. E., of Jersey City, is to take the water of the Passaic at or near Page's dam, above Chatham, and carry it through the mountain by tunnel to Millburn, as in the last plan. The supply of water could be increased by connecting the head waters of the Raritan, and, if needed, by opening the channel from the Rockaway at Berkshire valley to the Black river, and from that across to Dead river and the Passaic again. More than 100,000,000 gallons daily could be supplied in this way.

The plan proposed by General E. L. Viele, of New York, to which reference was made in the report of last year, is to locate works at the end of the mountain, near Little Falls, where all the water from the Passaic passes, and by the auxiliary use of steam power to elevate all the water that may be needed to a high natural reservoir in the mountain at that place. From that reservoir water can be distributed to all the cities, towns and villages between the Orange Mountain and the Hudson river, in abundance, and at any height that may be required. The plan is feasible, and ample for the purpose, and the supply of water all that can be desired.

Another plan is to take the water at the head of Little Falls, where all the water of the Upper Passaic passes, and where the whole supply can always be controlled. If the water power at Little Falls can be purchased, it may be used to drive pumps which would raise the water sufficiently to carry it in a tunnel through the mountain at the Great Notch. This need not involve the raising of water more than 50 feet. The Falls are 157 feet above mean tide, and will have a height of 30 feet after they are cut down 7 feet, to allow the drainage of the flat lands along the Passaic above them. Seventy-five per cent. of this height can be made effective in raising water. 100,000,000 gallons run over the Falls daily when the stream is lowest, with an *effective* head of 22½ feet, which is sufficient to raise 45,000,000 gallons 50 feet high. This is enough for the daily supply for many years to come, and if a high service were required a smaller quantity could be pumped into a reservoir much higher. If the water power could not be secured, a gravity supply can be obtained at the same level, by going a little farther away. The

Rockaway River, at Boonton, is nearly 400 feet above tide; water can be taken there and brought along near the present line of the Morris Canal to the Hook mountain, and then along the mountain to near Mead's Basin, and from thence across the Passaic and to the mouth of the tunnel as before. The Pequannock, Ramapo and Ringwood can all be conducted on a high level to meet the Rockaway at Mead's Basin, from there to follow the same course as above mentioned. In this plan sufficient water can always be had by storage, no present uses are interfered with, and the place is the nearest of any to the points for distribution. Water could be advantageously taken from the Morris Canal at Little Falls, if the rights for it were obtained.

The cost of pumping by water power is much less than by steam. The Commission of Engineers, appointed by the Mayor of Philadelphia in 1875, to report on the present and future water supply of that city, for their estimates assumed "the cost of running the water power machinery, including all repairs and renewals, at three cents per million gallons, raised one foot high; and the cost of running the steam machinery, including repairs and renewals, at fifteen cents per million gallons, raised one foot high." The water for Newark is now raised 165 feet high by steam, and that for Jersey City nearly as much, and also by steam. At Little Falls the water is now 150 feet above tide, if raised 50 feet higher it would have as great an effective head as that now in the Newark or Jersey City reservoirs, and the cost of raising it by water power would be less than one-fifteenth as much. The cost for a supply by gravity is the interest on the first cost of the works. In either case, however, it is a fair and hopeful subject of calculation, as to whether the change to an unobjectionable supply of water cannot be made without much increase in the annual expense.

The Croton aqueduct, which is a brick conduit capable of delivering 110,000,000 gallons daily, cost $30 per lineal foot, and the cost at the present time would probably not vary much from that. Cast iron pipes, four feet in diameter, which are large enough for the present supply of either Newark or Jersey City, are estimated to cost, when laid complete, from $15 to $18 per foot.

Either of the plans mentioned will answer to bring an abundant supply of pure water for present and future wants, and at a cost less than that of the Croton water works for New York when she had no larger population than that to be supplied here. And still other plans may be found on further examination, which will answer equally well. The one to be selected will be determined by financial considerations and engineering requirements, which will develop as the inquiries progress.

The supply of wholesome water is the first and important subject of this inquiry, but the question of expense is also of great interest, and it is not unreasonable to expect that though the first cost of works to supply water by gravity, or by pumping by water power, will be greater than the present works, the annual expense will be much less, and that an unexceptionable water supply may be had without increasing the burden of yearly taxation.

A plan has also been proposed by Andrew Clerk, C. E., of Jersey City, to take the water from the Passaic above Dundee dam, where it is at an elevation of 20 feet above tide water. Conduits properly laid from here would carry the water by gravity to the Newark or Jersey City pumping works, and from there it could be pumped up as it is now; or better for Jersey City the conduit could be carried from the dam direct to the foot of Bergen Hill, and then pumped up into the reservoir on top of the Hill. To prevent the pollution of the water by the sewage at Paterson, it is a part of the project to have intercepting sewers along the river banks in Paterson, which will conduct the sewage from that city along the valley, and discharge it into the river below Dundee dam.

The *map* of the Passaic water-shed, which accompanies this report, is intended to exhibit the various sources of water supply, and distribution for various cities and towns in eastern New Jersey. The reservoirs now existing are marked by horizontal lines; those which are proposed are marked by the streams in them. The small figures on the map show the heights of the surface, at the marked points, above mean tide, and may aid in the selection of lines of location for water pipes to supply different localities.

For these heights we are largely indebted to railroad and canal officers, who have given every facility for obtaining them from their records. Special mention should be made of the valuable contributions furnished to the list by R. C. Bacot, C. E., of Jersey City; F. H. McDowell, C. E., of the Montclair and Greenwood Lake Railway, Jersey City; J. W. McCulloch, Esq., of the N. J. Midland Railway; James Owen, C. E., of the Essex Road Board, Newark, and George H. Bailey, C. E., of the Newark Aqueduct Board.

The importance of preserving the waters of streams from pollution, is coming to be generally appreciated. At the session of the New Jersey Legislature in 1876, an act was passed "to prevent the willful pollution of the waters of any of the creeks, ponds or brooks of this State." Laws of New Jersey, 1876, p. 244. And the Parliament of Great Britain has passed an act entitled "The Rivers Pollution Prevention Act," 1876, applicable to England, Scotland and Ireland. It prohibits the polluting of any stream by solid matter, by sewage, by any manufacturer's waste or refuse, or by any mining products or poisonous wastes, and restricts the proceedings against them, which may be summary, to sanitary authorities. "Pollution of Rivers, 39 and 40, Vict. Ch., 75."

This action is a great step in advance of any previous legislation, and has been reached after very long and expensive investigations.

IRON ORE.

The continued depression of the iron manufacture throughout the year has been seriously felt by the mining industry of the State, not only in prolonging the quite general stoppage of mines and works, and in hindering all explorations, but also in further curtailing the operations of many individuals and companies, and thus reducing still lower the mineral production of the State. The ore mined in 1875 was considerably less than that of the preceding year. We have no statistics for the current year, but from a general observation of the mining districts, and the incomplete returns from a few parties engaged in mining and carrying ore, it seems highly probable that the aggregate for the year will fall considerably below that for 1875. It is hoped that we have "touched bottom" at last, and that as the general business of the country gets settled, even at low prices, the iron trade will soon get adjusted upon a firm basis, and create a steady demand for our best if not for all our ores. In such times of limited demand, with sharp competition and consequent low prices, there is a most urgent need of economy in all the details of mining—carrying and working up our ores. And our favorable location near the coal supply and the best markets are decidedly in our favor. These, together with the richness of many of our ores, ought to enable our miners to compete with other iron districts. The increasing consumption of steel makes a fair market for all ores suited to the production of Bessemer pig metal, and this fact seems to urge the careful survey of our iron mining district to discover such ores. The location of some of these, in the northwestern or Pequest Belt, was quite fully given in the report for 1873, and in the subsequent reports for 1874 and 1875, and it does not appear necessary to do more now than to call attention to the facts and generalizations previously published, and to urge further exploration and examination, in the hope that these may result in valuable discoveries, not of *iron* ores only, but of those fitted to make steel.

ZINC ORE.

The zinc mines of the State, at Ogdensburg and Franklin Furnace, Sussex county, continue to be worked steadily, and their product from year to year does not appear to fluctuate so much as that of our iron ore district. According to a new business arrangement a considerable proportion of the ores mined at Franklin Furnace is sent to Bethlehem, Pennsylvania, for making oxide of zinc (*zinc white*). These large beds of rich ore, if worked vigorously, are capable of supplying a greatly increased amount, and at prices that can compete with any other zinc ore district in our country. And we look to these two localities as destined to be centres of mining operations which will add very largely to the mineral product of our State. An examination of maps and reports previously published by the Geological Survey, or a careful survey of the ground, will convince any one that these are moderate statements, and compel their belief. They are unrivaled in extent and richness.

COPPER ORES.

The copper mines of the State are all idle, and no further notes or descriptions are necessary. It may be in place to add that, as has been previously stated in full in reports on the ores of this metal, none of them were even really *very* promising, or ever worked with steady profit.

CLAYS FOR POTTERY AND FIRE-BRICK.

The fire-clay, stoneware-clay, and other beds of refractory and pottery materials, have shared in the general business depression.

The mining of fire-clay, *kaolin* and *feldspar*, used in the manufacture of fire-brick, has been greatly reduced in amount of products. The stoppage of so many of the older iron furnaces and works, and the large number of such new furnaces, has almost stopped the work of construction, and consequently there is only the very limited demand for brick necessary for keeping in repairs the small number of works in operation. And the clay mining industry appears to be more prostrated than even the iron mining. For stoneware and pottery there is a larger demand, and such clays find market.

MISCELLANEOUS NOTES AND ANALYSES.

1. *Magnetic iron ore* from lands of Thomas Haggerty, one mile east of Warrenville, Warren county. This ore was taken as an average of several tons raised from a small opening made in 1874. The observations on the ground, made with the dip compass, showed a long and quite broad *attraction*, running a little east of north. In the northernmost opening, whence this specimen was taken, the hanging wall is clean, and the ore on that side of the *vein* is rich. Towards the foot-wall side it is largely mixed with feldspar, quartz and hornblende. In the southern hole the ore was coarse crystalline, and here also mixed with a comparatively large proportion of rock.

The analysis gave the following results:

Metallic iron	56.40	per cent.
Phosphorus	0.21	"
Sulphur	0.05	"

There is nothing remarkable in the character of this ore. It is a new locality in the northwest or Pequest Belt.

2. *Magnetic iron ore* from Ten Eyck's mine, near the State line, Vernon township, Sussex county.

Several openings have been made here for testing the ground by Mr. F. Ten Eyck, of Warwick, New York. The ore is lean, but is remarkable for the large amount of quartz in it, and the absence of the other minerals so common to our magnetic iron ores. The quartz and magnetite alternate in thin layers, forming a moderately fine crystalline aggregate. A partial analysis showed that there was about 50 per cent. of quartz in it. The metallic iron amounted to 33.91 per cent. The phosphorous was only .028 per cent. This low per centage of phosphorous is noteworthy, and more particularly this character associated with quartzose ore. This observation, mentioned in previous reports, receives in this an additional fact in its confirmation, tending to make this generalization of value. No ore has as yet been sent to market.

3. *Magnetic iron ore* from Squier's mine. The several openings thus named are on lands belonging to the estate of the late John Rutherfurd, a few rods east of the Greenwood Lake and Warwick road, and near the State line, West Milford township, Passaic county. The work of opening on this property was begun in January, 1875, under the direction of E. H. Wright, of Stockholm. The magnetic attraction was found to be steadily positive for a long distance, then negative for about 50 feet; then again positive to the end of the line, whose total length was 2,400 feet. The course of this line of attraction is north 38° 30′ east. Eight openings were made, including several cross cuts, which stopped at the ore and rock, and were sufficient to show the size of the *vein*. The average breadth of the ore in these several cuts and shafts, was found to be 12 feet. The largest opening was a drift on the *vein* running into a side hill, until the height of the breast was 78 feet. At the bottom of this open cut, there was eight feet of solid ore and ore forming the foot wall, so that its thickness was not here ascertained. A boring 14 feet into this wall was in ore throughout this distance. At the top of the hill, and at the breast, the removal of the earth and surface materials showed five separate veins, each about five feet in width. The dip, as obtained from the hanging wall, which is clean, is about 80° southeast. The other openings are shallow cuts, and pits sunk a little way into the ore and rock. On the foot-wall side of the vein there appear to be several *pockets* or smaller *veins* of ore, not connected with the main vein. The absence of any attraction, over the space between these two *lines* of ore, seems to show that they are distinct lines. One opening uncovered a breadth of 38 feet of ore, at a depth of 3 feet. The attraction was observed to extend over this, throughout an area of 400x60 feet. The ore contains varying quantities of feldspar, quartz, epidote and pyrite, mixed with the magnetite, but the average is moderately rich. Specimens of sur-

face ore, and from the deeper workings, were sent to the laboratory of the survey by Mr. Wright. Partial analyses of these show:

	1.	2.
Metallic iron	48.16	55.39
Phosphorus	0.14	0.067
Sulphur	3.02	1.74
Titanium	None	None
Manganese	None	None

1, is the surface ore.

2, ore from deeper part of working.

These figures indicate ore of good quality, and if the specimen 2 shall prove to be an average of the mine, it may be used in making Bessemer pig metal. About 1500 tons of ore have been mined. This mine was visited in December, but the most of details here given were communicated by Mr. Wright.

4. *Magnetic iron ore* from Stony Brook mine, sent to the laboratory of the Survey by the proprietor, M. J. Ryerson, of Bloomingdale. This mine is two miles southeast of Charlotteburg, and near the old Earle forge, in Pequannock township, Morris county. Ore was discovered here, and some mining done by the London Company prior to the Revolution. It was reopened and worked a little by Mr. Ryerson about sixteen years ago. There are five openings; of which the deepest is 30 feet. The *vein* is rather narrow, being only 2½ to 3 feet wide. It dips 60° south, 65° east. The analysis gave the following results:

Matter insoluble in acid	8.10	per cent.
Magnetite	89.33	"
Titanic acid	1.50	"
Phosphoric acid	Traces.	
Sulphur	None.	
Manganese	None.	

Or,

Metallic iron	64.69	per cent.
Phosphorus	Traces.	
Sulphur	None.	

These figures are quite unusual and remarkable in analyses of iron ores of this Highlands region. It is not only a rich ore, it contains nothing detrimental to the character of iron which may be made from it. It ought to do for steel. This remarkable character explains this notice of an old locality. Such ores are worthy of attention at all times, and particularly in these days of stagnation in iron mining. The analysis suggests further work upon this line for the determination of the capabilities of our ores, for it may be that in neglecting this we are leaving mines and ores which could be profitably worked.

5. *Nickel and Cobalt.* Two specimens of pyritiferous rock sent to the laboratory from Chester, Morris county, have been examined for nickel and cobalt, and found to contain small quantities of these metals. One of these was found on the farm of Wm. H. Sharp, between Chester and Peapack, the other on lands of John D. Evans, near Chester. The rock in both specimens holds the white pyrites, or marcasite, in very thin veins irregularly traversing it, and this mineral carries these metals, but in too small amounts for their profitable extraction. The Survey has received repeated notices* of the discovery of nickel ores, and it has made several examinations of such specimens supposed to contain working percentages, but so far they have proved to be nothing more than ordinary pyrite, with *traces* only of this metal. And from these it would seem as if this metal, as also cobalt, are not at all uncommon in much of the pyritiferous rock of the country. But these results do not all argue against the probability of yet discovering nicceliferous ores, and in some such form or combination as those here received. It may be proper to add here, that the niccoliferous pyrite, the more common ore of this metal, is mineralogically known as niccolite, which is whiter than our common pyrite.

6. *Magnesian Limestone,* quarried near the works at Oxford Furnace, Warren county. This specimen of blue limestone was analyzed carefully, in order to ascertain its value as a flux in making iron. The results of the analysis were as follows:

* NOTE.—Since the above was written a specimen supposed to contain nickel, from near Pottsville, has been received and examined The rock contained a very small percentage of pyrite, and this contained a trace only of nickel, showing less in the whole rock than can be detected by delicate chemical tests.

Carbonate of lime	50.30
Carbonate of magnesia	42.40
Alumina	0.33
Ferric oxide	0.97
Phosphoric acid	0.18
Silicic acid and quartz	5.50
Total	99.68

It does not differ materially from the average of the blue magnesian lime stones, of the northern part of the State, and is a true dolomitic stone. The phosphoric acid, which may yield its phosphorus to the iron made in using such stone, is comparatively small in amount, less than the average found in our magnetic iron ores, and it ought to be a good flux in blast furnace work.

7. *Infusorial Earth.* Another deposit or bed of this earth was discovered lately, near Andover, Sussex county, and a specimen sent to the laboratory by E. Wright, of that village. The locality has not been visited. Other deposits have been reported, but nothing is known of them. There has been some inquiry for infusorial earth for making artificial stone and silicate of soda. It is also employed in the manufacture of dynamite or giant powder. Those interested in searching for deposits of this earth, or seeking for supplies, are referred to a notice of the Drakesville bed, and some general account of the occurrence, uses &c., of infusorial earth, on pp. 54–56, of the Geological Survey Report for 1875.