GEOLOGICAL SURVEY OF NEW JERSEY

ANNUAL REPORT

OF THE

STATE GEOLOGIST

FOR THE YEAR

1890

TRENTON NEW JERSEY
THE JOHN L. MURPHY PUBLISHING COMPANY PRINTERS
1891

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To His Excellency Hon. Leon Abbett, Governor of the State of New Jersey and ex-officio President of the Board of Managers of the Geological Survey of New Jersey:

SIR—I beg leave to present herewith the Annual Report of the Geological Survey for the year 1890.

Respectfully submitted,

JOHN C. SMOCK,
State Geologist.

TRENTON, N. J., December 16th, 1890.

REPORT.

In the organization of the Geological Survey subsequent to the death of the late State Geologist, Dr. George H. Cook, September 22d, 1889, Irving S. Upson was appointed Assistant-in-charge of the office. The business management and general direction of the work were retained by him until the 1st of October, 1890, when I assumed charge of the Survey and entered upon the duties of the office as State Geologist. Mr. Upson has remained in charge of the office at New Brunswick, has done much of the clerical work and had the care and supervision of the distribution of the maps, reports and other publications. This annual report covers the work done under his direction and that under the present administration during the year 1890.

Frank L. Nason, Assistant Geologist, in the service of the Survey since 1888, has been engaged in the study of the crystalline rocks of the Highlands and of the magnetic iron ores of that district, and has prepared reports on his observations in the field.

C. W. Coman was hired as an assistant geologist in September and began work in Monmouth county. He has continued his field investigations throughout the season and has prepared a short summary of the results of his work.

George C. Bullock, Alfred A. Cannon and Burton S. Philbrook have given efficient service to the work of distribution in the office at New Brunswick.

Hatfield Smith has been retained as general assistant and he has given some time to the preparation of rock sections for microscopic study.

C. C. Vermeule, Topographer of the Geological Survey for the years 1880–1887, has been engaged in a special work on the Water-Supply and Water-Power of the State. He has revised the new editions of the atlas sheets which have been issued during the year. The results of the field-work done under his direction make up a large part of this report.

The office of the Survey has been removed to the State House in Trenton. The distribution is attended to by Mr. Upson, at New Brunswick, for the present.

GEOLOGICAL WORK IN THE NORTHERN PART OF THE STATE.

Frank L. Nason, Assistant Geologist in the service of the Geological Survey, has been at work in the northern part of the State throughout the field season. From April to the middle of June he was engaged in the survey of the outcrops of slaty rocks (hydromica slate) and the associated schistose rocks and crystalline limestones which crop out in small isolated areas along the southeast border of the Highlands. Several new localities have been found and noted by him, and the range of the outcrops has been traced and the boundaries defined from Montville, in Morris county, to Stony Point and Tompkins Cove, on the Hudson river, in New York. The areas of these outcrops have been outlined on the geological map, and the structural relations of the rocks to the adjacent formations have been determined. Further study, and particularly in the direction of lithological work, is necessary to supplement the field observations before publishing the detailed results of this Survey. More than one hundred typical rock specimens have been collected for the State Museum, for exhibition and for future studies.

During the summer and a part of the autumn he was at work in the limestone valleys, on the northwest border of the Highlands, and made a detailed survey of these rocks in the Vernon valley, in Sussex county. The "white limestones," "crystalline limestones," or "metamorphic limestones," as they are variously designated, in this valley, have been described in the reports of the Geological Survey since 1864, as members of the series of crystalline rocks of the Azoic or Archean age. Mr. Nason's careful examination of the outcrops has resulted in the discovery of organic remains in these limestones which give a clue to their age and determine their relative horizon. The fossils discovered have been referred by Prof. Charles E. Beecher, of Yale University, to the Cambrian and below the Potsdam sandstone formation, the oldest fossiliferous horizon hitherto known in the State. This discovery is of importance in the solution of the problem of the age of these limestones, which has been so long time discussed. It bears indirectly upon the question of the age of the associated crystalline schists of the Highlands also. As a contribution to our knowledge of the fossils occurring in the State, it is noteworthy.

The study of the outcrops has brought out clearly the intimate relations of the white limestones and the common blue limestones, and that of both of these formations to the sandstones and quartzites of the valley. The gradation from the white to the blue limestone within short distances and their conformity, indicate that they are parts of one series; metamorphic or altered structure is apparently to be assigned to diverse conditions. The so-called "gneisses" of previous reports are proven to be eruptive rocks—granites, diabases and scapolite rocks principally—and not interstratified beds or members with the limestones. The metamorphic condition of the limestones in the vicinity of these eruptive rocks is noteworthy, and suggestive of the cause of the altered condition of the former class. Inasmuch as the apparent interbedding of the "gneisses" and the white limestones was the ground for the contemporaneous age of these rocks, this determination of the true nature of these crystalline rocks associated with the limestones, upsets that hypothesis and eliminates the latter from the Archean series. The several sections made across the Vernon valley, between Franklin Furnace and McAfee, illustrate these statements, as also the full detailed notes of Mr. Nason's report. A small geological map shows their location and the areas of the several rocks described in his report.

A large number of specimens have been collected from the valley for exhibition and for future studies in the laboratory.

Additional detailed surveys of the other limestone areas on the western border of the Highlands, and in fact of all of the country of the crystalline rocks, are necessary to an accurate knowledge of the relative position and true nature of these formations, hitherto grouped under the generic title of Archean, and for their correct representation on the new geological map of the State. The valuable zinc-ore deposits, and magnetic and hematite iron ores on this side of the Highlands, in and near these crystalline limestone outcrops, show the importance of more information and of an accurate survey of these outcrops and of the adjacent territory, in order to a thorough acquaintance with the modes of occurrence and other data, which may become available in the exploration and searching for other deposits of extent and value. And it is hoped that further geological investigations may have a practical bearing upon the modes of searching for ore deposits in all of the Highlands.

In obedience to my instructions, given on assuming direction of the Survey, Mr. Nason began in October the work of visiting the iron mines and collecting notes upon their extent of opening, geological structure, statistics of working and output, markets and use of ore, ownership and leaseholds and other data of general interest, preparatory to a report on the iron mines of the State. The last report on them was in 1886. It was incomplete and wanting in detail. The demand for information about the iron ores and their location, and the condition of the iron-mining industry, led to the preparation of the report. The instructions were to make the inquiries as full as possible, and to collect as much material as the length of time left for field-work would permit to be done. The activity in the iron trade during the year, and the demand for ores, although at low rates, suggest the present as opportune for the presentation of this report. The possibilities of an enlarged output next year and the uncertainties of the more distant future put upon mine-owners and lessees the necessity of an increased production during this time of steady demand, and upon the Survey the desirability of publishing available data which can be of service to the mine manager and to the prospector and help in guiding him to new fields of enterprise. Such a report is of value to the capitalist outside of the State who may be seeking information concerning locations, leases, quality of ore, date of working, &c.

The need of representative specimens for exhibition in the rooms of the museum in the State House has made it desirable to use this opportune time to select the same when the mines were active. The making of such a collection of the ores, as well as the associated rocks which may accompany and mark the occurrence of these ores, has been an important part of Mr. Nason's work. And he has already collected 161 specimens of ores, of cabinet size, and 287 specimens of rocks illustrative of their occurrence. This collection will make an interesting part of the economics in a State museum. It may be added that the work has been helped by lists furnished from the office of the special department of the United States Census charged with the statistics of iron ore, under the direction of John Birkinbine, of Philadelphia, and David T. Day, Chief of the Department of Mining Statistics in the United States Geological Survey.

The results of the census inquiry will be awaited with interest, in the comparative showing for the decennial period 1880–1890.

The report on the iron mines contains a list of all of the openings and mines of magnetic iron ore which have produced ore to a commercial extent, and with references to all of the published notes thereon in the "Geology of New Jersey," 1868, and in the annual reports issued since that time. These references will enable those in search of information about any particular locality or mine to learn all that has appeared in print in the Survey reports. Although scanty in detail in the case of many of the mines, the notes taken together throw considerable light upon the history, time of working, extent of ore-body, quality of ore and advantages of location and enable one to form a more nearly correct and safe judgment as to the value of a mine, or of a mining district. The uninterrupted working and constant production of some of the best and most noted mines, the increasing development of others, and on the other side the chequered history with its brilliant prospects and sad disappointments, and the failures and long periods of inactivity which have marked certain others—these facts can all be read in these notes. That in all cases the history is in accord with the true value or capacity of a mine cannot be safely affirmed. There are no doubt idle mines which were abandoned, or closed for working, on account of disadvantages of location—thin beds of ore, pinching out so as not to be worked economically, or ores unsuitable on account of leanness, or because of the presence of foreign minerals, making the smelting difficult and costly. It is also highly probable that some of these abandoned mines await the coming of capital to open them and develop their deposits of ore, or of more persevering and intelligent management. To assume that in all of these apparent failures the cause is in the nature of the deposit, would be to accept the dogma of infallibility in man's direction. Hence, the suggestion is made here that this list may be studied with profit by those seeking investment in iron ores, or the direction of mining operations in new fields. Particular attention is called to the notes on the rocks found with the ores in the mines—mine rock—and on the country rock, in which ores are found to occur generally in this Highlands region, as useful hints to prospectors, both in the further development of old mine localities and in the discovery of new disposits of extent. The use of the miner's compass is also referred to, with some practical rules for the correct interpretation of its readings in the presence of ores.

GEOLOGICAL WORK IN THE SOUTHERN PART OF THE STATE.

In the southern part of the State preparation has been made for a detailed geological map, showing the limits and areas of the various superficial formations of sands, gravels, clays, peats, tidal marshes and other recent deposits. For this exhibition, the topographical maps of the Geological Survey are to be the basis on which these more recent geological terranes are to be laid down. C. W. Coman, who was hired in September as Assistant Geologist, began work in Monmouth and Middlesex counties and in the survey of the terraces along the coast and the lower stream valleys of the coast belt. These terraces were described briefly and their further extension indicated in part in the Annual Reports of the Survey for the years 1880 and 1885, and their heights and probable extent were shown on the topographic maps, but no systematic study of them had ever been made by the Survey. The results of Mr. Coman's observations on the terrace formations point to the occurrence of three well-marked terraces, one at the height of ten feet, a second about forty feet and a third sixty feet above the line of mean tide. They are evidently the old lines and marks of former water levels on this part of our coast, and mark some of the stages in the upraising of the land. The land is now relatively higher than it was in the terrace epoch. The broad-bottomed or U-shaped valleys in which the streams of the coast belt now flow are also marks of changes here and indicate the greater volume and size of the rivers which flowed therein during a subsequent period. The survey is, however, too incomplete to discuss the question of geological age and describe the succession of changes which all of these phenomena appear to indicate. The subject belongs to the geological history of the continent and is related to pure science, rather than to economic geology, although, inasmuch as these terraces are generally sandy or gravelly, they differ materially from the adjacent outcropping beds of clays, marls and sands of the underlying cretaceous formation and are distinctive features of the surface viewed from the standpoint of agriculture.

Some attention was given in this work along the coast to the beds lying upon the greensand marls, but the observations are over so limited a district as to forbid generalization.

In December Mr. Coman was transferred to the Delaware valley and he began the study of the gravels about Trenton. The work has been done so recently that it would be premature to announce results. It is safe to say that the area of the formation which may be termed the "Trenton Gravel," and which represents the estuary into which the old Delaware poured its flood of waters at the end of the Glacial Period, has been ascertained and its limits determined. The work rests so largely upon the topographic map that it is a forceful argument for accurate maps upon which to delineate the lines of geological formations, and also of their invaluable assistance in tracing such lines in the field. The relation of this Trenton gravel to the yellow gravels of South Jersey is yet to be made out, as also that of the brick clays to the latter gravel. The geological history promises to be an interesting one when it shall have been deciphered in these various gravels, sands, clays and other alluvial and diluvial deposits. So much stress has been put upon certain finds of rude implements in this Trenton gravel that it seems desirable for the Survey to decide upon its age by a most careful study.

WATER-SUPPLY AND WATER-POWER.

In accordance with the plans of Dr. Cook for the publication of the results of the work of the Geological Survey, the studies and field observations for the volume on Water-Supply and Water-Power have been carried on throughout a part of the year under the immediate direction of C. C. Vermeule, late Topographer of the Survey. The report is made on the observations of stream-flow and rainfall up to date. The census of the water-powers of the State is still in progress, and is, therefore, incomplete. These lines of investigation are concurrent and related intimately; the application of the facts obtained in these inquiries is quite diverse. That of water-supply is of the most vital importance to the city population. Comfort and health are both ministered to by an abundant supply of wholesome water for domestic and household use. And this statement applies to the masses of the people, since comparatively few are so situated as to be independent of a public water-supply. Good water is a powerful factor in our environment, and tends to our highest development. The earliest reports of Dr. Cook indicating the existence of streams of pure water and of natural reservoirs, and his later surveys, which showed clearly their location and accessibility to our city populations, are a part of the history of the Geological Survey. The questions of water-supply for nearly all of the cities in the northeastern part of the State are still unsettled. New sources are wanted by some of them; others are looking for an increased supply. Although full co-operation in a comprehensive plan, which should include all of these cities, is, perhaps, barred by their existing arrangements, some general control of the water rights by the State is far from being a utopian scheme or undemocratic. And the traditions of the Survey are in the line of indicating such a comprehensive system of supply as will tend to the highest development of these towns and cities, without prejudicing the rights of communities or existing companies, and at the same time maintain for the State its proper jurisdiction in its natural waters. These are as much a part of its economic resources as the soil and the mineral wealth beneath the surface.

In the southern and central parts of the State the supply of water by means of artesian wells is in much favor, both for villages and towns and for manufacturing purposes. They meet the wants of the smaller towns, and particularly at points on the Atlantic coast, where many have been sunk and abundant flows of good water have been secured. The possible limit to the volume of water which is obtainable from water-bearing beds at any given point, is not shown by any results thus far had, but for larger centers of population the recourse to streams will no doubt be necessary, even where artesian wells exist. And the growth of the cities in the southern part of the State will call attention to a report on the available sources of supply in the streams in that part of the State, or, possibly, to some general State system, drawing from the superabundance of good water flowing out of the forested hills of the Highlands. For many places in the southern interior and on the Atlantic coast belt, the artesian well is eminently satisfactory for a supply of water for domestic use. Their success is suggestive for other than household supply, viz., for flowing cranberry bogs and for the irrigation of crops on lands not otherwise tillable or adapted to cultivation.

The other line of inquiry, that of water-power, is a new one in the history of the Survey work. The first question asked is, What are the streams which may furnish power? And the complete answer to it gives the hydrography of the State. The topographic maps show the sources and courses of the streams, and their relation to the cities and towns and lines of transportation, or sites where their power can be utilized. Then follow the questions on the fall and volume of water at all seasons, and the sites, occupied or not, where this power is to be had or where it can be improved. Hence the great practical importance of a census of these water-power sites and their available horse-power, as ascertained by means of accurate gauging. This work of gauging is of necessity slow, and requires time for periods of observation long enough to eliminate exceptional features and to reach a safe and fair average estimate for the use of the engineer. The field-work was begun in February, and a system of weir-gauging was undertaken by reliable observers who were found willing and capable for this work. Several of these observers volunteered to keep records at their mill sites, thus aiding materially and reducing the cost of this part of the work. The Beattie Manufacturing Company, at Little Falls, kindly furnished a record from June, 1888, a valuable contribution, giving statistics of flow on one of our most important streams and at a valuable site. This census will give data of power in use and its work, notes of freshets, amount of fall, ownership and some statements about abandoned mill sites. It is believed that this report will be useful in attracting attention to the unused water-power of the State. Our situation so near the great Eastern markets, the many railway and canal lines, following the courses of the streams, and the healthy and beautiful sites for manufacturing towns, are all in favor of its development. The need of closer attention to economy of production must seek out such available sources of cheaper power. One disadvantage noted and urged against the use of water-power of the smaller streams is their varying stage of water and low condition in dry seasons. A remedy is suggested in the construction of reservoirs on these streams, for which there are in all cases natural advantages to aid in their construction. And these reservoirs on the tributaries of the Passaic, Raritan and Delaware are capable of being made attractive features in the landscape of the hills, thereby enhancing the value of the land for residential purposes, and for equalizing the flow for the purposes of city water-supply. In the thorough utilization of available natural water-power the State is far behind Massachusetts and Connecticut; and there does not appear to be any good reason for this difference. Attention is asked to this report of Mr. Vermeule, as a valuable statement of facts relating to water-power, with a full discussion of the flow of streams and its relation to rainfall, and of statistics of water-powers available and in use, and of sites not now at work. The full report on Water-Supply and Water-Power is to form the subject of the next volume in the series known as the Final Report, and it is expected that it may be ready for publication some time during the coming year.

ARTESIAN WELLS.

In answer to my request, Mr. Lewis Woolman has prepared a paper describing the recently-bored wells in the southeastern, coast belts of the State, and added notes on some of the older artesian wells. He has collected valuable data on the depth and thickness of the strata passed through in these borings, and specimens representative of these various beds, which make interesting suites for exhibition in a State collection. His observations confirm the existence of a southeastward dip of the beds, as stated in the Annual Reports of the State Geologist and in the Geology of New Jersey, published in 1868. This dip or descent in the upper and newer beds is shown by his sections to be at a lesser rate than that of the lower beds, and particularly less than in the greensand marl and associated beds. In these latter the dip, as stated in the reports on the marls, in 1868, is at the rate of 25 to 37 feet per mile;* the sections from these wells on the coast indicate a dip at the rate of 24 to 26 feet per mile. The greater thickness of some of the beds as they extend southeast, under the newer formations, is apparently confirmed.† The evidence of this greater thickness is strengthened by the configuration of the bottom of the ocean off the coast of the southeastern part of the State. As was pointed out in the report for 1884, the descent of the bottom for the first 100 miles is at the rate of three feet to a mile, whereas beyond 150 and 250 miles the rate of descent corresponds almost exactly to the dip of the cretaceous strata.

The existence of the diatomaceous earth in other localities and its place in the series as a bed of considerable thickness and persistence, are also pointed out in these notes of Mr. Woolman. Its correlation with the green, miocene marls of Shiloh, in Cumberland county, referred to in last year's report, is again noted with further evidence. The study of the surface in detail will, doubtless, result in the dis-

* Geology of New Jersey, 1868, p. 245.

† Annual Report State Geologist, for 1883, pp. 14-20; Annual Report State Geologist, for 1884, p. 127.

covery of other outcrops, and of its relations to the associated beds, as met with in well-borings and on the surface.

The important practical generalization of the paper is in the existence of three well-marked, water-bearing beds of sand at the depths of 554, 700 and 1,100 feet in the Atlantic City well, and at lesser depths in the country to the northwest, corresponding to the distance therefrom. Having this standard of reference at the east or southeast, and the well-known structure of the greensand marl formation at the west, and knowing the rate at which the beds descend in a general southeast direction, it is possible to indicate the probable depth below the surface at any given point, at which the water-bearing beds can be reached. The abundant supply of good water which is practically within reach at almost every locality in the southeastern part of the State, with the high degree of probability of obtaining a flowing stream of water, are advantages which invite and attract people to it. Thus the study of geological structure and the scientific examination of specimens from these well-borings are proving to be rich in practical benefits.

DRAINAGE.

The report on the drainage-work inaugurated by the Survey and carried on with so much success and such beneficial results, thereby adding to our available resources, is written by George W. Howell, of Morristown, and one of the Commissioners of the Drainage of the Passaic Wet Meadows.

On the Passaic the work of removing the obstructions in the river at Little Falls has progressed slowly, but steadily. The large area of country and the value of the lands affected, as well as the sanitary improvement which this drainage appears to promise to the resident population of the Upper Passaic valley, combine to urge the necessity of its speedy completion. The long history and varied results which attended the earlier efforts to drain these lands, and the promise of success of the latest plan, elaborated and begun by the late Dr. Cook, a native of the valley and attached so ardently to this work of improving the country of his early home, seem to call upon us to do all that can be done to make this drainage-work a substantial monument to his untiring perseverance, and add to the wealth of acreage in the State.

PUBLICATION.

The publication of the series of volumes constituting the final report has progressed as far as Volume II., which was issued in two parts. Part I. pp. x. + 642, appeared in 1889. It contains a Catalogue of the Minerals found in the State, by Frederick A. Canfield, A.M., E.M., of Dover, Morris county; a Catalogue of Plants found in New Jersey, by N. L. Britton, Ph.D., of Columbia College, New York. Part II. pp. x. + 824, contains a Catalogue of Insects found in New Jersey, by John B. Smith, Entomologist of the New Jersey State Agricultural Experiment Station, and a Catalogue of Vertebrates of New Jersey (a revision of Dr. C. C. Abbott's catalogue of 1868), prepared by Prof. Julius Nelson, Ph.D., of Rutgers College. These two parts of Volume II. have been distributed to about 2,500 individuals, public offices and libraries in the State and scientists in other States, following the list as used for the distribution of the first volume of the series. The interest shown by the people in the requests for these catalogues of natural history is gratifying and evidence of a growing desire on their part to learn more of the State and its minerals, its vegetation and its animal life.

DISTRIBUTION OF PUBLICATIONS.

The distribution of the publications of the Geological Survey, including the volumes of the final report, the annual reports and the maps of the topographic atlas, is time-consuming and expensive, and it has been necessary to retain the help employed at New Brunswick in continuing it on the increasing scale which the constant call for reports demands. This work has been in charge of Mr. Upson, who remains as Assistant-in-charge of the office. The continuance of the office at New Brunswick is rendered a necessity on account of want of room at the State House. The transfer of the collections, as well as the stock of reports and maps, to the State House, is to be made as soon as the rooms for the new office and the museum are ready for occupancy.

MUSEUM.

A museum, to be known as "The Museum of the Geological Survey," was established by law passed at the last session of the Legislature, and the rooms for it were ordered to be provided for by the proper authorities. The collections belonging to the State are those which formed a part of the old State Museum, and which were sent to the exposition at New Orleans, and the materials collected during the progress of the Survey since that time and stored at New Brunswick. They are mostly good representative specimens of ores, rocks, minerals, clays, marls and woods of the State, and are nearly all suitable for a new museum. In view of the establishment of a museum, I have had collections of our iron ores made which are full and typical of their occurrence. This will make an important and large addition to the material now stored in the State House. A State Museum which may contain representatives of the economic wealth of the State, is much wanted for their proper exhibition and for distributing information to the people. These collections, aided by maps and, particularly, by models (or relief maps), will be valuable object lessons, and illustrate the reports and catalogues of the natural history of the State.

The work for the coming year is to be directed mainly to the preparation of a detailed geological map of the State, on a scale of one mile to an inch, and on the topographical sheets of the Atlas of New Jersey as a base. It will be divided into two parts and appear in two series of maps. One of them will give the study of the structural geology and the maps will be on the plan and according to the usual style of geological maps. The underlying rock formations, irrespective of the surface, will be shown thereon. For this series a large part of the data of the Survey will be available and of the greatest service in completing the work. The study of the surface or superficial deposits or formations will be the other line of inquiry, and the maps will exhibit the nature of the surface and the actual outcrops. It will be more properly an agricultural map and show the distribution of the soils. For it very little useful material is on hand and the whole State must be traversed. The work is a great one, although not as laborious as that of the topographical survey. The proper discrimination between the varieties of surface deposits will demand much care and conscientious and faithful observation.

In order to accomplish this result, the assistance of the United States Geological Survey has been sought and aid has been promised the State. According to the plan proposed and accepted by the

Board, its help will be in the study of the crystalline rocks of the northern part of the State and the associated Paleozoic rocks and the adjacent red-sandstone belt. A detailed geological map of these formations, embracing about three-sevenths of the State, is thus to be done by the National Survey, leaving the rest of the State to our Survey. With this substantial assistance it is believed that the map, as proposed, can be completed within the current five-year period.

The United States Coast and Geodetic Survey, through its Superintendent, promises the continuance of the appropriation asked for by Prof. E. A. Bowser, in charge of the triangulation work, and is desirous of aiding more particularly in surveys and levelings to ascertain what are the changes now in progress on our Atlantic coast, and the amount of subsidence, as well as the wear of the coast. The question is one of importance to property-owners and others interested in lands on our sea-shore. The alterations in the shore line, as reported from time to time, and the subsidence of the land or rise of the water on the land, are questions which need to be answered by figures drawn from surveys and levelings, referable to accurately-located datum lines. The co-operation of the United States Coast and Geodetic Survey will be given toward the establishment of a few monuments and a survey of the shore with reference to them. Professor Bowser is to act with the State Geologist in the locating of these bench-marks and monuments, and in making the needful surveys. Of course the results from work of this kind are not to be expected at once. They must await the action of great forces which operate slowly, but surely and irresistibly.

UNITED STATES COAST AND GEODETIC SURVEY OF NEW JERSEY.

BY EDWARD A. BOWSER.

During the present season no work has been done on the United States Geodetic Survey of New Jersey. The next stations to be occupied are Colson and Taylor. These two stations will determine the old coast survey station, Lippincott, the monument at which is, I believe, lost.

An observing-tower, sixty-four feet high, should be built at Colson during the present fiscal year, and a reconnoissance should be made in April, before the leaves are on the trees, for opening vistas through the tree-tops from Colson to Taylor, Bridgeton, Burden and Lippincott, so that we may begin the measurements of the horizontal angles at Colson immediately after July 1st, 1891. As there is much tall timber on these lines, towers at least sixty-four feet high will be necessary also at both Taylor and Bridgeton. These towers will cost nearly $300 apiece, without the reconnoissance.

If New Jersey receives an allotment of about $400 for the present fiscal year, the observing tower at Colson can be built and the reconnoissance, or a part of it, can be made before June 30th, 1891. Then July 1st, 1891, we can begin the measurements of the horizontal angles at Colson and complete the above reconnoissance, and after these angles have been measured, if we receive a fair allotment (say $1,600), the tower at Taylor can be built and the measurement of the angles at that station can be begun and perhaps completed. It is very desirable that the old coast survey stations, Lippincott, Burden and Pine Mount, be recovered and re-marked.

THE POST-ARCHEAN AGE OF THE WHITE LIMESTONES OF SUSSEX COUNTY, N. J.

FRANK L. NASON.

GEOGRAPHY AND TOPOGRAPHY.

The white limestone belt of the northwest begins at Mounts Adam and Eve, in Orange county, N. Y., about four miles northwest of Warwick. A narrow tongue lies along the southeast flank of Mount Eve, and another tongue lies between the two hills.

From this point south the belt widens, till at Amity, N. Y., it attains a width of two miles. From Amity the belt again narrows as it approaches the New Jersey line. Near the New York State line the limestone lies against the eastern foot of Pochuck Mountain, and continues to a point about one mile and a half below the village of McAfee. At McAfee the white limestone seems to fill the entire valley between Pochuck and Hamburg Mountains, crossing the valley at nearly right angles. From here it follows the foot of Hamburg Mountain to Franklin Furnace. At Franklin Furnace the belt again crosses the valley and thence follows the eastern foot of the Pimple Hills to a little below the zinc mines at Sterling Hill.

Between the two points, Mounts Adam and Eve and the terminus below Sterling Hill, a distance of thirty-one miles, the belt of limestone appears to be continuous, but from this point to the Delaware river the line is indicated by isolated patches of limited area.

Between the terminus of the line at Sterling Hill and the Sussex railroad, still further south, there are between eighteen and twenty-five outcrops, varying in extent from one-fourth of an acre up to two or ten acres in extent.

The next largest outcrop lies along the eastern foot of Jenny Jump Mountain, in Warren county. The line here is not continuous, but is broken up into seven or more patches within a distance of five miles, the largest of which is near Southtown, at the extreme northeast point of Jenny Jump Mountain.

It is to be noted that here, as usual, the white limestone is flanked by the blue and is intimately associated with it.

A very limited outcrop is exposed in the Delaware, Lackawanna and Western railroad cut at Pequest Furnace.

The last exposure lies in a narrow valley about two miles in length, and running nearly east and west, between the Belvidere mines, northwest of Oxford, and Hazen Post Office.

Beginning at Mounts Adam and Eve, it will be noticed that the white limestone is flanked on either side by the blue or magnesian limestone. On the northwest border the blue limestone is cut out near the New Jersey line by the Pochuck Mountain on one side and the white limestone on the other.

On the southeast side the blue limestone follows along the border of the white, till it is cut out by the white limestone on the eastern slope of a small, precipitous hill one-fourth of a mile directly east of the hotel at McAfee. Between Mounts Adam and Eve and McAfee there are several places that will be mentioned more particularly later on, where the unchanged blue and the full crystalline, white limestone lie close together or grade into each other.

From McAfee to Franklin Furnace the blue limestone lies on the northwest flank of the white till it ends at Franklin Furnace, on the northeast point of the Pimple Hills.*

In order to get an exact idea of the boundary line between the white and blue limestone at McAfee, please have in mind the letter "M;" the two angles at the top of the letter pointing north will then represent two tongues of the unchanged blue limestone, while the angular depression in the middle of the letter will represent a tongue of highly-crystalline white limestone lying between the blue and pointing south. The right-hand side of the letter will then be flanked by the white limestone which lies along the western foot of Hamburg Mountain.

East of Furnace pond, Franklin Furnace, the blue limestone is A-shaped. Either flank of the A (the apex lying to the north) is white

* It should be noticed that the blue limestones do not really end here, but that they pass around to the left and then continue along the northwest border of the gneisses to the Delaware river. In several places along this border, white limestone in small knobs appears between the blue limestone and the gneiss.

limestone. From here the blue limestone runs due southwest and cuts out the continuous belt of white limestone at a point on the Pimple Hills, about one-eighth of a mile north of New York, Susquehanna and Western railroad. The blue limestone continues in a narrow tongue to a point a little more than five miles southwest of Sparta village. On the northwest border of this belt there are four isolated patches of the white limestone lying close to the gneisses of the Pimple Hills.

At the southwestern terminus of this belt of blue limestone there is a low water-shed which turns the course of the water to the southwest, where it finds its way to the Delaware through the Musconetcong river.

In this water-shed there are two small streams, one known as Lubbers run. In the narrow valleys occupied by these streams there are several patches of blue limestone, underlain by sandstone, as well as several patches or knobs of white limestone. The blue or magnesian limestone, with the exception of some slaty rock, fills the entire Musconetcong valley from Waterloo to Phillipsburg.

In the Pequest valley, bounded on the northwest by Jenny Jump Mountain, the blue and the white limestones bear about the same relations to each other as the ones already described.

The points to be borne in mind from this description are: First, the intimate association of the white and the blue limestones; second, that this same intimate relationship probably existed between the now-isolated patches of blue and white limestone in the water-shed just mentioned, before erosion or solution swept away the bulk of the formation. The probability that this relationship existed is reduced to almost a certainty by finding patches of limestone where the limestone, sandstone and white limestone grade into each other.

TOPOGRAPHY.

In the study of the topography of these limestone belts (the white and the intimately-associated blue) in their relation to the gneissic mountains on either side of them, three very striking features are observed which serve to point to their being a geological unit on the one hand, and to their being distinctly separated from the gneisses on the other hand. These features are as follows:

First. The strike of the axial ridges of the flanking mountains, Pochuck, Hamburg, Pimple Hills, Wawayanda and Sparta, is very nearly due northeast. The strike of the white limestone ridges and of the blue as well, when these ridges are both flanks white limestone, or one flank white and the other blue, is north, 5° to 15° east.

The exception to this rule is between McAfee and Hamburg, and on the north side of the Lehigh and Hudson River railroad. Here the ridges of white limestone and of blue and white mixed, have their axes nearly parallel to the axes of the gneisses.

Second. The highest point of the limestones in this valley is at the lowest point of the flanking gneisses. That is, from Franklin Furnace to McAfee, the average altitude of the limestones is a little over 700 feet. This altitude declines to the northeast to an average of less than 500 feet. To the southwest the average is less than 600 feet.

From Hamburg the Pochuck Mountain (gneiss) rises to the northeast from an altitude of 600 feet to 1,100 feet. From Franklin Furnace the Pimple Hills rise from an altitude of about 600 feet to 1,000 feet at the southwest. The same is true, though in a less marked degree, of the Wawayanda and Sparta Mountains.

The relations may be briefly expressed by comparing the slopes of these two formations to two wide angles. The sides of the angle representing the limestone, slope downward to the northeast and to the southwest. The sides of the angle, representing the gneisses, slope up in the same directions along the strike.

Third. The gneisses, almost without exception, are monoclinal, or overthrown anticlines with an almost universal dip to the southeast. The limestones are for the greater part marked anticlines, or if monoclinal the dips are about equally divided between the northwest and the southeast quadrants.

AXES OF DISTURBANCE.

To one who is at all familiar with the geography and geology of New Jersey, it will at once become apparent that the white limestone is distributed along axes of great disturbance. This disturbance is indicated—First, by violent and sudden changes in the dip and strike; second, by the presence, in great abundance, of eruptive rocks of various kinds; third, by the shattered condition of the rocks. In the white limestones this disturbance is marked, in addition to the shattering, by what in other rocks would be called slickensides. The limestones, in addition to the polished surfaces, have numerous bands of graphite from one-eighth of an inch to an inch in width, and occasionally two feet in length. This banding is not confined to the polished surfaces, but extends sometimes to the distance of a foot or more within the rock, where the bands disappear and the brilliant scales of graphite and the crystalline faces of the limestone take their places. The banding in every case is parallel to the sinuosities of the surface, and the bands show a distinct parallelism to each other. The graphite of the bands has not the brilliant natural surface of the graphite scales in the rock proper, but even when flaky has a dull appearance, as if having been rubbed. These markings are present in every quarry of the white limestones, and they have been found in many other places.

As would naturally be expected, the blue limestones have not this shattering in the same marked degree. Yet, when in close connection with the white limestone, it is observed, but with the absence of the bands of graphite.

Graphite in this case, however, is invariably present, but usually in fine dull scales, and only abundant in proportion as the change from blue to white has taken place. The sandstone which accompanies the blue and white limestone in such cases, when exposed, is broken but not polished, and the scales of graphite are then bright.

ROCKS ASSOCIATED WITH THE WHITE LIMESTONES.

The rocks associated with the limestones are as follows: Granites, scapolite rock ("geflecter gabbro"), boulder-like masses of various kinds, gneiss (?), pyroxene mica rock, sandstones and quartzites (fossiliferous), and mica diabase.

The granites are by far the most abundant of the foreign rocks of the limestone series. They occur in great dykes and bosses, and they are also interlaminated with the white limestones. At Franklin Furnace there is a great dyke running nearly due northeast across the limestones, which here strike about north, 5° east. The dyke shows itself in the quarry just across the railroad from the furnace, and it has been beautifully exposed by quarrying the limestone from either side of it. This dyke again appears on Mine Hill, and can be traced almost continuously for the whole distance.

In the Trotter zinc mine, on Mine Hill, great horses of granite are often encountered. In the public road along the north side of Furnace pond, a great exposure of granite appears, flanked on either side by white limestone. It is also the foot-wall rock of the front vein of zinc ore from the southwest opening to the northeast opening near Greenspot. The hills between Hamburg Mountain and the white limestone due east of Furnace pond, are also granite. In fact, these foot-hills of granite, with apophyses reaching into the limestone, occur along the Hamburg Mountain to a point nearly due east of McAfee. At this point the blue limestone begins, and the granite ends. A great medial line of granite, mentioned as occurring in the road north of Furnace pond, runs parallel to the strike of the white limestone and terminates in two precipitous hills, one north and one south of the road leading east from McAfee, and distant one-fourth of a mile from that place.* Another line of granite in the northwest border of the limestones first appears in the New York, Susquehanna and Western railroad cut, one-half of a mile northwest of Hamburg. The granite in this cut is in contact with the sandstone, and appears to be fused to it. At least the union between the two rocks is so close that a specimen may be broken off, part of granite, part of sandstone.

This line of granite runs nearly due northeast, and again appears in contact with the sandstone just south of the Pochuck mine road, one mile northeast of Hamburg. The same phenomenon is here repeated, and the sandstone is here overlaid by a slightly-changed blue limestone.

From this point towards McAfee, the dyke, or series of bosses, is enormously developed, and the greater part of the two hills lying to the east of Pochuck mine is composed of it. The hill just back of the school-house at McAfee is especially to be noticed as consisting of granite. Between the White Rock Lime Company's quarries at McAfee and the high hill east of them, this same dyke is again enormously developed. Without specifying further, the foot-hills at the southeast flank of Pochuck Mountain are largely made up of granite, and in one or two places quarries have been opened.

My special studies have not included the belt north of Sand Hills, but from a drive over the country, after a long study of the belt between Sterling Hill and Sand Hills, I observed the same succession of granite to a point a little above Amity, N. Y. I have by no means

* This granite dyke does not begin at Franklin Furnace quarry. It is an extension of the great dykes and bosses which occur in the "Wild Cat" southwest of the quarry, and which extend almost the whole length of Pimple Hills and even farther.

exhausted the localities at which granite occurs, but have simply indicated the lines along which are the greatest outcrops. So far as I know, there is not a single outcrop of white limestone which is not intimately associated with granite.

Lithologically, the granite is extremely simple. The two principal minerals are quartz and orthoclase feldspar. The other minerals in the granite appear to be accessory rather than essential constituents. In a personal letter from Dr. Geo. H. Williams, in which he describes a section of this granite from McAfee, he says: "Granite, with quartz in rounded grains, feldspar (orthoclase), with fine microperthitic structure, and a very little brown mica." This particular specimen (No. 1767), is from the limestone quarry by the roadside at McAfee, but microscopically it is not to be distinguished from the other outcrops save as they vary in coarseness.

In many places this granite has distinct traces of foliation, and may on this account have been mistaken for a gneiss. The proofs of its eruptive origin are abundant. Aside from its general appearance, which indicates its igneous origin, its relationship to its associated rocks is such as to settle the question beyond dispute.

First. It cuts obliquely across the line of the strike of the white limestone at Franklin Furnace.

Second. It has been proved by means of a diamond drill core at Franklin Furnace to be interlaminated irregularly with the limestones.

Third. At its contact with the sandstone near Hamburg the granite is not only knit closely to the sandstone, but at the Pochuck mine road it has fragments of sandstone and other rock imbedded in it.

Fourth. When sandstone and limestone of the blue limestone formation lie near the granite, graphite is more or less abundantly developed in both, and, in the sandstone, feldspar and mica crystals are numerous.

At Hardistonville, Dr. Charles E. Beecher* found recognizable species of trilobites in sandstone charged with graphite, and there were also fossils found in the limestone overlying the sandstone. Near Franklin Furnace, I was so fortunate as to find a fragment of a trilobite in a sandstone containing graphite.

Another locality is the Roseville mines, near Roseville pond (form-

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*In this paper, when mention is made of fossils being found in these rocks, the statement is made on the authority of Dr. Charles E. Beecher, who made the necessary field examinations at the instance of the writer.

erly Lion pond), which is mentioned by Professor Rogers. In this locality both the sandstone and the overlying limestone, in addition to being changed, have much graphite present in them.

Fifth. The contact phenomena are unmistakable. In the dyke at Franklin Furnace, there is a great abundance of fluorite, of a beautiful purple color, in the limestone, in contact with the granite, and near by, or within a few feet of it, it contains irregular blotches of chondrodite and crystals of green and brown tourmaline.

Sixth. There has already been a partial reference to the changes which are induced upon rocks of proved Devonian age, or older, by the presence of granite in dykes or bosses.* The fact is, in this field, when a blue limestone lies near a granite dyke, it becomés materially changed, and passes, by a steady but rapid gradation, into a white crystalline limestone at the dyke. The localities at which this may be observed are Franklin Furnace, in the woods one-eighth of a mile southwest of hill 737; at Hardistonville, on the banks of a brook in front of Carpenter's hotel. There is also a locality near Sand Hills, east of McAfee, and near Wright's or Lion pond, at Roseville.

In these places the evidence that the granite has changed the blue limestone to a graphitic white limestone, is most convincing. The question naturally arises, then, as to whether a hidden dyke of granite may not have occasioned the change from blue to white where there is no granite visible on the surface. Favorable evidence in support of this is found in the Pochuck mine tunnel, near McAfee, N. J. Here a tunnel is driven 250 feet, as an adit to the Pochuck hematite mine. In this tunnel granite is found abundantly in the white limestone, but it does not appear on the surface. It thus appears that whatever may be the age of the white limestone, the granite is younger than the limestone.

Scapolite rock or "geflecter gabbro," next to the granite, is the most abundant rock of igneous origin in the white limestone. In Norway, where first noted and described, it is known as an "apatite bringer." In Canada, where it was recently found, it has been described by Lawson and Adams.

In this region apatite, though present, is not abundant.

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*See Dr. George H. Williams: "Contact metamorphism produced in the adjoining mica schists and limestones by the massive rocks of the Cortland series near Peekskill." Am. Jour. Sci., III. series, vol. 36, p. 254. Prof. B. K. Emerson: "Description of the series of metamorphic Upper Devonian rocks." Am. Jour. Sci., Oct. and Nov., 1890.

To show that this is undoubtedly the same as the Norwegian rock, I will again quote from a personal letter from Dr. Williams, "No. 1791, York State Quarry, Rudeville: 'Beautiful and typical scapolite rock; white scapolite; green pleochroic hornblende; green non-pleochroic pyroxene; red sphene.'"

"No. 1792, same locality, same as No. 1791, but contains, in addition, a little plagioclase (anorthite?)." "Also Nos. 1772 and 1773." These last two numbers are from a quarry at McAfee.

In the "York State Quarry," at Rudeville, these scapolite dykes are most perfectly exposed. The scapolite rock in this quarry, in the south end, lies in three distinct dykes, and is almost perfectly conformable to the dip and strike of the limestone. The dykes are rather narrow, not exceeding four to six feet in width. If nothing else suggested their igneous origin, the fact that these three dykes unite into one great dyke, in the north end of the quarry, would suggest this idea most forcibly. In appearance the scapolite rock looks much like a hornblende feldspar rock, which is very common in the gneissic rocks of the Highlands. This resemblance is heightened by the perfect foliation of the dykes and their apparent conformability to their host. This foliation is strikingly characteristic of these rocks, even when they occur as boulder-like masses included in the limestone. These facts are probably responsible for the frequently-repeated statement, "The white limestones are everywhere interstratified with the gneisses and are conformable to them."

There seems to be little doubt of the eruptive origin of these rocks, in part at least, and facts tending to prove this are easy to find. These rocks, though apparently conformable to their host, are not always so. As has already been stated, dykes of this rock coalesce in the "York State Quarry." The contact phenomena, while not as well marked as in the case of the granites, are yet very prominent. The dykes, and especially the isolated boulder-like masses, are accompanied by a great quantity of fluorite.

On the underside of the dykes at Rudeville large cavities are frequently filled with scapolite crystals of various sizes. These crystals appear to have been formed originally in the limestone which has subsequently been removed by solution. These same scapolite rocks occur in boulder-like masses as well as in dykes, a fact which has already been alluded to. If one were not acquainted with their nature they would unhesitatingly be called water-worn boulders. The only thing which first suggests their having originated *in situ* is the distinct reaction rim which surrounds them. This rim or shell is made up largely of scales of dark mica (species not determined), hornblende and pyroxene.

The rim is often marked by a segregation of graphite, which extends to a considerable depth in the mass. The masses are perfectly rounded in form; their mineral composition is identical with that of the dykes. They usually have, when coarse-textured, a distinct foliation, and they invariably occur in the neighborhood of the dykes or of some other igneous rocks.

The localities where fluorite is most intimately associated with the boulders and dykes, is at the "York State" quarries, at Rudeville, and the limestone quarries at McAfee.

There are other boulder-like masses which occur in the limestone, more often of the nature of granite, and they consist largely of quartz and feldspar. These, however, are comparatively rare.

There are numerous bunches in the limestone which are made up of an ill-defined variety of minerals, usually of a pale-green color, containing much calcite, and having no sharp, well-defined boundaries. These are probably, as suggested to me by Dr. Williams, aggregations or segregations from impurities originally contained in the limestones themselves. These latter are very abundant. They can be very easily accounted for by supposing that the numerous cherty nodules in the blue limestones have, during the process of metamorphism, taken lime and magnesia from the body of the rock, and the lime-magnesia silicates are the results.

That there is a difference in origin of these boulder-like masses, there can be no doubt. The scapolite masses with, their fluorine minerals, suggest fumarole action, just as the others suggest a metamorphic product from mixtures originally present in the limestone.

There is yet another rock occurring, which is, no doubt, of igneous origin. It has not, that I know, any specific name. The rock consists almost wholly of pyroxene (diopside probably), and a dark mica which may be phlogopite.

In three localities, widely separated, one on Mine Mountain near Mendham, one on Jenny Jump Mountain, and one on Scott's Mountain, the crystals of mica have been large enough to suggest a possible economic value, while the crystals of pyroxene have been found eight inches long. In the localities at McAfee, one east and one west of the railroad, the mica consists in the main of fine scales closely bunched, while the pyroxene or diopside is in crystalline masses, having a perfect resemblance to "shot ore," save, of course, as to color and specific gravity. The proofs of the eruptive origin of these rocks is about the same as those of the other rocks, with this difference. The contact mineral in the limestones near this rock is almost wholly chondrodite.*

The most striking illustration of this is found one mile from McAfee, towards Hamburg, and on the west side of the road. The other locality is one mile due northeast of Franklin Furnace, in some old openings made in search of zinc. In this latter place, the bright-reddish chondrodite was mistaken for zincite. The chondrodite occurs here in large masses, while at McAfee it is in the limestone in globular masses the size of a pea.

MICA DIABASE.

This rock, so common in the white limestones, was described by Prof. B. K. Emerson under the name of kersantite. The dyke described by Prof. Emerson was the large one in the zinc mine at Franklin Furnace. This dyke cuts across the zinc and limestone at right angles to the strike. Its westward extension is found in the blue limestones and sandstones west of the mines; the eastward, is found about a mile eastward, near the foot of Hamburg Mountain.

Another dyke of this same rock, and at least equal in size, is found in the quarries at Rudeville. It is thirteen feet wide, has been exposed for one hundred and seventy-five feet in length and fifty to seventy-five feet in height. It appears to have many branching dykes, though these may be independent ones. Beautiful, thin, ribbon-like tongues are forced through the limestone in every direction in the vicinity of the dyke.

Dr. Williams' note on this is as follows: "No. 1795, great dyke at Rudeville; mica diabase; beautiful rock, but no longer quite fresh; idiomorphic; yellow and reddish pyroxene; biotite; abundant sphene; apatite; magnetite; plagioclase considerably altered and filled with secondary chloritic matters."

This rock is found in considerable abundance in the lime quarries

* This mineral was examined and pronounced chondrodite by Prof. S. L. Penfield, of the Sheffield Scientific School, Yale University.

at McAfee. A great mass of the same coarse rock occurs about one mile south of McAfee, toward Hamburg. It is now more like granite in its nature and is probably a great dyke.

The contact phenomena in the case of these rocks are not so prominent as in the case of the granites, gabbros and mica-pyroxene rock. Yet, at Rudeville, the course of the dyke is marked by an abundance of chondrodite, brown, black and green tourmaline. Fluorite, though present, is not as abundant as near the scapolite rocks. Where it breaks through the sandstones at Franklin Furnace, and east and west of McAfee, the sandstones are graphitic. In the two prominent localities at McAfee the blue limestones are brecciated; the interstices are filled with crystalline limestone, which is graphitic, and graphite is occasionally found in the blue limestone forming the breccia. It is thus seen that the various igneous rocks have a decided influence on the sandstone and limestone, and, in the matter of mineral alteration, on the white limestones.

GNEISSES.

As has already been intimated, gneisses are not certainly known in connection with white limestones. The gneisses reported to have been interstratified with the limestones have proved to be, so far as I have been able to identify localities cited, either "geflecter gabbro" or foliated granite.

SANDSTONES AND QUARTZITES.

Both of these rocks are found intimately associated with the white limestones, and in a few places in actual contact with them. In every instance the white limestone covers the sandstone. The harder quartzites are usually either under the sandstones or are near the granite or other dykes, and they are certainly one and the same bed.

In texture and mineral composition the sandstone of the white limestone is exactly the same as that found under the blue limestone. They are graphitic invariably when in contact with the white limestone, and often when under the blue. They have crystals of fresh-looking feldspar, probably orthoclase, and scales of white mica. They are often quite hard to distinguish from the granite. They are highly charged with pyrites. They are sometimes conglomeratic, with large, irregular-shaped, but rounded pebbles of milky quartz. Hematite and limonite are found intimately associated with the sandstones and the limestones in places. The most noteworthy place is in front of the hotel at McAfee. The place is an exceedingly interesting one from a geological standpoint, and will be referred to again.

Near by, but east from McAfee, is the Simpson mine, also intimately connected with the sandstone and limestone.

THE BLUE AND WHITE LIMESTONES OF THIS BELT.

Only a few words will be needed to point out the salient features of these rocks with reference to each other. The white limestones are not everywhere white, highly crystalline or "sparry," and, on the other hand, the blue limestones are not everywhere non-crystalline and blue.

The white limestones are not exclusively graphitic, for the blue limestones carry graphite as well, and, in addition, fossils.

The white limestones range from a highly-crystalline form to a rock which is nothing more than a fine-grained, clouded blue marble, while the blue limestones range from an earthy non-crystalline to white or cream-colored marble, carrying graphite. White, slightly-changed limestones have bleached nodules of a flinty nature, nearly or quite changed to crystalline quartz.

In the undoubted blue limestones there are characteristically large nodules of flint, and often these flint nodules, apparently not changed, have scales of graphite enclosed in them.

The white limestones have fine-grained, banded, boulder-like masses of limestone included in masses of coarsely-crystalline rock. The blue limestones are often brecciated, the breccia of all shades, according to location; and the interstices are filled with crystalline limestone, and both breccia and interstitial matter carry graphite.

The degree of crystallization in the white limestones depends upon proximity to an igneous rock, and this is carried to such an extent that a highly-crystalline white limestone changes to an undoubted blue at a distance from the igneous rock. The presence of graphite in fossiliferous sandstones and in the blue limestones likewise depends upon proximity to an igneous rock.

From this brief but by no means exhaustive statement of facts, it will be seen that there is but one positively distinguishing fact that separates the white from the blue limestone, and that is the presence of eruptive rocks. That is, as the blue limestones approach the line of igneous activity, they drop their distinguishing characteristics and assume by degrees those of the white, and *vice versa.* It follows, then, that a comprehensive description of the white limestones will not and cannot exclude the blue or magnesian rock.

ARRANGEMENT OF THE WHITE AND OF THE BLUE LIMESTONES AND ACCOMPANYING SANDSTONES WITH REGARD TO DIPS AND STRIKES.

In order to bring the relations to these rocks to a point of more easy comprehension, fifteen sections have been prepared from the more critical places where there is slight possibility of mistaking facts. These sections have not been drawn to scale vertically. The horizontal distance is six inches equal one mile.

Section I. is drawn due southeast through hill 750, one-half of a mile south of Pochuck mine, and one-third of a mile south of Simpson's mine, on hill 722.*

The extreme northwest end of this section † is made up of a series of slaty limestones, gritty limestones, moderately thick beds of limestone, and all underlaid by sandstone. This sandstone appears to be continuous to a point where it becomes more or less graphitic, when it is found in the form of angular blocks and mingled with blocks of white limestone, also graphitic. Farther to the east the white limestones are seen dipping to the southeast. The rocks are here so shattered and punctured by granite that it is difficult to make out the dip definitely, but it is southeast. Crossing the Lehigh and Hudson railroad and the swamps, we come to the northwest slope of hill 722. Here the series of blue limestones and grits is repeated and beautifully exposed, dipping in the same direction—northwest. The white limestone lies to the east at a considerable distance from the sandstone, which here is a hard quartzite. The white limestone comes next towards the east, and dips southeast.

It will here be seen that two hills with nearly parallel axes, and with their extreme flanks only one mile apart, are anticlinal in form and with the northwest flank of each of blue limestone, the southeast flank of white limstone and the axial ridges of graphitic sandstone.

Section II. is taken one-half of a mile northeast of Section I., and

* These figures are the altitudes of hills as given on the topographical maps of the Survey. They constitute the readiest and most accurate points of reference, and they can easily be found in the field with a map even without a barometer.

† See plate of sections and map facing page 50 of this report.

is parallel to it. Hill 750 is the same as in Section I. Especial attention is directed to hill 722. It will be seen by referring to Section I., that the northwest slope of this hill in that section was of blue limestone. In Section II. it is white. If the sandstones in Section I. are continuous to this point, then the limestones are also continuous, and the blue limestone has gone over to a white, unquestionably.

Section III. is taken about one-eighth of a mile northeast of Section II.

The shape of this hill is continuous on the northwest, but the blue limestone which is noticed on this slope in Sections I. and II. is in this section replaced by white limestone, in which granite and "geflecter gabbro" are very prominent.

It is hardly possible to determine the dip with any degree of satisfaction at this place, as the dips, owing to the extremely-disturbed nature of the rock, are nowhere constant. The prevailing dip is northwest, and about one-half of a mile to the northeast of this place there is an old mine-hole in which the dip is unmistakably to the northwest.

Here, again, the outcrop is not continuous from the blue to the white. This much, however, is to be noticed: the usual dip of the blue limestone in Sections I. and II. is 30 to 45°, strike northeast. The last outcrop before the white is reached is turned on its strike and the dip is nearly 80°. The rock is also much shattered. I will leave these facts without comment, as their obvious tendency is quite plain.

On the axial crest the sandstone is not present in beds, but is in angular blocks and is graphitic.

On the southeast slope of this hill blue limestone is found for the first time on the southeast slope of a hill in this locality. It is not in regularly-formed beds, but lies in irregular blocks on the slope of the hill. It is underlaid by the sandstone before mentioned. The limestone is in places brecciated with white interstitial matter.

The pebbles are somewhat rounded and look as if molecular rearrangement had been checked before a complete change from blue to white had been effected.

The comparatively slight depression between hill 750 and the hill east of it, is filled with granite and white limestone. The hill to the east consists very largely of granite, with an apparent axial crest of sandstone.

Section IV. The principal point to be noticed in this section is that the fact is here demonstrated that the sandstone underlies the limestone. It will be recalled that mention has been made of numerous angular blocks of sandstone on the crests of the limestone ridges, and that they were suggestive of a bed of broken sandstone rather than of transported blocks. At the summit of the hill, just west of the valley, a large open cut has been made in the east side of the hill in the search for iron ore. The opening is about fifty feet in depth and has been carried into the side of the hill for about the same distance. The cut on the east face of the hill is first in white limestone dipping southeast. Dipping under this conformably is a coarse pyritiferous conglomerate with beds of a fine-grained sandstone. The whole exposure is exceedingly hard and flinty.

Along the crest of this hill, towards the south, there are scattered blocks of graphitic sandstone, and there is one locality where there is a huge mass of fresh-looking quartzite. It may be only a boulder, though. However that may be, there *is* sandstone underlying the white limestone on the steep eastern face of the hill.

This hill is less than one-fourth of a mile south of the old ore dock of the Pochuck mine road, and less than one-half of a mile south of the cut just described.

One-fourth of a mile east of this place is a precipitous hill, alluded to before as lying east of the hotel at McAfee. This hill is very precipitous on its western face, but slopes more gently to the east. On the north side of the road is another hill of a less altitude by two hundred feet. Its general characteristics are the same as those of the hill in Section IV.

The western slope of the hill east of McAfee consists principally of a fine-grained granite. Angular blocks of this, mingled with blocks of white limestone, lie at the foot of the hill. The limestone is generally very coarsely crystalline, graphitic, and, in places, chondrodite is abundantly present. Near the north end of the hill, however, in the face of the cliff, and wholly surrounded by coarsely-crystalline and graphitic limestone, are masses of brecciated limestone, which, although not blue in color, are yet but slightly changed as to texture and color. It is a true breccia, however, and their angular boundaries are readily distinguished. It contains only scattering flakes of graphite.

Going to a point immediately above the cliff (about seventy-five feet vertically), and a little below the crest of the hill, on the eastern slope, there is found a very striking exposure of rocks. At the northern point of the hill the ground is well covered with large, angular fragments of a rather fine-grained, rotten sandstone. The blocks, if of moderate size, are stained to the depth of three inches by decomposing pyrites. Graphite is present in the sandstone. No fossils were found here. In fact, but little time was spent searching for them, but there is little doubt but that they may be found here by an expert paleontologist.

Lying on top of this sandstone is a graphitic, gritty limestone. It is brecciated, and the interstices are filled with crystalline limestone, as is usual. Among these blocks are larger blocks of almost pure limestone, save for the presence of large nodules of chert or flint. Some of the flint and the enclosing limestone is graphitic. Some of the flint seems to be slightly bleached by the driving off of organic matter, but the change has not gone far enough to crystallize it to any extent.

Tracing this breccia along the line of strike, it invariably fades into a white limestone and with granite not far from the line of change. The line cannot be traced continuously, on account of a thick underbrush. West of this line of breccia is white limestone and granite, to the east is blue limestone slightly changed, and a gritty limestone and sandstone beneath all. On the eastern face of this hill, the place, in fact, that I have been describing, is the point where the blue limestones are cut out by the white, and the white limestone south of this fills the entire valley between Pochuck and Hamburg Mountains.

In writing of this brecciated limestone, and of this most interesting locality, I find great difficulty in describing facts, that they may appeal to the ear in a measure as strongly as they do to the eye. On this account I have collected a suite of these transition rocks, as I have called them, from this locality, as well as from several others, so that my observations may be verified without the trouble and expense of seeking them in the field.* But, however strongly these facts, thus stated, appeal to one, when seen in the field they appeal with double force. And it seems to me that no one visiting this place with an unprejudiced mind, could go away doubting but that the sandstone which underlies the blue limestone, underlies the white also, and that here we see the Palæozoic blue limestone actually pass-

*These specimens are now in the laboratory of the Survey.

ing into the so-called Archean white limestones. When we reflect that this locality can be duplicated a dozen times, the probability seems to grade into absolute certainty. This hill 622 seems to be anticlinal in structure. In this light let us examine more minutely hill 750, noted in Sections I., II., III.

Section V. shows the southern point of this hill as a section through its summit. The middle elevation of this section is a part of a ridge of sandstone which rises to the south to a considerable height. To the west of it is a hollow and still farther west is a gritty limestone with a layer of sandstone, and the crest of the hill is a slaty limestone with a bed of pure limestone. The dip of these rocks is unmistakably northwest. The sandstone also has a northwest dip.

No more than fifty feet to the east of this sandstone is a large outcrop of white limestone and granite, which enlarges to the north. The limestone on either slope of this hill is traced to corresponding points in Section V. Here a sandstone dipping northwest is near by.

Towards the summit of the hill the bedded sandstone is replaced by angular blocks, and on the crest of the hill is a small exposure of a flat-lying limestone. To the west of this are angular blocks of graphitic sandstone. Passing still farther down the eastern slope of the hill, the bedded sandstone is found, still graphitic, but the dip cannot be determined. A little below this the brecciated blue limestone appears in great blocks, covering a greater part of the eastern slope, and then, farther down, these rocks are replaced by white limestone and granite. Section VI. is through a hill just south of the Pochuck mine road. It is made to show the relations of the limestone, sandstone and the underlying granite. The facts are unmistakable, and they are duplicated in the railroad cut north of Hamburg. It is one-half of a mile south of the point where Section V. is taken and is evidently closely related to it.

Sections VII. and VIII. represent either slope of hill 698, one and one-fourth miles north-northeast of Hardistonville. It is really the south end of hill 722, shown in Sections I. and II., the north end of which is white limestone. On the northwest slope of this hill is a series of limestones and grits exactly similar to those noted in Section V. and just as beautifully exposed as are those in hill 750 in Sections I., II., III., IV. and V.

Passing to the eastward, towards the crest of this hill, the same angular blocks of graphitic sandstone, mingled with blocks of white limestone, are again found. Farther yet down the slope the white limestone is found in solid masses cut up by great dykes and bosses of granite and "geflecter gabbro." The granite has much fluorite in places, especially when in contact with the white limestone.*

Section IX. shows the relation of this hill (698) to the hill just east of it (722), in the east side of which are the Rudeville quarries.

Leaving now the white limestones, which lie at the east foot of Pochuck Mountain, the next section, X., is taken at Hardistonville across the brook in front of Carpenter's hotel. The white limestones now lie along the west foot of Hamburg Mountain. It will be noticed that in this section, on the northwest end, Dr. Beecher found fossils in the unchanged blue limestone. Under this limestone is a fine-grained sandstone, which is filled with the remains of trilobites. There is also a noticeable amount of graphite present. In several specimens graphite is found near the head of a trilobite, within one-eighth of an inch. In the same specimen there are two places that look very much as if graphite had partially replaced the shell of a trilobite. A large granite dyke is near this sandstone, though no line of contact was found. There is present, however, a seam of almost pure graphite one to two inches thick. Dykes of mica-diabase as well as "geflecter gabbro" are also present.

There are also present confused masses of brecciated sandstone, blue limestone with white interstitial matter, and all very highly graphitic. The blue breccia is observed very abundantly on the north side of the brook.

If it is borne in mind that this brook is here the dividing line between the white and blue limestone, the significance of the breccia will become apparent. The blue limestone breccia has thus far been characteristic of the boundary between the two white limestones, though there are exceptions to the rule.

On the north side of the brook white limestone comes out again in close proximity to the blue, and it is, as usual, mingled with granite and gabbro. In places near by, also, are limestones slightly changed, which are filled with grains of sand, and with more or less graphite. This is also north of the brook, toward Rudeville. The line of

*If this ridge is followed north to the "York State Quarry," a brecciated blue limestone is found, lying on the crest of the hill and on the west edge of the quarry. Blocks of graphitic sandstone are traced almost continuously between these points.

contact in this section, north and south, between the blue limestones and the white, or when they come close together, reaches from Franklin Furnace to McAfee, a distance of six miles.* Again referring to the section, we observe that the sandstone appears in unmistakable beds, dipping under the white limestone.

Omitting for the present Section XI., attention is asked to Section XII. This section is taken three-fourths of a mile south of Carpenter's hotel, at Hardistonville, and it passes through hill 720 near its southern point. It will be noticed that at the extreme northwest there is blue limestone underlaid by sandstone. This is the same outcrop noticed in Section X., and it can be traced almost continuously from that point to this. It is on the west side of the road, and is in line with the outcrops of sandstone and blue limestone at Franklin Furnace, so often referred to in New Jersey geological reports.

Just across the road to the east there is a cultivated field. In this field there are numerous exposures of granite and white limestone. Leaving this field and entering the underbrush which covers the west slope of the hill, the same rocks crop out continuously. Near the summit of the hill the graphitic sandstone so often referred to crops out and dips unmistakably under the white limestone. This sandstone is exposed for a distance of twenty-five to fifty feet to the north, and then disappears under the limestone. As it also appears under the same white limestone at the summit of the hill, fifty feet above, it would seem as if the sandstone was bent into an anticlinal fold. Certainly it pitches under the limestone and dips to the southeast. Following this outcrop into the cleared field at the south end of the hill, the whole of the southeast point of the hill is seen to consist largely of a hard, flinty quartzite. A few rods to the north of this section line nearly the whole hill is made up of granite. This granite is in places well foliated, so well foliated that it resembles a gneiss, but on account of its mineral composition and field relations I cannot but believe it to be a true foliated granite. "Geflector gabbro" and mica-pyroxene rock are also abundantly found.

Hill 724 has but few exposures, and these are of the usual kind.

In the bed of the brook at the foot of hill 720 there is an outcrop of unchanged blue limestone. A few rods south of this there is white

* The same breccia is observed in several places in the road, going from this brook to Hamburg Mountain. One place is at the corner of the roads at Hardistonville, the other is about one-half a mile east, in front of a small house.

limestone, and yet a little farther, by the roadside, a boss of granite. Following the outcrop of sandstone and blue limestone along the west side of the road to Franklin Furnace, Section XIII. is taken across a triangular lot between two roads one mile north of Franklin Furnace station. There are two very strong points to be noticed in this section. First, there is the blue limestone on the northwest, underlaid by a fossiliferous and graphitic sandstone. A short distance to the east is granite and white limestone. This is succeeded by low, swampy ground, when no rocks are visible. Then comes the south end of hill 737. Here is the second point to which attention is directed. The western face is principally granite. In contact with this granite on the eastern face is a graphitic, highly-crystalline white limestone. Passing still to the east, within a distance of seventy-five feet, this white limestone has changed to an unmistakable blue, also dipping southeast. The change is gradual but rapid.

This is the northern point of the "A" (of blue limestone) before referred to, and it can be followed in an almost unbroken line to the fossil locality, north of Furnace pond.*

On the same section line and still farther east, is the southern spur of hill 724. This consists of white limestone intermingled with granite and "geflecter gabbro." Yet farther east are the gneisses of Hamburg Mountain.

Section XIV. is an especially important one. On the northwest are the usual limestones and sandstones, here resting on the upturned edges of the Franklin gneiss. Across this gneiss to the east is white limestone, and a thin bed of magnetite, which rests on granite and not on gneiss. This is shown in openings in the magnetite veins and in the tunnel which leads into the zinc mine. White limestone succeeds this, and then the well-known zinc-bed, here thirty-five feet thick. On top of this is a heavy bed of white limestone dipping southeast.

A little east of this, and by the roadside, is a large outcrop of sandstone having large flakes of mica and crystals of feldspar developed in it near the point of contact with a trap-dyke. There is also much fluorite present. Through the kindness of Mr. W. W. Pierce, superintendent of the works at Franklin Furnace, this sand-

* See accompanying Geological map facing page 50. Though the boundary line is sharply drawn on the map, from this point to Furnace pond the blue and the white limestone grade into each other.

stone was uncovered, thus showing its relations to the limestone. This excavating showed the sandstone going under the limestone with a northwest dip. This shows conclusively that the limestone is here bent into a synclinal fold, and is probably independent of the fold in the zinc mine.

Passing up the slope of this hill and to the east, white limestone and granite are found either on the section line or at no great distance from it. In the road across the north end of Furnace pond the white limestone dips southeast.

The next slope to the east of this is in the old furnace quarry, and is in the blue limestone. In this quarry fossils belonging to the Obolella fauna are found in a limestone which also carries graphite.*

This limestone dips northwest, and a little farther to the east dips southeast, thus showing an undoubted anticlinal fold. Following east across the strike of this outcrop, white limestone with granite and "geflecter gabbro" lies in a foot-hill next to Hamburg Mountain. Returning to the furnace quarry, where the fossils were found, and following along the line of strike for one-fourth of a mile in the back road (so-called) to Ogdensburg, is a point where within thirty to fifty feet the extreme phases of the two limestones are found; the crystalline white on the one side and the unchanged blue on the other. Between the two extremes is a perfect series of grading.†

This line followed along leads to a similar gradation series mentioned in Section XIII.

Section XIV. proves beyond all reasonable doubt three strong points: First, the sandstone here is associated with the limestone and probably underlies it. It is, no doubt, the same as the sandstone in hill 720 (Section XII.), but in Section XII. the dip is southeast, while in this section it is northwest. Second, there is a gradual passage from the highly-crystalline white to the uncrystalline fossiliferous blue. Third, the white limestones are proved to lie in anticlinals and the blue limestones, bounded on either flank by white, lie also in an anticlinal fold, the northwest dip passing along its line of strike from blue into a white limestone.

As to the dip of these blue limestones, hardly any of the older

* Graphite is neither abundant in this formation nor is it easily seen. The strong point is made, however, that the graphite proves the limestone to be highly metamorphic, and the presence of fossils proves its palæozoic age. The probability of a greater metamorphic action is thus greatly strengthened.

† This point convinced Dr. Beecher that the two limestones are the same.

geologists agree, judging by their sections. The reason is assumed to be that the jointing, which is here perfectly developed, makes it exceedingly difficult to get the true dip without great care.

Section XV. is drawn one mile south of the last, and passes through hill 689, just east of the Wallkill river.

The whole of the eastern slope of hill 743, along the foot of which runs the New York, Susquehanna and Western railroad, consists of white limestone, granite, "geflecter gabbro" in dykes and in boulder-like masses in the limestone.

The white limestone ceases suddenly at the Wallkill river, where there is a great outcrop of granite. On the east side of the river, and near its bank, is a slaty blue limestone dipping steeply northwest. In Munson's grove, a little east of this, and on the eastern slope of the hill, the blue limestone dips southeast against the foot of Hamburg Mountain.

It will thus be seen that the anticlinal of blue limestone in hill 689, though not continuous with the one in Section XIV., is probably the same, and that on the northwest slope the blue limestone in Section XIV. is replaced by white.

This makes the fifth locality where this fact is plainly observed, and it seems unreasonable to assume any other explanation than that the white limestone is the metamorphosed blue. This is the last section that I have studied in the Franklin belt. The reason is lack of time during this season and the fact that the exposures in other localities were more meager and not so striking as in the belt between Sand Hills and Sterling Hill. To the westward of hill 743, Section XV., lie the Pimple Hills, upon the west flank of which lie the blue limestones, with underlying sandstone occasionally exposed. Along this flank are several isolated patches of white limestone, in one of which are the well-known Andover mines of magnetite and hematite mixed with ores of lead and zinc. In the valleys or gorges of these hills are isolated patches of white limestone, always accompanied by great outpours of granite and other eruptive rocks. The same is true of the white limestone on the bordering blue limestone. There are also great and violent disturbances in the gneisses, and scattered about in places are abundance of angular blocks of sandstone, in every instance highly graphitic.

There is one more section (XI.) about one mile north of McAfee to which I wish to direct attention.

In this section the gneisses of Pochuck Mountain lie to the extreme northwest. Resting against the eastern flank is hill 748. It consists, as usual, of granite, "geflecter gabbro" and trap. White limestone is also present, but not abundantly. The dip of the white limestone is here west, 30° north. Going eastward, after crossing the road to McAfee, there is a remarkable hill of granite with very little white limestone. Following the brook which crosses the road at this point toward Black creek, we note that it passes the greater part of the distance over white limestone and granite. One-fourth of a mile from Black creek it cuts across the strike of the steep hills north and south of it and falls over a ledge of white limestone to the level of the swamp. South of the brook is a hill which consists largely of white limestone. It may be said here that this is close to the boundary line between the white and the blue limestone, as indicated on the geological map.

The hill north of the brook is far different. Beginning at the level of the brook is a ledge of highly-crystalline white limestone charged with graphite. Going up to the hill to the northeast we note the following changes:—First, the white limestone; second, a white limestone not so highly crystalline and with the graphite in occasional scales, but generally in blackish or dark-gray clots; third, a marble-like rock with no graphite scales, but dark-clouded, irregular bands; fourth, a limestone with slight traces of altération; fifth, a wholly-unchanged, blue, slaty limestone. These changes take place within a distance measured on the slope of less than one hundred feet. On the summit and on the eastern slope of the hill to the marsh level is the unchanged, blue, slaty limestone dipping north, 30° east.

This remarkable series of gradations can be traced for a long distance at the foot of the western slope of the hill.

About five hundred feet to the west of the foot of the hill are numerous angular blocks of graphitic sandstone. No dip or strike can be made out.

The dip of the white limestone is the same as that of the overlying blue limestone. In short, the white limestone, while grading into the blue limestone above, passes conformably under it. The probability is that the sandstone before referred to is the broken edges of a bed that passes under the limestones. Across Black creek the blue limestones underlaid by sandstone dip in the northwest quadrant.

This finishes the belt to which special study has been directed the past summer, but I wish to call attention briefly to two other localities of white limestone—one at Cranberry reservoir, on the Sussex railroad, and the other near Oxford Furnace. The white limestones near Cranberry reservoir are accompanied, as usual, by granite and "geflecter gabbro." The gabbro here has been mistaken for gneiss. There is so much of this rock injected into the limestone that the Furnace company at Stanhope gave up working it for flux at their furnace. No sandstone is seen here in connection with the limestone.

The locality at Oxford Furnace is especially interesting for several reasons.

At the iron mines to the east are numerous dykes of granite and mica-pyroxene rock. Here the limestone is highly crystallized; contains manganese, graphite and scales of mica. This passes to the west into a less crystalline limestone, gray in color, and jointed like a blue limestone. No eruptive rocks, save trap, are visible, and there is a small bed of zinc sulphide in the limestone. This sulphide has, however, numerous small scales of mica and a green mineral resembling willemite. This comes in such small and poorly-formed crystals that they cannot with certainty be determined. The whole aspect of the place points to the supposition that here we have the beginning of the metamorphism of a zinc sulphide and that Franklin Furnace is the final stage of metamorphic action.*

CONCLUSIONS.

The conclusions at which I have arrived from the study of the localities which I have described, and from other localities as well, are as follows: First, the white limestones of Sussex and Warren counties are of Post-Archean age. Second, the white and the blue limestones belong to a synchronous horizon. Third, that this horizon is the horizon of the Olenellus fauna. This last conclusion is based on the authority of Dr. Charles E. Beecher. Though I was convinced that the limestones and sandstones of this group would prove to be fossiliferous, I supposed that, should fossils be found, they would confirm the opinion of other geologists that these rocks were of Potsdam and Lower Silurian age respectively.

The extent of these conclusions is more far-reaching than is at first sight apparent. First, it demands that a careful search be made for fossils in the whole belt, or rather belts of limestones, sandstones,

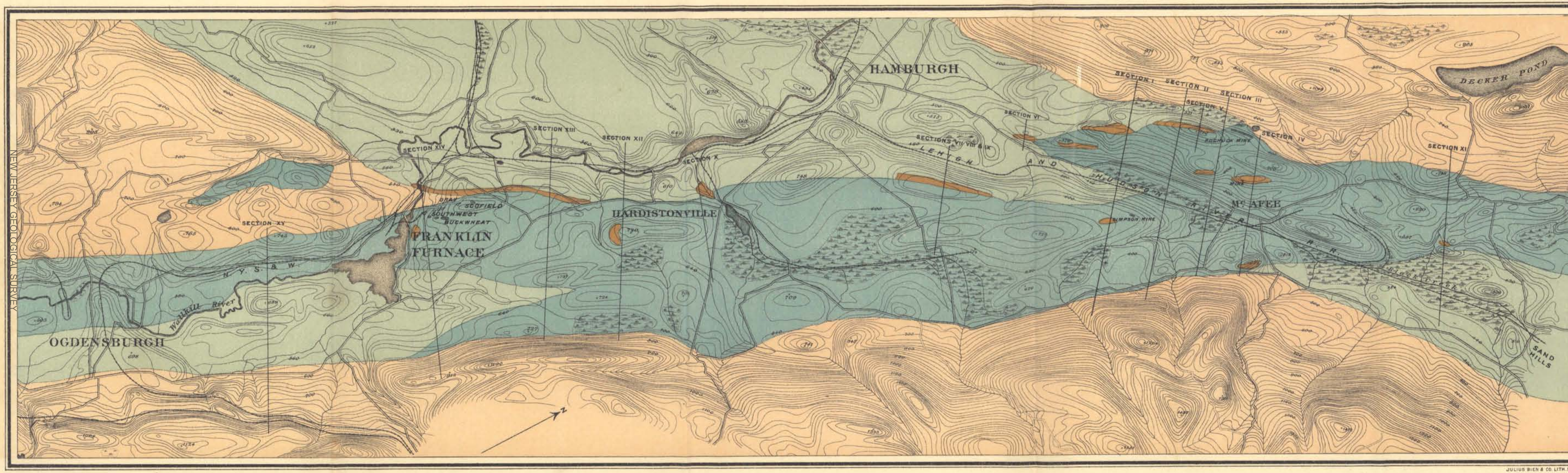
* The presence of manganese was proved by a chemical test.

slates and shales hitherto called and regarded as Potsdam, Trenton and Hudson river. The result may prove the existence of a great horizon of rocks in New Jersey, New York and Pennsylvania hitherto unsuspected and may also throw much light on the question as to the position of the Green Pond Mountain rocks. Second, and this point possesses for me a far greater interest than the first, in this belt are rocks, limestones, sandstones, slates and iron and zinc ores in every degree of metamorphism. The belt is penetrated by various kinds of igneous rocks, and the petrography and chemistry of rocks and minerals in every stage of metamorphism, induced by pressure and heat, can be traced out and its history deciphered to its minutest details. It is rare to find rocks of known geological age in which such favorable conditions exist. The histories thus elaborated can be used most advantageously in deciphering other localities whose history is written in less legible characters.

GEOLOGICAL SURVEY OF NEW JERSEY

A TOPOGRAPHICAL MAP
OF THE
WHITE LIMESTONE AREA
DESCRIBED IN THE ACCOMPANYING TEXT

Scale: 2 inches - 1 Mile.



EXPLANATION OF COLORS.

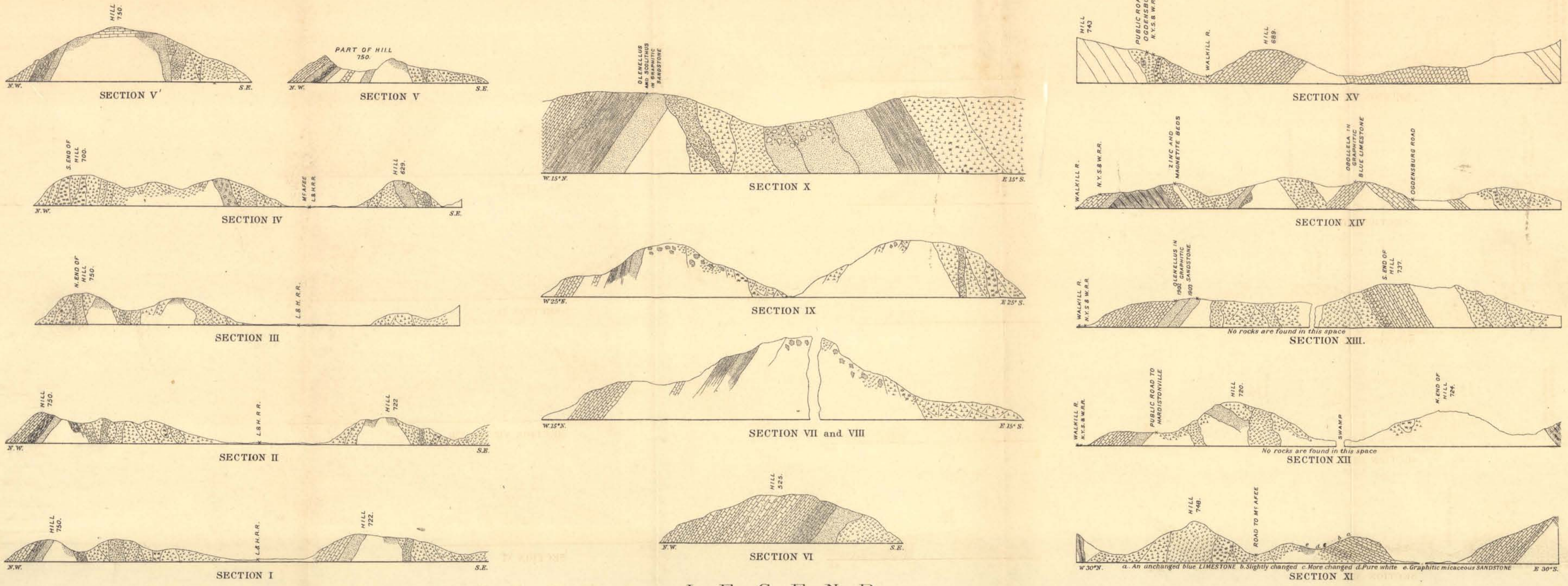
Sandstone, Graphitic and Fossiliferous.

Fossiliferous Blue Limestone

White Limestone

Gneiss

PLATE SHOWING SECTIONS DESCRIBED IN TEXT



LEGEND

Blue Limestone	Blue Limestone changing to White	White Limestone	Sandstone	Trap	Granite	Scapolite Geflecter Gabbro.	Shaly Limestone	Gneiss	Unknown

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IRON MINES.

NOTES ON THE ACTIVE IRON MINES.

FRANK L. NASON.

No special work on the iron mines has been done since 1886. In view of the fact that the iron industry seemed to be looking up, it was thought that a survey of the mining resources of the State would prove useful. Accordingly the work was begun in October. The objects of the survey were as follows:

First. Collecting mining statistics relative to the status of the mining industry.

Second. Collecting suites of specimens of ores and rocks; and—

Third. The study of the mine rocks, the country rocks and the relations of these to each other, and to the iron ore proper.

To the first two no special attention need be directed, as a study of the appended notes will amply explain them.

With regard to the third, special attention is directed, since it is believed that on the careful study of this topic hangs the future of successful iron-mining in this State.

The important facts to be noted in this connection in the appended report are, first, the fact that the mine rock, so-called, is actually distinct and easily distinguishable from the country rock.

This point being carefully borne in mind, it may be well to ask if it is not possible that some of the mines in the State considered "exhausted" may not be capable of further development. Especially should this question be considered when the ore has pinched out, whether by rolls in foot or hanging-walls, or by the coming down of the cap rock.

Second. It has become firmly established in my mind that the country rock of the great iron mines of our State is constant, and can be properly classified as the iron-ore carrier. It is also firmly believed that this country rock is sharply divided from the "vein" matter of mines, the term "vein" including the ore and associated *mine* rock. This statement was made in the Annual Report for 1889, and it has been confirmed by closer study during the current year.

The extent of the country rock proper is described in that report, p. 30, under the head "Type I., Mount Hope." For a description of the geograpical position and extent of these rocks, see Annual Report State Geologist, for 1889, p. 35, *et seq.*

It is believed that a careful study and comparison of these mine rocks with the country rock, will result in much practical good.

Another thing of great importance is careful surveys and records of mines. These, if preserved, often give much valuable information, which the abandoning of a mine cuts off.

I have here to tender my cordial thanks to mine-owners and superintendents, for information and for personal courtesies in being allowed to inspect the practical working of their respective mines. Without this kind assistance, much of the data herein given would have been impossible to obtain.

SHOEMAKER MINING AND MANUFACTURING COMPANY.

Office: Belvidere, N. J.

The mine is two miles south of Belvidere, on Buckhorn creek. This mine is owned by Edward Shoemaker, and is leased of him by the above company.

The ore produced is known to the trade as brown hematite. It is non-bessemer and runs about 45 per cent. metallic iron.

In mining, very little powder is used, the ore being soft enough to be removed by pick and shovel. Occasionally large lumps of ore have to be broken by powder. As the ore occurs in such a soft form it has to be mined in galleries that are closed on the sides, top and bottom. It is drained by a tunnel three hundred and fifty feet long to its present depth of sixty feet. The dip of the ore-body is southeast, with a strike to the northeast. The width of the vein varies from four to twelve feet.

The ore is washed by a log washer, as it is taken from the mines, to free it from the clay, sand and other dirt which occur with it.

Some very interesting geological features are disclosed by the tunnel. Unfortunately it was not possible to enter the tunnel in

October (1890), and the following notes were gained from Mr. James Arthur and from the debris thrown from the tunnel. As was before stated, the tunnel is three hundred and fifty feet long. The first thirty-five feet consist of a dark-green talcose slate, three hundred feet of a light, buff-colored clay slate; a flinty mass, probably quartzite, three to twelve feet; then the ore-body proper. A body of very white clay forms the hanging-wall. The mine was opened in 1888.

FRITTS MINE.

Owned by George Fritts.

This mine adjoins the Shoemaker mine on the northeast. There was very little being done at the mine (October, 1890). There is no apparent reason why it should not be as profitable as the Shoemaker.

ROSEBERRY MINE

Is about one mile northeast of the two mines, and is on the same line of strike. It is not worked at the present time, though much money has been spent in exploration.

LINCOLN BESSEMER ORE COMPANY.

Mr. Kaiser, Hazen P. O., Owner.
T. P. Marshall, Secretary and Treasurer, Trenton.

This mine is not in operation at the present time (October, 1890), but it is intended to start in about three weeks from the given date. The body of ore in the mine is eleven feet thick from foot to hanging-wall. About five feet of this is pure ore. The remainder of the vein being too lean to work profitably, a separating plant is to be put up for the purpose of concentrating the ores. For this purpose they will use a Carter ore separator and concentrator. This machine uses horse-shoe magnets instead of the more common electro-magnets. It is proposed to concentrate to a 65 per cent. ore.

They expect to employ about forty men. With this force it is calculated that they will be able to put out three hundred and fifty tons the first month, and to gradually increase the output.

SHARON ORE COMPANY.

P. C. Queen, Owner.

This is one of three mines located on the same deposit, and one and one-half miles northwest of Oxford Furnace.

The Queen mine is operated by the Sharon Ore Company. A one hundred and ten horse-power boiler furnishes steam for two hoisting engines, pumps and two large log washers. The ore averages 57.65 per cent. metallic iron. It is non-bessemer, and is used at the Durham Furnaces, Rieglesville, Pa.

The ore is a strong mixture of hematite, red and brown, and of magnetite (?).

The mine was re-opened July 17th, 1889.

FELLOWS MINE.

R. C. Fellows, Owner and Operator.

This mine adjoins the Queen mine and is a part of the same deposit of ore.

A sixty horse-power boiler furnishes steam for a hoisting engine and pumps.

The ore is shipped to Pequest Furnace, and is said to run as high as 60 per cent. metallic iron. This mine was also re-opened in 1889.

CHAMPION STEEL ORE COMPANY.

G. Riddle, Owner.

This mine is situated on the same outcrop as above, probably, and is located just east of the Queen and Fellows mines.

The company is at present engaged in sinking a shaft. Work was begun in October, 1890.

RAUB MINE.

American Zinc and Iron Company, Operators.

No ore has yet been raised. The company is now sinking a shaft near the old mine. There are only three men at work at present. The ore is to be concentrated. It is expected to get a bessemer ore.

OXFORD IRON AND NAIL COMPANY.

Owners and Operators of the Oxford Mines.

There are two mines on this property, which are now active, the Washington mine and Slope No. 3. The greater part of the ore mined is used at the company's furnaces. Some of the Washington ore, though, is sold to the Thomas Iron Company. The ores of both mines are non-bessemer. The ore from the Washington mine has sulphur in addition, and has to be roasted. This roasting is done in a Taylor gas roaster, one set near the mines and another near the furnace. A Blake crusher is used to break the ore for the roasters. Both of these mines have been worked almost continuously for one hundred years. Slope No. 3 is five hundred and sixty-five feet deep; Washington mine, four hundred and ninety.

The Washington mine and Slopes 1, 2, 3 and 4 are all parallel to each other, and lie nearly east and west. The dip is towards the south, about 45°, with a pitch to the east. In this respect these mines are almost unique, for the general direction of the dip and pitch of the magnetite ore deposits is southwest and northeast respectively.

The foot and hanging-walls of the Washington mine seem to consist mainly of a coarse feldspar and quartz rock, which has crystals of allanite enclosed. Hornblende or pyroxene is also present in small masses, and scales of biotite. The rock is very coarse. In places, magnetite is so much mingled with the rock, with quartz especially, that there has been some talk of concentrating by a magnetic separator.

The "spar" rock, as it is called, also comes into the ore-body proper. At times these horses completely fill the vein. At the extreme east end of the mine there is so much of the rock present that the vein is no more than three feet in width, although not one hundred feet to the west, the vein is twenty-seven feet wide from foot to hanging-wall. The rock is very treacherous, as it seems to decompose readily.

Slope No. 3 has comparatively little of this rock and its ores are far less sulphurous.

From the nature of the rock itself, as well as from its occurrence, there is little doubt but that it is an injected mass, and really has nothing to do with the country rock in general. The country rock of this mine is the Mount Hope type of rock, described in the Geological Report for 1889. The Mount Hope rock is found in the other mines, and from the close relationship of these mines (Washington and Slope No. 3) it is safe to assume that their general characteristics are the same.

KISHPAUGH MINE.

Ario Pardee, Owner and Operator.

After lying idle for a number of years, this mine is to be re-opened. Work was begun in January, 1890. The plan is to sink a vertical shaft about four hundred feet, and then drive to the vein. The shaft in October, 1890, was down two hundred and forty feet.

There are employed twenty-five men. They have one hoisting and one pumping engine. One Rand air-drill and compressor is used.

HUDE MINE.

Dickerson and Succasunna Mining Co , Owners.
Leased by A. Pardee.

Started in April, 1890, after being idle since 1883. The ore, magnetite, is low in phosphorus and sulphur. It is used at the Stanhope Furnace.

The metallic iron runs from 45 per cent. up; this is about the average, however.

There is an eighty horse-power engine for the purpose of supplying condensed air for the drills. The mine is very dry, as it is wholly above water level. An adit is driven in about two hundred feet, and has intersected three shoots of ore thus far. The mine is known as a saddle-back among miners. In reality it is an anticline. The strike is nearly north and south; the dips lie in the northeast and the northwest quadrants. The ore comes in short, irregular shoots or bunches, and is often faulted in a succession of short steps downward. The country rock of the mine is Mount Hope rock, or magnetite gneiss, but there are other rocks in the mine. One rock is of a coarse, syenitic nature, and is probably eruptive. Near this rock, in one of the ore shoots, is a great quantity of molybdenite. This mineral is usually confined to the hornblendic rock, but it sometimes impregnates the ore. The ore in one shoot carries as high as 1 per cent. of molybdenite. Molybdic acid is also present. The mineral is found chiefly in one shoot and close to the syenitic rock. Iron pyrites occur with the molybdenite, and also with the ores. In the workable ores, sulphur varies from 1.5 to 2.5 per cent.

HURDTOWN OR HURD MINES.

Hurd Heirs, Owners.
Glendon Iron Company, Operators.

This mine was idle for about six weeks during the present summer (1890), on account of the expiration of the old lease. The mine is at present down 3,625 feet on the slope. At this depth it had reached the old line of the Hurd estate, and it is now being worked under a new lease on an adjoining property. Work was resumed November 4th, 1890.

The ore is shipped to the Glendon Iron Company's furnaces, near Easton, Pa. Rand drills are used. Two compressors furnish air for the drills and for the mine pumps. Two boilers, a one hundred and twenty and a sixty horse-power, furnish steam.

The mine is 3,625 feet, on the northeast slope; and a pitch of about 30°. The vein stands nearly vertical, but has a slight underlay to the southeast. The country rock of this mine is Mount Hope. The walls are very hard and solid usually, and so need very little timbering, in spite of the size of the vein. There are very few offsets, and these are of slight extent save where the mine was first broken in two by the vertical fault noticed in the "Geology of New Jersey," 1868.

The long, straight pitch of this ore shoot could almost have been predicted from the contour of the country, and if the vein does not become exhausted, it will probably run at least half as far again before it will be seriously disturbed by a fault. The average width of the mine is twenty feet from foot to hanging-wall, and it is thirty-six feet from cap to bottom rock.

The ores of this mine are of rare purity and beauty. They have very little sulphur, but unfortunately they run too high in phosphorus for a bessemer ore. They are very free from rock. In fact, there is comparatively little mine rock. The mine has been worked more or less for eighty years. The lease which just expired began in 1875, since which time the mine has been worked continuously.

LOWER WELDON MINE.

Weldon Mining Company, Owners.
Coplay Iron Company, Operators.

The ore is magnetic, non-bessemer and carries about 1 per cent. of sulphur. It is used entirely by the Coplay furnaces, at Coplay, Pa. The mine is at present 360 feet deep. The shoot is very regular; pitches to the northeast, and dips southeast at an angle of 50°. The ore is beautifully interbanded with a rock. This rock is different from the country rock, and is foliated with thin micaceous partings. The bed proper is about six or eight feet thick, and carries about three feet of clean ore. The ore is generally shotty, but is occasionally compact. Much of the ore is too lean to work, but on account of its friable nature it could be very easily concentrated. Two hoisting engines and one Rand compressor (for the Rand drills) are used. A three-inch pipe is sufficient to drain the mine. Even this is not run all of the time, as the mine is very dry. The country rock, which is of the Mount Hope type, has a little more biotite and hornblende than is usual, and it seems to be very firm, so that the mines are safe.

UPPER WELDON MINE.

Leonard Elliott, Owner.
Richard Heckscher & Sons, Operators.

The ore, which is magnetite and non-bessemer, is consumed at the Swede Furnace, near Philadelphia, Pennsylvania. The mine, after being closed for some time, was re-opened in January, 1888. The ore shoots, as usual, pitch to the northeast and dip to the southeast 50°. The average width from foot to hanging-wall is about five feet of solid ore. The ore is banded and occurs in the same manner as in the Lower Weldon. The country rock and the mine rock are also the same as at the Lower Weldon.

There are at the mine three sixty horse-power boilers, which drive Ingersoll drills and compressor; one Welling pumping engine, one pumping engine and hoisting machine. The company is at present engaged in putting up concentrating works. The object is to remove the phosphorus from the rich ores and to concentrate the lean ores. The object is to make the whole output a bessemer ore. For this purpose they will employ Lovett, Tinny & Company's electro-magnetic separators. They use the wet process. The capacity is estimated at one hundred tons per day concentrates.

DICKERSON MINE, FERRO MONTE.

Dickerson and Succasunna Mining Company, Owners.
A. Pardee, Operator.

The ores are magnetic and non-bessemer. A great deal of the ore from this mine is highly magnetipolar. The ores which possess this property are very fine-grained and compact, and are usually very pure. The ores are used at the Musconetcong Iron Works, 75 per cent.; the balance goes to Pennsylvania furnaces. They run from 56 to 61 per cent. metallic iron. This percentage is based on ores from the main shoot of the mine. In what is known as the "Cow-belly" vein, which lies in the foot-wall, the ores are much leaner on the one hand and much higher in phosphorus on the other, the phosphorus here running as high as 2 per cent.

The width of the shoot of ore in this mine varies from ten to eighteen feet, with an average of sixteen. The distance from cap to bottom ranges from one hundred to three hundred feet. The strike of the vein is due northeast; dips southeast at an angle of 55° and upwards; pitches to the northeast at an angle of 63°. The mine is now one thousand two hundred feet deep, or three hundred and forty feet below sea level, reckoning by the contours on the topographical sheets. At this depth the body of ore does not seem to be as large as at first; the ores contain more rock and are more difficult to cob. The mine rock is a banded, foliated rock, consisting principally of feldspar, mica (biotite) and hornblende. It is usually fine-grained. It is very free from quartz. In the foot-wall, rock and ore are interbanded. In the hanging-wall the ore clings tightly to the wall rock, and the blasts tear out rock and ore, leaving a rough wall.

The country rock, both foot and hanging, is very firm, and so timbering is not so great a task as it would otherwise be. The great width and depth of the vein, however, make the use of large-sized timbers necessary, and it requires no little skill in placing them to the best advantage.

The adit to the mine at the present time is through a large vertical shaft eight hundred feet deep. This shaft is divided into two compartments. In one is a cage, with safety grips, capable of lowering ten men at a time. In this compartment, also, is the pump-rod. The adjoining compartment is used exclusively for the hoisting of ores and the lowering of timber and other materials. There are numerous offsets in the mine which throw the body of ore into the hanging-wall. There are also numerous rolls and pinches where the ore-body is much reduced.

HURD, HARVEY AND NEW STERLING.

New Jersey Iron Mining Company, Owners and Operators.

The Hurd and Harvey mines are at opposite ends of the same ore shoot. The strike is northeast-southwest. The two mines open into each other. The ores are magnetic and non-bessemer, but they are almost wholly free from sulphur.

The slope of the mines is 42° to 45° to the southeast. From cap to bottom rock the distance varies from one hundred to one hundred and thirty feet. The width from foot to hanging-wall is eighteen to twenty-five feet. This is the width of the shoot, but it is not all ore; there is considerable of a banded foliated rock, which occurs interbanded with the ore. This rock is wholly different from the country rock, which is of the Mount Hope type. The pitch of the rock is to the northeast. There are offsets noticed in these mines also, as well as in the Dickerson, Baker, New Sterling, &c., and the ore is thrown in the hanging-wall. The New Sterling is supposed to be opened on the old Irondale shoot, where the Old Sterling mine was located. The New Sterling was opened in February, 1890. It is six hundred feet on the slope. The Hurd and Harvey are about five hundred. The ores are shipped to Pennsylvania furnaces.

ORCHARD MINE.

J. Couper Lord Estate, Owners and Operators.

This mine has been worked continuously for forty years. It produces a magnetic, non-bessemer ore, and gives about 58.70 metallic iron. The ores are sold to various Pennsylvania furnaces.

Boilers of two hundred and fifty horse-power furnish steam for the pumps and hoisting engines, and for the compressors for the power-drills (Ingersoll). The mine is at present seven hundred feet deep on the slope, and is about one thousand feet long. The dip is southeast, and pitch northeast, as usual. The mine rock is the same as other veins. The country rock is Mount Hope also.

MOUNT PLEASANT MINE.

J. Couper Lord Estate, Owners.
Operated by the Mount Pleasant Mining Co.

This is a magnetic, non-bessemer ore, though the percentage of phosphorus is very low. The shipments of ores average 64 per cent. metallic iron. The ores are shipped largely to Pennsylvania furnaces. This mine has been worked almost continuously for nearly one hundred years. It is now seven hundred feet deep, and is three thousand feet in length. It pitches to the northeast, with a southeast dip. The ore-body is much disturbed by offsets, which are not at all regular. These offsets show a disturbance of the country rock as well. The mine rock is as usual, and the country rock is Mount Hope.

BAKER MINE.

Joseph Wharton, Owner and Operator.

The ore is magnetic and non-bessemer. It gives, on an average, 60 per cent. metallic iron.

Its markets are Pennsylvania furnaces.

The mine is at present (1890) four hundred and ten feet deep and six hundred feet long. The pitch of the ore shoot is northeast, but at a much lower angle than at the Dickerson mine. It has a southeast dip.

The mine was re-opened in 1884, and has been worked continuously since.

The country rock and the mine rock are the same as those at the Dickerson.

RICHARD MINE.

Thomas Iron Company, Owners and Operators.

The horse-power of the boilers which supply steam for the pumps, compressors and hoisting engines is 760. Rand drills are used.

The Thomas Iron Company consumes the entire output of ore from these mines. The ores are magnetic and non-bessemer. They average, as shipped, 65 per cent. metallic iron.

The pitch of the ore-body is northeast, and it dips to the southeast. There are several minor offsets in the mines, but the largest is between Shafts No. 1 and No. 2. The slope in No. 1 is at present about five hundred and fifty feet deep. The width of the vein from foot to hanging-wall ranges from ten to twenty feet. The mine rock is here, as usual, banded, but the lean ores are mixed with hornblende and mica.

The country rock is Mount Hope.

TEABO MINES.

Glendon Iron Company, Owners.
Henry Richards, Contractor.

The ore is magnetic and non-bessemer, with a little sulphur. The Glendon Iron Company use the greater part of the ore, though some is sold to other furnaces. The dip of the ore is southeast, with a northeast pitch. There are no offsets in the mine. The mine is at present eight hundred feet deep on the slope. The ore comes in two shoots, one above the other. The thickness of the shoot varies from six to fifteen feet, and is about sixty feet from cap to bottom rock. The rock between the two shoots varies between forty and sixty feet. The mine rock and country rock of this mine are as usual.

MOUNT HOPE MINES.

Mount Hope Mining Company, Owners and Operators.

The ore is magnetic and non-bessemer, and contains no sulphur. The entire output of the mines is used at the Thomas Iron Company's furnaces, in the Lehigh valley.

This mine has been continuously operated since it was opened.

In the old reports, the Mount Hope mines included the old Hickory Hill workings, as well as the Mount Hope mines proper. The Hickory Hill mines have long since been abandoned. Of the Mount Hope mines proper, the Jugular vein is the only one now working. While some of the old shoots have been abandoned, new ones have been opened. The mines now in operation are the Jugular, Side Hill vein and the Elizabeth drift. The Elizabeth drift is the last one opened, and a standard-gauge railroad track has been laid from it to the Mount Hope Mine railroad. It is supposed that this mine is on the Teabo vein. It is within fifty feet of the Teabo and Mount Hope line.

The pitch of the ore shoots is about 65° to 70° to the northeast, with a dip to the southeast. The height of shoot between cap and bottom is one hundred to one hundred and forty feet, with a width of ore from foot to hanging-wall of three to twenty-five feet.

The boilers are rated at six hundred horse-power, and supply steam for the hoisting, pumping and compressing engines. Sargent drills are used.

HIBERNIA MINES.

Under this head are the Lower Wood, Glendon, Scott, De Camp, Upper Wood and Willis (now Wharton) mines.

All of these mines are located on the same outcrop, and so are the same great ore-body. The length of this ore-body, which is now in active operation, and has been for a hundred years, is over one mile. Its greatest depth yet reached is 800 feet. The width of the deposit from foot to hanging-wall is from three to twelve feet solid ore. The total output per month for this deposit, leaving out the De Camp mine, which is now idle, is 10,043 tons, or at the rate 120,516 tons for the year. This is by far the largest and most wonderful deposit in New Jersey, and, in fact, of this entire iron-producing belt in Pennsylvania, New Jersey and New York. It is only exceeded by the Essex county mines in New York, and in the Lake Superior region. From the Willis (or Wharton) mine to the Lower Wood, the mine is remarkably free from offsets or faults. There seems to be a tendency among miners to regard this deposit as a true fissure vein—that is, a deep rent in the earth's crust of indefinite depth, which has subsequently been filled with the iron ore. There are many facts which can be observed which would nullify this hypothesis. The country rock of this mine is the same as that of all the great mines of this State, as well as in New York State west of the Hudson river. The mines of Essex county, New York, are no exception to this rule. The mine rock is the same as that of the other mines. The accompanying minerals are the same. The strike and dip, or underlay of the ore-body, are the same. It has been urged against the theory of aqueous deposit, that this mine has no cap rock; but it is true that at the Willis (or Wharton) mine the ore is pitching to the northeast. In other words, a cap rock is coming in over the ore, and this cap is going underground to the northeast, at about the usual angle. No bottom rock has thus far been struck. It will thus be seen that there is really no difference between this deposit and others of the State, except its great extent, and whatever is true of other deposits must be true of this one also.

The companies operating the mines of this tract are as follows: Glendon Iron Company operate and lease the Upper Wood mine; Scott mine, owned by the North Reformed Church of Newark; and own and operate the Glendon mine, formerly known as the Crane property. The ore is a magnetic, non-bessemer one, and the Glendon Iron Company use the entire output of the mines.

The mining plant consists of two one hundred horse-power boilers and four sixty horse-power boilers; these drive hoisting engines, pumps and compressors. Morris County Machine Company's compressors are used to supply air to the Rand drills.

The depth of the mines are as follows: Upper Wood, 750 feet; Scott, 750 feet; Crane, or Glendon, 700 feet. Width of vein, three and one-half to twelve feet in very solid ore.

No cap or bottom rock has been found. The ore is raised to the level of the Hibernia Underground railroad, four hundred and fifty to five hundred feet above bottom of mine, and run out to the stock piles, where the ore is cobbed and loaded on trains for shipment.

The De Camp mine is now idle on account of some disagreement or misunderstanding. It would, no doubt, prove as productive as ever, if worked.

WHARTON (WILLIS) MINE.

Owned and Operated by Joseph Wharton.

The mine produces a magnetic, non-bessemer ore. The ore goes in part to the Wharton Furnace, at Port Oram, and in part to Reading, Pennsylvania. They have a nest of boilers generating two hundred and twenty-five horse-power. This supplies steam for hoisting, pumping and compressing. Rand drills and Morris County compressors are used.

The mine is worked continuously. It has reached a depth of seven hundred feet. The ore dips 60° to 75° southeast. There is little or no rock in the ore, which is here about five feet from foot to hanging. In squeezes, hornblende and micaceous rock are thrown out. This mine is especially interesting from the fact that it is the only one on this property which ever gave any signs of a cap rock. Here, however, the cap is closing over the ore, sending it underground at an angle of 45° or more.

Mr. Cook, the superintendent, tells me, however, that in the cap the two walls are really parted by a thin vein of ore. The workable deposit, though, seems to be following the general rule thus far manifested in the mines of the State.

It will be interesting to watch further developments.

LOWER WOOD MINE.

New Jersey Iron Mining Company, Owners.
Andover Iron Company, Operators.

The ore averages 58 per cent. metallic iron. The ore is magnetic, non-bessemer and is used at the Andover Iron Company's furnaces, at Phillipsburg, and by the Reading Iron Company, Allentown Iron Company, and by the Lehigh Iron Company. The depth of the mine is at present five hundred and fifty-four feet, and it is one thousand nine hundred feet long The width of the vein proper is about nine feet, though much of it is rock. It probably runs the same as the other mines of the Hibernia tract.

This mine is reported as being worked prior to the Revolutionary war, and has been worked rather steadily since.

Near Chester many of the mines have been abandoned. There is some prospecting for new locations. The Blauvelt, Dickerson and Hacklebarney mines have been worked a part of the year.

DICKERSON MINE, CHESTER.

Col. Dickerson, Owner.
Seals & Thomas, Operators.

Messrs. Seals & Thomas are opening a new mine on Col. Dickerson's farm. A line of attraction three hundred feet long runs north-

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east-southwest across the lot. The deepest working is twenty-five feet. The vein is about four feet from foot to hanging-wall. They employ four men, including their own work, and ship about two hundred and fifty tons per month to the Crane Iron Company. The ore is magnetic and non-bessemer. Like most of the ores in this region, they are very red and ochreous for magnetite ores. This is owing to the unglaciated surface of the country. The rocks have not been scored as deeply as those farther north, and organic agencies have had time to operate on the ores. The same or a similar effect is noticed on the rocks, which are rotted to a greater depth.

BLAUVELT MINE.

Wiggins & Henderson, Operators.

This is a new opening on an old prospect vein. Six men, including the operators, put out two hundred tons a month.

The ore is bought by Sampson George, who sells to Pennsylvania furnaces. The ore is magnetic and non-bessemer.

Both this mine and the Dickerson employ no steam pumping or hoisting. So far, the mines are perfectly dry, and the hoisting is done by means of a horse whim.

HACKLEBARNEY MINES.

Chester Iron Company, Owners and Operators.

These mines are now in active operation. At present a water-wheel is being put in at the mines, which will work the mine pumps. The company is now working sixty men on the vein above the roaster. This needs no pumping. The ore runs high in sulphur, and on this account it has to be roasted. A Taylor roaster is used. In this roaster the coal does not come in contact with the ore, but is used to generate gas, which is led into the roaster and burned. The ore is fed in from the top, and is drawn from the bottom, so no stop is made except for repairs.

The ore is magnetic, and some of it is bessemer, while other parts of the same shoot run too high in phosphorus. The top of the shoot is the usual place to look for the bessemer ore, while the bottom runs too high in phosphorus.

Furnaces in Pennsylvania use the entire output.

The deposits of ore here are rather peculiar. Instead of coming in one large body, the ore seems to come in numerous and irregular shoots. The deepest mine is one hundred feet. The shoots vary in depth from fifteen to two hundred feet. The width of the veins from foot to hanging-wall is one to twelve feet. From twelve to fifteen bunches or shoots of ore are worked.

The ores from this mine are peculiar in being very compact, almost flinty in texture, and in their banding. The bands, which are plainly discernible when broken right, are parted by thin layers made up of mica scales. Hornblende and mica rock, containing small grains and bunches of ore, are common in these mines, as well as in other mines. Owing to the unglaciated country, the country rock, save that which is in immediate contact with the ore, is not to be seen without much search. It is probably Mount Hope type.

The mine has been idle for a year and a half, but it started again in August, 1890.

AUBLE MINE, NEAR PEAPACK.

John Auble, Owner.
W. Slup, Operator.

This mine has been re-opened during the present summer. It has never produced any ore to speak of, being nothing but a prospect hole.

The present operator now has a shaft on the slope fifty feet deep, and the length of the mine is about one hundred feet.

The ore seems to be of good quality, but is non-bessemer. It is two miles from the railroad.

RINGWOOD MINES.

Cooper & Hewitt, Owners and Operators.

Dr. Cook, in his "Geology of New Jersey," 1868, mentions twelve mines at Ringwood, and they are as follows: Blue, Hard, Mule, Little Blue, Bush, Cannon, St. George, Miller, Keeler, Cooper, Peters and Hope. These were probably not all in operation at a time, but they were known. For that matter, they are all mentioned by Prof. Rogers in his report, which was published in 1836. At Ringwood and Hibernia there were, according to him, magnetic separators employed for dressing ore for forges. They were called magnetic separators. (See Prof. Rogers' Report on the Geology of New Jersey, 1836, p. 143.) These mines were all mentioned by Rogers as being well known, and most of them were opened. It is supposed that they were worked by a London company as early as 1760. At least this date is cut on a foundation stone of their furnace.

Of the twelve mines mentioned, only two are now in operation—the Peters and the Cannon mines.

PETERS MINE.

The ore is magnetic and non-bessemer, and is used by Cooper & Hewitt's furnaces.

The mine lies in three shoots, known as No. 1, No. 2 and No. 3. Nos. 2 and 3 lie directly over each other; No. 1 lies in the hanging-wall apparently, but is probably a shoot belonging to the same deposit, but bent out of its course. The ore pitches away to the northeast, and dips to the southeast. The end of the Peters mine has been reached a little more than six hundred feet down the slope. The ore has not pinched out; it has simply been broken off, and probably by a fault. This fault has probably thrown the ore up, and it is quite possible that the Hope series of mines may be the broken outcrop of the Peters mine. However that may be, the Peters mine is worked out, and the mine will be abandoned as soon as the pillars can be wholly or partially recovered. To recover these pillars the mine is being uncovered. The depth to which the cap rock is now removed, November 28th, 1890, is about ninety feet. The underlay to the southeast makes it necessary to remove only the hanging-wall. The country rock of the Peters mine is of the Mount Hope type, and it shows very plainly to within a few feet of the ore vein proper. The rock in immediate contact with the ore is quite different. It consists of a white, glassy feldspar, and pyroxene and hornblende. It is very well foliated and splits easily. Near the surface this rock goes completely to pieces, and appears as a brick-red sand. Even where not so far gone, it is a very treacherous rock to mine through, as it has to be very carefully timbered. This decomposition is caused by the rapid rotting of the feldspar, while the hornblende and pyroxene decomposing more slowly, only change the color of the material to red. A coarse pegmatitic rock, which seems to be eruptive, is also common in the mine. This rock comes in the ore-body proper.

CANNON MINE.

Cooper & Hewitt, Owners and Operators.

This mine was opened at the same time as the Peters and by the same company. The dip and strike of the mine are as usual.

In the vicinity of this mine are numerous other shoots of ore, side by side and parallel. They do not seem to be of great depth and are very much disturbed. They are in general line with mines which extend to the Peters mine, more than a mile distant. The line is broken, though, at several points and shoved to the northwest.

The rocks in the immediate vicinity of the mine are much the same as those at the Peters mine. In this mine, as well as in the numerous mine openings near by, there is a great amount of eruptive granite of a very coarse nature. It consists of large crystals of bright-red feldspar, quartz and pyroxene or hornblende. This granite occurs in the country rock and in the ore-body, often enclosing masses of ore of various sizes. The quartz contains large crystalline nodules and sometimes crystals of rutile. Zeolites of different kinds also occur. "Berg kork" is also common in the seams formed by the slip of the rocks.

These mines are the only ones worked north of the Pequannock river and across the entire belt of the Highlands. In the early spring of 1888, a shaft was sunk on the Rutherford estate, near Buckabear pond. The shaft was sunk one hundred feet, but failed to strike any great body of ore. In the spring of 1890, the Kanouse mine was pumped out and re-examined, but it did not appear to promise enough to warrant its being worked for ore.

Although not yet in active operation, mention should be made of an extensive plant which is being erected at the old Ogden mines by Thomas A. Edison. It is proposed to mine the lean ore of this extensive deposit and to concentrate it to a 66 per cent. bessemer ore. The capacity of the mill (1,000 horse-power) is 2,000 tons in 24 hours. The Edison separator is to be used.

The above is a complete list of the mines now working in the State, as well as of the ones of which there is a prospect of re-opening. The number of men employed, the total output per month, and the number of mines are given below:

Number of mines working or preparing to work, 30. Number of men reported as employed, 2,164. Total number of tons of ore raised per month, 46,083. On this basis the total yearly output for 1890 was 552,996 tons. As this estimate is based on an average of nine months, it is probably nearly correct.

The average yearly output of the mines for the last nineteen years, according to the annual reports, has been 533,083 tons.

Although this is a good showing for the capacity of the New Jersey mines, it must be remembered that almost the entire output is from mines that have been known and worked for the last hundred years. Two rather prominent exceptions to this statement are the Kishpaugh, opened in 1871, and the Belvidere mines, opened about 1873.

It is, as yet, an open question as to whether the Belvidere mines belong properly to the Archean division of rocks and ores. From certain facts obtained from a study of the mines, it seems to be advisable to class them with such mines as the Andover, Tar Hill, Roseville, Pochuck and other mines which belong to the Cambrian or Taconic system of rocks.* The fact that the Belvidere and other mines are magnetic may be explained by metamorphism. In fact, in many rocks of an age as late as the Devonian small beds of magnetite occur.

If the surmise is correct, a new and comparatively unexplored field awaits the prospector, for search for iron ores, and especially for magnetic iron ores, have been confined almost exclusively to the Archean rocks.

Looking at these facts in one way, the capacity of the mines appears to be equal to any demand that may be made upon them. At the same time it must be remembered that the mines are continually growing deeper, and that at a rapid rate.

The Hurd mine, at Hurdtown, is now down 3,625 feet, on a slope of 30° average. This gives the mine a depth of 1,850 feet, or a depth of 850 feet (about) below the level of the sea. The Dickerson mine, the next deepest mine, is now down 1,200 feet, a depth of about 400 feet below sea level. The Mount Pleasant mines are next, with a depth of 900 feet, and they reach between 200 and 300 feet below sea level. The Hibernia mines are 800 feet in depth, but on account of their elevated position they are not at sea level. Other mines range in depth from 200 to 700 feet.

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*The term "Cambrian or Taconic" is here used, since the priority of use has not yet been settled acceptably by geologists. As used here it refers to a system of rocks younger than the Archean and older than the Silurian. (See in this report "The Post-Archean Age of the White Limestones of Sussex and Warren Counties," page 25.)

In 1873 the Dickerson mine was 600 feet deep; ten years later it reached a depth of 700 feet, and in the last seven years it has deepened 500 feet. This later rapid increase in depth is owing to the fact that only the main shoot of ore is worked.

The Hurdtown mine, in 1883, was 2,000 feet on the slope, and, as stated above, is, in 1890, 3,625 feet, an increase in vertical depth of over 100 feet per year.

In 1883 the depth of the Mount Pleasant mine was 500 feet. In 1890 the depth is 900 feet. Other mines have increased in depth at about the same rate. The Byram mine, for instance, was 735 feet deep, measured on the slope, in 1873; in 1882 it had reached a depth of 1,100 feet, and was abandoned. The mine was not worked out, "but the vein was narrow and the shoots short and irregular." The report (1873, p. 99) does not state whether the slope referred to the dip or to the pitch.

In the accompanying list of mines, which is taken from the Annual Report of the State Geologist, for 1883,* it will be seen that the boom in the iron market stimulated prospecting for iron ore to a great degree. In this list are enumerated three hundred and twenty-five openings. The mines which are starred (*) have never been worked, and thus cannot properly be classed as mines, or at most, have produced only a few hundred, or thousand, tons of ore. Of all the mines in the list the Kishpaugh, opened in 1871, and the Queen (one of the Belvidere mines), opened in 1882, are in operation to-day. The prospecting of twenty years has thus failed to discover, with two possible exceptions, a single mine of importance.

The thoroughness with which this prospecting seems to have been done, becomes apparent when we consider that the iron-ore belt proper consists of really less than 700 square miles, and that on an average two openings in search of ore have been made on every square mile in the belt. This certainly does not represent all that has been done, for there is hardly a farm that has not "attraction," and upon which diggings of greater or less extent have been made.

Another rather remarkable fact is, according to report, and the report appears to be capable of verification, all of the great mines of the State were exposed to the air, or at least covered with only a few feet of soil. This was certainly the case with the Hurdtown, Ring-

* This list has been, as stated, copied from the Annual Report of 1883, and has been corrected to date.

wood, Hibernia, Dickerson, Mount Hope, and with many other of the historical mines of the State.

The prospecting noted above seems thoroughly to have demonstrated the fact that there are no more great mines occurring under the conditions stated above, namely, exposed to the air or covered slightly by the soil. Another fact which has been demonstrated is that, so far at least, the great mines of the State lie in well-defined belts, and that outside of these belts no great mines, with one exception, have been developed.

Two very vital questions thus present themselves to those interested in mining in the State. First. Are there probably any other great deposits of iron in the State? Second. Is there any way of determining the positions of such deposits?

These questions will be discussed in the following pages.

ROCKS ASSOCIATED WITH THE IRON ORES.

The rocks associated with the iron ores of this belt of New Jersey may be roughly divided into two classes. These two classes are, first, country rock, or rock forming the adjacent walls of the iron-ore deposits; second, mine rock, or rock which is confined between walls of the ore-body proper, and is intimately associated with the ore. This division excludes eruptive rocks of various kinds, as well as the particular varieties of rock which may be found either in the country rock or in the ore-body itself. For in spite of the fact that there is a great similarity in these rocks, comparing country with country, or mine with mine, there is a wide variation in mineral composition and in mineral proportion among the rocks.

The country rock of the mines of the great magnetite belt of New Jersey was described in the Annual Report of the State Geologist, for 1889, page 30, as Mount Hope type.

As was there stated, the rock is well foliated.* This rock was so

* The term "foliation" among geologists is used to denote a structure in crystalline rocks, in virtue of which the rock will split more readily in one direction than in any other. The word is derived from a Latin word meaning a leaf.

Quarrymen often speak of this structure under the name of "the *grain* of a rock," and a skillful quarryman will tell by observation how the grain runs.

If the mine rock or wall rock from any of our mines be closely observed it will be named since it was observed that it was the country rock of the Mount Hope mines. Its mineral composition is quartz, feldspar (two kinds), and magnetite. At the Mount Hope mines a tunnel has been driven into the side of a hill, which has intersected five shoots of ore. Between each of these shoots of ore this peculiar rock is found. It will thus be seen that, for this particular mine at least, the rock is well named. In the other great mines of the State, by actual trial, it is found that this same rock makes up the "country" of the mines. As the belt of rocks passes from New Jersey into New York, the same holds true for the magnetic iron mines of southeastern New York, west of the Hudson river. East of the Hudson other conditions seem to prevail.

An extended study of the great iron-ore bearing rocks of the Adirondack Mountains showed that there also this peculiar rock enclosed the iron ore. In fact, on every side of the mountains, this rock lies in the form of an irregular circle around the core of eruptive rocks, which form the bulk of the higher peaks. This is especially true of the great ore deposits near Port Henry, Chateaugay and Crown Point.

In New Jersey and in southeastern New York this rock extends to a very great distance, even where no iron mines have yet been discovered. Its extent and position have been described in the report for 1889, already referred to.

As was then stated, the rock is found in the cut above Easton, Pa., on the Belvidere railroad. It forms the greater part of the rock of Scott's Mountain, and follows along northeast to Franklin Furnace. There it disappears under the limestone, but re-appears on the axial crests of Pochuck Mountain. Beginning again on the Delaware at Durham Furnace, Pa., this rock again reaches northeast through Schooley's Mountain, Mount Olive, Hurdtown, Ogden mines, Wawayanda and ends near Warwick, at the Parrot and Warwick

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seen that the minerals are arranged in parallel lines, and by trial it will be found that the rock will split along these lines very regularly, but will not split in any other direction. Crystalline rocks possessing this structure are called "foliated" rocks, and are said to possess a "gneissic" structure, and are called *gneisses*.

Rocks which do *not* possess this structure are called, in general, *granites*.

Schists are rocks composed wholly of mica, sometimes, or have so much of mica or graphite in parallel arrangement that they split very easily in this direction. In this case *foliation* is carried to a very high degree. In a *slaty* structure *foliation* is carried to such a degree of perfection that a rock will split nearly as perfectly as a roofing slate.

mines. The next belt begins near High Bridge, runs through Chester, Mine Hill, Port Oram, Mount Hope, Hibernia and Ringwood, includes the great mining belt in New York, including the Forest of Dean mines, and ends on the Hudson river at Fort Montgomery and Iona Island. It has not been noticed east of the Hudson.

It is also found on the crests of the Ramapo Mountains, and near Pompton, Boonton, Morristown and Mendham.

It thus appears that the great iron-ore deposits are connected with rocks of Mount Hope type, and that prospecting for iron must be confined to this rock. This statement is strengthened by the fact that outside of this rock no iron mine of importance has been opened in the Archean formation. So well recognized is this among miners, that a certain other rock, which is very abundant (see Oxford type, 1889, Rep. p. 80), is known among them as "hungry rock."

The mine rock, or rock which is mixed or interstratified with the iron ore, sometimes known among miners as "horses" of rock, is, like the country rock, well foliated, and it is often banded with hornblende and pyroxene, and sometimes mica. The hornblende and pyroxene often form bands in the ore-body proper, to the exclusion of other minerals, with some scattering grains and bunches of magnetite and sometimes sulphide of iron. A black mica often forms bands and bunches in the ore, and often thin bands of ore, from one-half of an inch to two or more inches in thickness, alternate with this. In fact, where beds or "shoots" of iron ore give out, this is the manner of giving out. The ore divides into strings, the mica and hornblende becoming more and more abundant, till it is no longer profitable to work the deposit. This is not true, of course, where the ore-body ends by being cut out by a fault.

One thing is very noticeable in mine rock; that is, its freedom from quartz or silicic acid. This is rarely or never present except as infiltrating veins of secondary origin. It is thus evident that the mine rock is *basic*, in contradistinction to the country rock, which is for the most part *acid*.

The fact that the mine rock is basic, or at least quartz-free, is really the only thing which serves sharply to separate the two rocks. The mine rock is, as has already been mentioned, foliated or banded, and this banding is parallel to the course of the bed or vein of ore, and this, in turn, as has often been pointed out, is parallel to the foliation in the country rock. It is thus evident that the same cause which produced the banding in one rock also produced it in the other.

There is another rock, which was briefly hinted at under the term eruptive, that is a kind of granite or pegmatite, which is of frequent occurrence in the mine as well as in the country. This rock can be readily determined in the mine by its quartz, which is absent in the mine rock proper. In the country, it can usually be distinguished on account of its coarseness and the absence of a distinct foliation. This rock is, in addition, characterized by the titanic acid which it usually carries. In some instances zircon is also present in considerable abundance.

As near as can be found out from personal observation and from inquiry, the "rolls" and "pinches" so often met with in mines are not due to the rolling in of the foot or the hanging-wall or to their approach to each other, but are in reality due to the thinning out of the ore-body proper. That is, if in a mine a body of mine rock consisting largely of pyroxene or hornblende or mica and feldspar rock should appear either on the foot or hanging-wall, and should develop to such an extent as to reduce the ore-body to a thickness no longer profitable to work, the country rock would be said either to "roll in" or to "pinch out the vein," as the case might be. A careful examination of this rock shows it to be, instead of the true country rock, the regular mine rock. In many cases where a mine has been abandoned on account of the ores pinching out, examination shows that the mine rock, for some reason or other, has developed in the place of the ore.

A beautiful example of this is seen at the Lower Weldon mine, on the Ogden Mine railroad. Here, at the south end of the mine, long, narrow strings or ribbons of ore can be seen interbanded with broader strings of mine rock. One specimen which was collected at this mine and which is in the laboratory at Trenton, is six inches in thickness and has two bands of pure magnetite three-fourths of an inch thick. Two inches of mine rock consisting of feldspar, with occasional grains of magnetite, separate them. Had these bands of ore been three or four feet in thickness and the rock in proportion, they would have been spoken of as two parallel shoots of ore and worked as such. As it is, the ore is said to pinch out.

Mr. Joseph Cook, superintendent of the Wharton mine, at Hibernia, tells me that the cap rock of his mine consists largely of hornblende and biotite, and other mine superintendents and foremen are authority for the statement that the rolls in the mines are micaceous or hornblendic.

Where an offset or fault occurs in a mine there is a different matter entirely. The miner goes through the rock in spite of pinches, and the foot-wall or the hanging-wall of the vein is then sharply distinguishable from the mine rock. Thus the mine rock at the Hurd mine, at Port Oram, is the same as that already described, and from an examination of the waste dump one would never suspect that the country rock is the same as that at the Dickerson mines. At my request, Mr. E. Mill, superintendent of the mine, kindly sent me a piece of the rock taken from an offset in the foot-wall. This specimen is of the Mount Hope type. The parting between the vein, including the mine rock, is very sharp, and on one side of the parting is the acid Mount Hope rock, and on the other the mine rock and iron ore. The point of this and one or two of the preceding paragraphs is this: Iron ores are not cut out or pinched out by the country rock as often as they are reported; but the ore is cut out by a development of mine rock within well-defined walls of well-defined country rock of the Mount Hope type.

In this place it may be well to call attention to certain rock-beds, or strata, referred to by Dr. Britton in his reports for 1885 and 1886 as diorite. The same rock is also referred to in the report for 1889, and under the same name. This diorite rock consists of hornblende and feldspar, with no quartz, and with occasional grains of magnetite. It is sharply separated from the adjoining Mount Hope rock, although closely welded to it. These bands are more highly impregnated with iron in some places than in others, and shafts have been sunk on them in hopes of finding workable deposits of iron ore. A shaft sunk on the Rutherford tract in the spring of 1888 by Colonel W. H. Scranton, is an example in hand. Inasmuch as there is this similarity, it may be well to study these rocks with the idea that these bands of diorite rock are but the remains, or signs, of a deposit of iron. Whether such signs are capable of closer interpretation, further study may reveal. In the ore shoot, or bed, the wall rock is well defined. There is no gradual thinning out of the ore till it becomes too lean to work, but there is an abrupt transition from the vein-matter to the country rock. This must not be taken as implying that the ore is rich enough to work the full width of the vein, for ofttentimes this is not so, as has been explained under "rolls" and "pinches." It simply means that a bed of ore, whether rich or lean, is a well-defined body, and is sharply separated from the country rock. If the ore grows lean as it approaches either the foot or hanging-wall, the rock which takes the place of the ore is still mine rock, and as such is easily distinguishable from the country rock. In many mines a smooth, greasy surface separates the vein-matter from the country rock. For mines of this kind the Hurd, Harvey and New Sterling, at Port Oram, are good examples. In other mines, as, for example, the Dickerson, the ore clings to the wall so firmly that a blast tears off portions of the country rock with the ore. There is, however, no thinning of the ore in this case. The principal points to be carried from this paragraph are, first, that the vein, or bed, is a well-defined body; second, that the country rock proper is never mingled with the ore-body.

So far as I have been able to note from personal examination of the mines of New Jersey, the "horses" or "horsers" of rock in mines are either large masses of the mine rock, usually biotite feldspar or hornblende feldspar rocks (quartz being absent in both cases), or of a granitic or pegmatitic nature. In this latter case the rock is very coarse, is easily distinguishable on account of the abundance of quartz, which in this case is clearly seen to be an original constituent of the rock. The other and rarer minerals are allanite, sphene, rutile, and usually more or less zircon. Mines in which rocks of this nature occur are Washington mine, Oxford Furnace; Hibernia mines and at Ringwood. At this latter place, at the Peters mine, an irregular-shaped dyke of pegmatite may be seen in the ore-body. At the Cannon mine the rock is much coarser and the feldspar is of a bright flesh-red color. There are many zeolite minerals found with it. It is to be noted that when rocks of this nature occur (granites and pegmatites), the country shows much disturbance and the ore-bodies are more or less irregular. At the Cannon mine the eruptive granite appears to have divided the ore-body into several short, irregular "shoots." Titanic acid in the form of rutile is found in this rock, while analyses of the ore show it to be comparatively free from it.

From what has been said in the foregoing paragraphs, it may be inferred, first, that *no* foliated, quartz-bearing rock occurs in the mines; second, that there are *no* "rolls" in the walls of country rock, or that the ore is never "pinched" out. Neither of these statements is true absolutely; but they are meant to express a *general* rule. One of these general rules is that the *absence* of granular quartz is characteristic of the mine rock, just as its *presence* is characteristic of the country rock. Another of these rules is that by far the greater number of rolls, pinches and squeezes are due to the replacement of the ore by the mine rock, and not by the intrusion of the country rock.

POSITION OF ORE-BODIES IN THE ROCK.

In the former reports of the Survey much has been said regarding the pitch and the dip of ore-bodies proper. It has been pointed out that these coincide with the position of the enclosing rocks, as indicated by the foliation of the rocks. It has been assumed that this foliation was produced by bedding or sedimentation in the same way in which beds or layers of sand and clay are produced by water to-day. This is supposed to be proved, since the deposits of iron ore, which are regarded as of aqueous origin, are so conformable to the position of the rocks. On the assumption, however, that the foliation in the gneissic rocks is evidence of sedimentary origin, there are several very stubborn facts to be explained. In the first place the pitch of the ore shoots, while generally in a northeast direction, vary greatly as to the amount. For instance, the pitch of the Dickerson mine is about 60° to the northeast, with a dip of 55° to the southeast. The Corwin and Sterling mines, a little more than a mile to the northeast, have a pitch of only 5° to 6°, and a southeast dip of from 30° to 45°. The Hurd, Harvey and North River mines, at Port Oram, agree closely with the last two mines. The Hurd mine, at Hurdtown, has a pitch of 30° to 45°, while the dip is nearly 90°. In short, by comparing the pitch of *rock* given in Annual Report State Geologist, for 1886, page 96 (a few mines are included), with the pitch of the *iron-ore* deposits given in the Report for 1883, page 55, this discrepancy will be observed. The pitch of the rocks varies from 5° to 40°, with an average of about 22°, while the iron ores vary from 15° to 60°, with an averge of 38°. It will thus be seen that the iron ores, on an average, have a steeper pitch by 16° than do the enclosing rocks.

If now the dip or underlay of the mines be compared with the dip of the rocks, some very suggestive figures appear. The average dip or underlay of one hundred and forty-eight mines or mine openings is 60°; the average dip of the same number of observations on rocks gives an average of 58°. It will thus be seen that in the matter of dip the rocks and the enclosed mines are far more intimately related than in the matter of pitch. This similarity is more striking when it is considered that the dip of the rocks is taken, for the most part, at a distance from mines.

It is probable, however, that observations of a sufficient number have not yet been made to warrant the assumption that the pitch of the ore-beds differs essentially from that of the enclosing rock. The bottom or the cap rock of a mine from which the degree of the pitch is obtained is never a certain factor, and the swelling downward or the pinching upward of the ore-body would give an apparently flatter or a steeper pitch, as the case might be, to the ore-body than to the enclosing rock; while, as a matter of fact, the pitch might be the same in both. In order to establish a point of this kind the most careful observations should be made, and the utmost caution should be observed lest the mine rock be mistaken for the country rock.

In studying out the formation of the Archean rocks, it should be borne in mind that dip and pitch are caused by forces acting at right angles to each other, and that the force which produces the dip of the strata tends to form long ranges or rolls in the rocks; the force which causes the pitch breaks these long rolls up into longer or shorter hills, and so brings to light strata which would otherwise have been deeply buried. Thus, in New Jersey, the Archean Highlands have probably been formed by a force acting from the southeast and thus the successive ranges of this belt have been formed. At the same time another force, acting at right angles to this, has produced the succession of hills with their gentler slopes falling away to the northeast. It is thus that we can account for the fact that one end of an iron-ore bed or shoot appears at or near the surface of the earth, while the other is deeply buried; and in the same way we account for a long succession of outcrops along the same line, each shoot "heading out" against a rock and another shoot taking its place at a distance farther on. At the same time each successive shoot may appear farther and farther to the east, or, in the miners' language, "thrown into the hanging-wall."

This may not at first sight appear plain, but if two blocks be placed end to end and then given an inclination or "dip," the raising of one block *vertically*, or depressing in the same line, the blocks will apparently be moved apart sideways. If the blocks are placed vertically no side displacement will be made. Of course both side and vertical movements may combine to thrust the ore-body to one side. It must be remembered that with a southeast dip, such as is generally characteristic of the New Jersey ore-beds, an *upward* movement would throw the ore into the *hanging-wall*, while a *downward* movement would throw the ore into the *foot-wall*. This is supposing, of course, that we are going to the northeast on a given ore-body. If we were going to the southwest, the throw would apparently be just the reverse.

As was before remarked, however, the probability is that both vertical lift and side thrust have been active in forming the offsets in our mines. It is evident, then, that if the structural geology of the mining belt be accurately worked out, the direction of the movement of any given ore-body could be determined, and thus it could be found. That is, the direction of the movement of the country rock, whether up or down, to the right or to the left, can be determined in most cases by a skillful geologist. It would follow, then, that the ore-body, being enclosed in the rock, must take the same direction. In regard to the presence of other great ore-bodies, which are buried so deeply that they have not appeared on the surface, other factors suggest themselves. Regarding the Archean rocks as sedimentary, let us see what would follow.

Let the order of deposition be represented by a series of blocks, letting gray blocks represent beds of rock and black ones beds of iron ore. Let the order of deposition be as follows: First a gray block, then black; two grays, one black; four grays, one black; two grays, and then deposition ceases.

If now the blocks were to remain horizontal, the iron (or black blocks) would never appear on the surface. Let them be tilted, or given an "underlay," and the tendency would be to expose a layer of the black; but if, in addition to the "underlay," the blocks be tilted endways, or given a "pitch," one end of a black block would appear on the surface, while the other would plunge deeper.

Further, only one black block might be exposed by the tilting, and we might desire to know if there were others. If the blocks were horizontal, as in the beginning, the obvious plan would be to sink a *perpendicular* shaft and this would reveal the nature of the underlying blocks, with the least expenditure of work. If now we remember that whatever the angle may be at which the blocks be tilted, they always maintain the same relative positions, it will be seen that, in order to discover the nature of the underlying blocks, the direction of the shaft must always be at *right angles* to the surface of the blocks.

What is true of our imaginary blocks is true of the rocks which they represent. And if one is puzzled to know in which way to go to get *under* a given shoot of ore, a recourse to a device of this kind may give very graphic assistance.

After all, it must be said that the study of rocks and their positions or structure is one of exceeding difficulty, and it is a fair question as to whether, in case it is contemplated to spend thousands of dollars in the search for ore deposits, it would not be wise to call in the assistance of one who is familiar with such studies.

The business of the miner is with the pursuit of certain substances, their economical extraction, and with the devices of securing his mine; and it is only incidentally that a knowledge of geology and mineralogy becomes of importance to him. The business of the geologist, on the other hand, has wholly to do with the rocks, their origin, position and movements, and the mine has no interest to him save for the light that it will incidentally throw on his subject. The mine is in the rock, and must of necessity partake of the motion of the rock. It must be remembered, however, that the miner's knowledge is *particular*, and that of the geologist is *general*. The knowledge of the two is thus supplemental.

Referring to the appended list of mines, a verification of the above statements will be found. There are more than one hundred "prospect" holes that have been opened at a cost of from one hundred dollars or less up to a thousand or more dollars.

It is probably the fact that if the prospectors who have done the exploring had called in the aid of men versed in rock structure to *supplement*, not in any sense of the word to replace, their knowledge, a great saving of time, labor and money would have been effected. The conclusion of the whole matter is this: There are no new mines in the State, and in the old ones exhaustion is only a matter of time. Previous efforts have failed to locate new deposits. Will it not be wise, then, to try one more method—that is, of combining the sound, practical knowledge of the miner with the knowledge of the geologists, as published in the Survey Reports? So far as can be seen at present this is a last resort.

SEARCHING FOR MAGNETIC IRON ORES WITH A MINER'S COMPASS.

The miner's compass is now so familiar an instrument that it needs no description. This caution, however, may be added, that in selecting an instrument the best is always the cheapest in the end. The liability to error, even in the best of compasses, is so great that this error ought to be eliminated, so far as is possible, by securing the best make.

Freedom of motion, and freedom from any causes that would tend to impede the action of the needle, must be looked after carefully, for even the slightest friction will cause a great error in pointing out the degree of attraction. This error is liable to still graver results if it is intermittent in its action, so as to impede the needle at one point and leave it free at another. It would follow, as a matter of course, that such an instrument must be handled with great care, or its more delicate parts would become injured and the instrument unreliable.

Even the best instrument, with the best of care, especially if it be new, needs to be constantly tried on neutral ground, or where no attraction exists. This is rendered necessary from the fact that the needle is usually so constructed as to rest at zero on neutral ground. These zero points are usually fixed on an immovable arc. It is a well-known fact that a needle parts with its magnetism to a certain degree. As it loses its magnetism its equilibrium is disturbed, and it is constantly recording a certain degree of *negative* attraction when no attraction exists.

Suppose, for example, in using a needle the following notes of attraction should be made in going over a given line:

I. —20°, —15°, —5°, 0°, +5°, +20°, +30°, +60°.
II. 0°, +5°, +15°, +20°, +40°, +50°, +80°.

Line I. shows the notes entered. If now the behavior of the instrument arouses suspicion, let it be taken where no attraction exists (this point must be selected with great care), and it may be found that the needle comes to rest indicating —20° attraction. Let the needle be tested in other localities, and if all agree on —20° this error must be eliminated from the notes in order to get at the correct indications.

Line II. shows the notes thus corrected. It is evident that if the compass has an error of —20°, and indicates this in the field, there is no attraction. If there is an indicated attraction of —15° there must be an attraction of +5°, and so on.

Where a compass is thus discovered to be in error the needle should be balanced. This balancing is done by removing one of the glass covers and placing a weight on the lighter end of the needle. A bit of shoemaker's wax is a very convenient material, as it can be readily applied and easily removed. This balancing should be done where no attraction exists, and when balanced so as to swing at zero, it should be tested at various points, to be certain of a correct reading. An instrument should be tested every day at least, when in use.

In making a survey with a needle its behavior is sometimes very strange and hard to interpret. Suppose that the notes along a certain line were as follows, and taken twenty feet apart: 40°, —30°, +25°, —50°, —25°, —5°, +60°.

If the behavior of a needle in the presence of a magnet be recalled, the interpretation is comparatively easy, and one or both of two conditions of an ore-body is indicated. First, +40° and —30° indicate a break in the ore-body, and that it is acting as an independent magnet; and the subsequent indications point to the conclusion that an ore-body one hundred and twenty feet long has at least two breaks or faults in it. Second, it is indicated by change from positive to negative, and *vice versa*, that the ore, instead of lying in a continuous body, lies in the form of large lenses, with rock between. It will be readily understood that both of these conditions may be present.

To determine whether the ore is lenticular and in isolated bodies, or whether a continuous body which has been broken, resort must be had to the geological features of the country. If the hills and the outcropping rocks are long and regular in shape, the ore is probably in lenses. If the contrary be true, and the hills are short and irregular and the rocks are much tumbled about, the probabilities are in favor of a broken ore-body. It has already been remarked that the great mines of New Jersey were found exposed on the surface, or at most covered by but a few feet of soil. If these outcropping ore-bodies had been passed over with a dipping-needle, their presence would have been revealed by a strong attraction, probably as high as 90°. As the line was followed northeast the attraction would grow fainter and fainter, and finally disappear. It would be noted, however, that the line of attraction was a long and steady one.

Suppose now if instead of five to ten feet of covering there had been fifty to one hundred feet, or even more. In this case the needle would not be so strongly attracted, even when standing over the main outcrop, and along the northeast line the corresponding attraction would be fainter, and would come to an end sooner. As a matter of fact, the entire surface of the mining belt of New Jersey, northeast of a line passing through or near Buttzville, Budd's Lake, Dover, Denville and Morristown, is glaciated, and in many places glacial drift covers the surface to the depth of several hundred feet. The summits of many of the hills are bare rock, but the valleys or depressions between the hills are deeply buried by drift and oftentimes these depressions have been the bottom of lakes or ponds which have become filled with peat or "black mud" mingled with soil washed in from the hills. This state of affairs reaches out of New Jersey and into New York.

A little thought will show that were a greater deposit of iron ore than has yet been found buried beneath this drift, it would give but feeble signs of its existence to a needle, if, indeed, it gave any at all. Whatever signs of attraction were observed over a drift-covered area, though, would be strongly indicative of a large ore-body, especially if the attraction extended for a moderately long distance.

Whether or not such bodies of ore exist remains yet to be demonstrated. It is to be observed, however, that *below* the glacial line the great ore deposits are more frequently found at or near the foot of hills, or in depressions, rather than on the summit of the highest hills. It is also to be observed that there are more productive mines in this area than in the glaciated area. And, finally, it is to be observed that all mines in the glaciated and drift-covered areas have been opened through but a few feet, if any, of drift.

This brings us back to the original question: May there not be large deposits of iron ore deeply buried by drift?

In prospecting on a property it is common for the prospector to go over the property according to no definite rule, and consequently, when the survey is finished, there is no clear idea of the relation of the different areas where attraction has been observed. There is an impression that it will, or will not, be wise to open up the property, and this decision is usually reached more by finding several points of *strong* attraction rather than by finding a line of *steady* attraction. There is only one way to eliminate such an element of uncertainty, and that is by making a map as one goes along. Take a piece of diagram paper, draw an outline of the property to be surveyed, and then fix a northeast-southwest line. Start on this line, note the attraction, mark it on the diagram paper, go ten feet or twenty feet northwest, again note and mark down the attraction on the paper. Continue in a northwest line till attraction ceases, then go ten, twenty or more feet northeast, and then note attraction going southeast. Cross the fixed line, observing every ten or twenty feet till attraction ceases in that direction. When the whole property has thus been traversed there is no trusting to the memory necessary; the exact results of the survey are under the eye. This mapping can be done as elaborately as the individual chooses. The property can be accurately surveyed, but all that is necessary is the fixing of a single line. The distances can be paced off accurately enough for practical purposes. If the results are favorable enough to warrant the sinking of a shaft, the exact point can be determined by accurate measurements.

Three very good maps plotted in this way are to be seen in the Annual Report of the State Geologist for the year 1873, page 94. Another great advantage of this method of map-making, however rudimentary it may be, is that it shows conclusively whether the ore deposit is a regular bed or is only an intruded or segregated mass of limited extent. It also shows the *direction* of the line of attraction. When the direction of the line is other than northeast-southwest it is well to examine the property very carefully, since experience has shown that in New Jersey the best mines lie in this direction. If, therefore, there seems to be a deviation from this line the position of the neighboring rocks ought to be very carefully studied. If the rocks "strike" or run in the same direction as the line of attraction the result is favorable; if not, the line of attraction is either an eruptive mass or a segregation. In either case, no thought of further development ought to be entertained.

There are many other points which could be suggested, but which practice in the field will more readily and forcibly suggest. It will hardly be necessary to point out that acute observation is necessary at all times, and that the nature and position of the rocks, as well as the topography of the country, must be taken into account, and that all of these contribute quite as much to the success of the prospector as the needle itself.

LIST OF IRON MINES,

WITH REFERENCES TO NOTES IN REPORTS OF THE GEOLOGICAL SURVEY.

NOTE.—The order of arrangement in this list is nearly the same as that of the Annual Report for 1883. The four belts are retained as convenient for reference. They have no geological existence, but are geographical divisions. Small openings which have not been developed into producing mines, are marked with a star, thus, *.

RAMAPO BELT.

*BERNARDSVILLE OPENING, Bernards township, Somerset county. Idle.

Annual Report, 1873, p. 24.
" 1874, p. 41.
" 1884, p. 73.

*JANES MINE, Bernards township, Somerset county. Never worked.

Geology of New Jersey, 1868, p. 544.
Annual Report, 1873, p. 24.
" 1884, p. 73.

CONNET, or WATER STREET MINE, Mendham township, Morris county. Opened in 1869. Idle now.

Annual Report, 1873, pp. 24, 25.
" 1879, p. 41.
" 1884, p. 73.

*BEERS OPENINGS, Hanover township, Morris county. Never worked. Idle.

Annual Report, 1878, p. 99.
" 1879, p. 41.
" 1884, p. 73.

TAYLOR OPENINGS, Montville township, Morris county. Opened about 1858. Idle now.

Annual Report, 1873, p. 25.
" 1884, p. 73.

*Cole Farm, Montville township, Morris county. Idle. Never worked.

Annual Report, 1874, p. 21.
" 1879, p. 41.
" 1884, p. 73.

Kahart Mine, Pequannock township, Morris county. Opened previous to 1868. Idle.

Geology of New Jersey, 1868, p. 544.
Annual Report, 1873, pp. 25, 26.
" 1880, p. 101.
" 1884, p. 73.

*De Bow Place, Pequannock township, Morris county. Never worked. Abandoned.

Annual Report, 1873, p. 26.
" 1879, p. 42.
" 1880, p. 101.
" 1884, p. 73.

Lanagan Mine, Pequannock township, Morris county. Mine abandoned.

Annual Report, 1873, p. 26.
" 1879, p. 42.
" 1884, p. 73.

*Jackson, or Pompton Mine, Pequannock township, Morris county. Mine abandoned.

Geology of New Jersey, 1868, p. 544.
Annual Report, 1873, pp. 26, 27.
" 1879, p. 42.
" 1884, p. 73.

De Bow Mine, Pequannock township, Morris county. Abandoned.

Annual Report, 1873, p. 27.
" 1879, p. 42.
" 1884, p. 73.

*Beam Lot, Pompton township, Morris county. Abandoned.

Annual Report, 1879, p. 42.
" 1884, p. 73.

KANOUSE and BROWN MINES, Pompton township, Passaic county. Abandoned.

Geology of New Jersey, 1868, p. 545 (Kanouse mine).
Annual Report, 1873, p. 28 (Kanouse mine).
" 1874, pp. 21, 22 (Brown mine).
" 1880, p. 102.
" 1884, p. 74.

*SLOAT FARM, near Midvale, Pompton township, Passaic county. Abandoned.

Annual Report, 1884, p. 74.

*BUTLER MINE, Hohokus township, Bergen county. Abandoned.

Geology of New Jersey, 1868, p. 544.
Annual Report, 1879, p. 42.
" 1884, p. 74.

PASSAIC BELT.

*LARGE OPENINGS, Clinton township, Hunterdon county. Abandoned.

Annual Report, 1873, pp. 28, 29.
" 1879, p. 43.
" 1884, p. 74.

ANNANDALE, or SHARP SHAFT, High Bridge township, Hunterdon county. Abandoned.

Annual Report, 1880, p. 102.
" 1884, p. 74.

HIGH BRIDGE, or TAYLOR MINE, High Bridge, Hunterdon county. Abandoned.

Geology of New Jersey, 1868, pp. 617, 618.
Annual Report, 1873, p. 29.
" 1879, pp. 43, 44.
" 1880, p. 102.
" 1884, p. 74.
" 1886, p. 143.

*SILVERTHORN, or KEAN MINE, High Bridge township, Hunterdon county. Abandoned.

Annual Report, 1879, pp. 44, 45.
" 1880, p. 102.
" 1881, p. 37.
" 1884, p. 74.

*EMORY FARM, High Bridge township, Hunterdon county. Abandoned.

Annual Report, 1879, p. 45.
" 1884, p. 75.

*SHARP FARM, High Bridge township, Hunterdon county. Abandoned.

Annual Report, 1879, p. 45.
" 1884, p. 75.

CREAGER PLACE, High Bridge township, Hunterdon county. Abandoned.

Annual Report, 1880, p. 102.
" 1885, p. 75.

OLD FURNACE MINE, High Bridge township, Hunterdon county. Abandoned.

Annual Report, 1873, p. 29.
" 1879, p. 45.
" 1880, p. 102.
" 1884, p. 75.

COKESBURGH MINE, Tewksbury township, Hunterdon county. Abandoned.

Annual Report, 1873, pp. 29, 30.
" 1884, p. 75.

*BURRILL FARM, Tewksbury township, Hunterdon county. Opened in 1878. Abandoned.

Annual Report, 1880, p. 102.
" 1884, p. 75.

*SUTTON FARM, Tewksbury township, Hunterdon county. Abandoned.

Annual Report, 1873, p. 30.
" 1879, p. 46.
" 1884, p. 75.

*FISHER, or FOX HILL MINE, Tewksbury township, Hunterdon county. Abandoned.

Annual Report, 1873, p. 30.
" 1874, p. 22.
" 1877, pp. 49, 50.
" 1879, p. 49.
" 1884, p. 75.

*WELCH FARM, Tewksbury township, Hunterdon county. Abandoned.

Annual Report, 1884, p. 75.

*POTTERSVILLE, or UPDIKE FARM, Tewksbury township, Hunterdon county. Opened in 1872 and 1873. Abandoned.

Annual Report, 1884, p. 75.

*BARTLE SHAFT, Tewksbury township, Hunterdon county. Opened in 1872 and 1873. Abandoned.

Annual Report, 1884, p. 75.

*WORTMAN SHAFT, Chester township, Morris county. Abandoned.

Annual Report, 1884, p. 75.

LANGDON MINE, Chester township, Morris county. Abandoned. L. W. Langdon & Son were the lessees.

Annual Report, 1879, p. 46.
" 1880, p. 103.
" 1884, p. 75.
" 1885, p. 97.
" 1886, p. 146.

PITNEY MINE, Chester township, Morris county. Abandoned in 1881.

Annual Report, 1884, p. 75.

*RARICK FARM, Chester township, Morris county. Never worked.

Annual Report, 1873, p. 31.
" 1879, p. 46.
" 1884, p. 76.

HACKLEBARNEY MINES, Chester township, Morris county. Active.

Geology of New Jersey, 1868, p. 557.
Annual Report, 1873, pp. 35, 36.
" 1879, pp. 47–49.
" 1880, p. 104.
" 1884, p. 75.
" 1885, p. 95.
" 1886, p. 142.

GULICK FARM, Chester township, Morris county. Abandoned.

Annual Report, 1873, p. 36.
" 1879, p. 49.
" 1884, p. 76.
" 1885, p. 98.
" 1886, p. 142.

CREAGER, or PEACH ORCHARD MINE, Chester township, Morris county. Abandoned in 1873.

Annual Report, 1873, pp. 36, 37.
" 1884, p. 77.

HEDGES MINE, Chester township, Morris county. Idle in 1890. Abandoned.

Annual Report, 1873, p. 37.
" 1874, p. 23.
" 1879, p. 49.
" 1884, p. 77.

DICKERSON FARM, Chester township, Morris county. This property adjoins the Hedges on the northeast. The openings are on the northwest range, and are reported as being 80 feet deep. The shoots are said to be short. No work has been done since the panic of 1873. The engine and pumps have not been removed. Worked on a small scale. Resumed in 1890.

Annual Report, 1873, p. 37.
" 1884, p. 75.

TOPPING FARM SHAFT, Chester township, Morris county. Abandoned.

Annual Report, 1873, pp. 32, 33.
" 1879, p. 46.
" 1880, p. 103.
" 1884, p. 75.

SAMPSON MINE, Chester township, Morris county. Abandoned.

Geology of New Jersey, 1868, pp. 537, 538 (Skellenger).
Annual Report, 1873, p. 33 (Skellenger).
" 1880, p. 103.
" 1884, p. 77.
" 1885, p. 98.

CROMWELL MINE, Chester township, Morris county, known since as the CHESTER HIGHLAND MINE. Abandoned.

Annual Report, 1886, p. 139.
(See references under Sampson mine.)

HEDGES FARM, Chester, Morris county. Abandoned.

Annual Report, 1884, p. 78.

*CREAMER FARM, Chester, Morris county. Never worked.

Annual Report, 1873, pp. 31, 33.
" 1884, p. 78.

HOTEL PROPERTY, Chester, Morris county. Abandoned.

Annual Report, 1873, p. 33.
" 1879, p. 46.
" 1884, p. 78.

COLLIS SHAFTS, Chester, Morris county. Abandoned.

Annual Report, 1873, pp. 31, 33.
" 1884, p. 78.

SWAYZE MINE, Chester township, Morris county. Abandoned about 1886.

Annual Report, 1873, pp. 33–35.
" 1879, p. 47.
" 1884, p. 78.
" 1885, p. 98.
" 1886, p. 151.

COOPER MINE, Chester township, Morris county. Abandoned.

Annual Report, 1879, p. 47.
" 1880, pp. 103, 123.
" 1884, p. 78.
" 1885, p. 99.
" 1886, p. 140.

*KEAN MINE, Chester township, Morris county. Abandoned.

Annual Report, 1884, p. 79.

*SQUIER'S MINE, Chester township, Morris county. Abandoned..

Annual Report, 1880, p. 103.
" 1884, p. 79.

LEAKE MINE, Chester township, Morris county. This old mine was re-opened and worked in 1882 by the late A. Beemer, of Dover. It reached a depth of 80 feet and the vein was reported to be five to eight feet wide. The northernmost openings are now known as SKELLENGER'S MINE. They were going in 1881 and 1882. Abandoned.

Geology of New Jersey, 1868, p. 558.
Annual Report, 1884, p. 79.

BEEMER MINE, Chester township, Morris county.

Annual Report, 1886, p. 138.

GEORGE SHAFTS, Chester township, Morris county. Abandoned.

Annual Report, 1881, p. 36 (Chester mine).
" 1884, p. 80.

CHILD SHAFT, Chester township, Morris county. Abandoned.

Annual Report, 1884, p. 80.

*HARDEN FARM, Chester township, Morris county. Abandoned.

Annual Report, 1873, p. 32.
" 1884, p. 80.

*WOODHULL MINE, Chester, Morris county. Abandoned about 1883.

Annual Report, 1884, p. 80.
" 1885, p. 99.
" 1886, p. 153.

*BUDD MINE, Chester, Morris county. Abandoned about 1883.

Geology of New Jersey, 1868, p. 558.
Annual Report, 1873, p. 32.
" 1879, p. 46.
" 1884, p. 80.

*QUIMBY'S MINE, Chester township, Morris county. Abandoned.

Annual Report, 1884, p. 80.

*TIGER'S MINE, Chester township, Morris county. Abandoned.

Annual Report, 1884, p. 80.

*DE CAMP SHAFT, Chester township, Morris county. Abandoned.

Annual Report, 1884, p. 80.

DANIEL HORTON MINE, Chester township, Morris county. Abandoned.

Annual Report, 1884, p. 80.

BARNES MINE, Chester township, Morris county. No work has been done at any of these localities since 1883. Abandoned.

For previous notes, see Geology of New Jersey, 1868, p. 558, for BARNES; also,
Annual Report, 1873, pp. 38, 39.
" 1879, p. 49.
" 1884, p. 80.

*LEWIS, or HERRICK MINE, Randolph township, Morris county. Abandoned.

Annual Report, 1873, p. 42.
" 1879, p. 50.
" 1884, p. 80.

COMBS MINE, Randolph township, Morris county. Abandoned.

Geology of New Jersey, 1868, p. 550.
Annual Report, 1879, p. 50.
" 1880, p. 104.
" 1884, p. 75.

THORP MINE, Randolph township, Morris county. Abandoned.

Annual Report, 1884, p. 80.

*HENDERSON MINE, Randolph township, Morris county. Abandoned.

Geology of New Jersey, 1868, p. 558.
Annual Report, 1884, p. 80.

GEORGE, or LOGAN MINE, Randolph township, Morris county. Abandoned.

Geology of New Jersey, 1868, pp. 558, 559.
Annual Report, 1879, p. 49.
" 1884, p. 81.

DAVID HORTON MINE, Randolph township, Morris county. Abandoned.

Geology of New Jersey, 1868, p. 559.
Annual Report, 1873, pp. 39, 40.
" 1879, p. 49.
" 1884, p. 81.

*De Hart Mine, Randolph township, Morris county. Abandoned.

Annual Report, 1886, p. 140.
Same as Lawrence mine.)

*Lawrence Mine, Randolph township, Morris county. Abandoned.

Geology of New Jersey, 1868, p. 559.
Annual Report, 1873, p. 40.
" 1879, p. 49.
" 1880, p. 104.
" 1884, p. 81.
(See De Hart mine.)

Dalrymple, or Carbon Mine, Randolph township, Morris county. Abandoned. Work at this locality was suspended in June, 1882. It was worked by the Lehigh Crane Iron Company up to that date.

Geology of New Jersey, 1868, p. 559.
Annual Report, 1873, pp. 40, 41.
" 1879, pp. 49, 50.
" 1880, p. 104.
" 1884, p. 81.

Trowbridge Mine, Randolph township, Morris county. Abandoned.

Geology of New Jersey, 1868, p. 559.
Annual Report, 1879, p. 50.
" 1884, p. 81.

Solomon Dalrymple Place, Randolph township, Morris county. Abandoned.

Annual Report, 1884, p. 81.

Cooper Place, Randolph township, Morris county. Abandoned.

Annual Report, 1884, p. 81.

Munson's Mine, Randolph township, Morris county. Abandoned.

Geology of New Jersey, 1868, p. 551 (Munson's mine).
Annual Report, 1879, p. 50.
" 1884, p. 82.

Van Doren Openings, Randolph township, Morris county. Abandoned.

Annual Report, 1879, p. 50.
" 1884, p. 82.

BRYANT MINE, Randolph township, Morris county. Abandoned.

Geology of New Jersey, 1868, p. 566.
Annual Report, 1880, p. 104.
" 1884, p. 82.
" 1886, p. 138.

CONNOR FOWLAND MINE, Randolph township, Morris county. Abandoned.

Annual Report, 1884, p. 82.

CHARLES KING MINE, Randolph township, Morris county. Abandoned.

Annual Report, 1884, p. 82.

KING MINE, Randolph township, Morris county. Abandoned. This mine was worked by John M. D. Barnes, under lease of A. Pardee, up to January, 1879. It has been idle since that date.

Annual Report, 1884, p. 82.

McFARLAND MINE, Randolph township, Morris county. Abandoned. This mine has been idle for years past.

Annual Report, 1884, p. 82.

EVERS MINE, Randolph township, Morris county. Abandoned. This mine stopped April, 1883. The last work done there was by the Saucon Iron Company.

For notes of these five mines, see references as follows:

Geology of New Jersey, 1868, pp. 566, 567.
Annual Report, 1873, p. 43.
" 1879, p. 50.
" 1880, p. 105.
" 1884, p. 82.

BROTHERTON MINE, Randolph township, Morris county. Abandoned. The lease of the Brotherton mine was abandoned by the lessees, Messrs. Pullman & George, in 1882. No ore was mined or shipped during the year 1883.

Geology of New Jersey, 1868, p. 567.
Annual Report, 1879, p. 50.
" 1880, p. 105.
" 1884, p. 82.

BYRAM MINE, Randolph township, Morris county. Opened previous to 1854. Abandoned in 1882.

Geology of New Jersey, 1868, pp. 567–569.
Annual Report, 1873, pp. 43, 44.
" 1879, p. 51.
" 1882, p. 70.
" 1884, p. 82.

BAKER MINE (SOUTHEAST), Mine Hill, Morris county. Active.

Geology of New Jersey, 1868, pp. 569, 570.
Annual Report, 1879, p. 52.
" 1884, p. 83.
" 1886, p. 136.

MILLEN MINE, Mine Hill, Morris county. Abandoned.

Geology of New Jersey, 1868, pp. 564, 565 (Millen mine).
Annual Report, 1879, p. 51.
" 1880, p. 105.
" 1884, p. 83.

RANDALL HILL MINE, Mine Hill, Morris county. Abandoned in 1881.

Geology of New Jersey, 1868, p. 570.
Annual Report, 1879, p. 51.
" 1880, p. 105.
" 1882, p. 70.
" 1884, p. 83.

JACKSON HILL MINE, Irondale, Morris county. Abandoned. Mentioned by Kitchell in 1854.

Geology of New Jersey, p. 570.
Annual Report, 1879, p. 51.
" 1884, p. 83.

BLACK HILLS MINE, Ferromont, Morris county. Abandoned. The Black Hills mine was worked under a lease to A. Pardee until June, 1883. It is owned by the Dickerson-Suckasunny Mining Company.

Annual Report, 1879, p. 51.
" 1880, p. 105.
" 1884, p. 83.

DICKERSON MINE, Ferromont, Morris county. Active.

Geology of New Jersey, 1868, pp. 570–574.
Annual Report, 1879, pp. 51, 52.
" 1880, pp. 105, 106.
" 1884, p. 83.
" 1885, p. 99.
" 1886, p. 140.

*CANFIELD PHOSPHATIC IRON ORE DEPOSIT, Ferromont, Morris county. Idle.

Annual Report, 1871, pp. 34–38.
" 1879, p. 51.
" 1884, p. 84.

CANFIELD MINE, near Vannatta Station, Morris county. Abandoned.

Annual Report, 1873, pp. 42, 43.
" 1879, p. 52.
" 1884, p. 84.

BAKER MINE (IN SWAMP), Vannatta Station, Morris county. Abandoned.

Annual Report, 1880, p. 106.
" 1884, p. 84.

BAKER MINE (ON HILL), Mine Hill, Morris county. Abandoned.

Geology of New Jersey, 1868, p. 575.
Annual Report, 1879, p. 52.
" 1880, p. 106.
" 1884, p. 84.

IRONDALE MINES, Irondale, Morris county. Abandoned.

Annual Report, 1884, p. 85.
" 1885, p. 100.
" 1886, p. 145.

ORCHARD MINE, Port Oram, Morris county. Active.

Geology of New Jersey, 1868, p. 578.
Annual Report, 1879, p. 54.
" 1880, p. 106.
" 1884, p. 86.
" 1885, p. 100.

ERB MINE, west of Mine Hill, Morris county. Abandoned.

Annual Report, 1884, p. 84.

SCRUB OAK, or DELL MINE, west of Mine Hill, Morris county. Idle. Owned by the Edison Company. They will put up a magnetic separating plant here.

Geology of New Jersey, 1868, p. 596.
Annual Report, 1873, p. 43.
" 1879, p. 54.
" 1880, p. 106.
" 1884, p. 84.

*J. D. KING MINE, near Port Oram, Morris county. Abandoned.

Annual Report, 1873, p. 43.
" 1884, p. 84.

JOHNSON HILL MINE, near Port Oram, Morris county. Abandoned.

Geology of New Jersey, 1868, p. 596.
Annual Report, 1873, p. 46.
" 1879, p. 54.
" 1884, p. 84.

HOFF MINE, near Port Oram, Morris county. This mine was abandoned by the lessees, the Andover Iron Company, in July, 1883.

Geology of New Jersey, 1868, p. 597.
Annual Report, 1873, p. 46.
" 1879, pp. 54, 55.
" 1880, p. 106.
" 1884, p. 84.
" 1885, p. 99.
" 1886, p. 144.

DOLAN MINE, Mount Pleasant, Morris county. Abandoned.

Annual Report, 1873, p. 46.
" 1879, p. 55.
" 1884, p. 85.
" 1885, p. 100.
" 1886, p. 141.

WASHINGTON FORGE MINE, Port Oram, Morris county. Abandoned.

Annual Report, 1884, p. 86.
" 1885, p. 100.
" 1886, p. 147.
(See Meadow mine.)

ORCHARD MINE, Port Oram, Morris county.

Annual Report, 1886, p. 148.

MOUNT PLEASANT MINE, Mount Pleasant, Morris county. Active.

Geology of New Jersey, 1868, pp. 578–582.
Annual Report, 1873, p. 44.
" 1879, p. 55.
" 1884, p. 86.
" 1885, p. 100.
" 1886, p. 148.

BAKER MINE, near Mount Pleasant, Morris county. Abandoned.

Geology of New Jersey, 1868, pp. 582, 583.
Annual Report, 1873, pp. 44, 45.
" 1879, p. 55.
" 1884, p. 87.

HURD MINE, Port Oram, Morris county.

Annual Report, 1886, p. 145.
(Also see under Irondale mines.)

RICHARD MINE, Mount Pleasant, Morris county. Active. Is working three slopes.

Geology of New Jersey, 1873, p. 583.
Annual Report, 1873, p. 45.
" 1879, p. 55.
" 1884, p. 87.
" 1885, p. 101.
" 1886, p. 149.

ALLEN MINE, Rockaway township, Morris county. Abandoned.

Geology of New Jersey, 1868, pp. 583–587.
Annual Report, 1873, p. 45.
" 1879, pp. 55, 56.
" 1884, p. 87.
" 1885, p. 101.
" 1886, p. 136.

TEABO MINE, Rockaway township, Morris county. Active.

Geology of New Jersey, 1868, pp. 587, 588.
Annual Report, 1873, p. 45.
" 1879, p. 56.
" 1884, p. 88.
" 1885, p. 101.
" 1886, p. 151.

MOUNT HOPE MINES, Mount Hope, Morris county. Active.

Geology of New Jersey, 1868, pp. 588–595.
Annual Report, 1873, pp. 45, 46.
" 1879, p. 56.
" 1880, p. 107.
" 1884, p. 88.
" 1885, p. 102.
" 1886, p. 147.

*DENMARK MINE, near Denmark, Morris county. Idle. Never operated to any great extent.

Geology of New Jersey, 1868, p. 597.
Annual Report, 1884, p. 88.

*GREENVILLE MINE, Greenville, Rockaway township, Morris county. Abandoned. Never operated.

Annual Report, 1873, p. 48.
" 1879, p. 58.
" 1884, p. 88.

CHESTER IRON COMPANY'S MINES, near Denmark, Morris county. Six openings have been made on lands of this company at the foot of the Copperas Mountain range and north of Denmark. The explorations have not led to active working, in consequence of the necessity of cartage to railway points. Idle.

Annual Report, 1873, p. 48.
" 1879, p. 58.
" 1884, p. 89.

PARDEE MINE, Rockaway township, Morris county. Abandoned.

Annual Report, 1873, p. 48 (Pardee & Canfield's mine).
" 1884, p. 89.
" 1886, p. 149.

WINTER SHAFT, Rockaway township, Morris county. Abandoned.

Annual Report, 1884, p. 89.
" 1885, p. 102.
" 1886, p. 153.

DAVENPORT MINE, Rockaway township, Morris county. Abandoned.

Annual Report, 1880, pp. 122, 123.
" 1884, p. 89.

GREEN POND MINES, Rockaway township, Morris county. Idle. Probably abandoned. These mines have been idle during the year.

Annual Report, 1873, pp. 48, 49.
" 1874, pp. 23–25.
" 1879, pp. 58–60.
" 1880, p. 108.
" 1884, p. 89.
" 1886, p. 141.

HOWELL TRACT OPENINGS, Rockaway township, Morris County. Abandoned.

Annual Report, 1884, p. 89.
" 1885, p. 103.
" 1886, p. 144.

KITCHELL TRACT OPENINGS, Rockaway township, Morris county. Abandoned.

Annual Report, 1879, p. 60.
" 1880, p. 108.
" 1884, p. 89.
" 1885, p. 103.
" 1886, p. 146.

CHARLOTTEBURGH MINE, Charlotteburgh, Morris county. Shut down in 1888. Has not been operated since.

Geology of New Jersey, 1868, p. 596.
Annual Report, 1873, p. 49.
" 1879, p. 60.
" 1880, p. 108.
" 1884, p. 90.
" 1886, p. 139.

SWEDES MINE, Rockaway township, Morris county. Abandoned.

Geology of New Jersey, 1868, pp. 551–554.
Annual Report, 1873, pp. 46, 47.
" 1879, p. 56.
" 1884, p. 90.

SIGLER MINE, Rockaway township, Morris county. Abandoned.

WHITE MEADOW MINE, Rockaway township, Morris county. Abandoned.

GIBB MINE, Rockaway township, Morris county. Abandoned.

BEACH MINE, Rockaway township, Morris county. Idle. For notes of these four mines, see

Geology of New Jersey, 1868, pp. 559, 560.
Annual Report, 1873, pp. 46, 47.
" 1879, p. 56.
" 1884, p. 90.
" 1885, p. 103.
" 1886, p. 136.

HIBERNIA MINES, Hibernia, Morris county. Active, except the De Camp mine.

Geology of New Jersey, 1868, pp. 561-564.
Annual Report, 1873, p. 47.
" 1879, pp. 56, 57.
" 1880, p. 108.
" 1884, p. 90.
" 1885, p. 103.
" 1886, p. 143.

BEACH GLEN MINES, Rockaway township, Morris county. Idle.

Geology of New Jersey, 1868, pp. 554-556.
Annual Report, 1879, p. 57.
" 1884, p. 91.
" 1885, p. 104.
" 1886, p. 136.

MERIDEN MINE, Meriden, Morris county. Abandoned.

RIGHTER MINE, near Meriden, Morris county. Abandoned.

COBB MINE, end of Splitrock pond, Morris county. Abandoned. These mines have been idle for several years.

Geology of New Jersey, 1868, p. 556 (Meriden mine).
Annual Report, 1873, p. 47.
" 1879, p. 57.
" 1880, p. 108.
" 1884, p. 91.

SPLITROCK POND MINE, at head of Splitrock pond, Morris county. Abandoned.

Annual Report, 1873, pp. 47, 48.
" 1874, p. 23.
" 1879, pp. 57, 58.
" 1880, p. 108.
" 1884, p. 91.

*Wood Mine, north of Splitrock pond, Rockaway township, Morris county. Abandoned.

Annual Report, 1883, p. 118.
" 1884, p. 91.

*Botts Mine, Rockaway township, Morris county. Abandoned.

Annual Report, 1884, p. 91.

Rockaway Valley Mine, Rockaway township, Morris county. Abandoned.

Annual Report, 1884, p. 91.

Decker Farm Opening, Rockaway township, Morris county. Abandoned. For notes of Botts, Rockaway Valley and Decker mines, see

Annual Report, 1873, pp. 49-51.
" 1879, p. 60.
" 1880, p. 109.
" 1883, p. 119.
" 1884, p. 91.

*Gould Mine, Rockaway township, Morris county. Abandoned.

Annual Report, 1884, p. 92.

Pike's Peak Mine (Stony Brook mine), Rockaway township, Morris county. Abandoned.

Annual Report, 1884, p. 92.

*Righter Lot Opening, Rockaway township, Morris county. Abandoned. For Gould, Pike's Peak and Righter mines, see

Geology of New Jersey, 1868, p. 556 (Stony Brook mine).
Annual Report, 1873, p. 51.
" 1876, pp. 54, 55 (Stony Brook mine).
" 1879, pp. 60, 61.
" 1880, p. 109.
" 1884, p. 92.

*Vreeland Mine, near Charlotteburgh, Passaic county. Abandoned.

Annual Report, 1879, p. 61.
" 1884, p. 92.

WANAQUE MINES, Pompton township, Passaic county. Was re-opened in 1886. Idle since.

Geology of New Jersey, 1868, pp. 545, 546 (Wynokie).
Annual Report, 1873, p. 52 (Wynokie).
" 1884, p. 92.
" 1886, p. 152.

*TELLINGTON MINE, Pompton township, Passaic county. Abandoned.

Annual Report, 1884, p. 92.

*RHEINSMITH MINE, Pompton township, Passaic county. Abandoned.

Annual Report, 1884, p. 92.

*MONKS MINE, Pompton township, Passaic county. Abandoned.

Annual Report, 1873, p. 52 (Monks mine).
" 1874, pp. 25, 26 (Tellington mine, Rheinsmith farm).
" 1879, p. 61.
" 1884, p. 92.

*WRIGHTNEOUR MINE, west of Monks Station, Passaic county. Abandoned.

Annual Report, 1881, p. 36.
" 1884, p. 92.

BOARD MINE, near Monks Station, Pompton township, Passaic county. Abandoned.

Annual Report, 1873, p. 52.
" 1879, p. 61.
" 1884, p. 92.

RINGWOOD MINES, Ringwood, Passaic county. Active.

Geology of New Jersey, 1868, pp. 546–550.
Annual Report, 1873, pp. 52–54.
" 1880, p. 109.
" 1884, p. 92.
" 1886, p. 150.

MUSCONETCONG BELT.

HAGER MINE, Holland township, Hunterdon county. Abandoned.

*DUCKWORTH OPENINGS, Holland township, Hunterdon county. Abandoned.

*BLOOM FARM, Holland township, Hunterdon county. Abandoned.

*MARTIN FARM, Alexandria township, Hunterdon county. Abandoned. For notices of the above mines, see

Annual Report, 1875, p. 35 (Bloom).
" 1879, p. 62, 63.
" 1880, p. 109.
" 1884, p. 93.

*PETTY FARM, Bethlehem township, Hunterdon county. Abandoned.

*WRIGHT FARM, Bethlehem township, Hunterdon county. Abandoned.

*CASE FARM, Bethlehem township, Hunterdon county. Abandoned. For notices of the above three mines, see

Annual Report, 1880, p. 123.
" 1884, p. 93.

CHURCH, or VAN SYCKLE MINE, Bethlehem township, Hunterdon county. Abandoned.

Geology of New Jersey, 1868, p. 616.
Annual Report, 1873, p. 55.
" 1879, p. 65.
" 1884, p. 94.

TURKEY HILL, or WEST END MINES, Bethlehem township, Hunterdon county. Abandoned.

Annual Report, 1884, p. 94.
" 1885, p. 104.
" 1886, p. 152.

SWAYZE MINE, near Valley Station, Hunterdon county. Abandoned in 1889.

Annual Report, 1874, p. 27 (Broderick and Harris mines).
" 1879, pp. 63, 64.
" 1880, pp. 109, 110.
" 1884, p. 94.

*ALPAUGH FARM, Bethlehem township, Hunterdon county. Abandoned.

*WILDCAT MINE, Bethlehem township, Hunterdon county. Abandoned.

*RODENBAUGH MINE, Bethlehem township, Hunterdon county. Abandoned. References for these three localities in

Annual Report, 1879, p. 65.
" 1880, p. 110.
" 1884, p. 94.

ASBURY MINE, Bethlehem township, Hunterdon county. Abandoned.

Geology of New Jersey, 1868, p. 617.
Annual Report, 1879, pp. 65, 66.
" 1880, p. 110.
" 1884, p. 95.

*MILLER FARM, Bethlehem township, Hunterdon county. Abandoned.

Annual Report, 1879, p. 66.
" 1884, p. 95.

MABERRY PLACE, Bethlehem township, Hunterdon county. Abandoned.

Annual Report, 1873, p. 56.
" 1879, p. 66.
" 1880, pp. 110, 124.
" 1884, p. 95.

*BANGHART'S MINE, Lebanon township, Hunterdon county. Abandoned.

Geology of New Jersey, 1868, p. 617.
Annual Report, 1879, p. 66.
" 1884, p. 95.

*EVELAND MINE, Glen Gardner, Hunterdon county. Abandoned.

Annual Report, 1880, pp. 110, 124.
" 1884, p. 95.

*TERRABERRY MINE, White Hall, Hunterdon county. Abandoned.

Annual Report, 1879, p. 66.
" 1884, p. 95.

ALVAH GRAY, or SAND FLATS MINE, White Hall, Hunterdon county. Abandoned.

Annual Report, 1873, p. 56 (Fritts Farm).
" 1879, p. 66.
" 1880, p. 124.
" 1884, p. 95.

*WHITE HALL (FRITTS FARM), White Hall, Hunterdon county. Abandoned.

Annual Report, 1873, p. 56.
" 1884, p. 95.

*CASTNER FARM, Lebanon township, Hunterdon county. Abandoned.

Annual Report, 1873, p. 56.
" 1879, p. 66.
" 1884, p. 95.

*MATTISON OPENING, Andersontown, Hunterdon county. Abandoned.

Annual Report, 1880, p. 124.
" 1884, p. 95.

HUNT, or PIDCOCK MINE, Lebanon township, Hunterdon county. Abandoned.

Annual Report, 1873, p. 58.
" 1879, p. 66.
" 1880, p. 111.
" 1884, p. 95.

*SHARP'S MINE, Pleasant Grove, Schooley's Mountain, Morris county. Abandoned.

Annual Report, 1879, p. 66.
" 1884, p. 95.

HANN MINE, Pleasant Grove, Schooley's Mountain, Morris county. Abandoned.

Annual Report, 1873, pp. 56, 57.
" 1879, pp. 66, 67.
" 1880, p. 111.
" 1884, p. 95.

*DERRENBERGER FARM, Schooley's Mountain, Morris county. Abandoned.

Annual Report, 1884, p. 96.

STOUTENBURGH MINE, Schooley's Mountain, Morris county. Abandoned.

Annual Report, 1873, pp. 57, 58.
" 1879, pp. 67, 68.
" 1880, p. 111.
" 1884, p. 96.

FISHER, or BEATTYESTOWN MINE, Schooley's Mountain, Morris county. Abandoned.

Geology of New Jersey, 1868, p. 618.
Annual Report, 1879, p. 68.
" 1884, p. 96.

MARSH'S MINE, Schooley's Mountain, Morris county. Abandoned.

Geology of New Jersey, 1868, pp. 618, 619.
Annual Report, 1879, pp. 68, 69.
" 1884, p. 96.

*DICKINSON MINE, Schooley's Mountain, Morris county. Abandoned.

Annual Report, 1884, p. 96.

*HUNT FARM, Schooley's Mountain, Morris county. Abandoned.

Annual Report, 1879, p. 69.
" 1884, p. 96.

*LAKE FARM, Schooley's Mountain, Morris county. Abandoned.

Geology of New Jersey, 1868, pp. 619, 620 (Dickinson mine).
Annual Report, 1879, p. 69.
" 1884, p. 96.

NAUGHRIGHT MINE, near Naughrightville, Morris county. Abandoned.

Annual Report, 1873, pp. 58, 59.
" 1878, pp. 99, 100.
" 1879, p. 69.
" 1880, p. 111.
" 1884, p. 96.

*SHARP FARM, Schooley's Mountain, Washington township, Morris county. Abandoned.

*RARICK FARM, Schooley's Mountain, Washington township, Morris county. Abandoned.

*HOPLER FARM, Schooley's Mountain, Washington township, Morris county. Abandoned. For notes of Sharp's, Rarick and Hopler, see

Annual Report, 1873, p. 59.
" 1879, p. 69.
" 1884, p. 96.

*POOLE PLACE, near Draketown, Schooley's Mountain, Morris county. Abandoned.

Annual Report, 1880, p. 112.
" 1884, p. 96.

*SHOUSE TUNNEL, east of Hackettstown, Morris county. Abandoned.

Annual Report, 1884, p. 97.

CRAMER MINE, east of Hackettstown, Morris county. Abandoned.

Annual Report, 1877, p. 49.
" 1879, p. 70.
" 1884, p. 97.

*APPLEGET FARM, Mount Olive township, Morris county. Abandoned.

Annual Report, 1880, p. 125.
" 1884, p. 97.

SMITH'S MINE, Mount Olive township, Morris county. Abandoned.

Geology of New Jersey, 1868, pp. 620, 621.
Annual Report, 1879, p. 70.
" 1884, p. 97.

LAWRENCE MINE, Mount Olive township, Morris county. Abandoned.

(See Mount Olive mine.)

MOUNT OLIVE MINE, Mount Olive, Morris county. Abandoned.

Geology of New Jersey, 1868, p. 601.
Annual Report, 1873, p. 59.
" 1879, pp. 70, 71.
" 1880, p. 112.
" 1884, p. 97.
" 1886, p. 148.

SOLOMAN MINE. See above. Abandoned.

Annual Report, 1886, p. 151.

DRAKE'S MINE, Mount Olive, Morris county. Abandoned.

(See Church mine.)

OSBORN'S MINE, Mount Olive, Morris county. Abandoned.

(See Church mine.)

HILT'S MINE, Mount Olive, Morris county. Abandoned.

(See Church mine.)

CHURCH MINE, Mount Olive, Morris county. Abandoned.

Geology of New Jersey, 1868, pp. 599-601.
Annual Report, 1873, p. 59.
" 1879, p. 71.
" 1884, p. 97.

KING MINE, near Drakeville, Morris county. Abandoned.

(See High Ledge mine.)

HIGH LEDGE MINE, near Drakeville, Morris county. Abandoned.

Annual Report, 1879, p. 71.
" 1880, pp. 124, 125.
" 1884, p. 97.

*MARIOT'S MINE, near Shippenport, Morris county. Abandoned.

Annual Report, 1884, p. 98.

GOVE MINE, near Drakeville, Morris county. Abandoned.

Annual Report, 1879, p. 71.
" 1880, p. 112.
" 1883, p. 128.
" 1884, p. 98.

BURT MINE, Drakeville, Morris county. Abandoned.

Annual Report, 1883, p. 128.
" 1884, p. 98.

*SILVER SPRING MINE, Morris county. Abandoned.

Annual Report, 1883, p. 128.
" 1884, p. 98.

*DAVENPORT MINE, near Berkshire valley, Morris county. Abandoned.

Geology of New Jersey, 1868, p. 602.
Annual Report, 1884, p. 98.

*LAKE VIEW MINE, Morris county. Abandoned.

Annual Report, 1883, p. 129.
" 1884, p. 98.

NOLAND'S MINE, Lake Hopatcong, Morris county. Abandoned.

Geology of New Jersey, 1868, p. 603.
Annual Report, 1884, p. 98.

HURD MINE, Hurdtown, Morris county. Active.

Geology of New Jersey, 1868, pp. 606-610.
Annual Report, 1873, p. 65.
" 1879, p. 72.
" 1884, p. 98.
" 1885, p. 105.
" 1886, p. 144.

LOWER WELDON MINE, Jefferson township, Morris county. Active.

Annual Report, 1873, p. 65.
" 1879, p. 72.
" 1884, p. 98.

WELDON MINE, Jefferson township, Morris county. Active.

Geology of New Jersey, 1868, pp. 610-612.
Annual Report, 1873, p. 65.
" 1879, p. 72.
" 1880, p. 112.
" 1884, p. 98.
" 1886, p. 152.

DODGE MINE, Jefferson township, Morris county. Abandoned.

Geology of New Jersey, 1868, p. 614.
Annual Report, 1879, p. 72.
" 1880, p. 112.
" 1884, p. 99.

FORD MINE, Jefferson township, Morris county. Abandoned.

Geology of New Jersey, 1868, pp. 614-616.
Annual Report, 1873, p. 66.
" 1879, p. 72.
" 1880, p. 113.
" 1884, p. 99.
" 1885, p. 105.
" 1886, p. 141.

SCOFIELD MINE, Jefferson township, Morris county. Abandoned. This mine continues to be worked by the Lehigh Crane Iron Company, David Jenkins, superintendent.

Geology of New Jersey, 1868, p. 615.
Annual Report, 1879, pp. 72, 73.
" 1880, p. 113.
" 1884, p. 99.
" 1885, p. 105.
" 1886, p. 151.

*GOBLE MINE, Jefferson township, Morris county. Abandoned.

*BOSS MINE, Jefferson township, Morris county. Abandoned.

*FRASER MINE, Jefferson township, Morris county. Abandoned.

*DUFFEE MINE, Jefferson township, Morris county. Abandoned.

*SHONGUM MINE, Jefferson township, Morris county. Abandoned. For notes on the Boss, Goble, Fraser and Shongum, see

Geology of New Jersey, 1868, pp. 612-614.
Annual Report, 1873, p. 62.
" 1884, p. 100.

*MINE NEAR WOODPORT, Morris county. Abandoned.

Annual Report, 1884, p. 100.

*CLINE OPENINGS, Pohatcong Mountain, Franklin township, Warren county. Abandoned.

*SMITH OPENINGS, Pohatcong Mountain, Franklin township, Warren county. Abandoned.

*DEAN OPENINGS, Pohatcong Mountain, Franklin township, Warren county. Abandoned. For above three mines, see

Annual Report, 1879, p. 73.
" 1884, p. 101.

*CARTER MINE, near Stewartsville, Greenwich township, Warren county. Abandoned.

Annual Report, 1880, p. 125 ("Willever & Godfrey mine").
" 1884, p. 101.

*CHAPIN AND LOMMASSON TUNNEL, near Oxford Furnace, Warren county. Abandoned.

Annual Report, 1873, p. 60.
" 1884, p. 101.

*LANNING MINE, near Oxford Furnace, Warren county. Abandoned.

Annual Report, 1873, p. 60.
" 1884, p. 101.

OXFORD FURNACE MINES, Oxford Furnace, Warren county. Washington and Slope No. 3 active.

Geology of New Jersey, 1868, pp. 637–640.
Annual Report, 1873, p. 61.
" 1879, pp. 74, 96.
" 1880, p. 113.
" 1884, p. 101.
" 1885, p. 105.
" 1886, p. 149.

*CREAGER MINE, near Port Murray, Warren county. Abandoned.

*MITCHELL MINE, near Port Murray, Warren county. Abandoned.

*JOHNSON SHAFTS, near Port Murray, Warren county. Abandoned.

*STEPHENSON MINE, near Port Murray, Warren county. Abandoned. Notes of Port Murray mines in

Annual Report, 1873, pp. 61, 62.
" 1879, p. 75.
" 1880, p. 113.
" 1884, p. 102.

*BALD PATE MINE, north of Port Murray, Mansfield township, Warren county. Abandoned. See Egbert Church mine.

*SHAFER, or WELCH PLACE, north of Port Murray, Mansfield township, Warren county. Abandoned. See Egbert Church mine.

EGBERT CHURCH MINE, north of Port Murray, Mansfield township, Warren county. Abandoned.

Geology of New Jersey, 1868, p. 624 ("Bald Pate mine").
Annual Report, 1873, p. 62.
" 1879, pp. 75, 76.
" 1880, p. 113.
" 1884, p. 102.

*SEARLE MINE, Independence township, Warren county. Abandoned.

Geology of New Jersey, 1868, p. 624.
Annual Report, 1884, p. 102.

*BARKER, or BULGIN MINE, near Vienna, Warren county. Abandoned.

Annual Report, 1882, p. 72.
" 1884, p. 102.

*BUCK'S HILL OPENINGS, near Hackettstown, Warren county. Abandoned.

*DAY MINE, near Hackettstown, Warren county. Abandoned.

*FRACE FARM, north of Hackettstown, Warren county. Abandoned.

*YOUNG FARM, north of Hackettstown, Warren county. Abandoned.

*PYLE FARM, north of Hackettstown, Warren county. Abandoned.

*AXFORD FARM, north of Hackettstown, Warren county. Abandoned.

*BRYANT MINE, near Warrenville, Warren county. Abandoned.

*EXCELSIOR MINE, Allamuchy township, Warren county. Abandoned.

*EUREKA MINE, Allamuchy township, Warren county. Abandoned.

*TUNISON PLACE, Allamuchy township, Warren county. Abandoned.

*WINTERMUTE FARM, Allamuchy township, Warren county. Abandoned.

HAGGERTY'S MINE, Allamuchy township, Warren county. Abandoned.

For the above twelve mines, see

Annual Report, 1873, pp. 63, 64.
" 1876, p. 52 (Haggerty's mine).
" 1879, p. 76 (Haggerty's mine).
" 1880, p. 127 (Wintermute's farm).
" 1884, p. 103.

BROOKFIELD, or WATERLOO MINE, near Waterloo, in Warren county. Abandoned.

Geology of New Jersey, 1868, pp. 626–628.
Annual Report, 1873, pp. 64, 65.
" 1879, p. 76.
" 1884, p. 103.

*FRENCHE'S PLACE, Byram township, Sussex county. Abandoned.

Annual Report, 1873, pp. 66, 67.
" 1879, p. 77.
" 1884, p. 103.

SMITH, or CASCADE MINE, Byram township, Sussex county. Abandoned.

Annual Report, 1873, p. 66.
" 1879, p. 77.
" 1884, p. 103.

*ALLIS OPENINGS, Byram township, Sussex county. Abandoned.

Annual Report, 1873, p. 66.
" 1879, p. 77.
" 1884, p. 103.

HUDE, or STANHOPE MINE, Stanhope, Sussex county. Active.

Geology of New Jersey, 1868, pp. 622, 623.
Annual Report, 1873, p. 67.
" 1879, pp. 77, 78.
" 1880, p. 114.
" 1884, p. 103.

WRIGHT, or BUDD MINE, north of Stanhope, Sussex county. Abandoned.

Annual Report, 1879, pp. 78, 79.
" 1880, p. 114.
" 1884, p. 103.

*SILVER MINE, near Stanhope, Byram township, Sussex county. Abandoned.

*HAGGERTY MINE, near Stanhope, Byram township, Sussex county. Abandoned.

LAWRENCE MINE, near Stanhope, Byram township, Sussex county. Abandoned.

Notes of these mines in

Geology of New Jersey, 1868, pp. 621, 622.
Annual Report, 1873, p. 67.
" 1884, p. 103.

*LAWSON OPENING, near Byram cove, Byram township, Sussex county. Abandoned.

Annual Report, 1880, p. 127 (Lawless).
" 1884, p. 104.

GAFFNEY MINE, Byram township, Sussex county. Abandoned.

Annual Report, 1879, p. 79.
" 1884, p. 104.

SICKLES MINE, Byram township, Sussex county. Abandoned.

Annual Report, 1873, p. 67.
" 1879, p. 79.
" 1880, p. 115.
" 1884, p. 104.

*SHERMAN FARM OPENINGS, east of Sparta, Sussex county. Abandoned.

Annual Report, 1879, p. 79.
" 1884, p. 104.

*BUNKER FARM OPENINGS, east of Sparta, Sussex county. Abandoned.

Annual Report, 1879, pp. 79, 80 (Sherman and Bunker).
" 1884, p. 104.

OGDEN MINES, Sparta township, Sussex county. Not active at present. Bought by the Edison Magnetic Separating Company. A large and expensive plant is erected here for concentrating and mining iron ore.

Geology of New Jersey, 1868, pp. 631, 632.
Annual Report, 1873, p. 68.
" 1879, p. 80.
" 1880, p. 115.
" 1884, p. 104.

*GREER FARM OPENINGS, Hardyston township, Sussex county. Abandoned.

Annual Report, 1879, p. 80.
" 1884, p. 104.

*HOPEWELL FORGE TRACT, Hardyston township, Sussex county. Abandoned.

Annual Report, 1873, p. 68 (Greer and Hopewell).
" 1879, p. 80. " " "
" 1881, p. 38. " " "
" 1884, p. 104.

CANISTEAR MINE, Vernon township, Sussex county. Idle.

*TRACY AND CRANE FARMS, Vernon township, Sussex county. Abandoned.

*HENDERSON FARM, Vernon township, Sussex county. Abandoned.

For notes of these three localities, see

Annual Report, 1873, p. 70.
" 1879, p. 80.
" 1880, p. 115.
" 1884, p. 104.

WILLIAMS MINE, Williamsville, Vernon township, Sussex county. Abandoned.

Annual Report, 1873, p. 70.
" 1879, p. 80.
" 1884, p. 105.

*RUTHERFORD TRACT OPENINGS, Vernon township, Sussex county. Abandoned. See Rutherford Tract Openings, West Milford.

*HUNT TRACT OPENINGS, Vernon township, Sussex county. Abandoned.

Annual Report, 1873, pp. 70, 71 (Rutherford and Hunt).
" 1879, p. 80 (Rutherford and Hunt).
" 1884, p. 105.

WAWAYANDA MINE, Vernon township, Sussex county. Abandoned.

GREEN MINE, Vernon township, Sussex county. Abandoned in 1888. These mines of the Thomas Iron Company have been described in .

Geology of New Jersey, 1868, pp. 632–637.
Annual Report, 1873, p. 71.
" 1880, p. 115.
" 1884, p. 105.

LAYTON MINE, near New Milford, in Vernon township, Sussex county. Abandoned.

*KIMBLE FARM SHAFTS, near Stockholm, West Milford township, Passaic county. Abandoned.

*BUDD & HUNT TRACT OPENINGS, West Milford township, Passaic county. Abandoned.

*RUTHERFORD TRACT OPENINGS, West Milford township, Passaic county. Abandoned.

CLINTON TRACT MINE, near Clinton, West Milford township, Passaic county. Abandoned.

*WALLACE MINE, north of Clinton, West Milford township, Passaic county. Abandoned.

*UTTER MINE, Uttertown, West Milford township, Passaic county. Abandoned. No reports of the working of any of these localities during the year have been received. They are in the nature of explorations rather than productive mines. For notices in previous annual reports, see following:

Annual Report, 1873, pp. 68, 69.
" 1879, pp. 81, 82.
" 1884, p. 105.

WELLING MINE, near Greenwood, West Milford township, Passaic county. Abandoned.

Annual Report, 1876, pp. 52, 53.
" 1879, p. 81.
" 1880, p. 116.
" 1884, p. 105.

CENTENNIAL, or SQUIER'S MINE, near State line, West Milford township, Passaic county. Abandoned.

Annual Report, 1876, pp. 53, 54.
" 1879, p. 82.
" 1880, p. 116.
" 1884, p. 105.

PEQUEST BELT.

SCHULER MINE, Oxford township, Warren county. Abandoned.

Annual Report, 1873, pp. 72, 73.
" 1879, p. 82.
" 1880, p. 116.
" 1884, p. 106.

ROSEBERRY MINE, Oxford township, Warren county. Abandoned.

Annual Report, 1873, p. 73.
" 1879, p. 82.
" 1880, p. 116.
" 1884, p. 106.

BARTON MINE, Oxford township, Warren county. Abandoned.

Annual Report, 1873, p. 73.
" 1879, pp. 82, 83.
" 1884, p. 106.

SHOEMAKER FARM, Oxford township, Warren county. Active.

Annual Report, 1873, p. 74.
" 1879, p. 83.
" 1884, p. 106.

REDELL MINE, Oxford township, Warren county. Abandoned.

Annual Report, 1873, p. 74.
" 1879, p. 83.
" 1880, p. 116.
" 1884, p. 106 (Riddle).

LITTLE MINE, now FELLOWS MINE, Oxford township, Warren county. Active.

Annual Report, 1873, pp. 74, 75.
" 1879, p. 83.
" 1884, p. 106.

QUEEN MINE, Oxford township, Warren county. Active.

Annual Report, 1882 (Queen mine).
" 1884, p. 106.

*OSMUN PLACE, Oxford township, Warren county. Abandoned.

Annual Report, 1882, p. 73.
" 1884, p. 106.
" 1885, p. 106.

RAUB FARM, Oxford township, Warren county. Is being opened.

Annual Report, 1873, pp. 75, 76.
" 1879, p. 83.
" 1884, p. 106.

PEQUEST MINE, Oxford township, Warren county. Abandoned.

Annual Report, 1873, pp. 76–78.
" 1879, p. 83.
" 1880, p. 116.
" 1884, p. 106.

*HOIT FARM, Oxford township, Warren county. Abandoned.

Annual Report, 1873, pp. 79–81.
" 1879, p. 83.
" 1884, p. 106.

*SMITH FARM, Hope township, Warren county. Abandoned.

Annual Report, 1873, p. 81.
" 1882, p. 73.
" 1884, p. 106.

*DEATS PLACE, Hope township, Warren county. Abandoned.

Annual Report, 1873, p. 81, 82.
" 1882, p. 73.
" 1884, p. 106.

*HENDERSHOT, or HOAGLAND PLACE, Hope township, Warren county. Abandoned.

Annual Report, 1879, p. 83.
" 1880, p. 127.
" 1884, p. 107.

COOK FARM, Hope township, Warren county. Abandoned.

Annual Report, 1881, p. 37.
" 1882, pp. 73, 74.
" 1884, p. 107.

KISHPAUGH MINE, west of Danville, Warren county. Is being re-opened.

Annual Report, 1873, pp. 82–84.
" 1879, pp. 83, 84.
" 1880, p. 117.
" 1884, p. 106.
" 1885, p. 106.
" 1886, p. 145.

*CORLISS FARM, Hope township, Warren county. Abandoned.

Annual Report, 1882, p. 74.
" 1884, p. 107.

*INSCHOW LOT, Hope township, Warren county. Abandoned.

Annual Report, 1873, p. 84.
" 1879, p. 84.
" 1884, p. 107.

*STIFF FARM, Hope township, Warren county. Abandoned.

Annual Report, 1873, pp. 84, 85.
" 1884, p. 107.

*POTTER FARM, Independence township, Warren county. Abandoned.

Annual Report, 1873, p. 85.
" 1879, p. 84.
" 1884, p. 107.

*STINSON FARM, Independence township, Warren county. Abandoned.

Annual Report, 1879, pp. 84, 85.
" 1881, p. 37.
" 1882, p. 74.
" 1884, p. 107.

*GARRISON FARM, Independence township, Warren county. Abandoned.

Annual Report, 1873, p. 85.
" 1881, pp. 37, 38.
" 1884, p. 107.

DAVIS MINE, Independence township, Warren county. Abandoned.

Annual Report, 1873, p. 85.
" 1881, p. 31.
" 1884, p. 107.

*ALBERTSON PLACE, Independence township, Warren county. Abandoned.

Annual Report, 1873, p. 85.
" 1884, p. 108.

*SHAW'S MINE, Independence township, Warren county. Abandoned.

Geology of New Jersey, 1868, pp. 659, 660.
Annual Report, 1872, p. 18.
" 1884, p. 108.

HOWELL FARM, Independence township, Warren county. Abandoned.

Annual Report, 1873, pp. 85, 87.
" 1878, p. 101.
" 1884, p. 108.

*CARROLL PLACE, Independence township, Warren county. Abandoned.

Annual Report, 1873, p. 87.
" 1884, p. 108.

*GREEN PLACE, Independence township, Warren county. Abandoned.

Annual Report, 1882, p. 74.
" 1884, p. 108.

*CUMMINS MINE, Independence township, Warren county. Abandoned.

Annual Report, 1881, p. 38.
" 1884, p. 108.

*AYRES PLACE, Independence township, Warren county. Abandoned.

Annual Report, 1881, p. 38.
" 1884, p. 108.

*SCHAEFFER FARM, Independence township, Warren county. Abandoned.

Annual Report, 1873, p. 87.
" 1880, p. 127.
" 1884, p. 108.

*MARING PLACE, Allamuchy township, Warren county. Abandoned.

Annual Report, 1884, p. 108.

*HIBLER, or LIVESEY'S SHAFT, Allamuchy township, Warren county. Abandoned.

Annual Report, 1873, p. 87.
" 1879, pp. 85, 86.
" 1880, p. 117.
" 1884, p. 108.

*WINTERMUTE'S OPENING, Allamuchy township, Warren county. Abandoned.

Annual Report, 1880, p. 127.
" 1884, p. 108.

*HAGGERTY'S DIGGINGS, Allamuchy township, Warren county. Abandoned.

Annual Report, 1873, pp. 87, 88.
" 1876, p. 52.
" 1879, p. 86.
" 1884, p. 108.

*GLENDON MINE, Green township, Sussex county. Abandoned.

Annual Report, 1873, p. 88.
" 1884, p. 108.

MCKEAN, or BIRD MINE, Byram township, Sussex county. Abandoned.

Annual Report, 1874, pp. 28, 29.
" 1879, p. 86.
" 1880, p. 118.
" 1884, p. 108.

*BYERLY OPENINGS, Byram township, Sussex county. Abandoned.

Annual Report, 1879, p. 86.
" 1884, p. 108.

ROSEVILLE MINE, Byram township, Sussex county. Abandoned.

Geology of New Jersey, 1868, pp. 628-631.
Annual Report, 1873, p. 88.
" 1880, p. 118.
" 1884, p. 109.

ANDOVER MINE, Andover, Sussex county. Abandoned.

Geology of New Jersey, 1868, pp. 640-657.
Annual Report, 1873, p. 88.
" 1884, p. 109.

SULPHUR HILL MINE, Andover, Sussex county. Abandoned.

Annual Report, 1873, p. 88.
" 1879, pp. 86, 87.
" 1880, p. 118.
" 1884, p. 109.

TAR HILL MINE, Andover township, Sussex county. Abandoned.

Geology of New Jersey, 1868, p. 657.
Annual Report, 1880, p. 118.
" 1884, p. 109.

*LONGCORE'S MINE, Andover township, Sussex county. Abandoned.

Geology of New Jersey, 1868, pp. 657, 658.
Annual Report, 1884, p. 109.

STIRLING HILL MINE, Sparta township, Sussex county. Abandoned.

Annual Report, 1877, p. 52.
" 1879, pp. 87, 88.
" 1880, p. 118.
" 1884, p. 109.

HILL MINE, Franklin Furnace, Sussex county. Abandoned. See below.

FURNACE VEIN MINE, Franklin Furnace, Sussex county. Abandoned.

Geology of New Jersey, 1868, pp. 658, 659.
Annual Report, 1873, p. 88.
" 1879, pp. 88, 89.
" 1880, p. 118.
" 1884, p. 108.

*GREEN'S MINE, Vernon township, Sussex county. Abandoned. See below.

*BIRD MINE, Vernon township, Sussex county. Abandoned.
Notes of these two mines in

Geology of New Jersey, 1868, p. 660.
Annual Report, 1879, p. 89.
" 1884, p. 109.

*CAREY MINE, West Milford township, Passaic county.

Annual Report, 1886, p. 138.

GEOLOGICAL WORK IN THE SOUTHERN PART OF THE STATE.

TERRACE FORMATIONS OF THE ATLANTIC COAST AND ALONG THE DELAWARE RIVER.

BY C. W. COMAN.

The following notes on the field-work of the fall of 1890 are submitted. Attention was chiefly directed to the study of (1) the sediments overlying the upper marl bed in eastern Monmouth county; (2) evidences of former shore lines above the present sea-level; (3) the gravel of the Trenton terrace.

STRATA OVERLYING THE UPPER MARL BED.

The most complete series is that shown in the beach bluff at Long Branch, south of the pier, in which the following beds appear, in a descending order from top of bluff.

1. Reddish-yellow, loamy sand	2 feet.
2. Yellow gravel, intermixed with loam	6 feet.
3. Clean, white gravel and sand	6 feet.
4. Thin band of red clay	3 to 5 inches.
5. Banded yellow and gray clay	3 to 3½ feet.
6. Dark-blue clay	2 feet.
7. Dark-brown, shaly clay, not plastic	1 foot.

The marl is not seen in the bluff, but is exposed at extreme low tide over an area of thirty or forty feet.

None of these strata are uniform for any considerable distance, except the lowest, designated as brown shaly clay, which is found wherever the upper marl is exposed, immediately overlying the latter, except at the Farmingdale pit, where a bed of pebbly clay, about eighteen inches in thickness, is interposed.

In the Long Branch section the thickness of the gravel stratum varies from twelve feet to a discontinuous film. The yellow banded and black clays are seen to merge into each other laterally in several places, and both are replaced for a distance of about forty yards by a very sandy, gray clay.

The marl exposed on the beach at low tide must belong to the middle marl bed, as the single marl fossil found here on the beach (which must have been washed from this outcrop), *Terebratula Harlani*, is not found in the upper marl. Moreover, the observed dip of the upper marl bed would not bring it down to sea-level at this point, while that of the middle bed would.

The complete stratigraphy of the formations overlying the upper marl cannot here be given, but as their lowest member, the brown clay shale ("Brown Astringent Clay" of the "Report on Marls"), is seen to rest directly upon both the middle and the upper marl beds, they overlap the latter, and are presumably unconformable to it.

Fossils.—The black clay exposed at Long Branch is literally filled, in many places, with plant impressions. From two localities on the beach were secured a number of impressions of shells of lamellibranchs, representing four species.

The brown clay shale at Long Branch yielded to search, only some bits of lignite; but from the same stratum near Farmingdale, where the Freehold and Jamesburg railroad crosses a little branch of Mingumhone brook, were secured a number of casts of gasteropods and lamellibranchs, representing probably four or five species. These have not yet been determined.

EVIDENCES OF FORMER SHORE LINES ABOVE THE PRESENT SEA-LEVEL.

These are, in general, wave-cut and wave-built terraces, lines of dunes, linear areas of cleanly-washed sand, representing old beaches, and elevated shell beds, or other remains of marine life.

As a terrace is a level-topped step, or shelf, cut into or built upon the face of a slope, it follows that it becomes a distinguishable feature of the topography of a shore only where the latter is bounded by cliffs, or at least presents a tolerably abrupt face on which the waves may act.

The Atlantic coast region of this State is generally level and low.

The surface materials are, moreover, for the most part incoherent sand and gravel, or soft clays, easily yielding to subaërial erosion. Hence, although isolated terraces have been noted at different levels along the portion of the coast studied, no continuous shore line, or series of terraces which could be properly correlated as such, has yet been traced. The shore-levels most distinctly indicated are three in number; the first at about ten feet, another between thirty and forty feet, and the third at about sixty feet above the present mean tide-level. There are other faint and doubtful indications of terraces at levels intermediate between those named, showing that while the elevation of the land was intermittent, halting a little at each of the main terrace-levels, it was but slightly so, the whole uplift being gradual and slow enough to allow a continuous wave record.

The ten-foot shore line is best displayed near Keyport, on the road between Lockport and Union. Here a beach, marked by low dunes, the outline of which is approximately indicated by the ten-foot contour line, is evident to the most casual glance for a distance of about half a mile and may be traced southward into the village.

Shells of *Modiola plicatula, Mytilus edulis, Mactra solidissima, Venus mercenaria, Mya arenaria* and others, all recent species, are abundant on the surface. From one-half to three-quarters of a mile of salt marsh and low-lying upland separates this beach from the present shore. At Old Bridge, on South river, the same level is marked by a sand flat and slight terrace on both sides of the river near the railroad and wagon bridges. The low sand flats on the north and east sides of the Navesink Highlands appear to have been formed at this stage, as were also a number of short terraces at the foot of the low bluffs bordering the Navesink river, between Oceanic and Red Bank. South of the Navesink river no distinct indications of a shore at this level were noted, except on the Manasquan river. On the south side of the river, near the railroad bridge, is a plainly-marked bench on about the line of the ten-foot contour, which may be traced at intervals up the river until it merges into the present flood plain of the stream.

The thirty to forty-foot levels are marked by a numerous series of terraces, extending from the Raritan river southward, many of which are clearly cut and easily recognizable, but their testimony is somewhat invalidated by their general lack of true beach deposits, the materials of which they are composed differing in no way from that of the adjacent terranes. The only stretch resembling a beach at this level is along the northern side of Rumson's Neck, between Red Bank and Fair Haven, where the red sand has been washed free from the stain of iron oxide and left of a white or light-yellow color. This strip of light-colored sand, which has an average breadth of about one hundred yards, seems pretty clearly to mark a former beach, but it is not at this point associated with any distinct terracing.

The terraces at about this level are many. On the southeastern extremity of the point between Lawrence brook and the Raritan river is a clearly-marked thirty-foot bench. About a mile northwest from the village of Washington, near the road leading to New Brunswick, the cretaceous clays have been cut into a very uneven terrace which appears to have been formed at several successive levels.

The whole valley of the South river, nearly up to Helmetta, is marked by indistinct terraces up to about the forty-foot contour. Above this line rise irregularly-contoured, gravel-capped hills; below it smooth terraces, and bottom lands are chiefly composed of fine sandy loam, probably washed down from the gravel beds of the higher ground and deposited in the water which then filled the valley up to the height of the upper terraces.

The eastern face of the Navesink Highlands is very steep, and must have been, before the formation of the Navesink beach, or when the latter was submerged, exposed to the full force of the Atlantic, and accordingly we find its profile notched by wave-cut terraces at both the thirty to forty-foot, and a little above the sixty-foot level. Near the southern extremity of the Highlands the lower terrace only is visible. This can be traced around to the Navesink river, along which benches occur as far as Red Bank, which is built on a terrace flat at this level. A terrace at the same level across the river from Red Bank may be seen from the Long Branch railroad at this point. Along the south side of Rumson's Neck, a possible indication of a shore line is the sudden crowding of the contours above the thirty-foot line, but no terracing could be made out here.

Between Deal Beach and the Manasquan river the sea-shore is bordered by a nearly level plain, from one and a half to two miles broad, which terminates abruptly against the highlands to the westward. The base of the high ground lies pretty uniformly between thirty and forty feet above the sea, but not invariably so, for the gently-sloping plain rises in places to about seventy feet.

The surface of the plain is in part a sandy loam and in part gravel, the distribution of the two having no apparent reference to the relative elevations of the tracts on which they occur. The hills are capped by a thick stratum of yellow gravel, beneath which are fine sand and sandy clay; but the soil of the uplands also is in places a fine loam, free from gravel.

If the upward limit of the coast plain was determined by a sea-level, we should find a line of beach sand and gravel and shells at that height. These do not occur. The base of the hills and the immediate plain are variously sandy, gravelly and loamy, like the rest of the plain; the only shells seen are occasional oyster and clam shells dropped upon the surface by man and fish-eating birds. Nevertheless, it is not easy to explain the peculiar topography without appealing to sea-shore action as a cause.

The higher shore line, that lying at about the sixty-foot level, or between sixty and seventy feet, left its most distinct record on the promontory of the Highlands of Navesink, which is terraced on the east side near the Navesink lights, and on the north side from Navesink Park pier eastward about a mile. Along this northern face, however, there has been a land slip, to which the terraced appearance is in part due. On the western side of the Highlands, this level is traceable on both sides of Claypit creek, for a short distance southeast of the village of Atlantic Highlands, and on the north side of the Navesink river, near the Atlantic Highlands branch of the New Jersey Southern railroad. The Manasquan river is terraced, not very distinctly, from Brielle, near the inlet, up as far as Fairfield, and the major part of the benchings fall at about the sixty to seventy-foot level, although the thirty to forty-foot shore line is also represented, and the present flood plain of the river forms a still lower series.

The flat-topped plateau south of Shark river, near New Bedford, may owe its form to this stage. In addition to those mentioned there are stream-formed terraces on most of the brooks and rivers of this region—one on Swimming river, south of Leedsville, the upper margin of which is thirty feet above the sea; on Hop brook, near the mouth of Willow brook, about fifty feet high; on Nut Swamp brook, about two miles from Red Bank, and on Lawrence brook, between the New Brunswick water-works pumping station and Milltown, several ranging from thirty to forty feet above sea-level.

It may be objected that the most of these terraces are along stream valleys, or at least re-entrants, and not on salients where wave-cutting is likely to have been most active, and that moreover they do not show characteristic beach deposits, such as lines of cleanly-washed sand and gravel, and shells, and that therefore they may all have been formed by the progressive cutting down of the stream-beds, while the land and sea maintained the same relative attitude as at present. Such an objection would be a valid one as urged against the testimony of most of the examples given, but the beach near Keyport and the terraces scored on the face of the Navesink Highlands have no connection with stream valleys, and are incontestable evidence that the sea has stood, relatively to the land, ten, thirty to forty, and sixty to seventy feet, respectively, higher than at present, within a period so recent as to allow the preservation of the features peculiarly liable to rapid destruction under ordinary subaërial erosion.

THE TRENTON GRAVEL.

The city of Trenton is built partly upon a terrace of river gravel. This is the most recent of the gravel deposits of the Delaware valley. Its limits on the New Jersey side of the river, in the vicinity of Trenton, have been traced out, and found to agree almost exactly with the course of the sixty-foot contour line except where that turns back along the various affluents of Assanpink creek. It forms an embayment, three miles wide at the river, extending nearly to Port Mercer, and bounded everywhere by higher ground, composed of older and different gravels. The Delaware and Raritan canal runs close along the western margin of the terrace, nearly to Baker's Basin.

The section at the gravel-pit of the Pennsylvania railroad at Trenton shows the terrace to be composed of coarse sand and well-rounded pebbles of sandstone, quartz, granite and gneiss, syenite, limestone, chert, &c., the most abundant being dark-gray sandstone. The gravel is coarse, the pebbles averaging larger than an egg, and boulders of two and three feet in diameter are not uncommon. The largest noticed was a nearly rectangular block, measuring eleven feet in length by about four feet square at the larger end. Some of the boulders retain faint traces of grooves and scratches, such as are commonly found on glaciated rocks. There is very little of the clay element present.

Within the areas of the Trenton terrace are several small elevations rising above the sixty-foot line. The gravel of these is of a different character from that of the terrace, being chiefly quartz and quartzite, stained exteriorly by oxide of iron to an orange-yellow hue.

As the terrace gravel overlies this yellow gravel, the latter must be the older. These enclosed areas of yellow gravel, then, were islands in the waters in which the terrace was formed.

On the east side of the Delaware the Trenton gravel does not extend south of the Trenton embayment—that is, about three miles south of the State House—but on the Pennsylvania side it covers the wide area included within the great bend in the river at Bordentown, and extends in a narrower strip to below Philadelphia.

WATER-SUPPLY AND WATER-POWER.

BY C. C. VERMEULE.

Since its inception the Survey has included the valuable hydraulic resources of the State among the natural sources of wealth which it was designed to aid in the development of. In the Geology of New Jersey, 1868, a short chapter was devoted to the subject, and several analyses of river and well-waters published. In every annual report since 1874, it has received some attention; more and more as the growth of our city population has continued at a rapid rate, and the demand for a larger and better supply of water consequently increased. Then, too, our State and local Boards of Health have become vigilant and critical, and a more general observance of sanitary laws has caused the rejection of sources once considered adequate. The completion of the Topographic Survey having furnished the fundamental data—a full knowledge of the character and size of the water-sheds of our streams—it is now possible for us to pursue the study of these resources more intelligently, and consequently to a better purpose than heretofore.

The remarkable increase of our urban population was sufficiently shown in the chapter on Population, of the Physical Description of 1888. The Annual Report for 1889 called attention to the widespread inquiry, on the part of our cities, for better and more abundant sources of water-supply.

These facts, the increasing demand and the facilities now afforded for a more thorough study of the subject, have pointed out that the time is ripe to take up a fuller investigation than the Survey has heretofore found it practicable to make.

In undertaking this task we have fully appreciated its magnitude, and the impossibility of collecting the large amount of precise data which a typical scientific investigation and discussion would demand. To illustrate, one eminent hydraulic engineer, whose advice was sought, remarked that what was really needed for a study of stream-flows, was a continuous gauging of the streams by self-recording gauges, and synchronous rainfall observations, also continuous, by self-recording gauges. This work of itself was not so far beyond our reach, and such gaugings of a number of typical streams would be of inestimable value to science, if continued for a period of ten or fifteen years. In fact, there are few more attractive fields for scientific investigation, and few which would yield greater returns for the outlay, than this of stream-flow, evaporation and rainfall. The far-reaching importance of such a study may be suggested in the course of this report.

But, however desirable it may be, refinement like this would call for corresponding breadth and accuracy of research in other directions, and would carry us far beyond the scope of this investigation and the means for carrying it forward.

The policy of accepting and making the utmost of the means at hand, which has always been pursued in the work of the Survey, while it may not always have rendered the attainments of an ideal possible, has frequently led to results which have, for many purposes, been quite as valuable. In the absence of time and means to make our investigation a typical one, therefore, we have proceeded with a view to producing such practical, economic results as we believe to be most needed for present use.

In the first place, steps were taken to avail ourselves of all that had been done elsewhere in this line, which would apply to our conditions. The collection of all possible data as to the peculiarities of our own streams, by such methods as were within our reach, was next begun. Gauges were set up on several streams, and readings taken daily, or oftener when practicable; and a careful examination and inquiry in the field begun, so as to avail ourselves of the experience of local observers whose familiarity with the phenomena of flow for long periods often enabled them to furnish much information which could be collected in no other way.

By such means as these a mass of valuable data as to the volume, rate and duration of flood-flows, and the least flow during protracted droughts, has been collected during the year. Continuous series of gaugings have been secured for the Paulinskill, Musconetcong, Ramapo, Passaic, Rahway, Raritan and Great Egg Harbor rivers for nearly a year, and on the Pequest for eight months, or enough to show its marked similarity to the Paulinskill. A three-months' series on the Upper Rockaway, with occasional gaugings for the rest of the year; a four-months' series on the Wanaque; six months on the Pequannock; several gaugings of the Rockaway, at Boonton, of the Assanpink and the Rancocas have also been obtained. On the Passaic it was found that the Messrs. Beattie, at Little Falls, had kept a record of the height of water on their stone dam from June, 1888, up to date. They kindly furnished us this valuable record and volunteered to keep it up, with such modifications as we suggested. This record on our most important stream has been utilized by measuring up the dam carefully and computing the discharge for each day. These gaugings are all necessarily approximate. So far as the application of proper formula and computation of discharge is concerned, the error is believed to be confined to within ten per cent. in all cases, and within five per cent. in cases of important series.

The aim has been, in cases where there was any uncertainty, to keep within the truth; and it is not at all probable that any excess is shown in any result, excepting the separate computations of flood-flows, where, in order to obtain the full maximum, the largest result was always taken; since the movement of flood-masses is such that discharges are usually in excess of the results of ordinary formulæ. The water-sheds and points of gauging are shown on the accompanying map. A full canvass of the water-powers of the State has been undertaken and completed for the State, as far south as the southern limits of the Raritan water-shed. The Maurice river and Great Egg Harbor water-sheds, and most of the Rancocas, in Southern New Jersey, have also been canvassed. This work has been done in conjunction with the above-mentioned studies and inquiries as to flood, dry-season and ordinary flows, and other phenomena of the streams.

The primary object of this work is the investigation of the water-supply resources of the State; but the subject of water-power is so closely allied that the two are advantageously coupled, and the availability of the streams for water-power, and the extent to which they are used for this purpose, will be made an important part of the inquiry.

The recent improvement of water-powers, and installation of several admirable plants, show that attention has once more been called to the value of this kind of power. The abandonment of water-powers once used for driving the many iron forges of Morris county, and the saw-mills all over the State, leads some to believe that the use of water-power has proven unprofitable. A moment's thought will show that water-power was not at fault in the matter. Blast furnaces had made forges unprofitable with any kind of power; the destruction of the forests had made saw-mills unnecessary, or else had made it necessary to go to points remote from the streams and set up steam mills where the timber was. There is a change going on in the business of making feed and flour also. Like everything else, it is being concentrated in large establishments, and small, poorly-equipped grist-mills are being driven out of business. From these causes a large number of small water-powers are being abandoned. Being scattered widely over the country they attract attention, and the natural inference is that water-power is falling into disuse, whereas, the fact is, there is a larger amount of such power now in use in the State than ever before. It is concentrated, and larger and more efficient powers are being constructed to take the place of the small, abandoned ones. A single water-power plant such as that of the Dundee Water-Power and Land Company, at Passaic, is equal to all of the abandoned forge-powers in the State. The two efficient plants recently erected on the Musconetcong by the Warren Paper Company, with 700 net horse-power, are equal in power to thirty of the abandoned saw-mill powers. Water-power is not falling into disuse in New Jersey; on the contrary, it is being used more efficiently than ever before. The cordial sympathy and interest which the owners and users of water-power have shown in our work, and the substantial aid which they have given, show that they feel the need of such an investigation as has been undertaken.

The above-mentioned considerations, and the fact that the increasing use of electricity and possibilities of electric transmission of power are opening up new fields for its use, make the time peculiarly auspicious for laying before the public a statement of our water-power resources, and calling special attention to our large, undeveloped powers.

The writer wishes to acknowledge his indebtedness to Mr. William E. Worthen, Past President of the American Society of Civil Engineers; Mr. Samuel McElroy, C.E.; and Mr. Lebbeus Ward, C.E., of the Board of Managers of the Geological Survey. These well-known hydraulic engineers have given cordial support to the work, by furnishing valuable data and advice. I also wish to acknowledge

the service rendered by the various mill-owners, where gaugings have been made, and to the gauge recorders, whose interest and co-operation have rendered it possible to do much which would otherwise have had to remain undone. These gentlemen are mentioned later on, where the results of gaugings are taken up and discussed.

It must be remembered that at the date of preparation of this report of progress, much of the data is still incomplete. All of it is very recently in hand, too recently for any full discussion of it, consequently the present paper must be taken simply as preliminary. The studies are unfinished, but they are far enough advanced to make their publication desirable. Criticism which has for its object the improvement of the final results, and which keeps in view the limited means for the accumulation of data, will be cordially welcomed.

SYNOPSIS OF PROPOSED INVESTIGATION.

After some preliminary study and consultation the following was agreed upon as an outline of the scope of the investigation:

1. A study of stream-flows, including an investigation of a system by which the low-season and ordinary flow of a stream may be safely deduced from the records of monthly rainfall, with the collection and discussion of gaugings of typical streams, and of flood and minimum flows.

2. Description of the various water-sheds, and computations of their ordinary and dry-season flows, in order to determine their adaptation to use for power and the supply of towns.

3. Deep and shallow well-supplies; their proper utilization and development. A review of the existing wells and of the results of well-driving in the State.

4. Quality of waters: A collection of chemical analyses and microscopic examinations of the surface and well-waters, in order to determine their fitness for domestic or manufacturing uses.

5. A review of existing systems of water-supply, considering sources, methods of utilizing and consumption.

6. The water-powers of the State. (*a*) A list of powers in use, with a classification by purposes to which they are applied. (*b*) A list of important undeveloped powers, with computations of the amount of power which may be successfully utilized.

7. In order to enable us to direct our researches intelligently, and

confine investigation to places where its utilization will be sanctioned by law, a compilation of decisions of the courts of the State affecting the ownership and use of rights in water is under preparation. As it will undoubtedly be acceptable to users of water in this connection, it will be incorporated with the report.

THE FLOW OF STREAMS.

The work of the year has been mainly directed to the study of stream-flows. This subject is a most important one, and is beset with many difficulties. Data are scarce and difficult to obtain. We cannot hope to get anything like an adequate series of gaugings of our own streams in time to make it the basis of these researches; consequently it has been necessary to gather everything that has been done in gauging streams in this latitude, resembling our own more or less closely, and base our studies upon these, endeavoring to get gaugings of our own streams long enough to establish their resemblance or difference to those streams of which we have gaugings.

The waters of the earth are taken up by the process which we call evaporation and formed into clouds, to be again precipitated to earth in the form of rain or snow. Thus our streams are supplied from month to month. Of the water which falls upon the basin of a stream, a portion is evaporated directly by the sun; another large portion is taken up by plant growth and mostly transpired in vapor; still another portion, large in winter but very small in summer, finds its way over the surface directly into the stream forming surface or flood-flows; finally another part sinks into the ground to replenish the great reservoir from which plants are fed and stream-flows maintained during the periods of slight rainfall, for the rainfall is frequently, for months together, much less than the combined demands of evaporation, plant-growth and stream-flow. These demands are inexorable, and it is the ground storage which is called upon to supply them when rain fails to do so.

It is very difficult to obtain accurate or even approximate measurements of the amount of these several demands. We have measurements of evaporation from water-surfaces, but there is very little water-surface exposed on our water-sheds, so we have measurements of the amount taken up by various kinds of vegetation, but our areas are of a mixed character and it is not always possible to apportion them properly among the various crops. The measurements of evaporation from the ground come the nearest to what we need, but few of these have been made with necessary precautions to secure exactly the same conditions which exist in nature. Nevertheless, these observations are very suggestive, and some of the results are here reproduced.

The following is Risler's table of daily consumption of water for different crops, quoted in an article on irrigation by W. Tweeddale, C.E. (Kansas State Board of Agriculture Report, December 31st, 1889):

	Inches.
Lucern grass	from 0.134 to 0.267
Meadow grass	from 0.122 to 0.287
Oats	from 0.140 to 0.193
Indian corn	from 0.110 to 1.570
Clover	from 0.140 to ......
Vineyard	from 0.035 to 0.031
Wheat	from 0.106 to 0.110
Rye	from 0.091 to ......
Potatoes	from 0.038 to 0.055
Oak trees	from 0.038 to 0.030
Fir trees	from 0.020 to 0.043

From these and other observations, Mr. Tweeddale concludes that from seed-time to harvest cereals will take up fifteen inches of water and grasses thirty-seven inches. These conclusions agree with practice in irrigation, and show plainly that the demands of plant-growth cannot be ignored in tracing the disappearance of rain. The figures also explain the low summer flow of streams flowing from a highly-cultivated water-shed. They do not necessarily explain the effect of forests in regulating flow, since many water-sheds, although cleared of trees, are not put under cultivation but still show some change in flow. The action of forests is probably largely to retard surface-flow by means of irregular surfaces, caused by roots, fallen timber, absorbent mosses and leaf accumulation, thus holding the water until it can be taken into the ground. This is not mere theory; it is based on observations made during many days spent in the forest, and is believed to almost if not fully account for the better-sustained flow of forest streams and their lighter flood-flows.

Evidently, if all of our water-shed should be covered with grain and heavy grasses, there would be very little water left for the sustenance of stream-flow during the summer. Fortunately, a much smaller proportion is so covered than is usually supposed, even in agricultural sections. Somerset county is a highly-cultivated section of the red sandstone plain. I have made an estimate of the proportion of the total area given to various crops, based on census figures, and the proportion of wooded area has been measured. Of the total area, 13 per cent. is wooded in large tracts, and 7 per cent. has been added for scattering timber, the remainder being devoted to general farming.

PERCENTAGE OF AREAS DEVOTED TO VARIOUS CROPS IN SOMERSET COUNTY, WITH QUANTITY OF WATER REQUIRED FOR EACH.

Crop.	Per cent. of whole area.	Water required in one growing-month.	
		In inches on crop area.	In inches on whole area.
Forest (oak and chestnut)	20	1.2	0.24
Wheat, rye, oats, &c.	20	3.5	0.70
Indian corn	11	4.5	0.49
Potatoes and other root crops	05	1.2	0.06
Long grasses	17	6.0	1.02
Short grasses	15	5.0	0.75
Orchards, &c.	05	3.0	0.15
Fallow lands and miscellaneous	07	4.0	0.28
Total	100	....	3.69

This gives a fair idea of the allowance which must be made for vegetation, although it is only a rough approximation. To this must be added something for extra evaporation from crop areas. This demand for 3.7 inches of water per month may be considered practically a constant one for the growing-months. It is to a large degree independent of the rainfall, and in fact a large part of the evaporation is also independent of rainfall.

Somerset county has been selected as a type of the larger part of our red sandstone plain, viz., that part lying southwest of the glacial moraine which passes through Morristown, Plainfield and Perth Amboy.

As a type of our Highland and Kittatinny valley region, Sussex county may be taken in the same way.

PERCENTAGE OF AREA DEVOTED TO VARIOUS CROPS IN SUSSEX COUNTY, AND QUANTITY OF WATER REQUIRED FOR EACH.

Crop.	Per cent. of whole area.	Water required in one growing-month.	
		In inches on crop area.	In inches on whole area.
Forest (oak and chestnut)	50	1.2	0.60
Water	02	5.0	0.10
Indian corn	05	4.5	0.22
Other cereals	09	3.5	0.32
Long grasses	03	6.0	0.18
Short grasses	24	5.0	1.20
Potatoes and other root crops	01	1.2	0.01
Fallow land	06	4.0	0.24
Total	100	....	2.87

The Southern New Jersey agricultural counties will not differ very materially from Somerset county, while the piny region will only call for about one inch of water per month for plant growth. The evaporation there is large, however; much greater than in Northern New Jersey, as we shall see when the study of the streams is taken up.

It would be difficult to determine just how much evaporation will take place in addition to the water demanded by plant growth. It is hardly probable that it is nearly so large as the evaporation from bare ground, and, for the heavier absorbents and closer-growing crops, such as long grasses and clover, there is probably no additional evaporation. Far more reliable data as to the loss of rain on water-sheds of a given type could be gathered by systematic gauging and rainfall observation.

The following tables of evaporation are copied from Mr. Fanning's valuable treatise on Water-Supply Engineering:

EVAPORATION FROM WATER AT EMDRUP, DENMARK.

Latitude, 55° 41′ N.; Longitude, 12° 34′ E. from Greenwich.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1849..........	1.1	0.3	1.8	2.5	4.1	5.8	4.7	4.0	2.6	1.1	0.9	0.6	29.5
1850..........	1.1	0.3	1.2	1.7	4.5	5.6	4.8	4.8	2.4	1.6	0.9	0.2	29.1
1851..........	0.5	0.4	0.7	1.7	4.2	4.8	5.7	5.1	2.7	1.5	0.6	0.5	28.4
1852..........	0.7	0.5	0.8	2.4	3.8	4.6	6.4	4.5	2.7	1.7	0.8	0.5	29.4
1853..........	0.5	0.1	0.7	1.0	4.1	6.2	5.1	4.2	2.8	1.1	0.6	0.5	26.9
1854..........	0.5	0.9	0.9	3.2	3.3	4.5	5.2	4.3	2.6	1.2	0.7	0.6	27.9
1855..........	1.0	1.1	0.5	1.2	2.6	4.1	4.7	4.1	2.8	1.4	0.9	0.7	25.1
1856..........	0.5	0.5	1.2	2.1	2.8	4.6	4.3	4.0	2.0	1.9	0.6	0.5	24.0
1857..........	0.7	0.6	0.6	1.4	4.1	6.6	5.9	4.3	3.2	1.4	0.7	0.4	29.9
1858..........	0.4	0.7	1.2	3.1	5.1	6.1	4.9	5.6	2.8	1.6	0.7	0.4	30.6
1859..........	0.3	0.5	0.7	1.9	4.3	5.8	5.3	3.8	1.8	1.0	0.7	0.3	26.4
Mean..........	0.7	0.5	0.9	2.0	3.7	5.4	5.2	4.4	2.6	1.3	0.7	0.5	27.9
Ratio..........	.301	.215	.387	.860	1.592	2.323	2.237	1.892	1.118	.559	.301	.215	.....

MEAN EVAPORATION FROM SHORT GRASS, 1852 TO 1859, INCLUSIVE.

Mean.......	0.7	0.8	1.2	2.6	4.1	5.5	5.2	4.7	2.8	1.3	0.7	0.5	30.1

MEAN EVAPORATION FROM LONG GRASS, 1849 TO 1856, INCLUSIVE.

Mean........	0.9	0.6	1.4	2.6	4.7	6.7	9.3	7.9	5.2	2.9	1.3	0.5	44.0

MEAN RAINFALL AT SAME STATION, 1848 TO 1859, INCLUSIVE.

Mean.........	1.5	1.7	1.0	1.6	1.5	2.2	2.4	2.4	2.0	2.3	1.8	1.5	21.9

EVAPORATION FROM EARTH.

MEAN EVAPORATION FROM EARTH, AT BOLTON LE MOORS,* LANCASHIRE, ENGLAND, 1844 TO 1853, INCLUSIVE.

Latitude, 53° 30′ N.; Height above sea, 320 feet.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Mean........	0.64	0.95	1.59	2.59	4.38	3.84	4.02	3.06	2.02	1.28	0.81	0.47	25.65
Ratio	.299	.444	.739	1.212	2.049	1.796	1.887	1.431	.945	.599	.379	.220	....

* Beardmore's Hydrology, page 325.

MEAN RAINFALL AT SAME STATION, 1844 TO 1853, INCLUSIVE.

Mean	4.63	4.03	2.25	2.22	2.23	4.07	4.32	4.77	3.79	5.07	4.64	3.94	45.76

MEAN EVAPORATION FROM EARTH, AT WHITEHAVEN, CUMBERLAND, ENGLAND, 1844 TO 1853 INCLUSIVE.

Latitude, 54° 30′ N.; Height above sea, 90 feet.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Mean	0.95	1.01	1.77	2.71	4.11	4.25	4.13	3.29	2.96	1.76	1.25	1.02	29.21
Ratio	.390	.415	.727	1.113	1.689	1.746	1.697	1.352	1.216	.723	.513	.419	....

MEAN RAINFALL AT SAME STATION, 1844 TO 1853.

Mean	5.1	3.4	2.5	2.2	1.9	3.1	4.3	4.3	3.1	5.3	4.5	3.8	43.5

The small range of the evaporation from water in the first table is suggestive. It seems to approximate to a constant in each month. Of the tables of evaporation from earth, that at Whitehaven seems to be the better adapted to our climate. It is more valuable for the dry months than for winter.

In many cases when evaporation is spoken of later on in this report, plant absorption is included, as it is not deemed practicable to separate them. The above tables, estimates and remarks are intended to be confirmative of later conclusions respecting loss of rain, rather than exactly indicative of the amount of such loss.

GROUND-WATER.

At the close of the winter and spring rains, the ground is saturated with water to a great depth. A large amount of water is held in storage, and all of that which lies above the level of the bed of a stream, within the boundaries of the water-shed, becomes available either to feed the stream at that point or else to satisfy the demands of plants and evaporation. This great reservoir will feed a certain amount of water to the stream irrespective of the rainfall. If the rainfall is sufficient to supply the evaporation and plant growth, the flow from ground-water will remain constant, because the head which forces it through the rocks and gravels is constant. When the rain is insufficient, the head will be drawn down and the flow will decrease at a certain fixed rate. The draught upon ground storage in this vicinity usually sets in between May 1st and June 1st, not often before the middle of May and rarely later than June 1st. Once the draught is fairly established and the water drawn down, unless the rainfall is greater than it usually is from June to August, it is all absorbed by the dried earth and does not reach down far enough to increase the head and consequent flow of ground-water. What may be called the under-run of a stream—the part which depends upon ground storage—may be easily determined by inspection of a continuous diagram of flow. In inspecting such diagrams as those of the rivers of New Jersey accompanying this report, it may be seen that rainfalls which, if occurring in May, or in the autumn after the ground-water has been replenished, would cause violent floods, have no effect at all upon the stream-flow when they occur during the dry months. This difference in effect cannot be ascribed to direct evaporation, for in the case of concentrated rainfall, evaporation has little time to act. It is due to the drawing down of ground-water, which leaves a great capacity for absorption of rain by the earth.

In the discussion of the flow of the Croton and Sudbury rivers, following, it is found that in extreme cases, like the drought of 1876 on the Croton, the depletion of the ground storage may amount to nine inches on the water-shed, and six inches by the end of August is not uncommon. It is also clearly shown that all of this must be made up before any of the rainfall, excepting the small amount which runs off the surface in very heavy storms, is available to increase the stream-flow. By a depletion of six inches it is meant that six inches in depth of rain on the water-shed will be required to again saturate the ground and restore the ground-water. The actual distance to which the water descends is not everywhere the same, nor is it intended to convey that an equal amount of water is drawn from all parts of the shed. A coarse gravel will yield up its ground-water much more freely than compact earths or rock. The amount given is the average for the whole shed.

The capacity for ground storage varies widely on different water-sheds. On steep, rocky surfaces the rain largely runs off. The rock, it is true, holds a large amount of water, but it is held tenaciously, and discharged at a low rate. This fact is partially compensated for by the greater differences of level on such a water-shed, which cause greater heads to force out the water. A rocky water-shed, as level as the sandy basins of Southern New Jersey, which discharge large volumes of ground-water, would probably yield a very trifling amount. Fanning gives the following data as to porosity of soils:

"Gravel, consisting of small water-worn stones or pebbles, intermixed with grains of sand, has ordinarily 20 to 25 per cent. of voids; marl, consisting of limestone grains, clays and silicious sands, has from 10 to 20 per cent. of voids; pure clays have innumerable interstices, not easily measured, but capable of absorbing, after thorough drying, from 8 to 15 per cent. of an equal volume of water.

"Water flows with some degree of freedom through sandstones, limestones and chalks, according to their textures, and they are capable of absorbing from 10 to 20 per cent. of their equal volumes of water.

"The primary and secondary formations, according to geological classification, as for instance granites, serpentines, trappeans, gneisses, mica slates and argillaceous schists, are classed as impervious rocks, as are usually the several strata of pure clays that have been subjected to great superincumbent weight.

"The crevices in the impervious rocks, resulting from rupture, may, however, gather and lead away, as natural drains, large volumes of the water of percolation."*

It must be remembered, however, that nearly all water-sheds on rock formation have a covering of disintegrated rock and drift gravels and sands, which furnishes a large part of the ground storage. A rock valley with a considerable descent, filled with drift sands and gravels, is admirably adapted to supply large quantities of ground-water.

From the above percentages we find that a depletion of 9 inches of ground-water, will draw down the water-table an average distance of from 35 to 45 inches in gravels, from 45 to 90 inches in marls, about 90 inches in clays, and from 45 to 90 inches in sandstones, limestones and chalks.

The streams of Long Island draw a very large amount of water from the masses of drift gravel and sand which compose their water-sheds. The following is an extract from Mr. Samuel McElroy's paper on the Hempstead Storage Reservoir: "This general

* Fanning's Water-Supply Engineering, page 102.

law of filtration in this formation, is illustrated very completely, and with wonderful annual uniformity in the daily discharge of the accumulating rainfall from the permanent saturated bed of the slope towards tide.

"A moderate estimate of this annual fall is 42 inches, and the percentage reaching this bed is not less than 60. This gives a daily surplus for discharge of 1,200,000 gallons per square mile towards tide; otherwise the remarkably-uniform levels of the bed would not be maintained as they are, as shown by the numerous wells."

These streams and their strikingly-large flows, are of peculiar interest to us, for the facts observed here have a direct bearing on the flow of our Southern New Jersey streams, which also have sandy water-sheds and remarkably uniform and well-sustained summer flows.

SURFACE STORAGE.

Another agent which tends to equalize flow to some extent, by carrying over some of the water of the wet season to the early dry months, thereby shortening the periods of very small flow, is surface storage. Water is held in natural lakes and swamps and fed out gradually to the stream. Some of the natural lakes in Northern New Jersey vary two feet in height of surface. The Paulinskill has about three square miles area of such lakes on 175 square miles of water-shed, and a storage of two feet would add an average of 3.75 cubic feet per second to the flow of the stream for one month. The flow would be much greater than this at first, and would gradually decrease to nothing. Artificial storage is much more efficient, as a greater depth of water can be controlled and the discharge regulated to meet the demand. Natural storage is an important factor in the flow of some streams, such as those of our northern counties, however, and must be taken into account.

SURFACE OR FLOOD-FLOWS.

We have seen that a portion of our rain finds its way over the surface to the stream. How much, depends on the condition of the ground-water and the steepness of the slopes. On the Sudbury it is observed that any rainfall exceeding four inches per month is accompanied by surface-flows. There is some limit to the rapidity with which water can be absorbed by the earth, even when dry, and, although the ground-water is low, sometimes rain falls in such enormous volume that disastrous floods are caused.

In the report on Climatology of New Jersey (1888) it is stated that single storms "rarely exceed four inches in depth, and three inches is a heavy rain. In the Newark record the number of rains over three inches in thirty-seven years and eight months was thirty-six. Eight of them occurred in July; eight in August; five in October; three in November; two each in December and May, and one in each of the other months."

The late Ashbel Welch stated,* during a discussion on the flow of streams, that in August, 1843, "twelve inches of rain fell in about as many hours in one night" near Bound Brook, but this extremely heavy rainfall was confined to a very narrow district. He also says that "the most destructive rainstorms I have seen have been in August, and next to that, July."

The following severe storms are mentioned in the Climatology of New Jersey:

Paterson, March 19th and 20th, 1881, 5.44 inches in 11 hours; Parsippany, March, 1875, 7 inches in a single storm.

In the month of August, 1848, 22.48 inches of rain fell at Newark, a fall without an equal in the records of the vicinity.

In the month of September, 1882, great floods occurred all over the State. They were caused by a very heavy storm which came after three months of deficient rainfall. By the method employed in estimating flows on the Croton, I find that by September 19th the deficiency of rain amounted to 4 inches on the Raritan water-shed. From the 20th to the 24th the records at New Brunswick show a fall of 11.84 inches of rain; those on the Croton water-shed showing about the same amount. It will be seen that there was a surplus of at least 7 inches after replenishing ground-water. As will be seen later, I have estimated that from the 22d to the 25th, during 64 hours, a total of 3.3 inches on the water-shed flowed over the dam above New Brunswick. On the Croton from 40 to 80 per cent. of the surplus rain goes off in floods in summer. On the Sudbury, a smaller water-shed, from 5 to 10 per cent. of the total monthly rain has to be allowed when such rain exceeds 4 inches.

* Transactions of the American Society of Civil Engineers, July, 1881.

A striking example of the effect of the manner in which the rain falls, whether highly concentrated or evenly distributed through the months and year, is shown in the years 1889 and 1890. On the Raritan, in 1889, there occurred six floods high enough to destroy the fencing on the meadows along the stream. In 1890 there was but one flood over the river banks, and that a very light one. Our records of flow on the Passaic show five floods of from 6,300 to 10,900 cubic feet per second; in 1890 the discharge did not once reach 6,000 cubic feet per second, and 5,000 was exceeded only once. Both were years of heavy rainfall, 1889 having 68 inches against 51 inches in 1890.

ANALYSES OF EXISTING SERIES OF GAUGINGS.

Since we have not, and cannot hope to have in time for our present purposes, long series of observations of flow of our New Jersey streams, we shall be obliged to base our estimates largely upon existing series of gaugings on similar streams. With this in view I have been at much pains to analyze such records as we have, keeping in view the observations which have already been made as to the various ways in which rain is dissipated. Unfortunately, good observations of flow are extremely scarce, but we have some which are valuable. The longest of these are the records of flow of the Croton, published by the Department of Public Works of New York City, in the Commissioner's report on the new aqueduct, in February, 1882. The flow over Croton dam is given from 1865 to 1881, but lacking the flow through the aqueduct, I have only been able to obtain the total flow from 1868, or for fourteen years. The method of gauging was crude, the height being measured once a day at Croton dam, and then the heads on the overfall averaged, in order to get the average daily discharge for each month. Only a good approximation was desired, however, and it appears to have been obtained. The method of averaging the heads themselves, instead of the cubes of their square roots, would not cause a serious error when the flow is pretty evenly distributed through the month, as it is most likely to be during the dry months. When a single flood of short duration occurred, this method would not give the proper weight to such a flow. Nevertheless, a careful analysis of these records does not show anything in the ordinary flow which is inconsistent with the rainfall, as a rule, although occasional months do show palpable errors. The average daily flows were reduced to total monthly flows, and these were reduced to inches on the water-shed for facility of comparison with the rainfall. The years embraced in this record were not seriously affected by artificial storage, and in this respect are more valuable than those since 1881.

On the west branch of the Croton, Mr. J. J. R. Croes, C.E., has made careful gaugings, covering three years, which are most valuable as representing a small water-shed (twenty square miles) on the Archean Highlands. I have not yet been able to fully discuss them.

On the Sudbury, in Massachusetts, Mr. Alphonse Fteley made a very valuable five-year series of gaugings with carefully-taken rainfalls. This stream has a water-shed of 77.8 square miles, resembling our northern water-sheds. This series is discussed later.

On the Connecticut, with a drainage area of 10,234 square miles above Hartford, we have an eight-year series, made by the United States Army Engineer Corps. The discussion of this series has been under way, but adequate rainfall records have not yet been obtained and it is incomplete.

It will be seen that we have a series here which fully represents our Northern New Jersey streams, and on this series we can base our computations of flow as soon as our gaugings are sufficient to demonstrate the peculiarities of each of the streams which have been selected as types of a certain class.

Unfortunately we have no series resembling our Southern New Jersey water-sheds, but it is believed that we can secure data enough there to base accurate estimates upon, from our own observations. Those streams are much more equable in flow. They deserve a full investigation because of their peculiar value for water-power.

Our aim, in the following discussion of flow, has been to deduce a safe rule which could be used for estimating stream-flow from monthly rainfall records.

RAINFALL AND FLOW OF CROTON WATER-SHED.

Area, 353.1 Square Miles.

	1868.			1869.			1870.			1871.			1872.		
	Rainfall—Inches.	Flow—Inches.	Percentage.	Rainfall—Inches.	Flow—Inches.	Percentage.	Rainfall—Inches.	Flow—Inches.	Percentage.	Rainfall—Inches.	Flow—Inches.	Percentage.	Rainfall—Inches.	Flow—Inches.	Percentage.
Jan.....	2.90	1.95	67	3.79	2.17	58	4.51	3.76	84	3.80	0.52	13	1.44	1.88	131
Feb.....	1.38	0.79	57	3.64	0.89	11	6.40	3.61	57	3.81	1.61	45	1.22	1.07	88
Mar....	2.55	3.83	150	5.48	4.71	86	3.80	3.24	86	4.27	3.36	79	2.59	1.31	51
Apr.....	3.87	4.60	119	2.11	3.16	150	5.45	4.00	73	3.01	1.90	63	3.04	2.97	98
May ...	8.79	5.44	62	4.52	2.75	61	2.30	1.69	74	3.45	2.90	84	3.69	1.20	33
June...	4.53	3.17	70	3.59	1.43	40	2.06	0.70	34	5.73	1.24	22	4.00	1.14	28
July ...	2.13	0.98	46	2.26	0.54	24	3.48	0.46	13	5.07	0.69	14	4.34	0.55	13
Aug....	6.98	1.73	25	1.92	0.33	17	5.10	0.43	8	5.24	0.68	13	5.99	1.24	21
Sept ...	9.88	4.69	51	3.20	0.23	07	2.85	0.32	11	1.44	0.55	32	3.69	1.13	31
Oct	0.87	2.84	326	9.46	2.39	25	4.73	0.40	8	6.18	1.60	26	2.15	1.07	50
Nov....	4.65	3.80	82	2.48	1.87	79	2.51	0.56	22	4.35	3.60	83	4.91	2.48	51
Dec.....	2.35	0.97	41	5.96	2.95	49	1.49	0.59	40	2.59	2.10	81	3.68	1.88	38
Year...	50.33	34.80	69	48.36	22.87	47	44.63	19.79	44	48.94	20.75	42	40.74	17.42	43

	1873.			1874.			1875.			1876.			1877.		
Jan.....	5.66	3.72	65	6.96	3.89	56	2.74	0.57	21	1.42	1.42	100	2.68	0.76	28
Feb.....	3.09	1.70	55	2.78	2.58	93	3.47	2.90	84	4.91	3.28	67	0.80	1.37	171
Mar.....	3.08	3.29	107	1.57	2.88	183	4.99	2.63	53	6.33	5.75	91	7.66	6.85	88
Apr.....	3.77	6.44	171	6.31	3.33	53	3.04	4.83	159	4.43	5.21	117	2.35	2.80	119
May....	2.91	7.43	255	1.99	2.90	146	1.08	1.68	155	3.99	1.89	47	0.85	0.82	97
June...	0.71	0.50	70	3.57	0.88	24	3.02	0.54	18	2.52	0.62	41	4.95	0.55	11
July ...	2.21	0.48	22	5.98	0.85	14	3.10	0.54	17	3.42	0.52	15	4.65	0.50	11
Aug....	5.73	0.53	9	2.75	0.69	25	10.33	4.41	43	1.20	0.49	41	2.54	0.48	19
Sept ...	3.73	0.47	13	3.56	0.51	14	2.11	0.82	39	5.21	0.36	69	1.49	0.32	21
Oct	5.13	1.09	26	2.40	0.70	29	3.61	0.53	15	1.50	0.37	25	8.88	0.71	9
Nov....	3.72	1.50	41	2.72	0.59	22	4.61	1.96	43	3.40	0.60	18	8.16	3.76	46
Dec.....	4.13	3.13	76	1.78	0.85	48	1.56	1.73	117	2.35	0.62	26	1.52	3.90	256
Year...	43.87	30.28	69	42.37	20.65	49	43.66	23.14	53	40.68	21.18	52	46.03	22.32	49

	1878.			1879.			1880.			1881.		
Jan.....	4.49	2.46	55	2.52	1.37	54	4.00	2.62	65	4.19	0.65	15
Feb.....	3.65	3.32	91	2.85	2.21	78	2.92	2.75	94	5.28	2.95	56
Mar....	3.10	3.64	117	4.96	3.92	79	4.51	2.89	64	6.14	5.42	88
Apr.....	2.85	1.61	57	5.10	4.70	92	3.99	1.96	49	1.67	1.69	100
May ...	4.97	1.48	30	2.45	1.86	76	1.17	0.85	72	3.74	1.26	34
June...	4.65	1.32	28	5.29	0.78	15	1.28	0.49	38	5.27	1.46	28
July ...	4.28	0.62	14	5.95	0.62	10	5.65	0.50	9	2.45	0.53	22
Aug....	2.66	0.62	23	5.83	1.04	18	3.60	0.50	14	1.71	0.50	29
Sept....	6.61	1.69	26	3.43	0.99	29	2.69	0.48	18	0.75	0.49	65
Oct	3.78	0.77	20	0.95	0.63	66	3.25	0.50	15	3.65	0.50	14
Nov....	4.36	1.70	39	2.49	0.75	30	2.97	0.49	16	4.50	0.50	11
Dec.....	8.74	6.49	74	4.26	1.88	44	2.49	0.51	20	6.37	1.49	23
Year...	54.14	25.72	48	46.08	20.75	45	38.52	14.54	38	46.17	17.44	38

OBSERVED AND COMPUTED FLOW OF CROTON RIVER BY NATURAL PERIODS.

YEAR ENDING	STORAGE PERIOD; December to May.* Rainfall—Inches.	Flow—Inches.	Corrected flow—Inches.	Corrected flow—Percentage.	Computed flow, 60 per cent. of rain.	GROWING PERIOD; June to August.† Rainfall—Inches.	Flow—Inches.	Corrected flow—Inches.	D = rainfall — 18.5 inches.	Computed flow = 1.50 + .4 to .8 D. Only +D used.	REPLENISHING PERIOD. September to November. Rainfall—Inches.	Flow—Inches.	Corrected flow—Inches.	E = rainfall — [6.0 + 0.75 D]. Only —D used.	Computed flow = 0.90 + .50 to .75 E.	YEAR. Dec. 1st to Nov. 30th. Rainfall—Inches.	Corrected flow—Inches.	Computed flow—Inches.
Nov. 30th, 1868..	22.01	18.55	19.65	89	18.20	13.64	6.88	4.88?	+0.14	1.61	14.85	11.83	11.83?	8.85	5.32	50.50	35.76	20.13
Nov. 30th, 1869..	21.89	14.15	14.95	68	13.13	7.67	2.80	1.50	—5.83	1.50	15.09	4.49	4.49	4.72	4.44	44.65	20.94	19.07
Nov. 30th, 1870..	28.42	19.28	19.28	65	17.05	10.59	1.59	1.59	—2.91	1.50	10.09	1.28	1.28	1.91	1.86	49.10	22.06	20.41
Nov. 30th, 1871..	19.83	10.88	11.05	56	11.90	16.04	2.61	2.61	+2.54	2.52	11.97	5.75	5.75	5.97	5.38	47.84	19.41	19.88
Nov. 30th, 1872..	14.57	10.53	11.13	76	8.74	14.33	2.93	2.33	+0.83	2.16	10.75	4.68	4.68	4.75	3.27	39.65	18.14	14.17
Nov. 30th, 1873..	25.19	23.96	23.96	95	15.11	8.65	1.51	1.51	—4.85	1.50	12.58	3.06	3.06	2.94	3.12	46.42	28.53	19.73
Nov. 30th, 1874..	23.74	18.71	18.71	79	14.24	12.80	2.42	2.42	—1.20	1.50	8.68	1.80	1.80	1.78	1.79	44.72	22.93	17.53
Nov. 30th, 1875..	17.10	13.46	13.46	79	10.26	16.45	5.49	5.49	+2.95	3.86	10.83	3.81	4.05	4.33	3.06	43.88	23.00	17.18
Nov. 30th, 1876..	22.64	19.28	18.54	82	13.58	7.14	1.63	1.50	—6.36	1.50	10.11	1.83	1.04	—0.66	0.90	39.89	21.08	15.98
Nov. 30th, 1877..	16.69	12.72	13.20	80	10.01	12.14	1.53	1.53	—1.36	1.50	9.87	1.03	3.43	2.85	3.04	38.70	18.16	14.65
Nov. 30th, 1878..	20.58	16.41	14.71	71	12.35	11.59	2.56	1.86	—1.91	1.50	14.75	4.16	5.86	7.82	4.56	46.92	21.93	18.41
Nov. 30th, 1879..	26.62	20.65	19.35	72	15.97	17.07	2.44	2.94	+3.57	2.93	6.87	2.87	1.87	0.57	1.34	50.56	24.16	19.24
Nov. 30th, 1880..	19.68	13.60	15.10	77	11.80	11.68	2.84	1.81	—6.32‡	1.50	8.91	1.47	0.86	—1.83	0.90	40.29	17.77	14.20
Nov. 30th, 1881..	19.77	12.45	13.95	70	11.86	13.17	2.75	3.41	—4.83‡	1.50	8.90	1.49	0.82	—0.72	0.90	41.84	18.18	14.26

* In 1880 and 1881 this period includes only December to April. † May included in 1880 and 1881. ‡ Rainfall—18.00; 4.50 being added for extra month of evaporation, &c.

NOTE.—In these computations no unnecessary refinement has been attempted. The effort has been to keep within the truth as indicated by these observations. The slight excess over observed flow in 1871 is not considered important in view of the strong probability of error in observations. The record for 1868 is considered wholly unreliable.

TABLE OF DROUGHTS—CROTON WATER-SHED. RAIN AND FLOW IN INCHES ON THE SHED.

YEAR.	Last month of storage period.			First dry month.		Second dry month.		Third dry month.		Fourth dry month.		Fifth dry month.		Sixth dry month.		Seventh dry month.		Eighth dry month.	
	Month.	Rain.	Flow.	Rain.	Flow.	Rain.	Flow.	Rain.	Flow.	Rain.	Flow.	Rain.	Flow.	Rain.	Flow.	Rain.	Flow.	Rain.	Flow.
1869	May	4.52	2.75	3.59	0.63	2.26	0.54	1.92	0.33	3.20	0.23	[9.46]	[2.39]	....	....	....	....	....	....
1870	May	2.30	1.69	2.06	0.70	3.43	0.46	5.10	0.43	2.85	0.32	4.78	0.32	2.51	0.56	1.49	0.59	2.74	0.57
1876	May	3.99	1.89	1.51	0.62	3.42	0.52	1.20	0.33	5.21	0.20	1.50	0.20	3.40	0.60	2.35	0.62	[4.19]	[0.65]
1880	April	3.99	1.96	1.17	0.85	1.28	0.37	5.65	0.35	3.60	0.24	2.69	0.25	3.25	0.12	2.97	0.49	2.49	0.51
1881	April	1.67	1.69	3.74	1.26	5.27	1.46	2.45	0.46	1.71	0.23	0.75	0.14	3.65	0.19	4.50	0.50	[6.37]	[1.49]
Averages	....	....	....	....	0.81	....	0.47	....	0.38	....	0.24	....	0.25	....	....	....	....	....	....

NOTE.—Figures enclosed by brackets are those of the wet month ending the drought. The flows in this table are corrected for draught from storage and for floods at beginning of month, from previous month's rain. As it would obviously be unfair to charge the stream with all of the water flowing from storage a distance of from eighteen to twenty-five miles, through shallow channels, I have allowed a loss of 20 per cent. of storage and only deducted 80 per cent. from the recorded stream-flows. The drought of 1870 ended with January, 1871, February showing a normal flow; that of 1880 with January, 1881; this being in both cases the eighth dry month.

There is a marked parallelism in the first four droughts, and the departure of the flow from a mean, for a given month, is very slight. The drought of 1881 has its early monthly flows somewhat increased by surface flows from heavy rains, and consequently has not always been used in making up the means.

TABLE OF MONTHLY FLOWS.

It is at once apparent that the table of rainfall and flow by months shows no relation whatever between the amount of rain falling and the amount of water flowing in any given month. This is in accord with what has already been pointed out. The Croton water-shed has a very considerable amount of natural storage. The Boyd's Corner reservoir was completed in 1873, and the one at Brewster's came into use in 1878. I have corrected the flows for amounts drawn from artificial storage and amounts stored, so far as my data would permit, in the second table. Too much must not be expected from these observations, and in making deductions from them my constant effort has been to keep within the truth. It must be evident to any observer that this cannot be done by any system of computation based on percentages of rainfall of the months from June to November, without adopting an absurdly low percentage. The second table (that of flow by natural periods) shows much more than that by months.

TABLE OF FLOW BY NATURAL PERIODS.

In this table we have endeavored to group the months by natural periods of flow and evaporation. The first or storage period is found by an inspection of the table of monthly flow, and of records of rain-fall, snow and temperature, to extend from December 1st to May 30th, usually. The years 1880 and 1881 are exceptions, however. Warm springs and light rains in April and May caused the storage period to end earlier than usual, and in these years the month of May has been set over to the second period, the allowance for evaporation for the period being increased accordingly. It is not probable that the period ever ends exactly at the end of May, but with only monthly records this is the nearest approximation which can be made. The reason for changing the end of this period from May 30th to April 30th will appear more fully when we come to consider the table of droughts on the Croton later on. The flows of the storage period, and in fact of each period, have been corrected by allowing for heavy rains falling in one month close to the end, so that they caused heavy flows in the following month.

STORAGE PERIOD.

In the storage period in this table we find a variation in the percentage of rain flowing which cannot be traced either to the amount of rain or the temperature. From what has been observed elsewhere it is attributed to the distribution of the rainfall, an evenly-distributed rainfall giving less flow than when concentrated. A certain amount of this variation is unquestionably due to inaccurate gauging. The range in the percentage of rain flowing is from 56 in 1871 to 95 in 1873. The method of averaging the heads on the weir, instead of averaging the cubes of their square roots, would cause a considerable error when the range of head is great, as it is during this period. There is no tendency of the percentage to decrease with the amount of rainfall. The range may safely be taken from 60 to 80 per cent. for this period, with the assurance that 60 per cent. will be within the truth. We have not attempted to subdivide this period. Fuller records may enable us to do so.

Probably the only safe way to utilize the whole flow of this shed is to provide storage for 60 per cent. of the rainfall, as above, less the consumption (which will approximate half the yearly flow) for the same period.

GROWING PERIOD.

Taking up next the growing period—June, July and August—we find that, unlike the first period, there is absolutely no agreement between rainfall and flow, and to figure percentages is worse than useless—it is misleading. One fact stands out strongly in this table, the tendency to a constant flow for all rainfalls up to 12 inches. The explanation of this is found in the tables of evaporation already given. At Bolton Le Moors we have an evaporation of 10.92 inches, and at Whitehaven, 11.67 inches for these three months. This table shows that for all rainfalls from 7 to 12 inches we have 1.50 inches of flow.

This fact is brought out more strongly by the corrected flow in the third column. A careful inspection of the flow by months shows that June frequently has much more flow than what is due to the rainfall in the month. In such cases an inspection of daily rainfall records has shown a heavy storm close to the end of May. A correction being made for these cases, we have the flows in the third column.

From the fact that this flow of 1.50 inches is constant for even very light rains, we conclude that it is drawn entirely from ground-water, and that ordinarily this represents the amount of depletion from flow. We also infer, from the fact that 12 inches of rain causes no additional flow, but as soon as we exceed this much the flow increases, that 12 inches represents the evaporation during the period. Consequently, if the rainfall is just equal to the evaporation, it will require 1.50 inches of rain to replace the ground-water, or, if the rain during the period has reached 13.5 inches, there is no depletion of ground-water. A careful comparison of the flow during the next period carries us one step further. If the rain during the growing period has been less than 13.5 inches, the deficiency has to be made up from the rain during the replenishing period, before that rain begins to increase the flow. The natural flow only draws 1.5 inches of rain from the ground, but evaporation will draw much more if the rain is deficient. The amount of this deficiency is shown in the fourth column (D). If instead of a deficiency we have an excess of rain over 13.5 inches during the period of growth, this excess will show in the flow of the stream. A deficiency is indicated by a minus sign, and an excess by a plus sign, in the column D. This record shows that from 40 per cent. to 80 per cent. of the excess will thus appear. When the rainfall is evenly distributed through the three months, only 40 per cent. will flow. If the excess of rain is all in one month, then 80 per cent. may be taken. Sometimes, doubtless, the entire excess flows off, but we have nothing to do with accidental flows in a conservative estimate. The column of computed flows is made up by the following rule, based on the above observations:

RULE FOR COMPUTING SUMMER FLOW.

When rainfall is 13.5 inches or less, 1.50 inches will flow; and of the excess of rain over 13.5 inches, 0.4 is to be added to this flow if each month shows an excess over 4.5 inches, or 0.8 if only one month shows an excess.

As to the distribution of this flow of 1.5 inches through the months, there are many cases when the flow is almost uniform, 0.5 inch flowing each month. The table of droughts is most instructive in this connection. An inspection of it will show that, beginning with the first month which shows a depletion of ground-water, either May or June, as the case may be, the first dry month gives from 0.6 to 0.8 inch of flow, the second from 0.37 to 0.54, usually 0.47, and the third 0.33 to 0.43 inch. The drought of 1880 runs close to the mean of the table, and is continued long enough to give us a good measure of the extreme capacity of ground and surface storage to supply the flow. From May to October, inclusive, the rain was remarkably deficient, while the flow amounted to a total of 2.18 inches. All of this must have been from natural storage, and as the flow fell off steadily from 0.85 inch in May, to 0.12 inch in October, this must be about the limit of the available natural storage of the Croton. The draught from evaporation must have been just about equal to the total rainfall for this period.

REPLENISHING PERIOD.

The last period is, as we have already noted, much affected by the rainfall during the second period. A careful analysis of the rainfall and flow in this period has convinced me that the evaporation amounts to just about six inches. This seems to agree quite well with the Whitehaven observations of evaporation already given. It is also found, as we should expect, that a deficiency of rain below what is required to supply evaporation and restore the ground-water in the second period, will have to be made up in this period, for the evaporation will make heavy draughts on the ground-water, which must be replenished. It is not to be supposed that evaporation from low ground-water will be as rapid as from saturated ground or surface-water, consequently I have allowed a difference of 25 per cent. between the deficiency of rain in the second period and the amount of water needed to make up for it in the third period. From this we get six inches for evaporation from September to November, plus 75 per cent. of the deficiency of rain in the growing period to represent the demand which must be first supplied from the rainfall of the replenishing period, the balance of rain being available for increasing the stream-flow. The column E is made up from this basis.

The minus quantities under D, in the second period, are the deficiencies of rain. When a plus sign occurs there is no deficiency to be made up, consequently we do not use the plus values of D, having already allowed for them in the flow of the second period.

It is further found that there is a nearly constant flow in this period for those years in which the rainfall is only equal to or less than 6.0 + .75 D; or, in other words, when there is no surplus of rain available to increase the flow of the stream, that flow will be drawn from ground-water and will usually amount to 0.90 inch. The flow of this period, then, will be found approximately by the following rule:

RULE FOR COMPUTING AUTUMN FLOW.

When E is zero or negative, the flow will amount to 0.90 inch, and when E has a positive value the flow will amount to 0.90+ from .50 to .75 E, .50 E being used when the rainfall is evenly distributed through the three months, or when excess occurs in September, and .75 E when there is an excess in October or November.

The reason for the variation in the amount of excess of rain which will flow lies in the fact that evaporation is not uniform but is much greater in September, and also in the greater evaporation if evenly distributed than if concentrated rainfalls.

The distribution of this autumn flow is quite regular where the rainfall is less than evaporation plus deficiency of summer rain. For heavy flows it is, of course, regulated by the distribution of the rain.

The table of droughts is instructive in this connection also. In 1876, 1880 and 1881, we find from the column E in the table by periods a deficiency of rain. Turning to the column of droughts, we find that in those years September gave an average flow of 0.17 inch, October 0.53 inch and November, in 1876 and 1880, 0.56 inch, September being the fourth month in the drought of 1876 and the fifth in 1880 and 1881. From this we infer that the distribution will approximate the following: September, 0.20; October, 0.35, and November, 0.35, for very dry years.

VALUE OF THE COMPUTED FLOWS.

The computations of flow in this table will be found to be very close in the second and third periods. It is not believed that any absolutely rigid mathematical rule will ever be discovered to fit so uncertain a matter as the flow of a stream, consequently the application of the proper co-efficient of D and E is left to good common sense, with the feeling that, so far as this record shows, no great error can possibly come from this source, even when that choice is based on a record of rainfall by months only. The disagreement in the storage period is more striking, and it will be found that nearly the whole error for the year is here. I have found no rule which will apply more closely than a percentage low enough to be within the truth, nor is it expected that any will be found. The flow in this period is more distinctly accidental; there are too many uncertain factors entering into the problem to make it safe to compute too closely, nor is it necessary. The wide divergence is where it will do the least harm throughout the computation, and it is claimed that this is accomplished without the enormous sacrifices of flow during intermediate stages which must follow from any system of monthly percentages.

While it is not supposed that these rules will absolutely fit any other water-shed, it is hoped that a method has been found which, with slight modifications of co-efficients, will be adapted to all similar sheds. By the courtesy of Mr. William E. Worthen, Past President of the American Society of Civil Engineers, I have obtained records of flow over Croton dam, and of draught from storage from 1881 to date, and as soon as the necessary additional data can be secured the study of this water-shed will be continued, and it will be determined whether these rules hold good for the entire period of twenty-two years. If so, we have found a valuable basis for the computation of such of our Northern New Jersey streams as our short records of gaugings indicate to be governed by the same laws as the Croton.

TABLE OF DROUGHTS.

We have frequently had to refer to this valuable exhibit and have left little to be said of it. These remarkable droughts are mentioned by Professor Smock in his Climatology of New Jersey, and some of their peculiar features pointed out. In 1880 wells and springs were said to be lower than they had been in thirty-eight years. The table speaks for itself as to rainfall and flow. It forms a good basis for estimate of the ultimate amount of storage called for to bridge over such periods, and it is seen that they occur, sometimes, with alarming frequency. In making up the table I have selected, by inspection, the month which marks the close of the period of full ground and surface storage, and have taken the month which first shows marked depletion of ground-water as the first dry month. This is June in three cases and May in two. The months are then set down consecutively to the end of the drought. It will be noted that once the drought is fairly inaugurated, a rainfall of over five inches in a single month has no effect in checking the subsidence of the stream.

This table furnishes a striking proof of the lack of connection between the rain falling in a month, in the dry period, and the water flowing in the stream during the same time.

The drought of 1869 was not very remarkable, lasting only from June to September, 10.97 inches of rain falling in the four months. In 1870 the drought lasted from June to January, 1871, or entirely through the growing and replenishing periods. The rainfall in June, July and August was 10.59 inches—much greater than for the same period in 1869; and the flow reached the ordinary 1.5 inches for that period. Had the ground-water been replenished in September, as usual, there would have been nothing unusual about the summer flow, but rain continued deficient, and during September, October and November we had only 10.09 inches, which was not enough to make up the deficiency until November, when the flow reached 0.62 inches. This gives us apparently a test by which we can determine when the storage has been replenished from the monthly rainfalls. Our total evaporation for autumn months agrees closely with the Whitehaven observations, hence we conclude that the evaporation has about the same distribution through the months, viz., September, 3.00 inches; October, 1.75 inches, and November, 1.25 inches. December and January evaporation may be taken at 1 inch per month.

The flow during the growing period we have seen to be a constant amount in dry years, consequently we begin with September first, to determine when the ground storage is replenished. Charging the storage with the rainfall, and crediting it with the evaporation, plus the flow of the stream, and the deficiency carried over from August, which is given in the table of flow for the growing period, we find that when the total supply exceeds the total draught the replenishment has been effected. For this purpose we may assume the constant flow to be as follows: September, 0.40; October, 0.30; November, 0.20 inch.

DROUGHT OF 1870.

	Supply—Inches.		Draught—Inches.
Deficiency at end of August,	......	....	2.91
September..........Rainfall...	2.85	Evaporation + flow...	3.40
October............ " ...	4.73	" " ...	2.05
November......... " ...	2.51	" " ...	1.45
Totals....................	10.09	....	9.81

Thus we find the replenishment just barely effected as the flow indicates, although rains continued so light in December as to give only the storage-flow.

DROUGHT OF 1876.

	Supply—Inches.		Draught—Inches.
Deficiency from August.....	......	....	6.36
September ....Rainfall...	5.21	Evaporation + flow...	3.40
October........... " ...	1.50	" " ...	2.05
November......... " ...	3.40	" " ...	1.45
December.......... " ...	2.35	" " ...	1.20
January............ " ...	4.19	" " ...	1.20
Totals	16.65	....	15.66

This, too, agrees with the observed flow. February flows are heavy. It must be remembered that when the replenishment has not been effected before the end of November, the freezing of the ground may prevent the necessary percolation. This has no very important bearing upon the flow, however, for it will ultimately be accomplished during the heavy flows of the early spring months.

DROUGHT OF 1880.

	Supply—Inches.		Draught—Inches.
Deficiency from August.....	......	....	6.32
September.........Rainfall...	2.69	Evaporation + flow...	3.40
October............. " ...	3.25	" " ...	2.05
November......... " ...	2.97	" " ...	1.45
December.......... " ...	2.49	" " ...	1.20
January........... " ...	4.19	" " ...	1.20
Totals....................	15.59	....	15.62

NOTE.—Ultimately we shall probably find it advantageous to employ in the computation of Croton flows the more exact method by months, as has been done with the Sudbury, but for the present this is deemed unnecessary.

DROUGHT OF 1881.

	Supply—Inches.		Draught—Inches.
Deficiency from August.....	......	....	4.83
September ....Rainfall...	0.75	Evaporation + flow...	3.40
October. .... " ...	3.65	" " ...	2.05
November .... " ...	4.50	" " ...	1.45
December.......... " ...	6.37	" " ...	1.20
Totals....................	15.27	....	12.93

There is a slight error in charging up the full deficiency of previous months, as there is no doubt some retardation of evaporation when ground-water becomes very low, but this does not affect the object aimed at.

I have dwelt at some length on this matter of extreme dry-season flows, for it is most important, both for the determination of the value of a stream for water-power and of its capacity for supplying water to cities for domestic consumption. It is a very hopeful indication of the value of the method of computing flows which has been here adopted that it gives reliable results, in the table of flow by periods, for such extreme seasons of drought as these under consideration. The deficiency of computed flows for seasons of heavy flow is of little economic importance, but to be within the truth in these extremely dry seasons is of the utmost value.

SUDBURY RIVER GAUGINGS.

The Sudbury river is at the extreme eastern end of Massachusetts, about fifteen miles west of Boston, and is one of the sources of water-supply for that city. In the Transactions of the American Society of Civil Engineers for July, 1881, we have given the results of gaugings by Mr. Alphonse Fteley, extending from January 1st, 1875, to February 29th, 1880, in a continuous series. These gaugings were made with scientific accuracy, and consequently the series, although short, is most valuable.

RAINFALL AND FLOW ON SUDBURY WATER-SHED.

Area, 77.8 Square Miles.

MONTH.	Rainfall—Inches.	Flow—Inches.	Percentage.	Rainfall—Inches.	Flow—Inches.	Percentage.	Rainfall—Inches.	Flow—Inches.	Percentage.
	1875.			1876.			1877.		
January	2.42	0.18	8	1.83	1.15	63	3.22	1.17	36
February	3.15	2.41	77	4.21	2.28	54	0.74	1.53	207
March	3.74	2.86	77	7.43	7.91	106	8.36	8.59	103
April	3.23	5.26	163	4.20	5.68	135	3.43	4.13	120
May	3.56	2.12	60	2.76	2.03	73	3.70	2.42	67
June	6.24	1.50	24	2.04	0.38	19	2.42	1.03	43
July	3.57	0.57	16	9.13	0.33	4	2.95	0.36	12
August	5.53	0.71	13	1.72	0.72	42	3.68	0.22	6
September	3.43	0.36	10	4.61	0.32	7	0.32	0.10	32
October	4.85	1.15	24	2.24	0.42	19	8.51	1.13	13
November	4.83	2.25	47	5.76	1.88	33	5.80	2.45	42
December	0.94	1.04	111	3.62	0.81	22	0.87	2.30	264
Year	45.49	20.41	45	49.56	23.91	48	44.00	25.49	58
	1878.			1879.			1880.		
January	5.63	3.23	57	2.43	1.25	50	3.57	2.00	56
February	5.97	3.97	66	3.56	2.76	77	3.98	2.98	75
March	4.69	6.26	133	5.14	4.16	81	....	....	....
April	5.79	2.81	48	4.72	5.38	114	....	....	....
May	0.95	2.49	260	1.58	1.99	126	....	....	....
June	3.88	0.87	22	3.79	0.71	19	....	....	....
July	2.97	0.23	8	3 93	0.28	7	....	....	....
August	6.94	0.85	12	6.51	0.70	11	....	....	....
September	1.29	0.28	21	1.88	0 24	13	....	....	....
October	6.42	0.92	14	0.81	0.13	16	....	....	....
November	7.02	2.92	42	2.68	0.35	13	....	....	....
December	6.37	5.67	89	4.34	0.82	19	....	....	....
Year	57.92	30.50	53	41.42	18.77	45	....	....	....

Here, too, although the water-shed is much smaller and should respond quicker than the Croton to the rainfall, we find no agreement between monthly rain and monthly flow. Mr. Fteley says of this water-shed: "The river, above the point where its waters are diverted, is formed by two principal affluents; the larger, draining about two-thirds of the gathering-grounds, rises in a hilly district and flows afterwards through an open valley with extensive swampy areas; the other flows through a hilly district, and although draining a territory only one-half as extensive, it has sometimes, after heavy rains, a volume as great as the larger stream. The whole water-shed controlled by the works covers seventy-eight square miles;

a portion of it (from one-sixth to one-eighth) is covered with woods; the remainder, with the exception of areas occupied by several villages, has a general agricultural character." It will be seen that this water-shed corresponds fairly well with those of our own northern streams and with the Croton. The winters set in somewhat earlier here than in our State. An examination of the table shows that the storage period usually extends from November to May. The diagrams of flow accompanying Mr. Fteley's paper also point out this fact, and further show that after May the flow steadily declines. Only in one year does it appear that the ground-water is not replenished in August, this being 1877, when there was continued low ground-water from June until October. In 1876, which was a year of great dryness on the Croton shed, heavy rains at the end of July broke the drought on the Sudbury. A careful study of this series of flows indicates that on a water-shed as small as this we must not disregard the fact that while a deficiency of rain in one month will cause a depletion of the ground reserve which must be made up in the following months, a surplus of rain will all run off and cannot be relied upon to have any effect on subsequent flow. Consequently we cannot deal with these flows in the broad way which we adopted with the Croton. We must take up the flow month by month during the dry months, beginning with June, for although May often shows less rain than evaporation, there is so much water carried over into that month from April that it cannot be treated separately, but must be included in the storage period. The actual drawing down of the ground-water does not begin until June, when vegetation has assumed a vigorous growth and the surface of the earth has dried.

SUDBURY RIVER FLOW.

TABLE OF DRY-MONTH FLOWS, SEPARATING GROUND AND SURFACE-FLOWS.

YEAR.	LAST MONTH OF FULL STORAGE.				FIRST DRY MONTH.			SECOND DRY MONTH.			THIRD DRY MONTH.		
	MONTH.	Rain.	Ground-flow.	Surface-flow.	Rain.	Ground-flow.	Surface-flow.	Rain.	Ground-flow.	Surface-flow.	Rain.	Ground-flow.	Surface-flow.
1876.....	May.........	2.76	*2.03	0.	2.04	0.38	0.	†6.60	0.23	0.10	5.22	0.72	....
1877.....	June........	2.42	0.81	0.22	2.95	0.36	0.	3.68	0.22	0.	0.32	0.10	0.
1878.....	June	3.88	0.77	0.10	2.97	0.23	0.	....	....	....	....	....	....
1878.....	August....	6.94	0.85	0.	1.29	0.28	0.	....	....	....	....	....	....
1879.....	June	8.79	0.71	0.	3.93	0.28	0.	....	....	....	....	....	....
1879.....	August....	6.51	0.70	0.	1.88	0.24	0.	0.81	0.13	0.	2.68	0.35	0.

* Largely influenced by storage in April. † Rain of 3.50 inches at end of month carried to next month. Surface-flows determined from diagrams of daily flows.

COMPUTED FLOW OF SUDBURY. DRY MONTHS.

YEAR.	MONTH.	Rainfall.	Evaporation + flow.	Excess (+) or deficiency (−).	COMPUTED FLOW. Constant.	Flood.	Total.	Observed flow.
1875	June	6.24	4.80	+1.44	0.75	0.62	1.37	1.50
	July	3.57	4.45	−0.88	0.35	0.00	0.35	0.57
	August	5.53	4.25	+0.62	0.35	0.27	0.62	0.71
	September	3.43	3.35	+0.08	0.35	0.00	0.35	0.36
	October	4.85	2.10	+2.75	0.75	0.48	1.23	1.15
	Total	....	....	....	....	....	3.92	4.29
1876	June	2.04	4.80	−2.76	0.35	0.00	.35	.38
	July	9.13	4.45	+2.61	0.35	0.45	*.80	*.33
	August	1.72	4.25	−2.53	0.25	0.00	*.25	*.72
	September	4.61	3.35	−0.64	0.22	0.23	.45	.32
	October	2.24	2.10	−0.02	0.35	0.00	.35	.42
	Total	....	....	....	....	....	2.20	2.17
1877	June	2.42	4.80	−2.38	0.75	0.24	0.99	1.03
	July	2.95	4.45	−3.29	0.25	0.00	0.25	0.36
	August	3.68	4.25	−3.04	0.22	0.00	0.22	0.22
	September	0.32	3.35	−5.31	0.10	0.00	0.10	0.10
	October	8.51	2.10	+2.42	0.35	0.85	1.20	1.13
	Total	....	....	....	....	....	2.76	2.74
1878	June	3.88	4.80	−0.92	0.75	0.00	0.75	0.87
	July	2.97	4.45	−2.17	0.25	0 00	0.25	0.23
	August	6.94	4.25	+1.06	0.35	0.35	0.70	0.85
	September	1.29	3.35	−2.06	0.25	0.00	0.25	0.28
	October	6.42	2.10	+2.77	0.35	0.64	0.99	0.92
	Total	....	....	....	....	....	2.94	3.15
1879	June	3.79	4.80	−1.01	0.75	0.00	0.75	0.71
	July	3.93	4.45	−1.28	0.25	0.00	0.25	0.28
	August	6.51	4.25	+1.30	0.35	0 32	0.57	0.70
	September	1.88	3.35	−1.47	0.25	0.00	0.25	0.24
	October	0.81	2.10	−2.39	0.22	0.00	0.22	0.13
	November	2.68	1.50	−0.61	0.10	0.00	0.10	0.35
	December	4.34	1.35	+2.53	0.35	0.43	0.78	0.82
	Total	....	....	....	....	....	3.02	3.22

* Heavy rain occurred at end of July, and these flows must consequently be taken together.

NOTE.—Flood-flows are computed for every month showing over 4 inches of rainfall, and for every month showing an excess of rain in column of Excess and Deficiency. Flood-flow taken at 10 per cent. of rainfall in June, October and November, and 5 per cent. in July, August and September. Constants of flow: June, or second month of excess, 0.75, and the first month thereafter in which there is an excess of rain, 0.35 inch; first deficient month, 0.25 inch; second deficient month, 0.22 inch; third, 0.10 inch.

TOTAL YEARLY FLOW—SUDBURY RIVER.

PERIOD.	STORAGE PERIOD. Second Excess Month to May.			DRY MONTHS.			YEAR.		
	Rain.	Observed flow.	Computed flow, 80 per cent. of rain.	Rain.	Observed flow.	Computed flow.	Rain.	Observed flow.	Computed flow.
Jan. to Oct., 1875............	16.10	12.83	12.88	23.62	4.29	8.92	39.72	17.12	16.80
Nov., 1875, to Oct., 1876...	21.37	20.09	17.10	19.74	2.17	2.20	41.11	22.26	19.30
Nov., 1876, to Oct., 1877...	23.07	18.71	18.46	17.88	2.74	2.76	40.95	21.45	21.22
Nov., 1877, to Oct., 1878...	23.91	21.06	19.18	21.50	3.15	2.94	45.41	24.21	22.07
Nov., 1878, to Dec., 1879...	23.84	21.21	19.07	23.94	3.22	3.02	47.78	24.43	22.09

Beginning with June, we find that the supply to our shed is confined to the rainfall; the draught is the evaporation, plus the flow from storage, plus a certain amount of surface-flow, or waste, part of which is extra evaporation from shallow pools of water lying on the surface. The greater part of this draught is caused by the inexorable demands of vegetation, which must be met either by rain or ground-water. For convenience, we assume that this draught is constant for a given month, and it really is nearly so. Evaporation, plus waste, has been found to be about as follows: June, 4.80; July, 4.45; August, 4.25; September, 3.35; October, 2.10; November, 1.50; December, 1.35 inches. I have arranged the dry-month flows in a table, in the order of their occurrence from full storage, and from this it is found that the constants of flow, *i. e.* the flow from ground-water, closely approximate the following: A month beginning with full ground-water will yield 0.75 inch flow; a month during which the ground-water has been replenished will yield in proportion to the earliness of the day on which the replenishment took place. For safety, 0.35 inch has been assumed for ground-water flow in such a month. The first month thereafter showing a deficiency of rain will yield 0.25 inch; the second, 0.22 inch; the third, 0.10 inch.

Our first problem, therefore, is to find which are full and which are deficient months. We saw, in considering the Croton shed, that when there is a marked deficiency of rain, evaporation from deep ground-water is somewhat retarded. We estimated that 25 per cent. of the deficiency might represent this retardation. These considerations are the basis for our table of computed flows for dry months.

TABLE OF COMPUTED DRY-MONTH FLOWS.

To find the excess or deficiency for a given month we take rainfall, less draught, less 0.75 of previous month's deficiency. An excess in previous month will have no effect on the flow, unless a heavy rain occurred close to the end of the month. In June, or any second consecutive month showing an appreciable excess, the flow will amount to 0.75, plus a flood-flow, which will be 10 per cent. of rainfall in June, October and November, and 5 per cent. in July, August and September. The constants of flow for other months will be for first deficient month, 0.25; second, 0.22; third, 0.10 inch; for first month in which we have an excess of rain, 0.35 inch. To these constants a flood-flow must be added for all rainfalls exceeding 4 inches in deficient months, and for all rainfalls in months showing an excess, using the percentages of rainfall above given for flood-flows.

In these computations, as on the Croton, the aim has not been so much to deduce a rule which would adhere closely to the observed flows as to secure one, based on correct principles, which would always be safe in low-cycle years, when applied to a record giving only monthly rainfall. It is but fair to point out that any such rule will not give the flow for exactly the same month in which the rain fell, but for a month, a few days later, giving the water enough time to reach the point of gauging. It is not to be expected that our flows will exactly correspond month by month with the observed flows, therefore, but rather that they should exhibit about the same range of extremes and the same length of dry periods. This they seem to do.

FLOW DURING STORAGE PERIOD.

This is shown in the table of yearly flows. So far as these records show, 80 per cent. of the rain during this period may be collected. If we compare with the Croton, however, it does not seem probable that this estimate is entirely safe. No conservative engineer would estimate higher than 70 per cent. for this period, lacking more lengthy observations.

CONNECTICUT RIVER FLOW.

The Connecticut river was carefully gauged at Hartford by Theo. G. Ellis, C.E., U. S. Army Engineer Corps. This valuable series extends from 1871 to 1878, inclusive. The daily flows have been partly reduced and charted for use in the office, since this example of a larger water-shed is most desirable, many of our stream basins being considerably larger than the Croton, and this, moreover, has enough points of similarity to the Delaware shed to make it most valuable as a standard by which to compute the flow of that stream.

The Connecticut shed has an area of 10,234 square miles above Hartford. The monthly flow falls as low as 0.7 inch in summer. As soon as proper contemporaneous rainfall statistics can be secured, these flows will be discussed and utilized. A comparison with Croton flows shows that the main differences are a minimum monthly flow of 0.70 against 0.32 inch on the Croton, a lighter early winter flow, and heavier and longer-sustained spring storage-flow, lasting usually into June.

OBSERVED FLOW OF NEW JERSEY STREAMS.

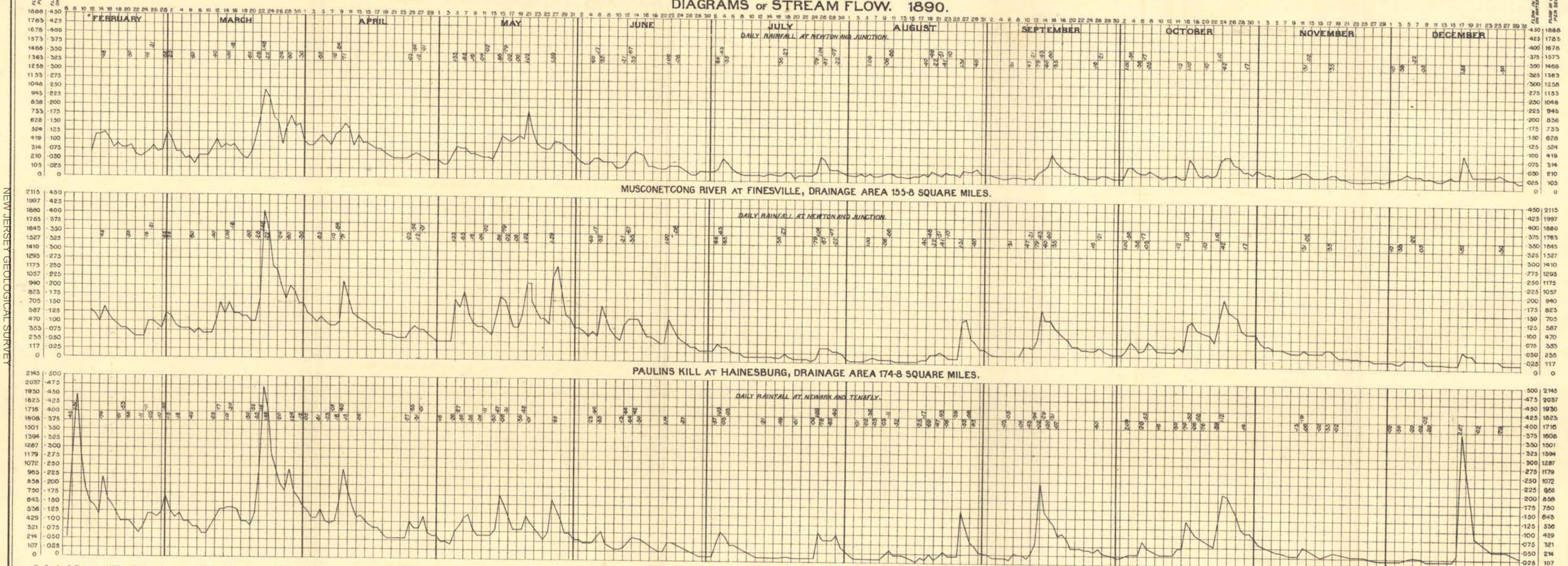
The following observations of flow are necessarily approximations, but they are believed to be quite close ones, and until it is possible to secure more accurate data they will be a safe indication, so far as they go, as especial care has been taken not to overrate the flow. Most of them were taken at dams, and the flow was computed by such weir formula as careful observation of the form of contraction and other conditions showed to be best adapted to the case. It is intended to thoroughly check them by channel-gauging, but this work is still incomplete. The several diagrams of flow accompanying have been selected to show typical streams. The Paulinskill is a type of Kittatinny valley streams; the Musconetcong of streams of the southwestern Highlands, although this diagram shows the effect of the storage afforded by Lake Hopatcong; the Pompton is a type of northeastern Highland streams; the Passaic, above Little Falls, is a large Highland stream and one of the most important of the State; the Raritan represents a mixed type, with its headwaters on one side in the Highlands and on the other in the clay and marl districts, with the larger part of its shed on the red sandstone plain, devoid of forests and under a high state of cultivation; while the Great Egg Harbor river is typical of the pine-forest streams of Southern New Jersey. The State is well represented in these diagrams. All have been reduced to inches on the water-shed, *i. e.* the flow for 24 hours is given in thousandths of an inch on the drainage area. By the side of the figures giving these inches the equivalent flow in cubic feet per second is given. By this method of charting the greatly-varying volume of flow due to difference of area is eliminated, and we can compare flow and rainfall, and the flow of one stream with that of another, more readily. The rainfall is given daily in inches, and where two or more stations are mentioned, the average rainfall is shown. It will be seen at once that the Raritan is the most fluctuating stream, for its area of water-shed, in this group. This is due not merely to the fact that it is deforested and its soil largely underdrained, but to the shape of its water-shed, which is such that all of the flood-flows from various branches are likely to meet between South Branch and Bound Brook, a few miles above the point of gauging, and the entire flood-flow must be discharged within a few hours, there being little low ground in the valley over which the waters can spread themselves; but more will be said of this when this river comes up for consideration in its regular order.

RAINFALL OBSERVATIONS.

I am indebted to Mr. E. W. McGann, of the State Weather Service, for my daily observations of rainfall. He has been at much pains to furnish me the necessary data when my wants extended beyond the limits of his printed tables of rainfall, which he has published only since June, 1890. The value of this work cannot be over-estimated, and when it is put upon a permanent basis much will have been done toward securing the data for more complete studies of phenomena of stream-flow, evaporation and percolation in the State.

We have good records of monthly rainfall extending back 65 years at Philadelphia, 92 years at Trenton and Morrisville, 47 years at Lambertville, 37 years at New Brunswick, 48 years at Newark and 55 years at New York, in continuous series, with a series 24 years in length at Lake Hopatcong, representing our Highland rainfall, and several shorter ones scattered over the State. These will give us about as great extremes of rainfall as are ever likely to occur, and will form the basis of our computations when our gaugings have progressed far enough to give us the necessary factors of flow.

DIAGRAMS OF STREAM FLOW. 1890.



MUSCONETCONG RIVER AT FINESVILLE, DRAINAGE AREA 155·8 SQUARE MILES.

PAULINS KILL AT HAINESBURG, DRAINAGE AREA 174·8 SQUARE MILES.

RAMAPO RIVER AT POMPTON, DRAINAGE AREA 159·5 SQUARE MILES.

Geological Survey of New Jersey. Report on Water Supply and Water Power.

JULIUS BIEN & CO. PHOTO LITH. N.Y.

STREAMS OF NORTHERN NEW JERSEY.

For a topographical description of these stream basins the reader must be referred to the Physical Description of New Jersey and the Topographic Maps. Only a few of the important peculiarities can be touched upon here. We will first take up the streams which have been gauged, and afterward give what data we can as to the others.

PAULINSKILL.

This stream lies in the main axis of the Kittatinny valley, which it drains for 25 miles, from Augusta southwestward to the Delaware. The lower 18 miles of the water-shed is quite uniform in width, averaging 7 miles, with its western border on Kittatinny Mountain from 1,000 to 1,200 feet above the stream, and its eastern border on a slate ridge about 400 feet above. The upper part widens out to 12 miles and has some swampy areas, which have been partially drained. The fall for the first 10 miles from the mouth averages 7 feet per mile, with little variation; for 20 miles above this it is 8.5 feet per mile, also very uniform. The distance by the stream from the remotest source to the mouth is about 36 miles. The bottom of the valley is blue limestone; the higher portions of the shed mainly slate. About 25 per cent. of the area is in forest. Much of the lower portion is in permanent pasture, while the ridges are devoted to general farming.

A gauge was set up at the mill of Messrs. G. C. Adams & Co., at Hainesburgh, about 25 miles above the mouth of the stream, and read by Mr. A. D. Cornell. There is a small amount of leakage through the dam, but not enough to cause any serious error. There are several mills above, but none of them have very large ponds, and while they hold back some water, it is not probable that the minimum flow for any week is very much reduced thereby, although the observed minimum for a single day probably is.

The following table gives the flow by months, in inches, on the water-shed, and also the maximum, minimum and average flow in cubic feet per second. The rainfalls given are means of observations at Newton and Junction. Newton is on the water-shed, while Junction is not, but it is believed that the mean of the two better represents the actual rainfall than Newton alone would do:

FLOW OF THE PAULINSKILL, 1890.

Water-shed, 174.8 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND. Greatest.	Least.	Average.
February 12th to 28th	1.97	1.58	655	272	437
March	6.15	4.44	1,894	317	672
April	2.81	2.88	996	272	451
May	6.58	3.88	1,219	229	470
June	3.42	2.29	726	146	357
July	5.30	0.71	229	43	108
August	5.21	0.73	597	29	112
September	4.01	1.60	726	111	249
October	5.17	2.31	868	165	352
November	0.69	1.20	423	95	188
December	3.07	0.66	230	63	99
Total	44.38	22.88	Flow = 52 per cent. of rainfall.		

For years of similarly large rainfall the Croton flow varies from 47 to 49 per cent. of the rainfall. The Sudbury flow is from 45 to 58 per cent. In this respect, therefore, there is no marked difference in the Paulinskill flows. The year has not been favorable for the determination of minimum flows, as the rainfall has been in excess. The least average flow for any week was from August 10th to 16th, 42 cubic feet per second; the next low week being the previous one which shows 45 cubic feet per second. A peculiarity of the year was the very small November rainfall, which caused a low run of the stream up to the storm of December 17th. From October 24th to December 17th, the total rainfall was 0.92 inch for 55 days. This was the driest period of the year. After the subsidence of the flood-flow from the storm of October 23d, which took place about November 3d, the flow for the first 30 days was 1.08 inches. For December, exclusive of a slight surface-flow after the 17th, the flow was 0.57 inch. These flows were practically all from storage.

In June, although there was no surface-flow carried over from May, the underrun of the stream, excluding surface-flow, was 1.73 inches. The rainfall was deficient for the month, or less than evaporation, and all of this flow must have been from storage—ground and surface. Swartswood and Culver's lake have both been utilized as reservoirs for mills, and are controlled for a depth of four to five feet, with extreme variations in height of 5.5 feet at Swartswood and 6.5 feet at Culver's. These and other lakes on the water-shed represent a total storage of 0.7 inch on the entire water-shed, which storage is allowed to flow pretty freely to feed the respective mills. This and the additional storage afforded by the meadows near Newton account for a very large first-month storage-flow. In July, the second month of deficient rain, as determined by the method pursued with the Sudbury river, the flow was 0.71 inch. In August, when the ground-water seems to have been replenished near the close of the month, there was a flow for the first 20 days at the rate of 0.30 inch per month. The flow due to ground-water on the Sudbury and Croton was about 0.75 inch the first month, 0.25 the second and 0.22 the third. Excluding the effect of surface-storage, it does not appear from the data in hand that the constants of flow for this stream will differ very much from this.

The surface or flood-flow percentages are evidently higher than for the Sudbury, and flood-flows occur with less monthly rain than on that water-shed. June, with 3.42 inches rain, gives a flood-flow of 0.56, or about 17 per cent., against 10 on the Sudbury.

From flood-marks at Hainesburgh the flood-discharge seems to be limited to 4,126 cubic feet per second, or 23 cubic feet per second per square mile of water-shed. The long, narrow shed below, and flatness of the upper, broad portion, favor a gradual discharge of surface-water. In cases of single heavy showers the time from the height of the shower to the height of the flood at Hainesburgh, does not exceed 24 hours. The duration of flood-flows is from 4 to 8 days, although the water is not over the river banks much more than one-quarter of this time. The discharge reaches 1,800 cubic feet per second before the banks are overtopped, or about 10 cubic feet per second per square mile. The following notes were made at various places on the stream:

Hainesburgh.—Water lowest this year (1890) of the past three years. Flood of September 18th, 1888, 4,126 cubic feet per second, or 23 cubic feet per second per square mile.

Kalarama.—Painter's mill is on a small branch of Paulinskill; drainage area, 1.7 square miles. Flood over in one day after heavy rain. Enough water to run 25 horse-power for three months of year; six months, 12 to 14 horse-power, and three months in summer, about 6 horse-power. It is estimated from this that this small stream has a summer flow of about 2.4 cubic feet per second, or 1.4 per square mile.

Jacksonburgh.—In drought of 1881 Mr. Samuel McConachy ran four hours by storing up the water. His mill is on a small branch of Paulinskill, having a drainage area of 7.8 square miles. His statements indicate a minimum flow of 1.9 cubic feet per second, or about 0.25 per square mile. Storm felt for only one day in stream.

Paulina.—Mr. A. U. Snover's mill, on the main stream, had enough water for one stone in the great drought of 1881, indicating a minimum flow of 17 cubic feet per second, or 0.13 per square mile, the water-shed being about 126 square miles. Rises within a day and stays up three or four days after a heavy rain.

Stillwater.—Mr. H. Hopler gives an extreme dry-weather run of mill, which indicates a flow of 16.5 cubic feet per second; agreeing closely with the figures at Paulina. Kill gets high in five hours and stays up one to two days, then recedes. Does not get very muddy.

Balesville.—From Mr. A. J. Bale's statements a flow of 6.3 cubic feet per second represents the minimum. The water-shed is about 50 square miles, indicating a flow of 0.126 cubic feet per second per square mile. The flow is steady. After a heavy rain the kill rises in a day and stays up two or three days. This is the highest mill on the main stream. Above this there are two branches.

Lafayette.—O. P. Armstrong's mill. Stream very steady. Does not rise rapidly unless the meadows are full of water; then it will be high in a day after a storm and take eight or ten days to run down. This is the eastern fork, and just above is the outlet of the Paulinskill meadows. The western branch has a rapid fall and steep water-shed. It rises suddenly and floods are of short duration.

Swartswood Lake.—This lake is utilized for storage for the mill of John W. Kean, Esq., on the outlet. The extreme variation between low and high-water levels is 5.5 feet, representing a storage of 121,000,000 cubic feet. Even with the large storage the flood-flow at the outlet has reached 1,070 cubic feet per second, or 65.8 cubic feet per second per square mile of water-shed. With this great storage the power at the outlet is a very good, reliable one, always sufficient for three run of stone on 17 feet head. The water-shed is about 16 square miles and this is a good example of successful utilization of a small water-shed for power by means of storage.

Culver's Lake, at Branchville, is also utilized for storage for mills. It has a storage capacity between extreme levels of 137,000,000 cubic feet.

PEQUEST RIVER.

This stream lies at the eastern side of the Kittatinny valley. In the midst of its water-shed, Jenny Jump Mountain, a ridge of gneiss, rises and covers some 17 square miles, the total area of the water-shed being 158.2 square miles. The southern and eastern border of the area is also on the gneiss, but most of it lies upon the blue limestone, and 30 square miles of this is very level, the remainder of the water-shed being of about the same slope as the Paulinskill. The length of the main stream is 32 miles from its remotest source, near Pinkneyville, to its junction with the Delaware river at Belvidere. Its principal affluent is Beaver brook, which comes in from the north two miles from the mouth and drains 37 square miles. The fall of the main stream for the lower 10 miles is 27 feet per mile; for four miles above this it is 2.5 feet per mile; and this brings us to the outlet of the great Pequest meadows which were drained some years since. These meadows have an area of about eight square miles, and before being drained they were extremely wet, under water much of the time, but they are now being brought under cultivation. In 1885 they were nearly half in timber, but this is now being cut off. The fall of the stream for five and one-half miles through these meadows is four feet per mile; the next six miles have a fall at the rate of 4.5 feet, and the valley continues nearly level to the source of the stream, which flows through a chain of small lakes. There is much drift on the basin, as it is crossed by the terminal moraine. Forest covers 18 per cent. of the shed. A gauge was set up at Belvidere and read

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from February 12th to July 24th by Mr. Clinton Cole. Unfortunately he left Belvidere, and there is a gap in the record until October 1st, when it was resumed by Mr. I. B. Keener.

FLOW OF PEQUEST RIVER.

Drainage Area, 158.0 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
February 12th to 28th	1.96	1.62	561	286	405
March	6.15	3.97	1,016	290	544
April	2.81	3.34	796	264	459
May	6.58	3.07	584	209	425
June	3.42	2.43	505	100	344
July 1st to 24th	2.02	0.76	319	58	127
August	....	....	....	....	....
September	....	....	....	....	....
October	5.17	2.17	428	145	306
November	0.70	1.47	312	132	208
December	3.07	1.08	327	95	149
Total	31.88	19.91			

The same rainfall observations are used as for the Paulinskill. This record seems to show a better-sustained flow than that of the Paulinskill, but there are some points of marked similarity in the diagrams of daily flow. The lowest weekly average flow in this record was, July 13th to 19th, 105 cubic feet per second; the same week on the Paulinskill giving 78 cubic feet per second. We have also the following gaugings, which were furnished me by Mr. A. B. Searles, having been taken by Mr. O. P. Lewis, during a time of low water:

Nov. 16th, 1874, 3:30 to 4:00 P. M., 66.45 cubic feet per second.
Nov. 17th, 1874, 1:30 to 2:30 P. M., 58.26 " " " "
Nov. 18th, 1874, 10:45 to 11:30 A. M., 57.38 " " " "

These agree closely with the lowest observed flow in July of this year. During the dry period last November, noted in discussing the Paulinskill flows, the Pequest discharged in the first 30 days 1.40

inches, and during the second month 1.08 inches. In June, the flow was 2.43 inches against 2.29 inches on the Paulinskill. In July, the flow for 24 days was at the rate of 0.93 inch for the month. These facts all point to higher constants of flow than any of the streams which we have considered. This comes from the great storage afforded by the drift gravels and the flat meadows above.

The surface-flows show much less fluctuation than on the Paulinskill. The floods do not reach a great height and require more time to discharge. The waters from the lower part of the main stream, where the slopes of stream and water-shed are steep, discharge first and are out of the way before the slow-moving floods from the flat upper shed have come down. The height is reached at Belvidere in about 36 hours, but the waters are not discharged in less than from 7 to 10 days. The contracted outlet and small preparation for heavy flood-discharges are noticeable at Belvidere. The highest flood-marks pointed out indicate a flow of 1,996 cubic feet per second, 12.5 per square mile, and this must be the extreme limit. This is a light discharge for Northern New Jersey.

At Ketcham's mills, one mile below Townsbury, the flood is said to reach its height in from 12 to 24 hours, remain high for two days and then recede slowly. Mr. Ketcham thinks the river is more fluctuating than it was before the drainage of the Pequest meadows, and gets lower in summer. Mr. John Green, at the mill just above, thinks that the drainage has improved the summer flow of the stream, as there is less loss from evaporation than from the great overflowed area of former years. The majority of the mill-owners seem to hold the latter opinion. The maximum discharge at Townsbury seems to be about 800 cubic feet per second, on 83.4 square miles of water-shed; about 9.6 cubic feet per second per square mile. As this point is at the outlet of the flat upper shed and the steeper parts are not involved, it appears to agree well with the observed discharge at Belvidere.

The dry-season flow here has been estimated from the run of mill to be about 14 cubic feet per second. This was in the great drought of 1881. The rate would be 0.17 cubic feet per second per square mile.

At Tranquility the maximum flood-flow indicated is 650 cubic feet per second, or 18.7 per square mile. At Huntsville, the greatest known discharge was 605 cubic feet per second, or 19.3 per square mile. These last two places are both above the Great Meadows, and the increase of flood-flow over Townsbury is apparent, but the drainage area is still very flat. The flood at Huntsville, referred to, remained very high for two days. The river does not get very muddy in floods.

Green's pond has a capacity of 10,000,000 cubic feet between its extreme levels. This is all natural storage. Hunt's pond is utilized for storage for the mill of T. F. Hunt, Esq., with a capacity of 7,245,000 cubic feet. Allamuchy pond is also utilized, with 27,000,000 cubic feet capacity. The flood-flow at its outlet is 40 cubic feet per second for 1.7 square miles of steep water-shed on Archean rock. With the same area on slate rock, with gentler slopes, Hunt's pond gives a maximum of 43 cubic feet per second. This is another good example of the utilization of a very small water-shed for power by means of storage. Mr. Hunt has always enough power for one run of stone in the dryest weather on 30 feet fall.

MUSCONETCONG RIVER.

This stream has a long, narrow water-shed in the Archean Highlands. The higher ground is Archean rock, quite well covered with soil; the valley bottom is limestone, with some slate in the foot-hills. The width at the mouth is 2 miles, very gradually increasing to 4 at Hackettstown, 26 miles up the valley, then narrowing to less than 3 to 6 miles farther up, at Waterloo. On these 32 miles of the course the stream flows at the southeast side of a very straight valley, above which the hills rise from 400 to 500 feet. Just above Waterloo the main stream comes into the valley from the plateau southeast, while the upper part of the straight valley is occupied by the principal affluent, Lubber's run. The combined sheds of the two forks widen out to 6 miles, and extend 12 miles northeast from Waterloo. This upper area is quite largely covered with drift, and is more wooded than the lower parts. Lubber's run has 87 per cent., and Lake Hopatcong 94 per cent. of its area in forest. On both branches there has been a considerable amount of storage utilized by the Morris canal, to feed that water-way. Lake Hopatcong has a drainage area of 25.4 square miles, and has been raised by a dam at the outlet so as to give a storage of 1,100,000,000 cubic feet. This storage is used to feed the canal in both directions, so that some of the waters of the Musconetcong are diverted to the eastern slope of the State. "It is stated that the Stanhope mill has rights to the original power at the outlet, and that an opening of 10 by 36 inches is kept for the purpose of supplying the mill." (Newark Aqueduct Board, report on Additional Water-Supply, J. J. R. Croes and George W. Howell.)

Stanhope reservoir, two miles below, affords additional storage.

On Lubber's run, Cranberry reservoir and Bear ponds are utilized for storage. This complicates the flow of the stream somewhat. There is naturally much disagreement between the canal company and the many mill-owners on the lower part of this valuable water-power stream. It is evident, from the diagram of this year, that the flow has been kept up during the dry months by allowing some water to run from storage. How it may be in very dry years is not evident, of course. There is a marked difference of opinion among the mill-owners themselves as to whether they are benefited or injured by the storage. The diagram which appears herewith shows the effect of storage, not only in the dry-season flows, but in the cutting down of flood-flow, as compared with other streams.

The source of this stream is in the Sparta Mountains, near the Pine swamp, 52 miles from the mouth. The fall for the lower 8 miles, is 16 feet per mile; the next 22 miles, from Hackettstown to Bloomsbury, have 12 feet per mile; from the mouth of Lubber's run to Hackettstown, 8.5 miles, the fall is 16 feet per mile; while from Lake Hopatcong down to the valley of Lubber's run, the stream falls 55 feet per mile, for 5 miles.

A gauge was set up at Finesville, at the mills of Messrs. Taylor, Stiles & Company, and taken in charge and carefully read by these gentlemen. These gaugings are believed to be very close to the truth, the overfall being favorable to good results. Several gaugings of the Morris canal flow were also made. The following table gives the results:

FLOW OF THE MUSCONETCONG, 1890.

Drainage Area, 155.8 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	Flow in cubic feet per second.		
			Greatest.	Least.	Average.
February 12th to 28th	1.97	1.41	512	227	348
March	6.15	3.22	1,019	148	436
April	2.81	2.59	632	206	360
May	6.58	2.76	801	166	377
June	3.42	1.32	334	72	184
July	5.30	0.83	265	61	113
August	5 21	0.72	166	61	96
September	4.00	0.83	357	61	117
October	5.17	1.20	334	89	167
November	0.70	0.80	188	72	113
December	3.07	0.97	384	72	130
Total	44.38	16.65			

Gaugings of the Morris canal indicate an average summer flow of 100 cubic feet per second, which is drawn from this water-shed. The winter flow may be taken at 80 cubic feet per second. This is equivalent to a draught of 0.72 inch per month, on the Musconetcong water-shed, for the eight months of navigation, and 0.57 inch per month for the winter months, making a total of 8 inches for the year, or 7.25 inches for the above period of gauging. Adding this, we have a total flow for the period of 23.90 inches. The Paulinskill shows 22.29 inches for the same period. The canal runs through the river at Waterloo, Stanhope and Saxton's Falls, complicating matters so that no actual gauging of the amount of flow from storage to the stream could be made. The above measurements indicate a general resemblance between this stream and the Paulinskill and Pequest.

At Finesville, it appears, from the statements of Messrs. Taylor, Stiles & Co., that the river has not run much lower in the last six years than the above record indicates. It requires four hours for the water to reach here from the mills just three miles above, which would indicate a velocity of 0.75 mile an hour. The maximum flood-flow, indicated by high-water marks here, is 1,960 cubic feet per second, about 12.8 per square mile, which seems very small, but is apparently correct. An ordinary flood discharges about 1,500 cubic feet per second. It should be noted that the extremely narrow lower shed and storage on the upper area both contribute to reduce the rate of discharge.

At Bloomsbury, Mr. F. G. Hoffman places his dry-season power at a rate equal to about 70 cubic feet per second.

At Imlaydale Mills, Mr. S. S. Cramer has a well-equipped mill, which indicates a low-season flow of a little less than 56 cubic feet per second.

At Stephensburg, the mill can run two run of stone about all the time, indicating a flow of 35 cubic feet per second.

At Hackettstown, Mr. Lewis J. Youngblood reports that he has not stopped his mill more than 30 days since 1863 for lack of water. He runs three run of four-feet stones, on 9.5 feet fall, with a breast-wheel. He uses about 70 cubic feet per second, and has a considerable pondage. At the saw-mill above, 12 horse-power was obtained all through the drought of 1881, on eight feet fall, indicating a flow of 26 cubic feet per second. The stream here is said to reach its height 24 hours after a heavy rain and requires two weeks to run down to its ordinary stage. At Saxton Falls, where the Morris canal and the river finally separate their flows, the flood-flow of the river is 1,080 cubic feet per second, the water-shed being about 68 square miles. This is at the rate of 15.9 per square mile, a low rate, agreeing with that at Finesville.

Many notes have been made indicating the peculiarities of other Kittatinny valley streams which have not been gauged, but these notes need not be given here, as they will be mostly valuable to indicate points of similarity or dissimilarity to the typical streams which we make use of in determining general laws, when we come to take up the several streams in detail later on.

DELAWARE RIVER.

This stream is a most interesting study in hydrology, and the results of a thorough investigation of it could not fail to be of great economic and scientific value. It has not been possible to do much with the gauging of it as yet. The only data which we have been able to obtain were some relating to maximum and minimum flows. At Centre Bridge a mark was made by Col. Simpson Torbett and Martin Coryell for the very low water of 1831, and since then, in 1879 and 1881, very low stages have been referred to the same mark. The mark is on the New Jersey abutment of the bridge. In 1831 the water was 12 feet below this mark; in 1879 12.5 feet, and in 1881 13.21 feet. (See Climatology, page 375.) During the past summer a section of the river was carefully measured and sounded a few hundred feet below the bridge, and the velocity of the current measured with mid-depth floats. Surface velocities were also measured in the same vertical. The mid-depth velocities averaged 0.85 of the surface velocities and the variation was very slight. The slope of the river was determined by leveling, and a computation of the mean velocity by means of Ganguillet & Kutter's formula gave 2.66 feet per second against 2.85 feet per second observed with mid-depth floats. This fair agreement was taken to establish the applicability of this formula to this portion of the stream. (N = .024 was selected from examples of similar gaugings.)

The flood section was carefully measured at the point of gauging, and the average slope of the stream bed for six miles above was found to be 3.22 feet per mile, or 0.61 feet in one thousand. Levels were taken for the surface slope of a slight flood of November 1st and found to show 0.42 feet in one thousand. From these observations it seemed conclusive that the slope of the flood of 1841 was 0.61 per thousand and this is borne out by comparison of known high-water marks. On this slope and the measured cross-section a computation of the flood discharge was made by Ganguillet & Kutter's formula, the results being given in the table below. (R = 20.28, N = .024, S = .0006.)

For the minimum flows the heights of the different surfaces were platted on the measured cross-section and the respective cross-section areas measured. The river slope was supposed to remain constant at what it was at the date of gauging, 0.24 in one thousand; it could not fall below this materially. The only material error in these assumptions arises from the lowering of the bed by erosion during the 59 years intervening between the first and last gauging. The effect of this would be to overrate the discharge for 1831, but the error is not believed to be serious.

In order to get the total flow from the water-shed, the feeder of the

Delaware and Raritan canal and the Pennsylvania canal were both gauged, the flow of the former being ascertained to be 515.5 cubic feet, and the latter 59.4 cubic feet per second. This total flow of 575 cubic feet was added to all gaugings save that of 1831, which antedates the construction of the canals. The following are the measured discharges, the first two being at the time of gauging with the river at an ordinary autumn stage, having been receding since the flood on the first instant, and at this time just beginning to swell again slightly:

COMPUTED FLOWS OF THE DELAWARE AT CENTRE BRIDGE.

Drainage Area, 6,790 Square Miles.

DATE.	Mean velocity—Feet per second.	Area of cross-section—Square feet.	CUBIC FEET PER SECOND.		
			Stream-discharge.	Canal flow.	Total discharge.
November 18th 1890	2.85	3,276	9,352	575	9,927
November 19th, 1890	2.93	....	10,021	575	10,596
DROUGHTS.					
September, 1881	1.31	850	1,113	575	1,688
November, 1879	1.71	1,319	2,255	575	2,830
Autumn, 1831	1.89	1,599	3,022	0	3,022
FLOODS.					
November 1st, 1890	5.89	8,425	49,623	575	50,198
January 18th, 1841	10.76	17,645	189,860	*1,000	190,860

During a discussion of the flow of streams at a meeting of the American Society of Engineers, of which he was then Vice President, the late Ashbel Welch, C.E., gave the following information. This was November 3d, 1879:

"The river Delaware discharges, at the dryest seasons, a little less than 2,000 cubic feet per second. * * * When I first knew the Delaware, nearly half a century ago, the minimum flow was probably 4,000 feet per second, twice as much as now.

"The 2,000 cubic feet per second was a measurement some years ago; the 4,000 cubic feet was a very rough measurement at the time

*The canal was discharging freely at this time, having broken its bank near Lambertville.

in various ways, none of them accurate, but still corroborating each other, so that I probably got results within 10 per cent. of the truth."

These statements agree with the results of our gaugings. No such figures can be taken as conclusive proof that there is a falling off in the summer flow of the Delaware. The rainfall records at Philadelphia certainly fail to show any comparison in dryness between 1831 and 1881. The latter drought was far more severe, and until we have gaugings for one or more equally dry years previous, we shall have no evidence that the flow of 1881 was exceptionally low. True, the opinion of so careful an observer as Mr. Welch is entitled to the greatest respect, but no one can claim it to be proven that there is a falling off in the flow. The weight of opinion and testimony is in favor of such an inference. It must be remembered, however, that great extremes of recent occurrence always overshadow earlier ones, seen in the dim perspective of memory only, and the most experienced mind cannot compare them with full justice to the earlier phenomena.

This is mentioned because of the fact that much similar evidence has been used to prove the effect of denuding water-sheds of their timber in decreasing the flow of streams. I have found no evidence of this in New Jersey, nor do I expect to find it, although I shall look for it most carefully. The fact is, that New Jersey forests were cut at a very early date, and have since grown again several times, being now cut like other crops, a piece here and one there, the other areas meanwhile becoming reforested. Probably the greatest period of deforesting was just at the close of the epoch of charcoal furnaces and forges. The evidence is strong that the cutting off of heavy virgin forests will cause more frequent floods, and that such has been the effect on the Delaware; it is reasonable to suppose that the summer flow will also be somewhat affected, but competent evidence of this is very difficult to obtain.

As to the flood-discharge, Mr. Welch gave it as his opinion that it reached 350,000 cubic feet per second. The above discharge of 190,860 cubic feet per second is believed to be the largest that ever occurs, for the area of cross-section for highest flood at Centre Bridge is about uniform for some distance, and the river banks are steep, the flood-width being only 140 feet wider than the width of the river at ordinary stages. These banks are of gravel and sand. Any higher velocity than that above given would cause much greater erosion than is apparent, and indeed it is difficult to see how even a mean velocity of nearly 11 feet per second is withstood.

The area of the water-shed above Centre Bridge is about 6,790 square miles, so the above flood-discharge is at the rate of 28.1 cubic feet per second per square mile. It is equal to a flow of 1.05 inch on the shed in 24 hours. The minimum flow in 1881 was at the rate of 0.25 cubic feet per second per square mile. The minimum flow of the Connecticut is said to be from 0.25 to 0.30 cubic feet per second per square mile, and the maximum, about 20. The Schuylkill dry-season flows, for several years, are given in the Census Report on Water-Power, and are interesting in this connection:

DRY-SEASON FLOW OF THE SCHUYLKILL.

Drainage Area, 1,912 Square Miles.

1816	771 cubic feet per second.
1825	680 " "
1867	617 " "
1874	380 " "
1876	310 " "

The last is at the rate of 0.165 cubic feet per second per square mile.

Of the Delaware floods, Mr. Welch says:

"The discharge in the highest flood ever known before 1841, that of 1787, was not more than two-thirds as much as that in the great flood of 1841."

J. J. R. Croes—"Has there been any great flood since 1841?"

Ashbel Welch—"There have been two, one of which was nearly if not quite as high. The flood of 1841 and two subsequent floods must have discharged nearly twice as much water as any previous floods since 1787, and 50 per cent. more than the flood of 1787. I suppose that there is not, at the lowest stages, more than half the water in the Delaware that there was half a century ago, and that the highest floods carry off 50 per cent. more per hour than any flood known before 1841." (Trans. Am. Soc. C. E., July, 1881, page 243.)

In the Annual Report of the Chief Engineer, United States Army, for 1873, Appendix U 19, there is a full report on the Delaware between Easton and Trenton, made by Assistant Engineer Mansfield Merriman. The following notes of floods, known locally as "freshes," have been abstracted:

"The time required to bring a raft from these points to Easton varies with the height of water and direction and force of wind. In ordinary rafting freshets of five to ten feet (*rise*), however, the time appears to be, from Delhi to Easton, 165 miles, 40 to 48 hours; from Walcott to Easton, 165 miles, 40 to 48 hours; from Hancock to Easton, 125 miles, 30 to 36 hours; from Callicoon to Easton, 100 miles, 24 to 30 hours; from Easton to Trenton the time is from 10 to 12 hours; so that the entire trip from Walcott or Delhi to tide-water is performed in from 50 to 60 hours, showing the mean velocity to be from 4.3 to 3.6 miles per hour.

"In general it may be said that the river is subject to three classes of floods: the ice floods, which happen at the breaking up of the river; the rafting floods, occurring later, from the spring rains, and the fall floods, caused by the storms of September and October, which, however, are very irregular.

"The ice floods, at Easton, are usually from 10 to 20 feet in height, but on many occasions have been known to rise much higher, the 'great flood' of 1841 having reached 35 feet. The great accumulation of water here is owing to the influx of the Lehigh, a very turbulent stream in time of freshets, and to the narrow, steep banks between which the Delaware is confined, its width being less than 600 feet.

"The rafting freshets in the spring are of less rise, but of longer duration than the ice floods; at Easton, ranging from 3 to 10 feet; at Lambertville, 1 to 8 feet, and at Trenton, 1 to 6 feet. A very remarkable rise, however, occurred on June 8th, 1862, which was 32 feet at Easton, and next to that of 1841, the greatest flood on record.

"The following is a partial list of the 'great floods,' with the heights to which they rose, as nearly as can now be ascertained:

NAME OF FLOOD.	DATE OF OCCURRENCE.	HEIGHT TO WHICH IT ROSE ABOVE LOW WATER.
Pumpkin fresh..........	October 6th, 1786.......	16 feet at Lambertville.
	—— —, 1798..	Not as high as last, but exact height not known.
Jefferson fresh..........	—— —, 1801........	14 feet at Lambertville.
	—— —, 1814........	14 feet at Lambertville.
	March —, 1832.......	12 feet at Lambertville.
	April —, 1836.......	14 feet 6 inches at Lambertville.
	April —, 1839.	14 feet 6 inches at Lambertville.
Great flood...............	January 8th, 1841..	35 feet at Easton, 23 feet at Bull's Island, 20 feet at Lambertville, 28 feet at Lamsin's island.
	October 13th, 1843.......	14 feet at Lambertville.
	March 15th, 1846........	17 feet 6 inches at Lambertville.
June fresh.	June 8th, 1862..	42 feet at Easton.
October fresh	October —, 1869.......	Exact height not known.

"The point which has been particularly forced upon my attention, in connection with this subject, is the great frequency with which floods now occur, as compared with the time previous to 1835. While the preceding table is supposed to contain the record of every 'great freshet' previous to 1841, it by no means shows those occurring since that date. In fact, they have become too common to be a matter of record. Previous to 1835, floods of 12 feet, at Lambertville, were considered very high, while 14 feet had been attained only three times within the memory of man—in 1786, 1801 and 1814. But since that time, floods of 14 feet have become common, while three have occurred—1841, 1846, 1862—in which probably one-third to one-half more water has been discharged than in any previously known. This is undoubtedly to be attributed to the clearing away of the forests in the river basin.

"To recapitulate, then, this branch of my subject, I may say that the stage of the river throughout the year is ordinarily as follows: January, frozen and medium height; February and March, breaking up and high; April, May and June, high; July, subsiding; August and September, low; October, low, but subject to high freshets; November, low, often very low; December, rising a little and freezing."

These stages agree well with those of the Connecticut, and the further agreement in low seasons and flood-discharges confirms the belief that the valuable record of flow of this stream may serve as a good basis for computing the flow of the Delaware. The flood of 1869 rose 32 feet at Shapnack island, below Dingman's Ferry. At Walker's Ferry it was 2 feet lower than in 1841; it began to rise at midnight of Sunday, reached its height Monday at 3 P. M., and was within its banks again Tuesday afternoon. There was a high freshet on April 1st, 1854, on the upper Delaware. December 15th, 1878, there was a freshet which was nearly as high as that of 1869 at Smith's Ferry, according to Mr. D. H. Smith. This freshet rose 20 feet at Carpenter's Point. Mr. Smith says an ordinary freshet requires a day to reach its height, stays at its maximum only an hour or two, and recedes in another day.

The collection of fuller flood-notes of this stream is desirable, and a careful study of its flow should be made. Almost everywhere the flood plain of the river has been built up to the height of maximum floods, for with its rapid current the stream tears away great volumes of earth, and as soon as the water spreads over the flats, and the current is checked, this detritus is deposited.

The Lehigh is a very violent stream, and carries much silt. The difference between it and the upper Delaware, which is clear, is very noticeable at Easton, their point of confluence. The drainage areas of the Delaware above Callicoon and of the Lehigh are about equal, and floods reach their height at Callicoon and on the Lehigh, at Easton, in about the same time after a storm. The flood-waters from the Lehigh will have all been discharged, however, before those from Callicoon reach Easton. Thus it is that, as a rule, the maximum discharge on the lower part of a stream of large water-shed is at a less rate per square mile, but of longer duration, than on the smaller tributary water-sheds. The flood-flow of the Lehigh appears to be at least 55 cubic feet per second per square mile.

RAMAPO RIVER.

This is one of the many branches of the Passaic. It rises in Orange county, New York, and is essentially a Highland stream. For a topographic description of the country which it drains, see the Physical Description of New Jersey, under "The Highlands." Its total drainage area is 160.7 square miles. Most of the course of the stream is in a low valley, among or to the east of the Highland ridges, which rise from 700 to 1,000 feet above. About 75 per cent. of the area is in forest. Tuxedo, Sterling, Mount Bashan and several smaller lakes afford a considerable natural storage. At Pompton, 1.5 miles above its confluence with Pompton river, the stream has a natural fall, over a reef of trap rock, of about 15 feet, this being increased to 20 feet by a dam. From the head of the pond, two miles farther up stream, the falls are as follows: From Suffern, at the New York line, 10.5 miles above, 5.7 feet per mile; from Augusta, nine miles farther, it is 18 feet per mile; from Turner, seven miles above, it is 7 feet per mile. The total length of the stream, from its remotest source, is 34 miles.

A gauge was set up at the works of the Pompton Steel and Iron Co., and read by Mr. Alfred Richards. The diagram of daily flows is published herewith. It shows a marked resemblance to that of the Paulinskill if we make proper allowance for the heavier rainfalls. The following table gives the flow by months:

FLOW OF RAMAPO RIVER, 1890.

Drainage Area, 159.5 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
February 7th to 28th	4.45	3.29	1,913	277	643
March	6.40	4.85	2,020	277	643
April	2.68	3.05	1,032	231	429
May	4.72	2.75	762	170	377
June	4.98	1.25	334	55	176
July	6.06	0.94	338	40	125
August	4.75	0.80	601	41	108
September	4.14	1.51	948	55	209
October	6.95	2.22	839	91	301
November	0.77	1.10	320	80	155
December	4.02	1.77	1,583	80	238
Total	49.92	23.53	Percentage for year, 47.		

For 14 days in July the discharge did not vary appreciably from 43 cubic feet per second, the average for the period. From August 3d to 9th, it was 41 cubic feet per second. These were the lowest weeks of the year. During the dry period—October 25th to December 17th—the rainfall here was 1.89 inches, more than double what it was on the Paulinskill water-shed. The flow during November was 1.10 inch, and for the first half of December at the rate of 0.67 inch per month. Allowing for the greater rainfall this indicates a similarity of dry-season flow for the two streams. The underrun of the stream in the summer months is quite well shown by the diagram despite the heavy rains. It appears to be about 0.90 for June, 0.32 for July, and 0.28 for August. These facts indicate a flow for dry months between that of the Sudbury and that of the Croton, but more closely approximating the latter.

Floods reach their height in from 24 to 36 hours after a heavy rain, usually within 24 hours, at Pompton, and recede in from four to six days. The highest water ever known was in September, 1882. It discharged at its maximum 10,540 cubic feet per second; 66.1 cubic feet per second per square mile. Floods of 4,600 cubic feet per second are said to be quite common. It will be seen that this is much heavier than on any stream heretofore considered.

WANAQUE RIVER.

This is another of the branches of the Passaic quite similar in character to the Ramapo. The Morris Canal Company utilized Greenwood lake, on this water-shed, for storage; the capacity being 1,340,000,000 cubic feet, according to Messrs. Croes and Howell. The water-shed of the lake has an area of 28 square miles. The draught from this storage runs down the Wanaque to the canal feeder below Pompton, increasing the flow of the stream in summer, while the flood-flows are somewhat diminished.

A gauge was set up, on the first of October, at the newly-erected dam of the H. J. Smith Electric Fuse Works and Pompton Spun Silk Manufacturing Company, at Pompton. It was read by Mr. James Frazer.

FLOW OF WANAQUE RIVER, 1890–91.

Drainage Area, 101.0 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
October	6.95	2.49	594	91	217
November	0.77	0.93	126	44	84
December	4.02	1.59	799	44	138
January	7.83	9.21	4,943	91	814
Total	19.57	14.22			

The snows in December, which appear as rain in the record, melted in January and increased the flow. This is an illustration of the inaccuracies which arise from dividing the rainfall and flow years in the midst of the storage period. January 1st is one of the worst times to make such a division if we attach any value to yearly percentages in statistics of flow.

The flow during the November dry period was, for the first month, 0.93 inch, and for the first half of December it was at the rate of 0.50 inch per month, showing some resemblance to the Croton and the Ramapo.

There were quite heavy floods, January 23d, all over the State, and on the Wanaque the flow reached 4,943 cubic feet per second, or about 49 cubic feet per second per square mile. The greatest floods are considerably above this and probably approximate closely to those of the Ramapo, 66 cubic feet per second per square mile.

PEQUANNOCK RIVER.

This is another branch of the Passaic, and with the Ramapo and Wanaque it forms the Pompton river just below Pompton. Its drainage area lies high on the Archean Highlands. For nearly its whole course it flows transversely to the ridge and valley structure of these Highlands, thus differing from the Ramapo and Wanaque, which flow through deep valleys. The headwaters of the Pequannock are at an elevation of nearly 1,500, while the mouth, at Pompton, is only 170; consequently the stream has great fall. From Post's dam, at Riverdale, two miles above the junction of the Ramapo, to New Foundland, 12.5 miles above, the fall is 45 feet per mile; thence to Wallace's Corners it is 9.2 feet per mile for 6.5 miles; for two miles above this, to Stockholm, it is 30 feet per mile. The water-shed is six or seven miles wide by 16 miles long, and the branches are quite uniformly distributed along the course of the main stream, mostly coming in from the northeast. Forests cover 78 per cent. of the area.

A gauge was set up at Post's dam and taken in charge by John F. Post, Esq., being read by his son from February 8th to May 5th and by Mr. J. H. Furey from September 27th to January 31st, 1891. Conditions here were not favorable to accuracy, and the flows given must be used with some caution. This is a matter of regret, as the stream is an important one, but the errors are not so great as to fail to point out any marked peculiarities of flow which might exist. The record is a broken one.

FLOW OF THE PEQUANNOCK, 1890–91.

Drainage Area, 84.7 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
February	4.45	3.38	686	125	273
March	6.40	4.02	891	155	296
April	2.68	2.70	382	75	205
May 1st to 5th	0.31	0.20	155	74	91
June	....	....	....	....	....
July	....	....	....	....	....
August	....	....	....	....	....
September 27th to 30th	0.58	0.08	90	25	45
October	6.95	3.61	959	25	264
November	0.77	1.42	301	25	100
December	4.02	1.03	437	25	75
January	8.06	5.17	2,352	48	387
Total	33.63	21.61			

These observations are insufficient to base any conclusions upon as to the flow of the stream, excepting that they are somewhat less than the actual flow and indicate a general resemblance to the Croton and Ramapo water-sheds. There are also indications that the rainfall stations do not fairly represent the fall on the shed. During the November dry period the rainfall for the first month was 1.42 inches, and during the first half of December at the rate of 0.44 inch per month. The large flow of the first month may be accounted for by the large natural and artificial storage of the many ponds of the water-shed. These facts point to a ground-flow quite similar to the Sudbury, and I have little doubt that this similarity will be verified by further observation.

The greatest known flood-discharge, according to Mr. Post, has not exceeded 4,460 cubic feet per second, or 52.6 per square mile of water-shed. A discharge of 43.7 cubic feet per second per square mile is rarely exceeded.

On January 23d, 1891, the discharge reached 23.52 cubic feet per second, about 27 cubic feet per second per square mile, as against 49 cubic feet for the same flood on the Wanaque.

Little information could be obtained along the Pequannock because of the fact that a water company is buying up the water rights, and several were not yet closed out at the time of going over the ground. At New Foundland Messrs. Bigelow Brothers claim to always have enough water for their saw-mill. They have little pondage, and their wheel requires 48 cubic feet per second when running full. Probably 24 cubic feet per second would suffice to run in the alternating manner which is usual with such a mill. At Mr. J. J. Laroe's grist-mill it appears that the flow falls below 44 cubic feet occasionally; to what extent below could not be determined. The stream here is said to rise quickly and run down in two or three days. It keeps quite free from mud in floods. At Stockholm it is said that the stream runs very low in summer with great regularity, at about the same time, and that it now runs much lower than formerly.

ROCKAWAY RIVER.

This is the next branch of the Passaic to the south, and is a Highland stream with a strong resemblance to the Pequannock in the character of its water-shed. It also flows southeast, across the Highland ridges, but its fall is less uniform than that of the Pequannock. For six miles above its junction with the Passaic the fall of the Rockaway is 2.3 feet per mile; thence to Old Boonton, two miles up, it is 32 feet per mile. This is at the base of the Highlands at the west side of the Central Passaic valley, and the river has a rapid descent as it issues from the plateau. From Boonton to Old Boonton, 1½ miles, the total fall is 240 feet, affording one of the fine water-powers of the State. For 11 miles above, to Dover, the fall is but 7.3 feet per mile, and thence to Woodstock, 12 miles by the stream, it is 16 feet per mile. From source to mouth the stream is 40 miles in length. The area of the water-shed is 157.2 square miles, and 80 per cent. is in forest. A gauge was set up at Boonton, and read by Mr. Martin Ginder. This is not a good locality for the purpose, but, nevertheless, the record is a valuable one. It has not yet been reduced. Another gauge was set up at Dover, and read by Messrs. Smith and Jenkins. It was impossible to obtain the flow at this point excepting on Sundays, when the mills were shut down. The gaugings are given as they were taken.

FLOW OF THE ROCKAWAY AT DOVER, 1890.

Drainage Area, 52.2 Square Miles.

Date.	Cubic feet per second.	Inches on water-shed in 24 hours.	Date.	Cubic feet per second.	Inches on water-shed in 24 hours.	Date.	Cubic feet per second.	Inches on water-shed in 24 hours.
March 30th...	253	.180	July 6th..	80	.057	Oct. 5th..	136	.097
April 6th...	182	.129	" 20th..	39	.028	" 12th..	104	.074
" 13th...	182	.129	" 27th..	272	.194	" 19th..	159	.113
" 20th...	115	.082	August 3d...	318	.226	" 26th..	208	.148
" 27th...	115	.082	" 17th..	39	.028	Nov. 2d...	116	.083
May 4th...	175	.125	" 24th..	78	.056	" 9th..	88	.063
" 11th...	103	.071	" 31st...	78	.056	" 16th..	88	.063
" 18th..	182	.129	Sept. 7th..	50	.036	" 23d...	61	.043
" 25th...	121	.086	" 14th	165	.117	Dec. 7th..	88	.063
June 1st...	128	.091	" 21st...	129	.092	" 14th..	43	.031
" 8th...	110	.078	" 28th..	89	.063	" 21st...	88	.063
" 15th...	115	.082	" 30th..	39	.028			
" 22d....	115	.082						
" 29th...	41	.029						

The above gaugings indicate a very large summer flow. The water-shed above Dover includes that of the Longwood valley above Port Oram, which is described under the gaugings at that point; and also the water-shed of Green Pond brook, 16.4 square miles in area. This latter shed has pondage aggregating 728 acres in area, and some swamps. A draught of 16 inches on this pondage would add an inch to the flow of the water-shed, and a draught of two feet would add half an inch to the flow of the entire shed above Dover. Comparing these gaugings with those at Port Oram, just above, they are found to indicate a much larger proportional flow, and I have not considered it safe to base any conclusions upon this Dover series, as there is danger that the flow is increased by large draughts upon artificial storage, which have been noted.

Another gauge was set up at the new mill of the Luxembourg Improvement Company, at Port Oram, and read from November 15th to January 15th by Mr. N. J. Peltier, the superintendent.

FLOW OF ROCKAWAY RIVER AT PORT ORAM, 1890–91.

Drainage Area, 29.9 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
November 15th to 30th	0.36	0.59	33	24	30
December	4.32	0.95	34	12	24
January 1st to 15th	2.90	2.20	409	31	120

This record, if continued, will give a good indication of the flow from the smaller Highland water-sheds of the class which have their drainage through deep, narrow valleys, of which we have many examples. The Rockaway above Port Oram runs through the Longwood valley, which has quite a moderate slope along its axis and some marsh, with considerable beds of drift, all of which features contribute to steady its flow. The hills rise about 600 feet above the valley, and 90 per cent. of the water-shed is in forest. During the November dry period the flow seems to have been at the rate of 1.20 inches per month for the first month, and 0.95 inch for the second. December shows a better-sustained ground-flow and less flood-flow than any of the other Highland streams, a result to be expected from the character of the water-shed. Inquiry along the stream seems to indicate that the flow rarely, if ever, falls below the above minimum of 12 cubic feet per second. Springs are abundant all through the valley, and the steady, well-sustained, dry-season flow is a matter of common observation. At Baker's Mills the stream is said not to respond promptly to very heavy rains, requiring 24 hours to reach its height, and freshets last from three to four days, remaining stationary for some hours. The stream carries little silt, remaining free from mud in floods.

At Boonton Mr. Charles F. Swain, Civil Engineer, made gaugings during the past summer as follows: August 6th, 109 cubic feet per second; August 15th, 136 cubic feet per second, and September 9th, 80 cubic feet per second. The area of the water-shed above this point is 148.9 square miles. The last was taken at night, and most clearly represents the ordinary run of the stream, rather underrating than otherwise. The Ramapo at this time averaged 93 cubic feet per second from 159.5 square miles of water-shed.

Mr. Charles F. Swain kindly furnished me with a copy of his report to the estate of J. Couper Lord on the water-power at Boonton, from which the following extracts are made:

"The average monthly flow for each month was ascertained by using the ratio for each month as found by previous gaugings of the Passaic at Paterson.

"The average flow of the smallest month of the dry year, which occurs about once in seven or eight years, I have estimated to be 20 cubic feet per second. The average for the smallest month of the average dry year, I have placed at 29 cubic feet per second."

The flood-flow indicated at Boonton, by known high-water marks, is at the rate of 4,800 cubic feet per second, or 32.2 per square mile.

UPPER PASSAIC.

This stream lies mostly on the red sandstone, and has much swamp on its water-shed. At Chatham it is reported to get very muddy in time of flood. Its low-season flow seems, from reported run of mills, to be about 25 cubic feet per second, rarely lower than this. The area of the water-shed is 99.8 square miles above this point.

PASSAIC RIVER.

The Passaic is one of the most valuable of our northern streams. It has been so fully described in these reports that little remains to be added. Its various branches, with the area of their water-sheds and percentage of forest, are given in the Physical Description of New Jersey. The head of tide-water is at Passaic, 13.5 miles above the mouth on Newark bay. At the foot of Dundee dam, four miles above, the stream is six feet above mean tide. Just above the head of tide, Saddle river comes in from the northern red sandstone plain, rising in Rockland county, New York, and draining 60.7 square miles, of which 28 per cent. is in forest. Dundee dam raises the river to 27 feet elevation, and at the foot of Passaic falls, 7.25 miles above, it is 40 feet above mean tide. Excepting Saddle river, only a few small branches are received below this point. At the falls the river leaps sheer 70 feet over a reef of trap rock, at a depression in First Mountain. From the top of this fall to the foot of the series of falls and rapids known as Little Falls, the rise is eight feet. Here there is a fall of 40 feet in three-quarters of a mile over another trap reef. This is the outlet of the Passaic valley proper, a flat-bottomed valley between the First and Second Mountains and the southeastern foot of the Highlands, 8 to 12 miles wide and 32 miles long. This valley is covered with great masses of glacial drift at various points, and has large areas of flat meadow. Three miles above Little Falls, and at about the same elevation with the head of the falls, the slope of the stream being very gentle, the Pompton river comes in from the north, being formed, as we have already seen in the study of those streams, by the confluence of the Ramapo, Wanaque and Pequannock at Pompton, six miles above the confluence with the Passaic. In these six miles the Pompton has a total fall of 10 feet. It is a violent stream and its floods come into the Passaic with so high a velocity that drift-wood is frequently carried far up the flat valley of the main stream, to the southward. Just above, on the main stream, lies the Great Piece meadows, through which the Passaic flows in a tortuous channel, spreading its waters, in time of flood, wide over the area, to stand for days and weeks until they can find an outlet at Little Falls, through the restricted passageway which is now being deepened and improved for the better drainage of this valley. From the mouth of the Pompton to where the Rockaway and Whippany are received from the west, 12.5 miles above, the fall is only 3 feet. The Whippany also has great meadows just above its mouth, over which its waters spread in floods. For nine miles above the mouth of the Rockaway the Passaic has a fall of 4 feet; 5½ miles above Lower Chatham bridge has a fall of 36 feet; about 6.5 feet per mile. Above this the stream has a drainage area of 100 square miles, most of which is very flat, although the headwaters are in the Highlands at Mendham, 23.5 miles above Chatham, by the stream. The total length of the stream which bears the name Passaic, from Mendham to the mouth, is 83.5 miles, measured by the stream. From source to mouth, in a direct line, is only 26 miles.

The area of the entire water-shed is 949.1 square miles; of this, 510 square miles is on the Archean Highlands; the remaining 262 square miles above Little Falls is in the Central Passaic valley, on the red sandstone, and the rest of the water-shed on the trap ridges and the lower eastern red sandstone plain.

At Little Falls it was found that the Messrs. Beattie, of the Beattie Manufacturing Company, had kept a careful record of the height of water on the dam by means of a gauge, and they kindly gave us the use of this and volunteered to keep gauge readings for us in the future. The dam was measured up, and appropriate weir formula applied to reduce the record to flow in cubic feet per second, and to inches on the water-shed. Some missing days have been carefully interpolated by study of the daily rainfall records and the habits of the stream. There are a few breaks in the record too long for such treatment, however. Nevertheless, the series is a valuable one, and the computed flows are believed to closely approximate accuracy, rather underrating the flow, if in error at all.

The gauge was often read several times in the day, and showed very regular changes, so that there is probably very slight error in assuming single readings to be the average for the day, as had to be done usually.

FLOW OF THE PASSAIC AT LITTLE FALLS, BY MONTHS, 1888–1891.

Area of Water-shed, 772.9 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1888.					
June 16th to 30th	1.68	0.56	1,311	538	775
July	1.88	0.71	954	322	476
August	7.86	1.30	3,684	332	873
September	7.86	4.57	11,285	388	3,166
October	5.29	2.86	2,623	1,200	1,917
November	4.22	3.28	3,082	1,410	2,272
December	4.83	4.73	9,509	1,653	3,171
1889.					
January	7.06	6.17	7,199	3,004	4,136
February	2.43	2.51	3,391	927	1,863
March	3.31	3.24	4,021	1,052	2,172
April	6.85	3.71	10,952	1,020	2,570
May	3.12	3.12	7,653	920	2,092
Total	56.39	36.76	65 per cent. of yearly rainfall.		

FLOW OF THE PASSAIC AT LITTLE FALLS, BY MONTHS, 1888–1891.—*Continued.*

Area of Water-shed, 772.9 Square Miles.

MONTHS.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1889.					
June	3.57	1.90	2,806	538	1,316
July	12.39	2.61	3,082	815	1,750
August	4.40	4.44	8,825	443	2,977
September	11.05	4.15	8,331	338	2,874
October	3.27	2.29	1,919	1,157	1,535
November	10.79	6.59	9,740	1,747	4,565
December	2.35	4.71	8,131	1,753	3,154
1890.					
January	2.70	2.40	2,617	1,164	1,609
February 1st to 14th	2.43	1.81	5,841	1,301	2,686
March	6.10	3.06	4,021	1,052	2,051
April	2.53	3.19	4,765	1,183	2,209
May	4.78	2.78	3,004	852	1,863
Total	66.36	39.93	60 per cent. of yearly rainfall.		
1890.					
June	4.99	1.72	1,584	581	1,191
July	6.25	1.46	2,238	338	979
August	4.47	1.27	2,264	415	852
September	4.05	1.55	2,264	424	1,073
October	6.07	2.76	3,597	646	1,851
November	0.75	1.56	2,264	696	1,081
December	4.20	2.26	4,240	646	1,515
1891.					
January	8.98	5.87	13,679	1,384	3,935
Total	39.76	18.45			

Unfortunately these have all been years of large rainfall, and the series does not exhibit the dry-month flow very well. Some valuable data are obtained, however, by a study of the diagrams of daily rainfall and flow. In 1888 the rainfall was deficient for June and July, and there was a steady draught upon ground-water from June 1st to August 21st. Our gaugings do not begin until June 16th, showing a flow of 0.56 inch for the last half of the month. July shows a flow of 0.71 inch, and to August 21st the flow is at the rate of 0.68

inch for the third month. From July 8th to August 21st, a period of 45 days, the flow was remarkably uniform, the average flow per week in regular order, being as follows: 1st, 448; 2d, 368; 3d, 365; 4th, 392; 5th, 523; 6th, 442 cubic feet per second. This shows a remarkably well-sustained flow, as the rainfall for this period was less than the evaporation, and fell in light, evenly-distributed showers. In June, 1889, we find that, exclusive of surface-flows, the flow was 1.40 inches, the rainfall being less than evaporation. In June, 1890, there seems to be an equally large flow exclusive of surface-flow, although the latter flow is not well defined. During the dry period in the autumn the flow for the first month was 1.43 exclusive of flow carried over from October rains. From December 1st to 17th, a second month's flow of 1.15 is indicated.

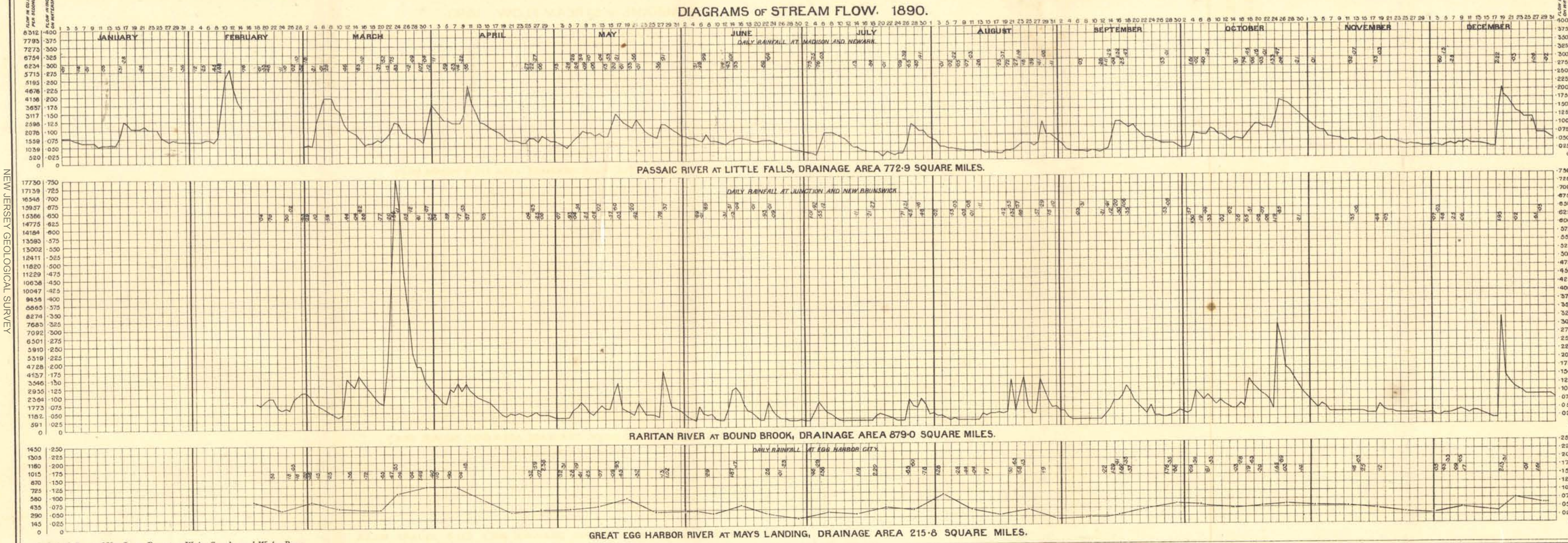
On October 10th, 1878, Messrs. Croes and Howell gauged the flow at Paterson during a very low stage of the river. They found it to be 195 cubic feet per second, and remark that it did not vary appreciably from this for ten or twelve days. (Newark Aqueduct Board, Report on Additional Water-Supply, 1879, J. J. R. Croes and George W. Howell, page 35.) This is at the rate of 0.28 inch on the watershed for the month. Inasmuch as the rainfall for June, July and August of that year amounted to 12.14 inches, or only the amount of evaporation, and April and May also had barely a sufficiency of rain, this month would be the fifth dry month of the scale.

In September, 1883, Mr. Lebbeus B. Ward found the flow at Paterson to be at the rate of 150 cubic feet per second. By the method employed with the Croton and Sudbury, this is found to be also the fifth dry month, and the flow is at the rate of 0.21 inch per month.

So far as we can tell at present, therefore, the dry-season flow is as follows: For the first dry month, 1.40 inches; for the second, 0.71 inch; for the third, 0.68, and for the fifth, 0.21 to 0.28 inch. On the Croton we found the averages of the table of droughts to be: First dry month, 0.81; second, 0.47; third, 0.38; fourth, 0.24, and fifth, 0.25 inch. It is probable that the flow for the first month, being largely from surface storage, is higher on the Passaic than on the Croton, but by the third or fourth month they are nearly the same.

The flood-flows are well shown in 1889, which year shows six freshets. In 1890 there was not a flood during the entire year.

DIAGRAMS OF STREAM FLOW. 1890.



Geological Survey of New Jersey. Report on Water Supply and Water Power.

JULIUS BIEN & CO. PHOTO. LITH. N. Y.

From high-water marks at Little Falls, a weir computation was also made for the great flood of September, 1882. The relation between the maximum flow, if continued for twenty-four hours, and the total flow for eight days has been determined from the floods of record, and is expressed by a factor which shows the number of days at the maximum rate of flow which would be required to deliver the total flood-flow for eight days, this being the average duration of the floods observed. It is found that for larger floods it is usually five days, the lower rate in January, 1891, being exceptional, as that was a period of breaking up of the river, when the flows are complicated by ice and melting snow. This factor has been used to estimate what would be the total flow in cases where we only have the maximum rate of flow, as in the case of the great flood of September, 1882, and Messrs. Croes' and Howell's gauging of the flood of 1878.

FLOODS ON THE PASSAIC AT LITTLE FALLS.

Area of Water-shed, 772.9 Square Miles.

DATE.	Maximum flow in cubic feet per second.	Flow for 24 hours at maximum rate—Inches on water-shed.	Flow for 8 days in inches on water-shed.	Equivalent number of days at maximum rate.	REMARKS.
Jan. 23d to 31st, 1891	13,679	0.656	2.769	4.22	Heaviest January rainfall in 47 years, at Newark, 8.71 inches.
Jan. 12th to 19th, 1891	6,546	0.315	1.799	5.70	
Nov. 28th to Dec. 5th, 1889	9,740	0.468	2.532	5.41	Rainfall, 5.6 inches, from November 19th to 28th
Nov. 10th to 17th, 1889	6,340	0.305	2.145	7.00	Rainfall, 4 inches, from 8th to 18th.
Sept. 15th to 22d, 1889	8,331	0.400	2.426	6.06	Rainfall, 10 inches, from 10th to 20th.
Aug. 1st to 8th, 1889	8,825	0.423	2.393	5.66	Rainfall, 8 inches, July 27th to August 3d.
April 27th to May 4th, 1889	10,952	0.570	2.717	5.00	Rainfall, 5.5 inches, April 25th to 28th.
Dec. 18th to 26th, 1888	9,509	0.457	2.410	5.29	3.5 inches rain on the 17th.
Sept. 18th to 25th, 1888	11,285	0.543	2.970	5.47	6 inches rain from 9th to 18th.
Sept., 1882	19,105	0.919	4.595	(5.00)	Over 12 inches rain from 21st to 24th. Flow for 8 days estimated.
Dec. 12th, 1878	17,913	0.809	4.045	(5.00)	At Dundee; area of water-shed, 822.7 square miles.

The flood of 1882 was said to have been nine inches lower on the dam at Paterson than the flood of 1854, and nine inches higher than the flood of 1878, gauged by Messrs. Croes and Howell at Dundee. The maximum flow in 1882, at Little Falls, was at the rate of 24.2 cubic feet per second per square mile; that of 1878, at Dundee, was at the rate of 21.8 cubic feet per second per square mile. It is reasonable to assume, therefore, that the maximum flood-flow for the Passaic is not much below 28 cubic feet per second per square mile.

The effect of the larger surface storage of the water-shed and of the spreading of flood-waters over the flat lands of the central valley and gradual emptying of them through the outlet at Little Falls, is apparent all through the above table of flows by months. The flow in months following a month of heavy rainfall is frequently equal to or greater than the rainfall for that month, even in summer. December, 1888, August and December, 1889, are prominent instances of this. Evidently this river is a most interesting study in hydrology, and the importance of a more exact knowledge of the laws governing its flow need not be urged to be appreciated.

HACKENSACK RIVER.

Mr. Charles B. Brush, C.E., Engineer and Superintendent of the Hackensack Water Company, furnishes the following data of rainfall and flow of the Hackensack, at New Milford.

	Average Daily Discharge. Million Gallons.	Average Daily Rainfall. Million Gallons.
November, 1883, to November, 1884......	100	218
November, 1884, to November, 1885......	133	214
November, 1885, to November, 1886......	96	194
November, 1886, to November, 1887......	106	224
November, 1887, to November, 1888......	176	270
November, 1888, to November, 1889......	197	303

The water-shed is flat, and has large swampy areas. Its area is 114.8 square miles.

RAHWAY RIVER.

This stream drains, above the point of gauging, 40.4 square miles, the western half of which is on the steep trap ridges known as First and Second Mountains. The remainder of the shed is on the red sandstone, and is largely covered with glacial drift. It was selected as a type of drift-covered water-sheds of small extent. It is found to be extremely fluctuating, rising almost immediately and falling rapidly after reaching its maximum flow. Its numerous mill-ponds render the establishment of a self-registering, continuous gauge a necessity for accurate determination of its flow. This could not be done, of course. A gauge was set up a mile above Rahway, and was read by Mr. Addison C. Russell. The lowest recorded flows have not been given as the minimum, as they were evidently affected by holding back of the water in the ponds above. The average flow for the lowest consecutive three days has been taken instead.

FLOW OF THE RAHWAY RIVER, 1890.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
February 18th to 28th	2.21	0.99	143	70	98
March	6.95	5.00	1,015	59	175
April	2.61	2.59	292	46	93
May	4.65	2.35	147	50	82
June	4.97	2.95	373	44	106
July	5.72	2.36	292	26	82
August	4.97	3.04	534	32	106
September	4.68	2.19	195	41	79
October	6.79	4.47	781	67	156
November	0.80	3.25	147	94	117
December	4.35	3.82	716	60	134
Total	48.70	33.02	68 per cent. of yearly rain.		

A quantity equal to an average flow of about 1.5 cubic feet per second is stored on the headwaters and diverted for the supply of the city of Orange.

It is evident at once, from the distribution of the flow, that this belongs to the class of streams with large ground storage, such as those of Long Island. It is different in its flood-flows, because of the steep slopes of its headwaters, which send off large surface-flows, but the lower, drift-covered areas yield a large ground-flow in summer, and while the flood-flows are a little muddy, these ground-flows are known to be very clear and remarkably pure.

By aid of the diagram of daily flows, the surface-flow and flow from ground-water are quite readily separated. It is found that from June to September the ground-flow is close to 1.5 inches per month, no month having been deficient in rainfall, and the flood-flows are close to 25 per cent. of the total rainfall. Strictly speaking, they are

50 per cent. from the steep half of the water-shed and practically nothing from the flat portion. During the dry period, from October 25th to December 16th, the flow from ground-water was fully 3 inches. For the first half of December the rate was, for second dry month, 2.25 inches. These facts indicate a very large ground storage, with free delivery, and the probability of a flow in the fourth and fifth dry month almost as low as that of the Croton. This can only be tested by gaugings in dryer years than the past has been.

No measurement of maximum flood-flows has yet been obtained, but the rate is apparently much higher than on any of the other streams which have been measured. At Cranford, the flow during the drought of 1881 appears to have been sustained at about the rate of 9 cubic feet per second on a water-shed of 39 square miles. Floods, after very heavy rains, are said to reach their maximum in twelve hours, and require two or three days to run down, but sometimes the river falls in twenty-four hours. A flood in 1889 remained at a high stage for fourteen days. River does not get very muddy and runs down perfectly clear in two days. At the mills of the Diamond Paper Company, at Millburn, this stream is said to be very steady and remarkably pure, with no trace of mineral matter.

RARITAN RIVER.

The total area of the water-shed of this stream is 1,105.3 square miles. It is the largest stream of the State, excepting the Delaware, but is not nearly so important as the Passaic, from the fact that no considerable portion of the waters are united into one channel until they are within seven miles of the head of tide-water, and but 17 feet above sea-level. The Passaic at Little Falls unites the drainage of 772.9 square miles at an elevation of 158 feet, while the Raritan, at Raritan, has but 468 square miles, at an elevation of 49 feet, and Bound Brook, 875 square miles, at an elevation of 17 feet. Nevertheless, the Raritan basin is a productive agricultural section, and a large amount of water-power is utilized along the various branches. The flood-flows have a peculiar interest because of the populous and highly-cultivated condition of the valleys, which renders them more destructive and consequently makes a knowledge of the laws governing them more essential.

The water-shed is fully described in the physical description of the

State, and its character is better shown by a study of the topographic maps than it can possibly be by any written explanation. A few facts not so apparent may be pointed out, however, in discussing its flow. There is very little storage anywhere on the water-shed, excepting on the Millstone, part of which is a sand-hill stream, with some of the characteristics of Southern New Jersey streams; but enough of the area is on steep trap and red sandstone slopes to give it a pretty high rate of flood-flow. Only 13 per cent. of the shed is in forest. Of the 879 square miles above the point of gauging, about 150 square miles area is on a highly-cultivated part of the Highlands and on the trap ridges; about 98 square miles, including the water-shed of the upper Millstone, is on the flat clay and marl district, and the remainder on the low, level, red sandstone plain. On the whole, the water-shed is an excellent type of the red sandstone district, free from glacial drift.

A gauge was set up at the Delaware and Raritan canal dam, about one and one-half miles below the village of Bound Brook, and was read by Mr. William Fisher. The following table gives the flow by months, the daily flow being shown by the diagram accompanying:

FLOW OF THE RARITAN AT BOUND BROOK, 1890.

Drainage Area, 879.0 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
February 17th to 28th	1.58	0.98	2,772	1,406	1,938
March	6.26	6.13	17,818	872	4,727
April	2.74	2.26	3,265	874	1,773
May	4.95	1.95	4,060	752	1,489
June	3.97	1.32	2,824	462	1,040
July	5.68	1.18	2,022	498	898
August	5.18	1.58	3,405	498	1,205
September	4.31	1.34	2,823	493	1,064
October	6.74	3.06	7,133	859	2,360
November	0.88	1.30	1,779	781	1,016
December	3.55	2.16	7,526	462	1,654
Total	45.84	23.26	Percentage of yearly rainfall = 51.		

The less amount of storage than in the case of the Passaic, and the more prompt response of the flow to rainfall, are at once apparent. As was the case with the Rahway, the line between ground-flow and surface-flow is sharply drawn in the diagram, owing to the short duration of floods. It is shown that in June, the rainfall being less than surface-flow and evaporation, the ground-flow was close to 0.70 inch. In July it tended to a constant at 0.60 inch per month, and in August about the same. In the autumn dry period it was 1.30 in November, and at the rate of 0.75 inch during the first half of December. The late Ashbel Welch, Esq., made a gauging at a very low stage of the river, which gave 180 cubic feet per second. (Tenth Census of the United States. Report on Water-Power.) Unfortunately, the month and year are not given, so that we have no means of placing this flow in its proper order in the dry-month flows. It is at the rate of 0.23 inch per month. There are good reasons for believing that the flow falls at least as low as 0.20, but not much lower than 0.15 inch per month.

The flood-discharge is at a very rapid rate, being affected not only by the lack of storage but by the shape of the water-shed, which is such that all the principal branches focus at a point near Bound Brook, and discharge their flood-flows simultaneously instead of delivering one at a time, as is the case on long, narrow sheds, when the branches are pretty evenly distributed along the main stream.

There have been three great floods on this river during the century, completely throwing into the background scores of other freshets which would otherwise be considered heavy. The first occurred November 24th 1810, the second July 17th, 1865, and the third September 24th, 1882. Of the last I have been able, by careful inquiry, to obtain fair measurements at the Bound Brook dam. It began to rise about 3 P. M. of the 22d, had covered the canal bank at the dam, 11.5 feet above the crest, Saturday at 3 P. M., and reached a height of 14.2 feet above the crest at 5 A. M. of Sunday, the 24th, when it was at its maximum, falling within the river banks again by 7 A. M. of Monday. The overfall at the dam was drowned, so that the head for computation is reduced to 12.7 feet, and conditions were such that the safest computation is that for a free overfall with this head. This gives the following rates of flow, bank-full of the river at this point having been ascertained to be a flow of 7,000 cubic feet per second.

September	22d, 3 P. M.	7,000	cubic feet per second.
"	23d, 3 P. M.	35,500	" " " "
"	24th, 5 A. M.	52,000	" " " "
"	25th, 7 A. M.	7,000	" " " "

This gives a total discharge for these 64 hours of 6,489,000,000 cubic feet, or 3.36 inches on the water-shed. This amount of water would cover Middlesex county 10 inches in depth. It is at the rate of 59.3 cubic feet per second, maximum discharge.

Some pains have been taken to determine the relative height of the other two great freshets. Mr. John D. Field, of New Brunswick, saw the freshet of 1810, and was fully familiar with the flood-marks along the river. He is of the opinion that it was probably equaled by the later floods, but never exceeded. Mr. D. F. Vermeule is also familiar with the lower part of the river, and thinks that the flood of 1865 was not so high as that of 1882. Mr. Lewis D. Clark, at Bound Brook, has marked most of the high freshets, and says the freshet of 1882 was 2 feet higher at his house on the river bank than that of 1865. The total rise here in 1865 was 16 feet. He also thinks that the freshet of 1810 was 3 feet lower than that of 1882. Others give the difference to be from 10 inches to 3 feet, but at the greater figure it would be fully accounted for by the building of the dam below, in 1833, which caused a difference of 5.5 feet in the height of the river immediately at its site, raised the ordinary level a foot or two at Bound Brook, and restricted the flood outlet to the opening between its high abutments at the river banks. Mr. Lawrence Vanderveer, of Griggstown, says that the water was 2 feet higher at the mouth of Beden's brook in 1882 than it was in 1810, from known marks of the early freshet; but this may be true at this point without indicating a greater flood on the main stream. Altogether the weight of evidence is to the effect that the floods of 1810 and 1882 were of about equal volume, and the flood of 1865 was somewhat below the others. It is well established that there were no others nearly so high in the intervals, although there was a high one at the time of building the dam in 1832 or 1833, and another in 1836 or 1837.

Mr. Vanderveer says that in 1810 it is said that heavy rains began on the 9th and continued at intervals until the 24th, when the flood reached its height. He also mentions a case in July, 1863, when an extremely heavy shower fell on a narrow district extending from Ten-

Mile run to the Sourland Mountain, causing Beden's and No Pike brooks to rise very high in two hours, whereas at Princeton and Plainville, a few miles to the south and north respectively, there was not a trace of rain. In the weather record kept by the late P. V. D. Spader, Esq., at New Brunswick, extending from 1847 to 1890, the freshets of 1865 and 1882 are mentioned, the former being noted to be the "greatest since 1810." Strange to say, this record gives no evidence of the cause of the flood of 1865 in its rainfall. The rain for June amounted to only 2.31 inches, and from July 1st to 16th it was but 1.32 inches. On the 17th there was a fall of 1.85 inches, but the total from June 1st having been but 5.5 inches, it is evident that this was entirely inadequate to cause a flood-flow of over two inches per day. Neither does the cause appear in the monthly records at Newark and New York. It must have been extremely heavy local rains on the upper water-shed. The cause of the flood of September, 1882, is apparent and has already been pointed out. Rains had been deficient from the 1st of June to the 11th of September; on the 12th there was a fall of 2.40 inches, which partly made up the deficiency, and then from the 20th to the 23d came 11.84 inches fall at New Brunswick, which was sufficient to replenish the exhausted ground-water and leave seven inches to run off in surface-flows or be evaporated from surface pools. With the rainfall record at New Brunswick and the method of examination employed in our analysis of the Sudbury and Croton flows, the fact that a great flood occurred at this date could have been demonstrated, had we had no record of it.

Mr. Clark furnishes the following information about other floods: From 1858 to the present time there have been three notable freshets, those of 1865 and 1882, already noted, and one on February 12th, 1886, which was about sixteen inches lower than that of 1865. The flood of 1865 rose with great rapidity—as much as six inches in five minutes. Freshets usually rise at Bound Brook within twelve hours after the end of a heavy rain, and run down in twenty-four hours.

The following list of floods, mostly collected by Mr. D. H. McLaury, of New Brunswick, although incomplete, may give some idea of their frequency and relative height for recent years. Heights are given above high-tide mark at Albany street bridge, and some idea of corresponding heights above may be gained from the rise in 1882, which was 12 feet at New Brunswick, 13 feet at Raritan Landing, 14.2 feet on the dam, and about 16 feet at Bound Brook. Some floods, with their height at Raritan Landing, have been added:

FLOODS ON THE RARITAN AT NEW BRUNSWICK.

Date.		Height in feet.	Remarks.
July	30, 1873	4.25	Rain, 5.94 inches, from 27th to 29th.
August	14, 1873	4.50	5.29 inches rain, on 14th.
September	18, 1874	9.00	7.10 inches, from 15th to 18th.
March	26, 1876	6.00	3.33 inches, on 25th and 26th.
September	18, 1876	5.00	2.57 inches, on 17th, after wet period.
October	5, 1877	6.50	4.30 inches rain, on 4th and 5th, after a month of dry weather.
September	24, 1882	12 00	Rain, 11.84 inches in 4 days. No greater freshet during the century.
August	4, 1885	3.75	Rain, 3.30 inches, on the 3d.
February	12, 1886	9.00	Rain, 2.5 inches, with melting snow and ice.
January	15, 1887	3.75	Rain of 1 inch; thaw and break-up of river.
February	19, 1887	—	Over banks; rain, 1.52 inches, and thaw.
July	23, 1887	8.00	Rise at Raritan Landing; rose rapidly at midnight; 1.43 inches rain after a wet period.
August	2, 1887	4.00	After 6 weeks of very sultry weather, a shower of 4.62 inches in 1 hour and 15 minutes.
January	2, 1888	6.00	From December 28th to January 1st, 3.82 inches rain, with melting snow and ice.
February	25, 1888	—	Over banks. Rain, 1.60 inches, and thaw.
July	5, 1888	3.50	Heavy shower.
September	20, 1888	(?)	A flood; no record of height.
December	18, 1888	4.00	Rain of 3 inches, on 17th.
January	7, 1889	4.00	Rain, 1.82 inches, on 6th, with thaw.
April	28, 1889	(?)	Rain, 3.67 inches, 26th to 28th.
June	1, 1889	4.20	Rain, 2.20 inches, May 26th to June 1st.
August	15, 1889	5.50	Showers of 2.56 inches, following wet period.
November	28, 1889	8.00	Rise at Raritan Landing. Rain of 2.54 inches, 27th to 28th, following a wet month.
March	23, 1890	7.00	Discharge, 17,818 cubic feet per second; rise at Raritan Landing; 4 inches rain, 11th to 23d.

Date.	Height in feet.	Remarks.
December 18, 1890	3.60	Slightly over banks, a discharge of 7,500 cubic feet per second. Rain, 2.40 inches, after a dry period, but falling on frozen ground.
January 2, 1891	—	Over banks. Melting snows, with light rains.
January 12, 1891	7.00	Rise at Raritan Landing. Rain, 1.5 inches, with thaw.
January 22, 1891	8.00	Rise at Raritan Landing. 1.50 inches rain, following a wet period.

It is notable that after the great flood of 1882, no freshet of importance occurred until February, 1886; and another indication of the fickleness of the stream has been before pointed out—the numerous floods in 1889, and the entire absence of them after March, in 1890. It is instructive to compare the computed volumes of flow on the Raritan and Passaic in September, 1882. On the Raritan we find it to be 3.36 inches on the water-shed in sixty-four hours, while on the Passaic it is 4.6 inches in eight days. The probability is that during the period of eight days the depths discharged by the two streams did not vary materially, but that of the Raritan was more concentrated at first, and consequently more disastrous.

Streams of Southern New Jersey.

These streams are of an entirely different character from those which we have heretofore discussed. The evidence of this is everywhere at hand in the small preparations made for flood-flows, the limited bridge openings, the long embankments of sand and gravel thrown boldly across the valleys, with small provisions for flood-discharge, in a manner which would mean disaster within a few months if attempted on our northern streams, yet these constructions stand for centuries here. Such evidence is conclusive as to small flood-flow. The remarkable way in which the flow of these streams is sustained through the dry season, however, is of greater economic importance. This feature makes up in a degree for the less amount of fall, and makes them most valuable for water-power. A small amount of storage will enable a mill-owner to utilize almost the whole flow of the stream, and immunity from the perils of floods and the scantiness of droughts renders his control of the motive power almost as perfect as if it were steam. It is greatly desired to make the study of these streams thorough, for the fuller utilization of them is a matter of much importance to this portion of the State. It has been exceedingly difficult to secure satisfactory gaugings of many of them, because very few of the overfalls are so constructed as to be available for the purpose, and when they are in proper condition, the pondage is very large, and the flows complicated accordingly. Fortunately there is a strong likeness between them, and one will serve as a type of all. The most available locality for the purpose was found to be on the Great Egg Harbor river, at the mills of the Mays Landing Water-Power Company. This river is an excellent type of the Atlantic Coast streams of Southern New Jersey. Its drainage area is 215.8 square miles, and it is practically all covered with pine forest. The soil is principally light sand, with some gravel, all extremely porous, and rain falling upon it sinks immediately, surface-flow being almost unknown. All of the rain thus goes into the ground storage, to be fed out to the streams along the shallow valleys, causing the broad belts of saturated cedar swamp which border all streams. A few miles above Mays Landing, at Weymouth, there is a large artificial pond, which is almost the only one on the water-shed. Owing to the great draught of the mill, it was impossible to secure accurate measurements at Mays Landing more than once a week. The accompanying diagram of flow shows these gaugings by a small dot. For this reason the line of flow is shown somewhat more regular than it would be with daily gaugings, yet enough observations were made to prove that the actual line of flow only varied slightly from this, and that the river actually rose and fell in great waves of gentle ascent and descent, apparently being scarcely affected at all by single rains, unless they were exceptionally heavy.

The gauge was taken in charge by Mr. James M. Blaisdell, the superintendent for the water-power company, and every facility and courtesy was extended by him to enable us to ascertain the flow. From careful tests and checks it does not appear probable that daily gaugings would change the result of the total monthly flow in the table more than 10 per cent. at the utmost, and certainly would not decrease them.

FLOW OF GREAT EGG HARBOR RIVER AT MAYS LANDING, 1890.

Drainage Area, 215.8 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
February 16th to 28th	2.40	0.86	463	322	383
March	6.06	2.39	723	327	447
April	3.37	2.44	734	268	470
May	3.71	1.88	491	270	348
June	2.33	1.27	352	126	244
July	5.13	1.33	302	201	249
August	5.31	1.46	541	97	273
September	6.06	1.05	366	114	203
October	6.30	1.67	346	270	313
November	0.71	1.32	325	142	255
December	4.49	1.52	438	180	284
Total	45.87	17.19	37 per cent. of yearly rain.		

This table shows at once a greater total loss of rain than any of the previous ones. At the same time it shows a steadier and better-sustained summer flow, especially when we note the range of flow in cubic feet per second. It is of great scientific importance that the flow of this stream during a period of prolonged drought shall be determined. Until recently there was a plant of 120 horse-power at Mays Landing on a net fall of 10 feet. With the considerable storage this plant always had enough water, with an appreciable waste over the dam at night, so that it was considered desirable to increase the capacity, and new wheels have been recently put in. It would require, to run the old plant 10 hours per day, at least 59 cubic feet per second continuous flow. Above Millville the Maurice river has a water-shed 218 square miles in area, of the same character as this, excepting that it has 67 instead of 88 per cent. in forest. The run of the mills there indicates a flow of about 85 cubic feet per second during dry periods. Consequently it seems that for the present we may assume a minimum flow for this stream of 60 cubic feet per second, or 0.30 inch per month, with the probability that this is very rarely reached. Referring to the above monthly flows, and the diagram of daily flows and rainfall, we find that at the end of the period of light rainfall in April a flow is indicated which must have been at about the depletion of the great surface storage of the swamps of the water-shed. From this point to the 1st of September there is a gradual falling off in the low run of the stream, indicating a depletion of ground storage. The intermediate swells in the line are flows from swamp storage which has been replenished by the heavy rains. This assumption gives us the following flows from ground-water: May, 1.40; June, 1.00; July, 0.75, and August 0.63 inch. September starts in at the rate of 0.60 inch, but a replenishment of swamp storage increases the flow gradually and the continued heavy rains of October seem to have replenished the ground-water again; for after their cessation the flow for November, which was entirely from ground-water apparently, reached 1.32 inches again, or the same that we have taken from the diagram as the ground-water flow of May. Although the demands of vegetation are less, the evaporation is more than on the Croton water-shed, and there is also some loss, probably, through the gradual movement of the ground-waters seaward, down the gently-inclined strata of the formation. We may assume the same rate as was used upon the northern shed, therefore, for all months excepting May, which would undoubtedly not be greater than August, there being no cultivation and exposure of earth to increase evaporation, and practically no demand from vegetation during that month in the piny districts. The effect of winds, which is to increase evaporation so much elsewhere, is also here annulled by the timber; consequently the evaporation is taken at three inches, as for August.

	Rain.	Evaporation + Flow.
May	3.71	4.88
June	2.33	5.27
July	5.13	5.33
August	5.31	5.46
September	6.06	4.05
October	6.30	3.42
Totals	28.84	28.41

Of course, in order to apply this method practically, we must have data by which we may determine what will be the proportion of surface-flow. This appears to be about 7 per cent. of the total rain, but the data for its determination is still insufficient.

On Rancocas creek, gaugings have been made at Pemberton, the gauge having been set up at the mill of Anthony J. Morris, Esq., who kindly undertook to read it. The reduction of these gaugings is exceptionally tedious and has not yet been completed. A series was also taken on the Assanpink, at Lawrence Station, by G. W. Davenport, Esq. These also are not yet computed.

Messrs. Asher Atkinson, Cyrus F. Sproul, P. D. Staats and W. C. Ogden have assisted at various times in gauging and procuring data for this report, while Mr. John Prince has prepared the diagrams and done other office work.

The following table gives in a form convenient for reference and comparison the extremes of flow—some of which have already been mentioned :

EXTREMES OF FLOW, NEW JERSEY STREAMS.

RIVER.	PLACE.	Area of water-shed.	MAXIMUM. Cubic feet per second.	MAXIMUM. Per square mile.	MINIMUM. Cubic feet per second.	MINIMUM. Per square mile.	REMARKS.
Paulinskill	Hainesburgh	....	4,126	42.0	174.8	0.240	Least in 1890.
Paulinskill	Paulina	....	....	....	17.0	0.180	From run of mill in 1881.
Paulinskill	Stillwater	....	....	....	16.5	....	From run of mill in 1881.
Paulinskill	Balesville	50.0	....	....	6.8	0.126	From run of mill in 1881.
Painter's Mill branch	Kalarama	1.7	....	....	2.4	1.400	From run of mill.
Jacksonb'gh br'ch.	Jacksonburgh	7.8	....	....	1 9	0.250	From run of mill in 1881.
Swartswood lake outlet	Swartswood lake	16.0	1,070	65.8	....	....	
Pequest	Belvidere	158.0	1,996	12.5	....	....	
Pequest	Townsbury	83.4	800	9.6	14.0	0.170	Min. from run of mill.
Pequest	Tranquility	34.8	650	18.7	....	....	
Pequest	Huntsville	31.4	605	19.3	....	....	
Pequest	Allamuchy pond	1.7	40	23.5	....	....	
Pequest	Hunt's pond	1.7	43	25.3	....	....	
Musconetcong	Finesville	155.8	1,960	12.8	....	....	
Musconetcong	Saxton Falls	68.0	1,080	15.9	....	....	
Delaware	Centre Bridge	6790 0	190,860	28.1	1,688	0.250	
Ramapo	Pompton	159.5	10,640	66.1	....	....	
Wanaque	Pompton	101.0	4,943	48.9	....	....	January, 1891, not the greatest.
Pequannock	Pompton	84.7	4,460	52 6	....	....	
Rockaway	Dover	52.2	2,250	43.0	....	....	
Passaic	Paterson	796.9	....	....	195	0.240	Croes and Howell, October, 1875.
Passaic	Paterson	796.9	....	....	150	0.190	L. B. Ward Sept., 1883.
Passaic	Dundee	822.7	17,913	21.8	....	....	Croes and Howell, December, 1878.
Passaic	Little Falls	772.9	19,105	24.2	....	....	September, 1882.
Passaic	Paterson	....	....	28.0	....	....	Probable max. in 1854.
Rockaway	Boonton	148.9	4,800	32.2	....	....	
Raritan	Bound Brook	879.0	52,000	59.3	....	....	September, 1882.

For convenient comparison, a list of like extremes for some American rivers, taken from the Report on Water-Power, United States Census, 1880, are appended :

EXTREMES OF FLOW FOR SOME AMERICAN STREAMS.

RIVER.	PLACE.	Drainage area, square miles.	EXTREMES OF FLOW. Maximum cubic feet per second.	Minimum cubic feet per second.	Maximum cubic feet per second per square mile.	Minimum cubic feet per second per square mile.	AUTHORITY AND REMARKS.
Merrimack......	Lowell....	4,085	81,000	1,275	19.83	0.31	Lakes and artificial reservoirs. Wooded.
Merrimack......	Lawrence.........	4,599	96,000	1,400	20.87	0.31	Lakes and artificial reservoirs. Wooded.
Concord...........	Lowell..............	361	4,449	59.84	12.32	0.17	C. Herschel. Stream sluggish and swampy. Few woods. Hilly and rolling. Some reservoirs.
Sudbury...........	Framingham....	78	3,228	2.80	41.38	0.036	A. Fteley. Hilly and swampy. One-sixth to one-eighth wooded.
Charles.............	Newton Upper Falls..............	215	....	44	....	0.20	J. P. Kirkwood. Hilly and rolling.
Hales' Brook, Mass......	....	24	....	3 24	....	0.135	J. P. Frizell.
Connecticut.....	Hartford..........	10,234	207,448	5,219	20.27	a 0.510	T. G. Ellis. Numerous lakes and artificial reservoirs. Wooded. Mountainous in parts.
Connecticut.....	Dartmouth......	3,287	....	1,006	....	0 306	C. Herschel. Numerous lakes and artificial reservoirs. Wooded. Mountainous in parts.
Housatonic......	....	790	....	130	....	0.165	H. Loomis. Report New York Committee Public Works, 1879.
Croton..............	....	338.82	25,367	50.80	74.87	0.150	J. J. R. Croes and G. W. Howell.
Croton (west branch).........	....	20.37	1,109	0.407	54.44	0.020	J. J. R. Croes. Very broken and undulatory. Hills steep and rocky. Largely wooded. Little cultivated.
Passaic	Paterson.........	818	....	178	....	0.22	J. J. R. Croes and G. W. Howell. Some lakes and swamps. Hilly.
Passaic	Belleville.........	962	19,914	225.60	20.73	0.023	J. J. R. Croes and G. W. Howell. Some lakes and swamps. Hilly.
Delaware....	Lambertville....	6,500	350,000	2,000	53.85	0.300	Ashbel Welch. Hilly and rolling. Many lakes. Well wooded.
Schuylkill........	Philadelphia...	1,800	....	307 to 378	....	0.17 to 0.21	E. F. Smith and H. P. M. Birkinbine. Hilly and rolling. No lakes. Some reservoirs.
Hackensack.....	....	84	....	27	....	0.33?	C. D. Ward. Flat. No lakes or reservoirs, except mill-ponds.
Ohio................	Pittsburgh........	19,900	....	2,271	....	0.114	J. H. Harlow. Hilly and mountainous. No lakes. Wooded.
Potomac..........	Cumberland.....	920	17,900	25	19.46	0.022	W. R. Hutton and Patterson. Narrow valleys. Steep slopes. Wooded. No lakes.

EXTREMES OF FLOW FOR SOME AMERICAN STREAMS—*Continued.*

RIVER.	PLACE.	Drainage area, square miles.	EXTREMES OF FLOW. Maximum cubic feet per second.	Minimum cubic feet per second.	Maximum cubic feet per second per square mile.	Minimum cubic feet per second per square mile.	AUTHORITY AND REMARKS.
Potomac	Dam No. 5	4,640+	92,772	863	22.15	0.0783	Quoted by W. R. Hutton. Narrow valleys. Steep slopes. Wooded. No lakes.
Potomac	Great Falls	11,476	175,000	1,063	15.25	0.093	W. R. Hutton. Country more open. No lakes.
Rock Creek	Hoyle's Mill	64.40	....	7.50	....	0.114	Quoted by W. R. Hutton.
Kanawha	Cha'ston Pool	8,900	120,000	1,100	13.49	0.123	Gill, Scott and Hutton. Mountainous. Steep. No lakes. Wooded.
Greenbrier	Mouth of Howard's creek	870	....	97	....	0.120	McNeill. Mountainous. Steep. No lakes. Wooded.
Shenandoah	Near Port Republic	770	....	128	....	0.167	James Herron. Hilly. Limestone. No lakes. Many springs.
James	Richmond	6,800	....	1,300	....	0.191	E. D. Whitcomb and W. E. Cutshaw. Mountainous in upper part. No lakes. Wooded.
Neuse	Near Raleigh	1,000	....	....	....	0.193	W. C. Kerr. Low water. Open. Clay and loam. No lakes. Few extensive woods.

WATER-POWER.

One of the practical applications of the determination of the flow of our streams will be to point out their resources for power, as has already been remarked. It is intended to make such computations of flow as will be a safe guide to the amount of power which may be depended upon at a given point. There is nothing which tells so fatally against the use of water-power as a few examples of disastrous attempts to use a stream for more power than it is really good for. Such attempts are often made, and then, when inevitable failure comes, the blame is laid at the doors of water-power, which is declared to be unreliable, when the fault lies wholly in bad judgment. No one attempts to work a 50 horse-power boiler and engine plant up to 100 horse-power. Why should a 50 horse-power stream be expected to develop two or three times that amount? Yet the stream may, in many cases, be made to yield double the power by a judicious location of plant and doubling of the available fall. There is no lack of examples of admirably-equipped and located water-power plants in the State. It may be invidious to mention a few where so many are equally good, yet the works of the Millville Manufacturing Company, on Maurice river, and of the Mays Landing Water-Power Company, on Great Egg Harbor river, are such excellent examples of successful utilization of comparatively small streams of gentle slope; and the two mills of the Warren Manufacturing Company, on Musconetcong river, of similarly efficient utilization of a stream which is a fair type of our smaller northern rivers, that we feel it may be a help to those who may be in search of good examples to speak of them.

VALUE OF WATER-POWER.

Much has been written and many computations have been made of the relative cost of steam and water-power. So many factors, which cannot be expressed in figures, enter into the problem, however, that it scarcely seems worth while to reproduce them. When we know that for many kinds of manufacture such power is now successfully in use, is well liked and considered highly profitable by the users, we know that water-power has a value. Perhaps no better standard of that value exists than the figures of rental per horse-power given in the census report on water-power, 1880, for the leading water-powers of the United States. The following list is extracted relating to powers in this section of the country:

TURNER'S FALLS, MASSACHUSETTS.

Connecticut River. Turner's Falls Company, Owner.

Available power equals 17,600 theoretical horse-power in low water of ordinarily dry years, night and day.

Rates for Power.—Usual rate has been $7.50 per annum per horse-power (not further specified), but there is no established rate for the future.

BELLOWS FALLS, VERMONT.

Connecticut River. Bellows Falls Canal Company, Owner.

Available power equals 12,000 theoretical horse-power in low water of ordinarily dry years, night and day.

Rates for Power.—Nominal rate, $7.50 per annum per horse-power (not further specified).

UNIONVILLE, CONNECTICUT.

Farmington River. Union Water-Power Company, Owner.

Available power equals 860 theoretical horse-power in low water of ordinarily dry years, night and day.

Rates for Power.—Perpetual lease at $175 per mill-power per annum, a mill-power being 7½ cubic feet per second under a head of 18 feet, or 15.34 theoretical horse-power—that is, the price is $11.35 per theoretical horse-power per annum.

OCCUM, CONNECTICUT.

Shetucket River. Norwich Water-Power Company, Owner.

Available power equals 200 theoretical horse-power in low water of ordinarily dry years, night and day.

Rates for Power.—Twenty dollars per annum per horse-power (not further specified).

BARRETT'S JUNCTION, MASSACHUSETTS.

Swift River. Barrett's Junction Water-Power Company, Owner.

Available power equals 200 theoretical horse-power in low water of ordinarily dry years, night and day.

Rates for Power.—Nine dollars per annum per horse-power (not further specified).

BIRMINGHAM, CONNECTICUT.

Housatonic River. Oosatonic Water Company, Owner.

Available power equals 1,375 theoretical horse-power in low water of ordinarily dry years, night and day.

Rates for Power.—Power leased for 99 years, per square foot. *Permanent water*, $20 per annum per theoretical horse-power; *second surplus*, $8 per annum per theoretical horse-power. Company does not guarantee power in any case.

ANSONIA, CONNECTICUT.

Naugatuck River. Ansonia Land and Water-Power Company, Owner.

Available Power.—Total effective (rated) power of wheels in use, 1,600 horse-power.

Rates for Power.—Water leased by the square foot, under a head of 30 inches, estimated to produce 30 theoretical horse-power. *Permanent water*, $600 per annum per square foot; *surplus water*, $250 to $500 per annum per square foot ($20 per annum per horse-power).

COHOES, NEW YORK.

Mohawk River. The Cohoes Company, Owner.

Available power equals 9,450 theoretical horse-power in low water in ordinarily dry years, night and day.

Rates for Power.—Perpetual lease of land and power with reserved rent amounting to $14.67 per annum per theoretical horse-power.

LOCKPORT, NEW YORK.

Erie Canal. Lockport Hydraulic Company, Owner.

Available power equals 2,500 to 3,238 theoretical horse-power.

Rates for Power.—Perpetual lease or absolute purchase. Price, from $8.33 to $11.11 per annum per theoretical horse-power.

PASSAIC, NEW JERSEY.

Passaic River. Dundee Water-Power and Land Company, Owner.

Available power equals about 800 theoretical horse-power in low seasons of ordinarily dry years, night and day.

Rates for Power.—About $33.33 per annum per gross or theoretical horse-power, for 12 hours a day.

PATERSON, NEW JERSEY.

Passaic River. Society for Establishing Useful Manufactures, Owner.

Available power equals about 2,150 theoretical horse-power in low season of ordinarily dry years, night and day.

Rates for Power.—Seven hundred and fifty dollars per annum per square foot of orifice, under a head of 2.75 feet to center, equivalent to about $36 per annum per theoretical or gross horse-power.

RARITAN, NEW JERSEY.

Raritan River. Raritan Water-Power Company, Owner.

Available power equals 216 theoretical horse-power in low season of ordinarily dry years, night and day.

Rates for Power.—Nominal price, $300 to $400 per annum per square foot of orifice, under a head of 30 inches to center of orifice.

TRENTON, NEW JERSEY.

Delaware River. Trenton Water-Power Company, Owner.

Available power equals 3,000 to 4,500 theoretical horse-power in low seasons of ordinarily dry years, night and day.

Rates for Power.—Three and four dollars per square inch, under a head of 3 feet; equivalent to about $37.50 and $50 per annum per theoretical horse-power.

FREDERICKSBURG, VIRGINIA.

Rapahannock River. Fredericksburg Water-Power Company, Owner.

Available power equals 3,000 to 4,500 theoretical horse-power in low season of ordinarily dry years, night and day.

Rates for Power.—From $5 to $15 per horse-power (not further specified).

MANCHESTER, VIRGINIA.

James River. City of Manchester, Owner.

Available power cannot be stated.

Rates for Power.—Fifty-year leases at $4 per annum per square inch of orifice, under a head of 3 feet; corresponding, theoretically, to between $29.60 and $42.10 per annum per theoretical horse-power, according as the fall is 22 or 14 feet.

From this list it will be seen that the highest prices are commanded in our immediate vicinity, and that from $33 to $37 is the range for the water delivered at the forebay. This may be taken as a measure of the expense warranted for the purchase of mill privilege and construction of dam and raceway. At $33 per horse-power the rental for 100 horse-power would pay 6 per cent. interest on $55,000. Of course the actual value will vary with the location. Judging by the above table, it ought not to fall much below $15 anywhere in the State.

The possibility of a widened field of usefulness through the medium of electric transmission has been referred to before. Examples of the practical application of this agent are not wanting already, and the further development of the idea is assured in the near future.

CANVASS OF WATER-POWER.

During the past season a partial collection of the water-powers of the State has been made in connection with our inquiries concerning the flow of the streams. This canvass is practically finished for the Raritan water-shed and all of the State north of Trenton. Some water-sheds have been included in Southern New Jersey, but the statistics there are still incomplete. The completion of the work will require only a short time. Such a work is necessarily done at some disadvantage, as it is difficult to procure reliable information in some cases. No pains have been spared to secure accuracy so far as we have gone. A few owners have failed to respond to our inquiry. We will esteem it a favor if all owners of water-power will send us at once any corrections or additions which may be necessary, in order that the completed canvass may be as accurate as possible. The horse-power has been based on the kind and size of wheel in use and its known efficiency, so far as possible. When this would not answer, estimates have been made of the amount of power which should suffice to do the work of the mill, and the gross power has been computed from the net by an estimated efficiency for the whole plant. Not merely the efficiency of wheels under experiment has been used, but the length of time they have been in use and the manner in which they are set have also been taken into account.

SUMMARY OF POWER IN USE.

As Northern New Jersey is complete, the following summary of the amount of power applied to certain kinds of manufacture may prove of interest:

STREAM.	Grist and flouring mills.	Saw, turning furniture and other wood-working.	Fabrics and fibres; woolen, cotton, silk, felt, &c.	Paper.	Rolling mills, forges and other iron works. Machinery.	Miscellaneous manufactures.
Delaware and Small Branches	1,056	119	199	487	61	314
Flat Brook	105	32	....	....	....	....
Paulinskill	614	216	....	....	89	42
Pequest	735	205	....	....	25	....
Musconetcong	795	47	....	955	155	55
Wallkill and Branches	402	107	....	47	37	....
Passaic and Small Branches	320	223	2,185	324	661	879
Saddle River	248	202	92	50	25	75
Ramapo	10	60	45	....	80	....
Wanaque	90	46	110	....	....	25
Pequannock	104	218	60	275	12	365
Rockaway	149	40	284	260	825	200
Whippany	247	75	70	276	72	....
Hackensack	191	168	....	....	45	....
Elizabeth	36	....	....	....	....	....
Rahway	94	34	128	100	....	....
Raritan and Small Branches	346	10	205	25	....	426
South River	339	49	....	....	....	279
Millstone	532	22	18	....	....	....
North Branch	751	142	16	....	107	36
South Branch	1,678	216	12	....	775	....
Total for Northern New Jersey	8,852	2,231	3,424	2,799	2,969	2,696

This gives an aggregate of 22,971 horse-power, which is distributed among the water-sheds as follows:

Delaware	6,306
Wallkill	593
Passaic	9,282
Hackensack, Rahway, &c	806
Raritan	5,984

The power is most largely employed in flouring mills, as they are able to adjust their run to the stage of the stream. The other classes of manufacture divide the power quite equally.

UNDEVELOPED POWERS AND STORAGE.

In the canvass all mill sites which have been once in use are included so far as possible. There are besides a number of fine sites which have never been occupied. These will be taken up fully and their capacity and special features pointed out at a later stage of the work. A few of the principal ones may be mentioned here.

On the Delaware the largest single fall is at Foul Rift, near Belvidere, where the power has been estimated at 3,500 horse-power. All along the river there is a large amount of unutilized fall, amounting in the aggregate to much more than all the power in use at present in the State. At Trenton the water-power is not nearly all developed because of the opposition of the fishermen to the tightening and improvement of the dam at Scudder's Falls. The proper way to develop the Delaware powers is unquestionably by low dams and by raceways, but the dams need to be reasonably tight. The value of water-power at so good a locality as this, and the benefit which would accrue by the full development of the 3,000 horse-power of the stream, is evident.

The recent opening up for lease of the fine power of the estate of J. Couper Lord, at Boonton, has had a most beneficial effect upon that town. Wheels are in already with a capacity of 945 horse-power, yet this is upon only 100 feet of the total fall of 240 feet in the Rockaway at this point. This is a fine water-power and one of the many cases where storage and consequent increase of the capacity of the stream must in time prove profitable, for when the power comes to be needed every cubic foot of water which can be added to the flow on so large a fall will have a considerable value. Storage for the purpose of increasing the power of a stream has been quite largely applied in some of the Eastern States. It was introduced in this State, on the Pequannock, by Peter Hasenclever before 1768. He improved many of the ponds on that water-shed in order to secure a better and steadier power for the iron works of the London Company.

Storage was quite general with the early users of water-power, a natural lake being often raised by a dam as the cheapest means of securing the requisite capacity. Most of our northern lakes were so utilized, and good power often secured on very small water-sheds. Lake Hopatcong was originally raised for a forge at the outlet. Splitrock, Macopin, Hank's, Cedar, Buckabear, Wawayanda, Culver's, Swartswood and many other lakes may be mentioned as instances. Besides these were many entirely artificial storage ponds, in both Northern and Southern New Jersey. The largest in the State is the one at Millville, on Maurice river. It has an area of 926 acres of open water-surface. The dam is 2,200 feet long and 24 feet high.

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Mays Landing, Batsto, Harrisville and many other illustrations might be given. If storage proves profitable on limited falls it should be much more so on the great falls of the State. Suppose we take the Rockaway as an example, and apply to it the Croton flow in the great drought of 1880. From June to October, inclusive, the Croton fell below 0.50 inch per month. In order to have kept it up to 0.50 inch per month, we should have needed in those five months a storage capacity equal to 1.17 inches on the water-shed, or, say, 1.50 inches to allow for evaporation. Now, on the Rockaway, a flow of 0.50 per month would equal 66.75 cubic feet per second, day and night, at Boonton, while, if we allow the flow to fall to the lowest natural rate of the Croton, it will be but 0.12 inch per month, or 16 cubic feet per second. Supposing we have utilized 200 feet fall, in the latter case our power will sink to 364 horse-power, while with storage it will be kept up steadily at 1,516 horse-power, a difference of 1,152. Now, if the power will rent at $30 per horse-power per annum, this difference is worth the income from $576,000 at 6 per cent.; but the return will come not merely from the additional power, but from the ability to guarantee a certain amount of power, which will place the works in a position to command a higher rental. I have purposely taken an extreme case for illustration. The Rockaway probably never falls so low as this, and furthermore, a comparatively small amount of storage immediately at the head of the fall would make it an easy matter to retain all of this additional flow for use during twelve hours of the day, so that the actual increase from the storage would be double what we have computed, or over 2,300 horse-power. The successful application of the principle will be determined by the ability of the parties undertaking the storage to control the requisite amount of fall, or to secure the pledges of the parties who do own the fall to pay a fixed price per annum for a guarantee of a certain amount of water from storage; and also upon the facilities for impounding the requisite amount of water, at a cost which will not be prohibitive. When a considerable amount of fall has been utilized on a stream, there seems little doubt that storage may be applied, instead of the installation of an auxiliary steam-power plant, with a considerable gain to the users.

WATER-POWERS OF NORTHERN NEW JERSEY.

Flat Brook and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Flat Brook	Flatbrookville	Sussex	Samuel Gariss	Grist and saw	12	......	......	Burned down.
" "	Walpack township	"	Mrs. Charles Haney	Grist	6 }	30	50	
" "	" "	"	" " "	Saw	6 }	10	20	
" "	Peters Valley	"	John Kean	Grist	7	17	23	
Big Flat Brook	Sandyston township	"	John D. Snook	Saw	16	22	31	
Branch at Tuttle's Corner	Tuttle's Corner	"	Samuel Smith	"	15	......	......	Not in use.
Little Flat Brook	Layton	"	John B. Rosenkrans	Grist	20	28	40	
" " "	Hainesville	"	Washington Lantz	Flouring	20	30	42	

Paulinskill and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Paulinskill	Columbia	Warren	Heirs of Pace Love	Saw	13	......	......	Not in use.
"	Warrington	"	E. G. Bulgin	Grist	8	50	100	
"	Hainesburgh	"	G. C. Adams & Co.	"	9 }	75	110	
"	"	"	" " "	Saw	9 }	20	83	
"	Paulina	"	A. N. Snover	Grist	7½ }	30	50	
"	"	"	A. W. Snyder & Co.	Saw	7½ }	17	24	
"	"	"	A. J. Hill	Grist	9	......	......	Not in use.
"	Marksboro	"	George Wale	Photographic lenses	6	17	24	
"	"	"	W. H. Clarke	Grist	9 }	28	40	
"	"	"	" "	Saw	9 }	28	40	
"	Hardwick township	"	John Vanstone	Sorghum	4½	......	......	Not in use.
"	" "	"	Bert Wintermute	Saw	6½	12	20	
"	Stillwater	Sussex	H. Hopler	Grist	8	20	40	
"	" township	"	James Butler	"	7	20	40	
"	Baleville	"	J. H. Northrup & Co.	Turning	6	20	40	
"	"	"	A. J. Bale	Grist	7 }	20	29	
"	"	"	" "	Carding	7 }	20	50	
"	Lower Lafayette	"	Coolver & Huston	Grist	20⅝ }	40	66	
"	" "	"	" "	Saw	8 }	10	20	
"	" "	"	" "	Foundry	12 }	......	......	Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Paulinskill and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Paulinskill	Lafayette	Sussex	Coolver & Huston	Foundry	11			Not in use.
"	"	"	O. P. Armstrong	Grist	27	30	50	
Yard's Creek	Hainsburgh	Warren	Mary Pierce	Carding	13	10	20	
Branch at Kalarama	Kalarama	"	Isaac D. Lanterman	Saw	18	7	11	
" " "	"	"	John Painter	Grist	32	24	34	
Jacksonburg Creek	Jacksonburg	"	Mrs. Isaac F. Reed	Distillery	10	10	25	
" "	"	"	Samuel McConachy	Grist	18	15	25	
" "	"	"	J. M. Place.	Saw	16	39	56	
Blair's Creek	Blairstown	"	John I. Blair	Grist	20	30	42	
" "	Hardwick Centre	"	John Voss	Saw	12	10	20	
" "	" township	"	Oman McGraft	"		8	16	
" "	"	"	Clark Bird	Feed and saw	20	60	86	
Trout Brook	Middleville	Sussex	Casper Losey	Saw	13	10	20	
" "	Stillwater township	"	Betsy Wintermute	Foundry	16	15	21	
" "	" "	"	" "	Saw	16	15	30	
Branch at Swartswood Lake	Swartswood Lake	"	John W. Kean	Grist	17	30	42	
" " " "	Stillwater township	"	C. T. Unangst	Grist and saw	35	20	40	
" " " "	" "	"	E. S. Decker	Tannery	18	15	30	
" " Fredon	Emmons Station	"	Richard Varnstone	Saw	18	10	20	
" " "	Fredon	"	William Smith & Bro.	Grist	50	21	30	
" " Branchville	Branchville	"	V. H. Cressman	Flouring	22	40	57	
" " "	"	"	William Bell	Woolen	13			Not in use.
" " "	"	"	V. H. Cressman	Feed	24	41	58	
" " "	"	"	William Space	Woolen	50			Not in use.
" " "	"	"	William McDonalds	Feed and saw	18	20	33	
" " "	Mount Pisgah	"	William Bell	Saw	14			Not in use.
" " "	" "	"	" "	Forge	18	30	5	" "
" " "	" "	"	E. A. Ely	Machine shop	12	14	23	
" " "	" "	"	James Perry	Bark	14	10	17	
" " "	" "	"	William Bell, in trust	Lumber	20			Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Pequest River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Pequest	Belvidere	Warren	A. B. Searles	Flouring	17½	128	170	
"	"	"	G. K. & A. McMurtry	Saw	17½	45	60	
"	"	"	Ira B. Keener	Flouring	7	26	37	
"	"	"	Uhler & Lake	Furniture	7	35	50	
"	"	"	E. Van Uxem	Spokes	18	16	22	
"	"	"	Geo. K. & A. McMurtry	Flouring	18	104	150	
"	"	"	Belvidere Agricultural Co.	Agricultural machinery	18	25	36	
"	Bridgeville	"	Mrs. William Mackey	Grist	6	30	60	
"	Butzville	"	David Anderson	"	9	33	44	
"	Townsbury	"	Heirs of Andrew Ketcham	Saw	10	10	25	
"	"	"	J. B. Smith	Feed	12	25	50	
"	"	"	John Green	Grist	12	25	50	
"	"	"	" "	Saw	12	15	30	
"	Tranquility	Sussex	Heirs of E. V. Kenedy	Flouring	5	25	37	
"	Huntsville	"	Geo. V. Northrup	Saw	10	15	21	
"	"	"	" " "	Grist	12	30	42	
"	Springdale	"	Seymore Stickles	"	6	20	50	
Beaver Brook	Sarepta	Warren	William Hutchinson					Not in use.
" "	"	"	John R. Buttz	Grist	8	10	15	
" "	"	"	Charles Bartow	"		24	48	
" "	Hope	"	John Sweazy	"	25	48	70	
Honey Run	Sweazy's Mill	"	" "	"		10	15	
Glover's Pond Outlet	Glover's Pond	"	—— Vasbinder	Saw	20	10	15	
Trout Brook	Hope	"	Levi J. Howell	Grist		12	24	
Green's Pond Branch	" township	"	John Parks					Not in use.
" " "	" "	"	Smith Hilderbrant	Cider	9	10	20	
" " "	" "	"	" "	Saw	12			
Furnace Brook	Oxford Furnace	"	Oxford Iron and Nail Co.	Flouring	28	36	72	
Branch at Vienna	Vienna	"	Charles Barker	"	36	37	53	
" " Petersburg	Petersburg	"	Robert Ayres					Not in use.
" " Warrenville	Warrenville	"	Lackawanna Iron and Coal Co.	Saw	20			" "
" " Johnsonburg	Johnsonburg	"	Elridge Harden	Grist		15	30	
" " Hunt's Pond	Huntsburg	Sussex	George Current	Saw	18	19	38	
" " " "	"	"	Theo. F. Hunt	Grist	30	22	31	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Pequest River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Branch at Alamuche	Alamuche	Warren	Rule H. Drake	Saw	20	21	85	
" " "	"	"	Morris Haggerty	Grist	28	24	40	
" " "	"	"	Joseph Ayres	Saw	26	10	25	
" " "	"	"	Rutherford Stuyvesant	Grist	80	86	72	Not in use.
" " Andover	Andover	Sussex	Heirs of John Seward Wills	Flouring	28	15	25	

Pohatcong Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Pohatcong	Carpenterville	Warren	Isaac T. Riegel	Saw	9	25	86	
"	Springtown	"	Nathan Druckenmiller	Grist	7	12	30	
"	"	"	Thomas Paullus	"	8	12	25	
"	"	"	P. W. Skinner & Bro	Flouring	8	21	40	
"	Greenwich township	"	John Kenedy	Grist	10	15	87	
"	" "	"	——— Hulsizer	"	10	25	87	
"	Franklin township	"	Levi Cressman	Flouring	7½	17	24	
"	Pleasant Valley	"	New York Life In. Co	Feed	11	24	60	
"	Washington	"	John Neilson	Grist	8	15	25	
"	Karrville	"	William Larrison	Flouring	11	24	84	
"	"	"	William Karr	Wheelwright	6½	8	16	
"		"	William Ketcham	Saw	18	15	80	
Hihichehockhi	Stewartsville	"	Jacob Shillinger	Flouring	23	30	43	
Brass Castle Creek	Brass Castle	"	Assign. of James Lomerson	Grist	60	45	56	
" " "	Washington township	"	John Smith	Saw	11	......	......	Not in use.

Musconetcong River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Musconetcong	Riegelsville	Warren	John L. Riegel & Son	Grist	20 }	175	250	
"	"	"	" " "	Paper	20 }	255	864	
"	Finesville	Hunterdon	Taylor, Stiles & Co	Machine knives	6	75	107	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Musconetcong River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Musconetcong	Finesville	Warren	I. A. Jacoby	Grist	6½	48	70	
"	"	"	" "		9			Not in use.
"	Hughesville	Hunterdon	Warren Manufacturing Co.	Paper	27	310	487	
"	Warren Paper Mills	"	" " "	"	48	360	514	
"	Bloomsbury	Warren	T. G. Hoffman	Foundry facings	9½ }	80	114	
"	"	Hunterdon	" "	Grist	9½ }	44	62	
"	Asbury	Warren	J. C. Reed and others	"	5½	36	60	
"	New Hampton	"	S. S. Cramer	"	5	30	42	
"	" "	Hunterdon	Martin Wyckoff	"	7	50	70	
"	Changewater	Warren	Bowers Snuff and Tobacco Co.	Snuff	9	35	50	
"	Point Mills	Hunterdon	J. D. Pidcock	Grist	9	25	50	
"	Penville	"	Peter Lance	"	8	50	70	
"	Stephensburg	Morris	John P. Sharp	"	8½	55	90	
"	Beattystown	Warren	White & Simanton	"	7	30	60	
"	Lower Hackettstown	"	Zephaniah Hoffman	"	8	36	72	
"	Hackettstown	"	Prost & Co.	"	5	36	60	
"	"	"	Lewis J. Youngblood	"	9½	50	80	
"	Upper Hackettstown	"	J. C. Welsh	"	9	36	60	
"	Near Saxton Falls	Morris	Archer Stevens' Sons	Saw	8	12	20	
"	Waterloo	Sussex	Smith Bros.	Grist	18 }	36	60	
"	"	"	" "	Plaster	18 }	40	80	
"	Old Andover	"	Matilda Van Doren					Not in use.
"	Stanhope	"	Musconetcong Iron Co.					" "
"	Lake Hopatcong	"	Morris Canal					" "
Branch north of Port Murray.	Mansfield township	Warren	H. S. Beatty	Grist	22	18		Burned down in June.
" at Hackettstown	Hackettstown	"	James Boyd	Tannery	24	15	37	Not in use.
" " "	"	"	Christopher Morton	"	10	5	10	
" near Drakesville	Drakesville	Morris	Jonathan Coleman	Saw	15			Not in use.
" south of Stanhope	Stanhope	"	Heirs of John Seward Wills	"	22	15	30	
" " " "	"	"	" " " "	"				Not in use.
" at Waterloo	Waterloo	Sussex	John French	"	50	20	40	
Lubber's Run	Lockwood	"	Pope & Appleton	Forge				Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Musconetcong River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Lubber's Run	Roseville	Sussex	Robert L. Byerley	Forge	....	....	....	Not in use.
" "	Columbia	"	W. W. & L. F. Sutton	"	....	....	....	" "
" "	Near Columbia	"	Watson McPeek	Saw	....	....	....	" "
" "	Sparta township	"	Lance Goble, Agt.	"	20	....	....	" "

Delaware River and Small Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Branch at Montague	Montague	Sussex	Jacob C. Hornbeck	Grist	22	12	24	
Vancampen's Brook	Calno	Warren	John Zimmerman	Saw	18	10	20	
" "	Mill Brook	"	Heirs of Bartley Fuller	Grist	22	19	31	
" "	Walpack township	Sussex	David R. Hull	Saw	15	12	24	
Pophaudusing Branch	Oxford Church	Warren	John C. Prall	Grist	24	30	60	
" "	" "	"	George Keiser	Tannery	16	10	25	
Buckhorn Creek	Hutchinson's	"	Samuel A. Depew	Saw	12	....	....	Not in use.
" "	"	"	" " "	"	20	....	....	" "
" "	Harmony township	"	Mrs. Archibald Davis	....	....	....	....	" "
" "	Roxburgh	"	Isaac Young	Foundry	8	15	20	
" "	"	"	R. M. Bowlby	Grist	45	36	60	
Lopatcong Creek	Phillipsburg	"	W. D. Hagerty	Saw	20	20	30	
" "	"	"	P. W. Skinner & Bro.	Flouring	14	24	34	
" "	"	"	F. G. Warne	Soapstone	18	12	18	
" "	Lopatcong	"	S. C. Purcell	Flouring	8	12	30	
" "	" township	"	John Holden	Grist	20	12	30	Not in use.
" "	Lower Harmony	"	" "	"	22	47	73	
" "	" "	"	William Vanatta	"	9	24	60	
" "	" "	"	Elijah Allen	"	18	12	24	
Branch at Carpenterville	Carpenterville	"	John Reese	"	10	....	....	Burned.
Alexsocken Creek	Mount Airy	Hunterdon	Annie Blackwell	"	11	12	30	
Wickecheoke Creek	Locktown	"	Robert Holcomb	"	15	12	24	
" "	Sergeantsville	"	R. G. Johnson	"	25	12	24	
Lockatong Creek	Delaware township	"	Mahlon Strumpel	Grist and saw	24	10	17	
" "	Idell	"	Newbury Hagar	Grist	17	16	32	
" "	"	"	Henry Cook	"	21½	48	30	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Delaware River and Small Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Nishisakawick Creek	Frenchtown	Hunterdon	D. R. Worman	Flouring	20	24	34	
" "	"	"	" "	Grist and bone	24	15	25	
" "	Everittstown	"	Joseph Huff	Grist	21	36	60	
" "	"	"	Joseph Wilson	"	20	......	......	Not in use.
Harihokake Creek	Frenchtown	"	E. R. Case	Saw	......	......	......	
" "	Mount Pleasant	"	Daniel Johnson	Grist	29	27	40	
" "	" "	"	Rev. Joseph Manning	Saw	14	10	25	
Hakihokake Creek	Milford	"	W. & E. T. Thomas	Flouring	30	84	120	
" "	"	"	" " "	Grist	12	36	50	
" "	Little York	"	J. M. Duckworth	"	30	36	60	
" "	" "	"	S. V. Eckel	"	33	35	50	
" "	" "	"	Samuel Kemenhower	Saw	23	12	30	
Spring Mill Branch of Hakihokake	Spring Mills	"	Jacob R. Anderson	Grist	27	25	50	
Delaware & Raritan Canal Feeder	Prallsville	"	Joseph Smith & Co	Flouring	8½	40	57	
Delaware & Raritan Canal Feeder	Lambertville	"	New Jersey Rubber Co	Rubber	15	......	......	Not in use.
Delaware & Raritan Canal Feeder	"	"	" " " "	"	15	100	140	
Delaware & Raritan Canal Feeder	"	"	Caroline Ely	Grist	19	45	64	
Delaware & Raritan Canal Feeder	"	"	F. F. Lear	Flouring	18	60	86	
Delaware & Raritan Canal Feeder	"	"	" "	Saw	18	15	25	
Delaware & Raritan Canal Feeder	"	"	Lambertville Paper Co	Paper	14	96	137	
Lambertville Water-Power Company	"	"	M. Sheppard	Twine	9½	40	80	
Lambertville Water-Power Company	"	"	William Mann Paper Co	Paper	9½	218	310	
Lambertville Water-Power Company	"	"	O'Brien Brothers & Co	"	9½	79	112	
Lambertville Water-Power Company	"	"	James C. Weeden	"	9½	94	134	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Delaware River and Small Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Delaware & Raritan Canal Feeder	Titusville	Mercer	George Agnew	Flouring	26	30	42	
Delaware & Raritan Canal Feeder	"	"	" "	Rubber	26	75	107	
Delaware & Raritan Canal Feeder	Somerset Junction	"	John Howell Borrough's Est.	Grist	18 28	24	34	
Trenton Water-Power Co.'s Raceway	Trenton	"	City Water Works	Pumping	9	20	27	
Trenton Water-Power Co.'s Raceway	"	"	Wm. Kennedy	Sawing and planing	12	40	55	
Trenton Water-Power Co.'s Raceway	"	"	B. W. Titus' Sons	Cotton and woolen	12	25	33	
Trenton Water-Power Co.'s Raceway	"	"	Golding & Sons Co.	Potters' material	14	97	121	
Trenton Water-Power Co.'s Raceway	"	"	A. Thompson & Co.	Flouring	12	19	24	
Trenton Water-Power Co.'s Raceway	"	"	Nelson Thompson	"	12	12	16	
Trenton Water-Power Co.'s Raceway	"	"	Chas. W. Howell	"	13	80	120	
Trenton Water-Power Co.'s Raceway	"	"	S. Zigenfuss & Co.	"	12	70	88	
Trenton Water-Power Co.'s Raceway	"	"	Fisher & Norris	Iron works	14	6	10	
Trenton Water-Power Co.'s Raceway	"	"	Phœnix Iron Works	Machinery	14	40	65	
Trenton Water-Power Co.'s Raceway	"	"	Samuel K. Wilson	Woolen and worsted	12 17	100	135	Partly from Assanpink creek.
Trenton Water-power Co.'s Raceway	"	"	William Walton	Flouring	17	20	27	
Trenton Water-Power Co.'s Raceway	"	"	Saxony Woolen Mills	Woolen	11	60	75	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Wallkill River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Wallkill	Hamburg	Sussex	Glenn Estate	Forge	......	......	......	Not in use.
"	"	"	W. H. Ingersoll	Flouring	21½ }	75	107	
"	"	"	" "	Plaster	21½ }			
"	"	"	Augustus Cochran	Paper	24 }	47	78	Not in use.
"	"	"	W. H. Ingersoll	Saw	24 }			" "
"	Lehigh Junction	"	Franklin Iron Co	Forge	......	......	......	" "
"	Franklin Furnace	"	" "	Furnace				
"	Sparta	"	James L. Decker	Grist	18	19	31	
"	"	"	" "	Distillery	11	5	10	
"	"	"	James F. Titman	Flouring	21	38	51	
"	"	"	Dr. Andrus	Grist	25	......	......	Not in use.
Branch at Decker Pond	Vernon township	"	Henry L. Sammis	Saw	40	15	30	
" " " "	" "	"	" "		......	......	......	Not in use.
" " " "	" "	"	Thomas L. Babcock	Saw	16	12	24	
Papakating Creek	Frankford township	"	Daniel Wyker	"	12	8	20	
Clove River	Deckertown	"	R. J. Quince	Grist	16	24	40	
" "	North Deckertown	"	Albert Fuller	"	12	25	41	
" "	" "	"	William T. Wright	Lumber	22	20	33	
" "	Clove	"	William Titsworth	Saw	......	......	......	Not in use.
" "	Wantage township	"	John Decker & Mary Decker	Grist	24	24	40	
" "	" "	"	Dr. Charles Cooper	"	35	24	48	
" "	Coleville	"	Theodore C. Marthis	"	16⅓ }	20	32	
" "	"	"	Edward Baker's Estate	Spokes	16½ }	10	25	Not in use.
" "		"	J. E. Post	Saw	14 }			" "
West Branch of Papakating	Woodbourne	"	Philip Elston	Grist	40	......	......	" "
" " "	Plumbsock	"	Nancy Compton and Emma Stelle	"	20	24	60	
" " "	"	"	John Smith	Saw	18	32	52	
Branch at Wykertown	Wykertown	"	Samuel J. Corsen	Grist	40	......	......	Not in use.
Beaver Run	Wantage township	"	James Cox	"	16	12	24	
" "	" "	"	Benj K Jones	Foundry	24	37	60	
Branch at Hardystonville	Hardystonville	"	Milton I. Southard	Grist	20	36	60	
" near Ogdensburg	Ogdensburg	"	Augustus Tallman	Feed	18	10	25	
" at Lake Grenell	Monroe Corners	"	Mrs. Susan Kemble	Grist	8	15	37	
" " "	" "	"	J. C. Wilson	"	12	21	35	
Pochuck	Wawayanda	"	Victor H. Wilder	"	18	......	......	Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Wallkill River and Branches—Continued.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
Pochuck	Wawayanda	Sussex	Victor H. Wilder	Cheese box factory	10			Not in use.
"	"	"	" "	Saw	18			" "
"	"	"	" "	Furnace	35			" "
"	"	"		Creamery	8			" "
"	Vernon township	"	Martin Thaddock	Saw				" "
Branch at Glenwood	Glenwood	"	Daniel Bailey	Flouring	28	25	86	
" "	"	"	Norman McKirk	Saw	15	10	25	
" " Vernon	Vernon	"	Joseph Burroughs	"				Not in use.
" " "	"	"	S. E. Wood	Feed	18	12	24	

Passaic River and Branches.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
Second River	Belleville	Essex	De Witt Wire Cloth Co.	Wire cloth	11	40	80	
" "	"	"						Not in use.
" "	"	"	Hendricks Bros		12			" "
" "	"	"	" "		20			" "
" "	"	"		Copper	19	100	200	
" "	"	"	National Print Works	Print works	18	25	36	
" "	Bloomfield	"	James Moffet	Brass rolling mills	20	25	40	
" "	"	"	Wheeler Bros		12			Not in use.
Silver Lake Branch of Second River	Silver Lake	"	Thos. A. Edison	Grist	14			" "
Yantecaw	Delawanna	Passaic	J. & R. Kingsland	Paper	22 / 15			" "
"	Nutley	"	" "	"	17	65	90	
"	"	Essex	Nutley Water Co.	Water-works	8	10	14	
"	Franklin	"	—— Hilton	Woolen	6	40	80	
"	"	"	Underhill Mfg. Co.	Woolen underwear	12	37	61	
"	Bloomfield	"	E. H. Davey	Trunks and binders' boards	11	45	75	
"	"	"	Thomas Oakes & Co.	Woolen	16	38	54	
"	"	"	A. T. & Joseph Morris	Grist	12			Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
Yantecaw	Bloomfield	Essex	Estate of Albert Moore	Saw	10	15	30	
Passaic	Passaic	Passaic	Dundee Water-Power and Land Co.	Miscellaneous	22	1200	1300	
Weasel Brook	Clifton	"	Richard A. Westervelt	Grist	15	...	...	
" "	Athenia	"	A. R. Post & Co.	Saw	12	12	24	
Saddle River	Garfield	Bergen	—— Zabriskie	Cotton	5	...	...	Not in use.
" "	"	"	C. R. Van Dusen	Grist	6⅓	42	70	
" "	Lodi	"	Byrne Bros. & Co.	Bleaching and dyeing	7½	...	...	
" "	Rochelle Park	"	D. Romaine	Rubber shoddy	6	58	71	
" "	Arcola	"	Dunlap & Co.	Blankets	4	10	25	
" "	Midland township	"	J. Henry Blauvelt	Grist	7	11	18	
" "	" "	"	" "	Saw	7	10	20	
" "	Paramus "	"	Abram F. Z. Demarest	Grist	6½	12	30	
" "	" "	"	John D. Berdan	"	12	25	41	
" "	" "	"	" "	Saw	12	15	25	
" "	Orvil township	"	Thomas Eckerson	"	6	12	24	
" "	" "	"	" "	Cider and saw	6	5	10	
" "	" "	"	D. A. Blauvelt	Grist	8	15	37	
" "	" "	"	O. J. Victor		7	...	...	Not in use.
" "	Saddle River	"	Abram Dates	Grist	6	10	25	" "
" "	" "	"	William W. Packer	Saw	7	10	25	
" "	" "	"	" "	Foundry	6	15	30	
" "	North Saddle River	"	J. Raymond Ackonback	Grist	4	20	50	
" "	" " "	"	Dr. O. Blyneth	Woolen	7½	20	33	
" "	" " "	"	W. J. C. Ward	Mechanics' tools	8	10	20	
" "	Orvil township	"	John E. Hopper	Saw	8	8	16	
" "	" "	"	Abram C. Hopper	"	8	15	25	
West Branch Saddle River	" "	"	Mary Halstead and Geo. De Baum		...	...	...	Not in use.
" " " "	" "	"	Henry P. Post	Grist	9⅓	12	24	
" " " "	" "	"	" "	Saw	9⅓	10	25	
" " " "	" "	"	Martin Tice	Feed and saw	8½	10	25	
" " " "	" "	"	G. J. Hopper	Saw	11	10	25	
East Hohokus Branch of Saddle River	Undercliff	"	Abram J. Zabriskie	Saw and silk	6	15	30	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Hohokus Branch of Saddle River	Undercliff	Bergen	Estate of John R. Terhune	Rubber	11	25	42	
Hohokus Branch of Saddle River	"	"	" " "	Saw	13⅓	12	24	
Hohokus Branch of Saddle River	"	"	" " "	Turning	13½	10	20	
Hohokus Branch of Saddle River	"	"	McCafferty & Buckley		30	80	110	Not in use.
Hohokus Branch of Saddle River	Hohokus	"	W. D. Rosenkrantz, Agent	Cotton yarn	40	50	70	
Hohokus Branch of Saddle River	Waldrick	"	M. D. White	Saw and bark	18	18	26	
Hohokus Branch of Saddle River	"	"	Martin Margoff	Cotton	10	12	17	
Hohokus Branch of Saddle River	"	"	Charles White	Paper	13	50	70	
Hohokus Branch of Saddle River	Allendale	"	Richard Christopher	Grist	10	13	21	
Hohokus Branch of Saddle River	"	"	" "	Saw	10	8	13	
Hohokus Branch of Saddle River	"	"	A. A. Lydecker	Flouring	10	20	30	
Hohokus Branch of Saddle River	"	"	Jacob J. Smith	Saw	8	10	20	
Hohokus Branch of Saddle River	North Wyckoff	"	John Gardiner					Not in use.
Hohokus Branch of Saddle River	" "	"	G. G. Ackerman	Flouring	9	20	30	
Hohokus Branch of Saddle River	" "	"	John W. Pulis	Grist and saw	11⅛	10	17	
Hohokus Branch of Saddle River	" "	"	John Haubner	Tannery	20			Not in use.
Hohokus Branch of Saddle River	Camp Gaw	"	J. H. Sturr	Grist	13	12	20	
Hohokus Branch of Saddle River	" "	"	" "	Saw	12	12	20	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
Branch at Ramseys of Hohokus Creek	Ramseys	Bergen	Abner Benedict	Grist and bark	10	6	17	
Branch at Ramseys of Hohokus Creek	Allendale	"	Charles Christopher	Saw	12	10	20	
Branch at Wyckoff of Hohokus Creek	Wyckoff	"	P. S. Pulis	Saw and cider	4	4	10	
Branch at Saddle River of Saddle River	Saddle River	"	Thomas Van Buskirk	Saw	15	18	36	
Branch at Hawthorn	Hawthorn	"	Alyea Bros.	Grist	13	20	33	
Goffel Creek	"	Passaic		Dyeing	18			
" "	Van Winkle	"	S. P. Van Winkle	Grist	12	20	50	
" "	" "	"	" " "	Cider	10	4	10	
" "	" "	"	Joel M Johnson		11			Not in use.
" "	Midland Park	Bergen	D. Baldwin	Cotton	16	12	20	
" "	" "	"	Metropolitan Bank of New York	"	24	12	20	
" "	" "	"	G. Morrough's Sons	Woolen	30	23	32	
" "	Wortendyke	"	Metropolitan Bank of New York	Silk	14	12	17	
" "	Wyckoff	"						Not in use.
Branch at Van Winkle of Goffel Creek	Van Winkle	Passaic	Maria Van Blarcom	Saw	16	10	20	
Branch at Van Winkle of Goffel Creek	" "	"	Preston Stevenson	"	22			Not in use.
Branch at Van Winkle of Goffel Creek	Midland Park	Bergen	Isaac G. Snyder	Paint	16	8	13	
Passaic	Paterson	"	Society for the Establishment of Useful Manufactures	Miscellaneous	66	1,760	2,850	
Haledon Creek	Haledon	Passaic	Henry L. Butler	Carpets	12	10	20	
Peckman's Brook	Jackson Park	"	James Edge	Bolts and nuts	6	8	13	
" "	" "	"	Estate of George Jackson	Scouring	10	20	30	
" "	Little Falls	"	S. Sindle	Grist	19	20	33	
" "	" "	"	" "	Felt	19	20	33	
" "	" "	"	James Van Ness	Dyeing	18	40	67	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
Peckman's Brook	Cedar Grove	Essex	F. J. Marley	Saw	18	10	14	
" "	" "	"	" "	Hubs	18	12	17	
" "	" "	"	Elias Van Ness		7	...	...	Not in use.
" "	" "	"	Anthony Bowden	Cotton	16	12	20	
" "	" "	"	Andrew J. Wood	Woolen	11	...	...	Not in use.
" "	Verona	"	J. J. Thatcher	Bronze powder	36	30	42	
" "	"	"	American Bronze-Powder Co	" "	13	15	30	
" "	"	"	Montclair Syndicate	Saw	18	20	50	
Passaic	Little Falls	Passaic	Beattie Manufacturing Co.	Carpets	14	320	440	
"	Chatham	Morris	Geo. T. Parrot	Flouring	10	42	60	
"	"	Union	John P. Edwards	Machine	8	50	80	
"	"	"	" "	Paper	8	...	...	Not in use.
"	Stanley	Morris	Mrs. William Bonnell	Grist	8	40	80	
"	"	"	Armour Brothers	Paper	7½	52	75	
"	Millington	Somerset	William Leeson	Grist	6⅓	24	40	
"	Logansville	"	Richard Irwin's Estate	Saw	$6\frac{5}{12}$	12	24	
"	Franklin	"	F. Van Doren	Flouring	20	40	57	
"	"	"	Edna McMurtry	Saw	13	10	25	
"	Washington	Morris	William Little	Turning	16	62	90	
"	" "	"	Abram Brockoven	Saw	10	20	40	
Green Brook	Caldwell township	Essex	Barney Cook and Henry Francisco	Cider	10	8	16	
" "	" "	"	Thomas C. Sindle	Grist	29	30	42	
" "	" "	"	" "	Saw	29	15	21	
" "	" "	"	O. Dorson	Grist	25	...	...	Not in use.
" "	" "	"	Sindle & Anderson	Turning	25	15	21	
" "	" "	"	O. Dorson	Saw	12	...	...	Not in use.
Ramapo River	Pompton	Passaic	Pompton Steel and Iron Co.	Steel & iron works	20	80	160	
" "	Oakland	Bergen	Samuel B. Demarest	Silk	4½	20	30	
" "	"	"	" "	Saw	4½	12	20	
Franklin Lake Stream	"	"	James H. Van Blarcom	"	10	30	60	
" " "	"	"	Rev. Eugene Dikovich	"	10	...	...	Not in use.
" " "	Crystal Lake	"	H. M. Ranson	"	11	...	...	" "
" " "	" "	"	J. B. Ewing	Silk	21½	25	37	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Franklin Lake Stream	Franklin Lake	Bergen	Daniel Yeomans	Feed and saw	6	10	20	
" " "	" "	"	" "	Turning	6	10	20	
Branch at Mahwah	Mahwah	"	Winter & Bro.	Saw	6	......	......	Not in use.
" " "	"	"	Henry Wanamaker	"	6	8	16	
Wanaque River	Pompton	Passaic	H. J. Smith	Silk	15	110	157	
" "	"	"	" "	Electrical fuse	9	25	36	
" "	Wanaque	"	Edward J. Skerrett	Turning	4	12	24	
" "	"	"	Peter J. Brown	Grist	7	24	48	
" "	Midvale	"	Cooper & Hewitt	Old forge site	15	......	......	Not in use.
" "	"	"	John Taylor Johnson	" " "	9	......	......	" "
" "	Monks	"	Daniel A. Wheeler	Saw and feed	12	28	40	
" "	"	"	Cooper & Hewitt	Old saw-mill site	8	......	......	Not in use.
" "	Hewitt	"	" " "	Furnace	82½	......	......	" "
West Brook	Midvale	"	Albert Albeglse	Saw	10	8	13	
Ringwood Creek	Boardville	"	Cooper & Hewitt	Old forge site	10	......	......	Not in use.
Greenwood Lake Branch	West Milford	"	P. L. La Roe	Grist	11	18	30	
" " "	" " township	"	Albert Terhune	"	17	20	50	
" " "	" " "	"	Albert S. Terhune	Saw	14	10	16	
" " "	" " "	"	Albert S. Terhune	"	20	16	26	
Pequannock River	Riverdale	Morris	East Jersey Water Co., Hon. J. F. Post, Lessee,	"	9	30	60	
" "	"	"	East Jersey Water Co., Hon. J. F. Post, Lessee	Bark	8	12	24	
" "	"	"	East Jersey Water Co., Robert Slater, Lessee	Hatters' felt	14	60	87	
" "	Bloomingdale	"	East Jersey Water Co., W. G. Linnen, Lessee	Grist	12	12	30	
" "	"	Passaic	East Jersey Water Co., M. J. Ryerson's Heirs, Lessees	"	15	12	30	
" "	"	"	East Jersey Water Co., M. J. Ryerson's Heirs, Lessees	Turning	15	5	12	
" "	"	"	East Jersey Water Co., M. J. Ryerson's Heirs, Lessees	Saw	15	10	25	

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WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Pequannock River	Bloomingdale	Morris	East Jersey Water Co., Bloomingdale Soft-Rubber Co., Lessee.	Soft rubber	14	100	143	
" "	Butler	"	East Jersey Water Co.	Paper-mill site	18			Not in use.
" "	"	"	Butler Hard-Rubber Co.	Hard rubber	30	260	370	
" "	"	"	James C. Reynolds	Paper	15	100	143	
" "	"	"	Pequannock Valley Paper Co.	"	17	175	250	
" "	"	"	Demarest & Co.	Excelsior	18	125	179	
" "	Smith's Mills	Passaic	East Jersey Water Co., H. D. Smith, Lessee.	Grist	11	36	72	
" "	" "	"	East Jersey Water Co., Geo. and Thos. Smith, Lessees	"	10			Not in use.
" "	Charlottesburg	"	Cooper & Hewitt	Feed	14			" "
" "	"	"	" " "	Hardware	19			" "
" "	New Foundland	Morris	Bigelow Brothers	Saw	9	36	50	
" "	" "	Passaic	J. J. Laroe	Grist	6½	20	30	
" "	Stockholm	Morris		Old forge site	20			
" "	"	Passaic	A. M. Booth	Pocket-knife works	14	12	24	
" "	"	Sussex	Nancy Riggs	Old forge site	16			Not in use.
" "	Hardiston township	"	Naval H. Margin	" " "	12			" "
" "	" "	"	John E. Forgerson	Grist	22	24	40	
" "	" "	"	Amos Faber	Old saw				Not in use.
" "	" "	"	Isaac William Arden	" "	10			" "
Stockholm Branch	Stockholm	"	Mrs. Walter	Tannery	18	5	12	
" "	"	"	Edward Kincaid	Grist and distillery	20			Not in use.
Pascack Brook Branch	"	"	John Lynn	Old forge site	15			" "
" " "	Canistear	"	Ira Day and Adam Smith Estate	" " "	14			Not in use.
" " "	"	"	John Baxter	" " "	14			
" " "	"	"	Isaac Snyder	" saw-mill site	14			Not in use.
" " "	"	"	Ezra Day	" " " "	14			" "
Pine Brook	Westville	Essex	M. N. Crane	Feed and saw	23	20	33	
" "	"	"	Geo. B. Harrison	Grist	20			Not in use.
" "	Caldwell	"	Stephen R. Gould	Bark				" "

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Pine Brook	Caldwell	Essex	George Budd	Old paper mill	25			Not in use.
" "	"	"	Dr. Charles H. Hunter	Snuff	10			" "
Rockaway River	Montville township	Morris	Heirs of Benj. Starkey	Woolen	7	20	50	
" "	" "	"	Albert Zabriskie	Grist	4½	21	34	
" "	Old Boonton	"	M. Fitzgibbons	Straw-board paper	30	260	370	
" "	Boonton	"	J. Couper Lord Estate	Nails	23.58 }			Not in use.
" "	"	"	" " "	Agricultural	49 }	63	90	
" "	"	"	" " "	Paint	28.7	150	214	
" "	"	"	" " "	Rolling mills	31.63	267	380	
" "	"	"	" " "	Brass works	31.87 }	95	136	
" "	"	"	" " "	Nails	28.82 }	62	89	
" "	"	"	United States Aluminum Co.		29 }	200	186	J. C. L. Estate.
" "	"	"	Electric Light Co. and Interchangeable Tool Co.		31.87 }	108	154	" " " "
" "	Powerville	"	Powerville Felt-Working Co. (Limited)	Roofing felt	10	188	270	
" "	Rockaway	"	Wm. F. Brann	Axe factory	8			
" "	"	"	E. D. Halsey	Grist	11 }	24	40	
" "	"	"	"	Forge	11 }	15	40	
" "	"	"	"	Saw	11 }	10	20	
" "	Dover	"	Dover Iron Co.	Rolling mills	9½	15	30	
" "	Port Oram	"	Luxembourg Improvement Co.	Hosiery	8	21	30	
" "	Baker's Mills	"	Henry and William Baker	Grist	10	24	48	
" "	" "	"	" " " "	Forge site	7			Not in use.
" "	Lower Longwood	"	A. A. Wilcox	" "	12			" "
" "	Upper Longwood	"	Hon. John Kean, Jr	" "	15			" "
" "	Woodstock	"	Zophar Tallmage	Distillery	7			" "
" "	Petersburg	"	David C. Wallace	Grist	12	15	20	
" "	Milton	"	Enos Davenport's Estate		7			Not in use.
" "	"	"	Horace Chamberlain	Grist	15 }	20	30	
" "	"	"	" "	Saw	12 }	10	20	
" "	"	"	J. R. Riggs	Old Stanborough Forge	10			Not in use.
" "	Russia	"	"	Old forge site				" "
" "	Hopewell	"		" "				" "

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Whippany River Branch of Rockaway	Whippany	Morris	George Ball	Grist	7	18	80	
Whippany River Branch of Rockaway	"	"	Henry Conger	Cotton	15	70	120	Idle.
Whippany River Branch of Rockaway	"	"	McEwan Brothers	Paper	19	60	100	
Whippany River Branch of Rockaway	"	"	Diamond Mills Paper Co.	"	28	100	145	
Whippany River Branch of Rockaway	Monroe	"	James A. Muir	"	17	66	100	
Whippany River Branch of Rockaway	"	"	J. F. Muir	"	18	......	......	Recently burned.
Whippany River Branch of Rockaway	Morristown	"	Martin & Caskey	Grist	5	18	30	
Whippany River Branch of Rockaway	"	"	Mary Slagle	"	8	18	30	
Whippany River Branch of Rockaway	"	"	Heirs Stephen Vail	Turning	7 }	30	60	
Whippany River Branch of Rockaway	"	"	" " "	Machine shop	7 }	60	120	Not in use.
Whippany River Branch of Rockaway	Brookside	"	Aaron Whitehead	Grist	28	38	60	
Whippany River Branch of Rockaway	"	"	M. M. & E. J. Connet	Flouring	30	38	60	
Whippany River Branch of Rockaway	"	"	E. J. Connet	Saw	24	22	35	
Branch at Troy Hills, Branch of Whippany	Troy Hills	"	Geo. B. Smith	Grist	19 }	15	30	
Branch at Troy Hills, Branch of Whippany	" "	"	" " "	Turning	19 }	6	10	
Branch at Troy Hills, Branch of Whippany	" "	"	" " "	Saw	21 }	11	19	
Branch at Malapardus, Branch of Whippany	Whippany	"	B. F. Howell	"	15 }	12	30	
Branch at Malapardus, Branch of Whippany	"	"	" "	Machine shop	15 }	6	12	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Branch at Speedwell, Branch of Whippany	Morristown	Morris	Mrs. John Ledgewood	Grist	20	12	80	Not in use.
Branch at Speedwell, Branch of Whippany	"	"	" " "	Foundry site	12	......	......	Not in use.
North Branch of Whippany	Morris Plains	"	J. H. Branat	Paper	20	50	100	
" " "	" "	"	F. W. Jaqui	Flouring	27	70	100	
" " "	" "	"	J. Fletcher Johnson	Cider	25	......	......	Not in use.
" " "	" "	"	Arthur Thompson	Saw	8	......	......	Old site not in use.
" " "	Tabor	"	A. W. Cutler	Feed and saw	15	5	10	
Montville Stream Branch of Rockaway	Montville	"	Andrew Decker	Grist	21	15	80	
Montville Stream Branch of Rockaway	"	"		Print & dye works.	25	55	80	
Montville Stream Branch of Rockaway	"	"	J. Comley	Novelty works	18	50	70	
Montville Stream Branch of Rockaway	"	"		Grist-mill site	10	......	......	Not in use.
Dixon Pond Branch of Rockaway	Rockaway Valley	"	C. B. Dixon	Grist	23	15	25	
Dixon Pond Branch of Rockaway	" "	"	" "	Old forge site	20	......	......	Not in use.
Den Brook Branch of Rockaway	Union	"		Old paper-mill site	12	......	......	" "
Den Brook Branch of Rockaway	Shongum	"	Opennaki Association	Forge site	15	......	......	" "
Den Brook Branch of Rockaway	"	"	A. W. Cutler	Saw-mill site	12	......	......	" "
Beaver Brook Branch of Rockaway	Beach Glen	"		Old forge site	10	......	......	" "
Beaver Brook Branch of Rockaway	Meriden	"		" " "	8	......	......	" "
Beaver Brook Branch of Rockaway	Split Rock	"	Cobb Estate	Old furnace site	35	......	......	" "
Mill Brook Branch of Rockaway	Mill Brook	"	William E. Teed	Old distillery site	18	......	......	" "

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Mill Brook Branch of Rockaway	Mill Brook	Morris	Adams Davenport	Grist	22	12	24	
Mill Brook Branch of Rockaway	" "	"	" "	Saw	16	10	20	
Mill Brook Branch of Rockaway	" "	"	Thomas A. Lindsley	Old forge site	30			Not in use.
Mill Brook Branch of Rockaway	" "	"	Martin and Isaac Searing	Old saw-mill site	10			" "
Mill Brook Branch of Rockaway	" "	"	James M. Bryant	Saw	14	10	20	
Green Pond Brook Branch of Rockaway	Middle Forge	"	U. S. Government	Old forge site	15			Not in use.
Green Pond Brook Branch of Rockaway	Denmark	"	E. P. Merritt	" " "	30			" "
Hard Bargain Brook Branch of Rockaway	Hard Bargain	"	Stephen Strait's Estate	" " "				" "
Canoe Brook	Millburn township	Essex	Geo. W. Reeves	Saw-mill site	15			" "
" "	Livingston township	"	F. C. Reiley	Grist-mill site	7			" "
Dead River	Liberty Corner	Somerset	Abram Ten Eyck	Saw-mill site				" "
Branch near Logansville	Logansville	Morris	Van Doren Phœnix	Grist	15	12	30	
Branch at Pleasantville	Pleasantville	"	Joseph Hoar	Saw	10	10	20	
" " Green Village	Green Village	"	Joseph Dixon	"	10			Not in use.
" " " "	Silver Lake	"	H. M. Olmstead	Flouring	12	52	75	

Hackensack River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Hackensack River	Oradell	Bergen	William Veldran	Saw	4	10	14	
" "	"	"	" "	Grist	4	70	100	
" "	Harrington	"	John J. Bogert	"	4½	25	35	
" "	Rivervale	"	C. O. Colligan	Chair factory	6½	20	30	
" "	"	"	" "	Saw	6½	10	20	
" "	"	"	" "	Wheelwrights' supplies	6½	20	30	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Hackensack River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Hackensack River	Rivervale	Bergen	Hiram Bellis	Grist and saw	6			Not in use.
Branch at Overton	Overton	"	John C. Meister	" " "	12	12	80	
" " "	Schraalenburgh	"	Cranmond Kenedy	Grist	10			Not in use.
" " "	"	"	Sarah Demarest	"	9	12	24	
" " "	Bergen Fields	"	W. S. Bogart and Henry Cooper	Chair factory	8	8	10	
" " "	" "	"	W. S. Bogart and Henry Cooper	Saw	8	10	20	
" of Trenekill	Harrington	"	Maria Demarest	Grist	6			Not in use.
" " "	Cresskill	"	J. D. Farrington	Saw and grist	12			" " "
" " "	"	"	J. R. & V. B. Demarest	Hardware and brass	16	45	60	
" " "	"	"	Hon. W. W. Phelps	Saw	18			Not in use.
" " "	Closter	"	Moses T. Taylor	"	12	8	20	
" " "	"	"	D. Bingham	Grist				Not in use.
Pascack Creek	Westwood	"	Jacob R. Hopper	Saw	7	8	20	
" "	"	"	Robert Yates	Grist and saw	7	36	72	
" "	Pascack	"	W. B. Ackerman	Saw	7½	10	15	
" "	Park Ridge	"	George Van Riper	B. bbins				Not in use.
" "	" "	"	Catharine Pretre	Grist	7	12	20	
" "	Montville	"	Garret J. Lerring	Bent wagon wood	12	15	30	
" "	"	"	Philip Beckelle	Saw	12	8	15	
Musquapsink Creek	Westwood	"	Isaac D. Bogert	Grist	6	12	24	
" "	"	"	" " "	Saw	6	10	20	
" "	Hillsdale	"	Henry C. Storms	"	12	8	16	
" "	Pascack	"	Paul Bates	Grist	18			Not in use.
Bear Brook	Park Ridge	"	John Cummins	"	18	12	24	
" "	" "	"	James Leach	Chair factory	18			Not in use.
Upper Montville Branch	" "	"	J. H. Wield & Co	Bobbin "	18	23	32	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Elizabeth River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Elizabeth River	Salem	Union	John Kean	Grist	10	12	22	
" "	Irvington	Essex	William A. Ostrander	"	22	24	35	
" "	"	"	Elias Durran					Not in use.
" "	"	"	Mahlon S. Drake	Rule factory	20			" "
West Branch of Elizabeth River	Salem	Union	John Kean	Saw	18			" "

Rahway River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Rahway River	Rahway	Union	John Fedder Estate	Grist-mill site	10			Not in use.
" "	Cranford	"	Taylor, Bloodgood & Co.	Woolen	6⅝	28	40	
" "	"	"	John A. Morrough	Grist	8	30	45	
" "	"	"	Elias Vreeland Estate	Saw	5½	18	30	
" "	Milltown	"	J. Edgar Meeker	Paper	7 }	30	50	
" "		"	" "	Saw	7 }	10	20	
" "	Millburn	Essex	A. L. Henderson	Paper	15	20	30	
" "		"	Charles A. Lightbipe	Hat factory site	16			Not in use.
" "	"	"	" " "	" bodies	22	100	170	Not working.
" "	"	"	Diamond Mills Paper Co.	Paper	27	25	40	
Robinson's Branch	Rahway	Union	M. H Acken	Flouring	19½	15	25	
" "	Clark township	"	Martin Fate	Mill site	6?			Not in use.
" "	Willow Grove	"	John Lambert	Grist	22	12	20	
Normahiggin Brook	Branch Mills	"	Silas Miller	"	11	12	22	
" "	" "	"	C. T. & A. M. Parkhurst	Paper and feed	16	25	50	
East Branch of Rahway	Maplewood	Essex	H. O. Pierson	Flouring	18	25	35	
" " "	Millburn	"	William Smith	Grist	10			Not in use.
" " "	"			Wall Paper	15			Not used.
" " "	Springfield	Union	Frederick Crane Chemical Co.	Paper-mill site	15			Not in use.
" " "	"	"	Frederick Crane Chemical Co.	Chemical works	16			Power not used.
" " "	"	"	——— Jennings	Paper-mill site	12?			Not in use.
" " "	Summit	"	William H. Bryant	Saw	10	6	12	
Raritan River	New Brunswick	Middlesex	Norfolk and New Brunswick Hosiery Co.	Hosiery	11	150	215	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Raritan River	Raritan	Somerset	Wm. W. Adair & Co.	Flouring	12½	62	90	
" "	"	"	Rynear Veghte	Paint	14	36	50	
" "	"	"	Raritan and Somerville Water Co.	Pumping station	16	85	110	
" "	"	"	Wm. H. H. Wyckoff	Grist	14	20	35	
South River	Bloomfield Mills	Middlesex	Bloomfield Mills Co.	Licorice and spice	7¼	112	160	
" "	Spottswood	"	A. A. Devoe	Grist	8	24	48	
" "	"	"	" "	Snuff	8	30	60	
" "	Helmetta	"	Geo. W. Helme & Co.	"	8	12	20	
" "	Jamesburg	"	James Buckelew Estate	Flouring	14	80	100	
" "	"	"		Shirt factory	13	125	180	
Tennent's Brook Branch South River		"		Mill site	11			Not in use.
Deep Run Branch South River	Dill's Mills	"	Leonard A. Bampton	" "				" "
Iresick Brook Branch South River		"		" "				" "
Matchaponix Brook Branch South River	Spottswood	"	Wm. A Skinner	Snuff				
Matchaponix Brook Branch South River	Texas	"	Mrs. Amanda Garner	Mill site				Not in use.
Matchaponix Brook Branch South River	Matchaponix	"	Bloomfield Mills Co.	" "	6½			" "
Matchaponix Brook Branch South River	Mount's Mills	"	Perrine Estate	Flouring and saw	8	40	70	
Matchaponix Brook Branch South River	Englishtown	Monmouth	Wm. H. Parker	" " "	11	40	70	
McGellaird's Brook	"	"	J. W. Taylor	" " "	10	35	60	
Lawrence's Brook	New Brunswick	Middlesex	City of New Brunswick	Water works	15	216	300	
" "	Milltown	"	Meyer Rubber Co.	Rubber works	7⅔	70	100	
" "	Brookford	"	James Parsons	Snuff		15	25	
" "	Davidson's Mills	"	C. C. Beekman	Grist	11	17	24	
" "	Deans	"	Aaron Dean	" and saw	9½	45	75	
Branch of Lawrence's Brook	Baptist Lane	"	Dr. Smith	Cider	14	4	8	
Grog Brook Branch Lawrence's Brook		"	William P. Hageman	Grist	17	16	32	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Branch at Bloomington	Bloomington	Somerset	William Voorhees	Grist	12	15	25	
Bound Brook	Near Bound Brook	"	J. H. Sebring	" and saw	4½	15	30	
" "	New Market	Middlesex	M. Otto	"	8	25	50	
" "	New Brooklyn	"	H. J. Baker & Bro.	"	9	28	40	
" "	" "	"	Lehigh Valley R. R. Co.	Water tank and saw-mill	4½	10	14	
Green Brook Branch Bound Brook	Green Brook Road	Somerset	William Holman	Grist	5½	....	....	Not in use.
Green Brook Branch Bound Brook	Plainfield	"	Andrew Cadmus Estate	Saw	5	....	....	" "
Green Brook Branch Bound Brook	"	Union	French Bros.	Flouring	17	37	52	
Green Brook Branch Bound Brook	"	Somerset	Charles Hyde	Grist	12	35	58	
Green Brook Branch Bound Brook	Scotch Plains	"	Harper, Hollingsworth & Darby	Fur factory	22	54	77	
Green Brook Branch Bound Brook	" "	"	E. A. Seeley	Paper	3	25	50	
Middle Brook	Bound Brook	"	Bound Brook Water Co.	Grist	38½	31	44	
Millstone River	Weston	"	Henry Conger	Hat factory	4¾	18	36	
" "	Blackwell's Mills	"	E. B. Cook	Flouring	4	50	82	
" "	Griggstown	"	Charles Dixon	Grist	4	30	50	
" "	Rocky Hill	"	Isaac Shaw	"	4	40	80	
" "	Kingston	Middlesex	Charles B. Robinson	"	3½	....	....	Not in use.
" "	Aqueduct	"	The Misses Gray	Flouring	5	25	50	
" "	Wescott's Mills	"		Grist	10	....	....	Not in use.
" "	Bergen's Mills	Monmouth	——— Davison	"	11	27	39	
Beden's Brook Branch of Millstone	Stoutsburg	Somerset	J. Hervey Stout	Grist and saw	10	26	42	
No Pike Brook Branch of Beden's Brook	Bridge Point	"	Wm. S. Terhune	Grist	6	21	35	
Stony Brook Branch of Millstone	Princeton	Mercer	Joseph H. Brewer	"	8	23	40	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Stony Brook Branch of Millstone	Rosedale	Mercer	A. B. Reeder	Grist	10	17	30	
Stony Brook Branch of Millstone	"	"	" "	Saw	10	12	20	
Stony Brook Branch of Millstone	Pennington	"	Charles A. Reed	Grist	9	13	26	
Stony Brook Branch of Millstone	Titus' Mills	"	W. W. Titus	Flouring	7	25	36	
Stony Brook Branch of Millstone	Moores	"	Joseph H. Moore	"	8½	25	36	
Stony Brook Branch of Millstone	"	"	" "	Saw	8½	10	20	
Stony Brook Branch of Millstone	Lindvale	"	Robert Crosedale	Grist				
Beden's Brook Branch of Millstone	Rock Mill	"	Geo. Anderson	Saw				Not in use.
Beden's Brook Branch of Millstone	" "	"	Peter Cray	"				
Bear Brook Branch Millstone	Princeton Junction	"	J. H. Grover	Flouring	11	30	50	
Cranbury Brook Branch Millstone	Plainsboro	Middlesex	—— Lovett	Grist	8	20	33	
Cranbury Brook Branch Millstone	Cranbury	"	John Petty	"	7	12	20	
Rocky Brook Branch Millstone	Hightstown	Mercer	G. W. Norton	Flouring	10	28	40	
Rocky Brook Branch Millstone	Etna	"	Charles Keeler	Grist and saw	12	40	57	
Rocky Brook Branch Millstone	Perrineville	Monmouth	Charles Allen	Grist	22	40	50	
Hutchinson's Brook Br'nch Millstone	Ely's Mills	Mercer	S. D. Ely	"	9	40	57	
North Branch	Milltown	Somerset	Heirs of Michael Van Derveer	Flouring	6	36	50	
" "	North Branch	"	Tunison & Beekman	"	4	36	50	
" "	Kline's Mills	"	Jacob Kline	Grist and saw	6	10	20	
" "	Pluckamin	"	Thomas Moore	Grist-mill site	7½			Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches.—Continued.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
North Branch	Hub Hollow	Somerset	Ludlow & Bedell	Feed and saw-mill and hub factory	10	35	60	
" "	Windham township	Morris	Peter Z. Smith	Saw	12	20	30	
" "	Chester township	"	J. Wesley Swackhamer	Grist	9½	29	40	
" "	Roxiticus	"	Aaron Hoffman	Old mill site	6			Not in use.
" "	"	"	Sarah Lidell	Grist	23	25	50	
Lamington River Branch of North Branch	Burnt Mills	Somerset	N. Welch	"	5	25	50	
Lamington River Branch of North Branch	Vliet's Mills	"	George Moore	"	9	12	25	
Lamington River Branch of North Branch	" "	"	" "	Saw	9	10	20	
Lamington River Branch of North Branch	" "	"	William Rhinehart	Creamery	4	3	6	
Lamington River Branch of North Branch	Pottersville	Hunterdon	Robert Craig	Flouring	7½	40	60	
Lamington River Branch of North Branch	"	"	" "	Grist	17	26	35	
Lamington River Branch of North Branch	"	"	H. M. Sovereign & Son	Foundry and machine shop.	16	107	150	
Rockaway River Branch of Lamington	White House	"	William H. Reger	Flouring	9	21	30	
South Branch of Rockaway	Lebanon	"	Isaac P. Hoffman	"	23	25	35	
North Branch of Rockaway	White House	"	Mrs. C. S. Hall	Grist	24	40	80	
" " " "	New Germantown	"	John Lane	"				
" " " "	" "	"	" "	Woolen				
" " " "	Tewksbury township	"	David Reed	Saw	12	10	20	
" " " "	Mountainville	"	Robert Craig	Grist	9	12	24	
" " " "	"	"	Jonathan Potter	Distillery	8	2	4	
" " " "	"	"	J. N. Wilcox	Grist	22	12	24	
" " " "	Fairmount	"	Frederick Hoffman	Saw	20	10	20	
" " " "	"	"	Geo. B. Sutton	Tannery	15	10	20	
" " " "	"	"	" "	Saw	15	10	20	
" " " "	"	"	Andrew Philhower	Grist	20	25	50	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Cold Brook Branch of Lamington	New Germantown	Hunterdon	Peter W. Melick	Flouring	20	24	31	
Pottersville Branch of Lamington	Pottersville	Somerset	John C. Latourette	Grist	12	7	14	
Black River Branch of Lamington	"	Morris	Robert Craig	Saw	12	40	60	
Black River Branch of Lamington	Hacklebarney	"	John H. Miller	Flouring	18 }	58	82	
Black River Branch of Lamington	"	"	" " "	Saw	18 }	10	15	
Black River Branch of Lamington	"	"	Chester Iron Co.	....	....	....	....	
Black River Branch of Lamington	"	"	" " "	....	....	....	....	
Black River Branch of Lamington	Milltown	"	William Cardovin	Carding	9	16	32	
Black River Branch of Lamington	"	"	A. W. Cooper	Grist	17	60	100	
Milltown Branch of Black River	"	"	Richard Stevens	Distillery	20	8	16	
Tanner's Brook Branch of Black River	Washington township	"	John Castner	Saw	7 }	10	20	
Tanner's Brook Branch of Black River	" "	"	" "	Cider	7 }	5	10	
Tanner's Brook Branch of Black River	Parker	"	Jacob Lauerman	"	11	8	16	
Mine Brook Branch of North Branch	Mine Brook	Somerset	James Dow	Feed and saw	18	10	20	
Mine Brook Branch of North Branch	Barker's Mills	"	C. Barker	Flouring	35	27	40	
Mine Brook Branch of North Branch	Bernardsville	"	T. G. & J. V. Bunn	Grist and distillery	26	35	50	
Mine Brook Branch of North Branch	"	"	Charles McMichael	Flouring	28	14	20	
Peapack Brook Branch of North Branch	Schomp's Mills	"	Willliam A. Schomp	Grist	10	14	23	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Peapack Brook Branch of North Branch	Peapack	Somerset		Grist	....	....	....	
Peapack Brook Branch of North Branch	Gladstone	"	Lewis Van Doren	Old mill site	....	....	....	Power not used.
Branch below Roxiticus, Branch of North Branch	Mendham township	Morris	S. J. Shurts	Saw	22	10	20	
Burnett Brook Branch of North Branch	Roxiticus	"	J. R. Nesbitt	Grist	24	25	40	
Burnett Brook Branch of North Branch	Mendham township	"	Peter Cramer	Saw	12	....	....	Not in use.
Burnett Brook Branch of North Branch	" "	"	James Able	Grist and saw	13	20	40	
Indian Brook Branch of North Branch	" "	"	James H. Lawry	Grist	24	50	82	
South Branch	South Branch	Somerset	Theodore Amerman	Flouring	6½	45	64	
" "	" "		" "	Saw	6½	10	20	
" "	Neshanic Station	"	Andrew Lane	Flouring	6' 10"	80	114	
" "	Riverside	"	G. C. Higgins & Bro.	"	5½	75	107	
" "	Three Bridges	Hunterdon	John C. Hopewell's Estate	"	5	50	70	
" "	Flemington	"	Kershaw & Chamberlain	Grist	5	40	60	
" "	Stover's Mills	"	Isaac Stover	Flouring	6	55	80	
" "	" "	"	" "	Saw	6	15	20	
" "	" "	"		Flax	6	....	....	Not in use.
" "	Rowland Mills	"	Ellen Cokesfair	Grist	6	40	60	
" "	Sunnyside	"	L. Cramer	"	9	40	60	
" "	Hamden	"	C. V. Dilley	Flouring	8	40	60	
" "	"	"	M. C. Cramer	Grist	5	20	40	
" "	Clinton	"	E. V. Parry	Flouring	7½	40	60	
" "	"	"	Philip Gulick	Grist	7	40	60	
" "	High Bridge	"	Charles Conover	"	8½	23	40	
" "	" "	"	E. Dorland & Sons	Flouring	7½	80	110	
" "	" "	"	Taylor Iron Works	Foundry	14	210	800	
" "		"	" " "	Forge	33	520	750	
" "	Readingsburgh	"	John Hockenbury	Saw	8	....	....	Not in use.
" "	"	"	G. W. Alpaugh	Flouring	14	100	140	
" "	"	"	" "	Saw	8	15	20	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
South Branch	High Bridge township	Hunterdon	Abram Hoffman	Saw	5	10	20	
" "	Califon	"	B. Cole	Grist	7½	25	40	
" "	"	"	" "	"	6½	25	40	
" "	"	"	" "	Feed	8	12	20	
" "	Tewksbury township	"	L. H. Trimmer	Grist	4½	25	50	
" "	Middle Valley	Morris	H. P. Dufford	"	6	35	60	
" "	German Valley	"	Henry Fleming	"	7	25	40	
" "	" "	"	Henry Weise	Saw	7½	15	30	
" "	Naughright	"	Andrew Dufford	Grist	3½	25	40	
" "	"	"	Jacob Naughright	"	5	15	25	
" "	Bartley	"	Wm. Bartley & Sons	Foundry and machine	10	25	34	
" "	"	"	" " "	Saw	10	21	30	
" "	"	"	J. M. Conover	Flouring	14	38	54	
" "	"	"	Heirs of Joshua Solomon	Old Forge				Not in use.
" "	Mount Olive	"	Richard Stephens & Co.	Flouring	22	40	57	
" "	" "	"	" " "	Saw	33	45	75	
Holland's Brook Branch of South Branch	Readington	Hunterdon	Peter S. Nevius	Grist and saw	8	12	30	
Neshanic River Branch of South Branch	Hillsborough Township	Somerset	J. E. Adams	Feed and wood	10	28	40	
Neshanic River Branch of South Branch	Clover Hill	Hunterdon	George Rae	Grist	9	36	90	
Neshanic River Branch of South Branch	Copper Hill	"	William Hill	Feed and bone	6	36	60	
Neshanic River Branch of South Branch	Sand Brook	"	H. Moore	Grist	30	24	40	
Neshanic River Branch of South Branch	Grover	"	John C. Carrell	"	26	36	50	
Prescott's Brook Branch of South Branch	Allertown	"	Geo. Stryker	Grist and saw	14	16	40	
Prescott's Brook Branch of South Branch	Round Valley	"	Isaac P. Hoffman	Grist	18	24	40	
Branch at Hamden, Br'nch of South Branch	Hamden	"	Fanny Grant	Grist and saw	22	12	24	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Cakepoulin Creek Branch of South Branch	Sidney	Hunterdon	Henry Dusenbury	Grist	15	35	70	
Cakepoulin Creek Branch of South Branch	"	"	Samuel Stevenson	Paint				Not in use.
Cakepoulin Creek Branch of South Branch	Kingtown	"	Archer Taylor	Grist	12½	24	48	
Cakepoulin Creek Branch of South Branch	Pittstown	"	William M. Taylor	"	16	12	20	
Cakepoulin Creek Branch of South Branch	"	"	Hiram Deats	Foundry and machine shop.	28	20	80	
Cakepoulin Creek Branch of South Branch	"	"	E. H. Deats	Saw	21	15	20	
Cakepoulin Creek Branch of South Branch	Littletown	"	Daniel Little	Grist	80	15	20	
Midvale Branch of South Branch	Midvale	"	James Voss		15	10	20	
Beaver Brook Branch of South Branch	Annandale	"	Joseph Hampton	Grist	24	22	80	
Mulhockaway Creek Branch of South Branch.	Union township	"	I. H. Butler	"	12	12	24	
Mulhockaway Creek Branch of South Branch.	Pattenburgh	"	W. T. Bird & Bro	"	28	24	48	
Spruce Run Branch of South Branch	Union township	"	Joseph H. Exton	Saw	20	17	24	
Spruce Run Branch of South Branch	" "	"	" "	Flouring	24	40	57	
Spruce Run Branch of South Branch	Glen Gardner	"	T. Edgar Hunt	Peach baskets	22	85	50	
Spruce Run Branch of South Branch	" "	"	" " "		14			Not in use.
Spruce Run Branch of South Branch	" "	"	G. F. Painter	Grist	20	19	38	
Spruce Run Branch of South Branch	Clarksville	"	T. Frank Cawley	"	17′ 10″	21	35	
Spruce Run Branch of South Branch	Newport	"	Benjamin Apgar	"	28	20	40	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Spruce Run Branch of South Branch	Newport	Hunterdon	Isaiah Bryant	Saw	12	10	17	
Spruce Run Branch of South Branch	"	"	Josiah Apgar	Grist	21	24	40	
Branch at Schooley's Mountain, Branch of South Branch	Schooley's Mountain	Morris	J. V. Stryker	Saw	15	8	20	
Drake's Brook Branch of South Branch	Flanders	"	D. G. Vliet	Grist	8	18	36	
Drake's Brook Branch of South Branch	"	"	S. H. Dorland	Flouring	14	50	70	
Drake's Brook Branch of South Branch	Drakesville	"	R. H. Cary	"	15	42	60	
Branch at Flanders' Branch of Drake's Brook	Flanders	"	H. M. Sovereign	Woolen	23	12	17	
Branch at Flanders' Branch of Drake's Brook	"	"	P. A. Hoffman	Grist	31	33	55	

ARTESIAN AND OTHER BORED WELLS.

In seeking an available water-supply, recourse is had in many localities to boring deep wells which tap subterranean reservoirs in water-bearing strata. The common dug well so often draws water from surface beds and even from the surface of the ground in many cases, that it cannot be classed with deep, bored wells as a source of supply of water of good quality. The history of these deeper wells in this State shows that there is a great variation in the depth at which a satisfactory supply is obtained; and, further, that the depth is determined by the varying conditions of location and geological structure. Some of the more dense and compact beds are impervious and hold no water; others, as some of the sandstones and limestones, are so traversed by open joints and fissures as to be dry; others, again, are so open and porous that they have capacity for large volumes of water. The conditions favoring a water-bearing horizon are not only the capacity for holding water, but also such a position between tight and impervious beds that there may be a natural reservoir, from which it may not be drained away through fissures to deeper levels. The water-level and the pressure must be maintained by favorable conditions, so that when tapped it can serve as a fountain or source from which there can well up an abundant supply, making either a flowing well, that is, an artesian well, or one which can be pumped readily and continuously without lowering greatly the head of water. In consequence of the contaminated surface-waters, and the failure of shallow wells to give water enough of good quality, many wells have been bored in the State, particularly in the red sandstone plain and in the southeastern coastal belt. The localities of wells which have been described in the Annual Reports of the Geological Survey are given in a list appended to this section of the report. The absence, generally, of artesian wells in the Highlands and in the Kittatinny and the Upper Delaware valleys is here noteworthy. That flowing wells might be obtained in some localities in these districts is highly probable.*

In the greensand marl and plastic clay belts, the results have been in some cases unfavorable, and failure to secure water has caused the abandonment of further efforts in those localities to find it. The successful wells are, however, such as to justify further trials, and at other points in this part of the State. Some of the failures are to be attributed to a lack of care and to boring too deeply—passing through and beyond water-bearing sands or gravels, and other porous beds, and shutting them off by the pipe or casing of the well. The caution to avoid this cause of failure cannot be too strongly impressed upon all who are about to put down wells of this kind. Another difficulty met with in a few localities is the fine sand which flows with the water up the pipe, and sometimes stops the flow of water. Continued pumping may overcome the trouble, or the use of a gauze-pointed pipe to keep out the sand. In some places the difficulty is best overcome by boring deeper and tapping a lower horizon or level of water. The geological structure of the southern part of the State shows the existence of many beds which are open and porous and water-bearing. The fine sandy beds in the series of the Raritan clays; the sand beds of the greensand marl formation, and the sands and gravels so common in the overlying and more recent strata of Tertiary age, southeast of the marl belt, are possible sources whence bored wells can draw satisfactory supplies. At many points there may be several water-bearing beds in the vertical section of a well, and a choice of water from these respective horizons. The deep wells at Atlantic City have proved there the existence of at least three horizons of water. Putting aside the question of cost, which is of course the practical one, it may be said that there is not a locality in the southern part of the State where a large supply of water cannot be reached by deep boring. From what is known in the history of deep wells there, it is safe to say that deep, bored wells are practicable everywhere in South Jersey. The beginnings only of the development of our subterranean wealth of waters are as yet made. These deep reservoirs of good water are a part of the natural resources of the State; and, in their great extent, underlying so much of its territory, in the quality of their water, suited to household uses and free from liability to pollution, and in their accessibility nearly everywhere

*See Ann. Rep. State Geologist, 1885, pp. 109, 110.

through borings of practicable depth, are comparable in value with the great iron ores of the Highlands, and other deposits, recognized by every one as belonging to the domain of our mineral wealth. They belong properly under the head of mineral resources of the State. As the country becomes more densely populated, and the large areas of territory now uncleared and in forest, are improved and put under cultivation, there will be need of water, and the supply by means of deep, bored wells will be more and more found practicable and satisfactory. At present our wells draw from the higher levels generally, and there is no attempt to utilize more than one horizon at any given point. Increasing demands for larger supplies will doubtless lead to the putting down of deeper wells, or wells tapping other levels and drawing from them the needed additional quantity. The records of the deeper wells, as well as the geological structure, suggest the practicability of using all the reservoirs which are found.*

Notes of New Wells and of Wells Not Reported in the Annual Reports of the Geological Survey.

Messrs. P. H. & J. Conlan, of 216 Market street, Newark, report the following wells put down the past year in Newark and Hoboken, and in the cities of New York, Philadelphia and Easton. These latter wells are of interest because of their being not only in closely adjacent territory, but also and more particularly because of their location in geological formations which are represented in the State:

Prof. J. C. Smock, State Geologist, Trenton, N. J.:

Dear Sir—Besides the well No. 5 at Atlantic City,† we also put down the following wells in this vicinity during the past year:

NEWARK.

Ten-inch well for Hill's Union Brewery. Eighty feet to rock (soft). Total depth, 496 feet. Yield, 150 gallons per minute.

Six-inch well for the Murphy Varnish Company. Found quicksand to a depth of 100 feet; then alternate layers of clay and quick-

*Attention is asked to a careful reading of the paper by Mr. Woolman, given in this report. It is instructive and pertinent in this connection, and highly suggestive to those who may be seeking additional supplies of water.

† See at end of this section.

sand to 200 feet, at which depth a water-bearing gravel bed was struck. This well yields 200 gallons per minute.

Twelve-inch well, 100 feet to rock, with 8-inch hole 390 feet in rock, for P. Ballantine & Sons, Freeman street. Well yields 200 gallons per minute.

Eight-inch well for R. G. Salomon, Nesbitt street. Twenty feet to rock and 292 feet in rock. Sixty gallons per minute.

Reilly & Osborn, Railroad avenue and Hamilton street. Two hundred and twenty-five feet of 6-inch well, yielding 75 gallons per minute. Alternate layers of clay and sand. No rock.

Six-inch well for Maybaum & Eckert, South Orange avenue, near city line. Twenty feet to rock and 64 feet in rock. This is a remarkable well, located on very high ground and flowing 8 gallons per minute. Will pump about 20.

Six-inch well for M. Buehler, Springfield avenue. Thirty feet to rock and 227 feet in rock. Fifty gallons per minute.

Six-inch well for Peter Lowentrandt, Kent and Bremer streets. Twenty feet to rock and 140 feet in rock. Twenty-five gallons per minute.

Eight-inch well for Jumbo Brewery, Hayes street. Twenty-five feet to rock and 351 feet in rock. Sixty gallons per minute.

BELLEVILLE.

Six-inch well, 40 feet through clay and quicksand, for Maas & Waldstein, near the pumping-station, Belleville. Fifty gallons.

HOBOKEN.

C. Hirtler's Sons, Washington street, Hoboken. Six-inch well, yielding 60 gallons per minute; 130 feet deep, 90 feet being in rock.

NEW YORK CITY.

Yuengling's Brewery, One Hundred and Twenty-eighth street and Tenth avenue, New York City. Ninety feet of 10-inch well to rock; 515 feet 8-inch hole in rock. One hundred gallons per minute.

Manhattan Athletic Club, Madison avenue and Forty-fifth street. Eight-inch well, 15 feet to rock and 291 feet in rock. Flows 15 and pumps 40 gallons per minute.

PHILADELPHIA.

P. Schemm & Son's Brewery. Two hundred and thirty-two feet of 8-inch well, 20 feet to rock (mica). Seventy-five gallons per minute.

Arnholt & Schaefer's Brewery, located about one-half mile from Schemm's. We are now down to a depth of 800 feet. Only water found so far is at 700 feet. About 6 gallons per minute.

EASTON, PA.

Seitz Brothers' Brewery. Seventy-one feet, 33 of which are in rock (hard limestone). Encountered a fissure with water at a depth of 65 feet.

The foregoing are the principal wells put down in this vicinity during the past year.

ATLANTIC CITY.

We herewith send you report of well No. 5, put down by us at Atlantic City.

Formation similar to well No. 4, except that the clay bed encountered at a depth of 38 feet in No. 4 was not struck in No. 5 until a depth of 440 feet was reached. Nor did we find the water-bearing stratum met with at a depth of 570 feet in No. 4.

The clay bed continued from 440 to 710 feet, with a very hard stratum of concrete, one foot thick, at a depth of 680 feet. After passing through this concrete, the clay became darker in color and somewhat harder.

A fine water-bearing stratum of gravel and sand was found at a depth of 720 feet, and continued to a depth of 735 feet. This stratum yields 250 gallons of fine water per minute, and 10 seconds after the pump stops the water will rise to the surface and flow over the top of casing.

This well has 6-inch casing to a depth of 440 feet, at which depth we found it necessary to reduce the casing to 4½-inch, which size is continued to the water-bearing stratum.

TRENTON.

Two large wells have been put down at the John A. Roebling's Sons Co.'s Wire Works. The first one, located near the corner of South Clinton and Mott streets, was dug 60 feet deep through the gravel and sand of the Trenton terrace formation, to the clay. This well is 20 feet in diameter and yields a large supply of water. A boring from the bottom passed through clay 68 feet, then through gravelly clay and seams of clay to the rock, which was struck at a depth of 160 feet. It was sunk eight feet deep in the rock, but failed to strike water.

A second well was dug in the autumn, at the side of the canal below Hamilton avenue, through 40 feet of sand and gravel, to the clay.

The greater thickness of the clay bed here, as compared with that at the State Prison, about 1,000 feet to the southwest, is noteworthy.

FREEHOLD, MONMOUTH COUNTY.

The present water-supply of Freehold is obtained from wells about two miles north of the town. Prof. John Enright, one of the Water Commissioners, writes as follows, describing their location, capacity and history:

"Our wells are located in a meadow, one and one-half miles distant from the Court House, at a point 100 feet above sea-level and 78 feet below the Court House steps. The meadow has been made such mainly by digging out marl, which here appears within three or four feet of the surface.

"We sunk our first well, which was somewhat experimental, on the opposite side of the brook from where the present ones are located. This well we bored to a depth of 210 feet, into what is generally known here as the second stratum of water-bearing sand. This deep well was a failure. It did not yield 10 gallons a minute when the steam-pump test was made. The 'second stratum' seemed to consist of alternating layers of clay and sand. Pieces of lignite with particles of sulphide of iron plainly visible in them, came up in quite large pieces from this depth. One piece was seven inches long. The well flowed a very small jet. Accordingly, we abandoned this lower stratum and concluded to try the upper stratum.

"The second well was sunk to a depth of 50 feet. The marl was penetrated at a depth of 40 feet, and from 8 to 10 feet of coarse sand followed. This yielded a good flow at the surface, probably 10 gallons a minute. The well was a 3-inch one. The steam pump was then put on and a yield of over 100 gallons a minute was secured. During the pumping the water lowered in the well to a depth of 18 feet, at which point it remained constant.

"We then bored 8 of these wells, but used 4½-inch pipe. The extra-size pipe did not make an increase in the flow. Four of the wells are located on the bank-side of the meadow and four on the brook-side, and are in a line nearly parallel with each other. These we connected with a central pipe-line through the meadow, leading to a receiving cistern. The pipe enters the cistern, which is 28 feet deep, at a point 6 feet below the surface, and continues down the cistern a distance of 15 feet, thus making a siphon. This acts automatically. As we pump the cistern down, the arm of the siphon lengthens and the flow of water increases. The object of this arrangement is to prevent pumping sand from the wells. The sand that comes through the siphon settles at the bottom of the wells.

"The capacity of the wells acting through the siphon is about 250 gallons per minute. The tendency seems to be to an increased flow the more the water is pumped.

"The time consumed in the actual boring of these wells was not more than three hours after everything was ready."

HARTFORD, BURLINGTON COUNTY.

A well was bored by F. & W. Stothoff, in the autumn of 1890, on the farm of Samuel C. Roberts, one and one-half miles north of Hartford. The site is about seventy feet above tide-levels. The strata passed through were the following:

	Feet.
1. Soil and red sand and clay	39
2. Laminated sand	7
3. Clay marl	54
4. Clay marl, with greensand	17
5. Clay marl, with more clay	8
6. Dark clay	32
7. Dark-colored sand	6
8 White sand	4
	167

Small bits of wood, some of it pyritiferous, and a *shark's tooth* were found at the bottom. The water rose in the pipe nearly to the surface of the ground, but on pumping, the pipe was filled with inflowing fine sand with the water, and stopped the pump. The use of a gauze-pointed pipe was to be tried, to shut out the sand.

BEACH HAVEN, BURLINGTON COUNTY.

BY LEWIS WOOLMAN.

Early in the year 1890 two wells were drilled, both of them to the same depth, at Beach Haven, N. J., by Uriah White. One is located at the Engleside and the other at the Baldwin. By the courtesy of Robert B. Engle and of the contractor, duplicate series of specimens were received from the well first put down. A 3-inch bore was made to a depth of 430 feet, entering at 420 feet a coarse-sand stratum, from which overflowed a stream of fresh water, yielding about ten gallons a minute, the writer being present when the last 80 feet were bored and the flow obtained. From an examination of the specimens of earths, coupled with information verbally received, the following record has been compiled:

	Thickness of Strata.	Total Depth.		
Beach sand	to 17 feet.	17 feet.		Recent = 80 ft.
Mud, with roots	1 "	18 "		
Sand	62 "	80 "		
Sand and gravel, fossiliferous pebbles	10 "	90 "	Fossiliferous gravels.	Quaternary = 200 feet.
White clay	5 "	95 "		
White sand, a few fossiliferous pebbles	20 "	115 "		
White sand, alternating from fine to coarse	45 "	160 "	White and yellow sands.	
Yellow, tenacious clay	2 "	162 "		
Black, tenacious clay	3 "	165 "		
White sand	10 "	175 "		
Yellow sand	5 "	180 "		
White sand	35 "	215 "		
Yellow sand	35 "	250 "		
Gray sand	30 "	280 "		
Greenish sand and clay mixed	10 "	290 "	Diatom clay bed.	Miocene = 150 feet.
Greenish marly clay, containing diatoms.	75 "	365 "		
Dark marly clay, containing diatoms	55 "	420 "		
Coarse gray sand, water-bearing	10 "	430 "		

A comparison of the specimens of earth from these wells with those from the wells at Atlantic City exhibits a close correspondence in the character and succession of strata, with the exception of the omission of one of the beds at Atlantic City, which omission will be referred to again.

The upper 280 feet in the wells at both places present considerable resemblance in the existence in the upper portion, of gravels containing fossiliferous pebbles derived from old Devonian and Silurian rocks, succeeded in the lower part by alternations of white and yellow sand, having interbedded a few seams of peculiarly tough, tenacious clays, either white, yellow or black in color. Fragments of wood characterize this division in both wells.

About 100 feet of reddish-brown sand that occurs at Atlantic City, next below the above-described gravels and sands, is here wanting, probably lost by erosion before the deposition of the overlying beds.

Almost or quite every foot of the lower 150 feet at Beach Haven shows under the microscope fossil forms of marine diatoms. These are associated with a few marine sponge spicules. This is undoubtedly the same diatom clay bed met with in the Atlantic City wells. The portion richest in diatoms is at 410 feet, and here occurs a rare form, *Coscinodiscus excavatus*, found also at Atlantic City at 500 to 535 feet, in both cases a short distance above the water-yielding stratum. The water-bearing gray sand in this well and in the well at Atlantic City, at 554 feet, is most probably the same. The sand, however, is coarser here. This horizon, as learned by the Atlantic City borings, occurs midway in a bed about 300 feet thick of impermeable diatomaceous clays. Geologically, these are of Miocene age.

MILLVILLE, CUMBERLAND COUNTY.

RECORD FURNISHED BY GEO. B. WOOD.

Elevation about 10 feet above high tide.

	Thickness of Strata.	Total Depth.
Sand, more or less coarse but always sharp......	to 120 feet.	120 feet.
Layer of stone about two inches thick.		
Thick blue clay, very hard to get through...	30 "	150 "
Fine white sand...	10 "	160 "

This well is cased with a 10-inch pipe. G. B. Wood writes that "it is appreciated as a drinking-fountain by the workmen," that "it would answer for making steam," that "it would be healthy for domestic use," but that "it would not do for bleaching purposes," which was the object in putting it down.

PORT NORRIS, CUMBERLAND COUNTY.

There are two wells at this place, both situated near the mouth of Maurice river, one on either side. Both wells were drilled by Caleb Risley & Son, some years since. From memory they now furnish the following record, which may be regarded as approximately correct as to the figures. The depth may possibly be slightly less, say ten to twenty feet.

	Thickness of Strata.	Total Depth.
Salt mud	20 feet.	20 feet.
White quicksand, like glass sand	50 "	70 "
Blue clay	6 "	76 "
Alternations of sand and blue clay, with 18 inches of "clam and other shells" near the bottom, about	124 "	200 "

Examination under the microscope of material from the bottom of one of the wells shows marine fossil diatoms.

ELECTRIC LIGHT WORKS, SEA ISLE CITY, CAPE MAY COUNTY.

RECORD FURNISHED BY URIAH WHITE, WHO BORED THE WELL.

	Thickness of Strata.	Total Depth.
Beach sand	to 6 feet.	6 feet.
Marshy clay, containing usual shells of the coast	2 "	8 "
(A) White fine sand, with one or two thin streaks of clay	42 "	50 "
Coarse gravel, light-gray color, with boulders, some as large as hens' eggs	10 "	60 "
(B) Whitish sand, slightly coarser than (A), a few clay streaks	190 "	250 "
Dark-blue or drab clay	6 "	256 "
(C) Whitish sand, still coarser than (B)	44 "	300 "
Blue clay	50 "	350 "
Very fine quicksand, dark-blue or gray in color; fine, white, comminuted shell floated out with the water used in the jetty process	40 "	390 "
Green or gray marl, like that in Monmouth county, New Jersey	74 "	464 "

Water flowed to the top from a depth of 50 feet; nearly all the distance to 300 feet it seemed to be salt or brackish. At the latter depth it was cut off by casing while drilling through the clay. The flow comes from between 350 and 390 feet.

Artesian Wells and Water-bearing Horizons of Southern New Jersey.

BY LEWIS WOOLMAN.

In an article in the Annual Report for last year (1889), entitled "Artesian Wells at Atlantic City, N. J.," it was stated that fresh water flowing above the surface had been obtained at the depths of 554 feet and 1,100 feet. Since then another well has been drilled and an additional flow of good water found at about 700 to 720 feet, thus demonstrating the existence of at least three water-bearing horizons underneath that city.

It is the purpose of this paper to indicate the probable continuance of these three horizons under the beaches, south of Barnegat Inlet and beneath the southern interior, to a distance of from 25 to 30 miles or more from the coast, measured along the railroads leading from Atlantic City to Camden—also to show the intimate connection of the two upper of these horizons with a clay bed having a thickness of about 300 feet, and which, for reasons advanced herein, is designated the diatomaceous clay bed—also the relative position some distance below the same bed of the third or lowest of these horizons, and likewise the occurrence, probably somewhat higher stratigraphically, of still another water-bearing sand available for the supply of the Cape May peninsula.

The Atlantic City borings, of which a lithographed columnar section is exhibited in last year's Annual Report, reveal a clay bed nearly 300 feet thick between the depths of 382 feet and 677 feet. The color of the clay as it is first brought out and before becoming dry is either of a dark-bluish or a dark-greenish tinge. The upper third of the bed is mostly a compact clay, the central portion is composed of alternating layers of sandy clays and pure clays, with some interbedded sand seams, the lower third becomes again a pure tough clay with some traces of shells at the base.

The upper water-bearing stratum, or that at 554 feet, is a sand about ten feet thick within the sandy central portion and about midway of the entire bed; the middle water-bearing stratum, or that at about 700 feet, is just underneath the diatomaceous clay bed, and is probably a coarse gravel about eight feet thick.

The borings at Beach Haven (see page 267) penetrated a similar bluish clay for 140 feet, immediately above the water-producing sand, which is there reached at 420 feet to 430 feet. Considering the gentle southeast dip and the northeast and southwest trend of the strata, underlying the sands and gravels seen almost everywhere upon the surface of Southern New Jersey, it seems probable that the wells at this locality draw from a stratum identical with the upper horizon at Atlantic City. Another strong proof of such correspondence, that of a similarity of contained fossil remains of organic life, will now be brought to notice.

Specimens of material taken every few feet throughout the entire vertical extent of the clay bed at Atlantic City, and of that portion of it passed through at Beach Haven, were examined microscopically and found to contain throughout minute, silioceous skeletal remains of a very low order of plant life called diatoms.*

Within the area upon the seaward side of an irregular line joining Barnegat, Hammonton, Vineland and Bridgeton are also a number of other flowing artesian wells located upon ground but little elevated

* These are entirely invisible to the naked eye, and can be seen only by the use of a strong magnifying glass, or better still, by the aid of a compound microscope. They constitute, however, notwithstanding their infinitesimal size, a very considerable proportion of the body of the clay, amounting at a number of depths to about 20 per centum.

Each diatom is composed of two valves, bound together by two hoop-like bands. In some species these bands lap over each other somewhat like the lid over a pill-box, while in others they merely have their edges opposed but in contact. Each completed diatom is called a frustule.

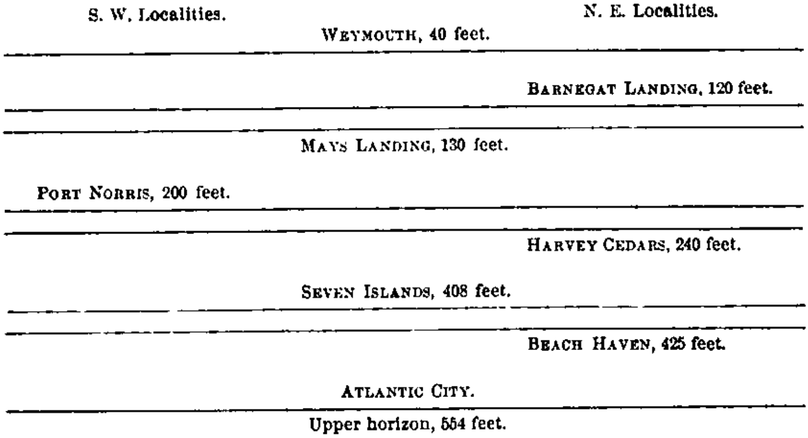
Being made of pure silica, they are not injured by acids and may therefore be boiled therein to destroy the bulk of the earth in which they may be found. They are thus cleaned and prepared for mounting in balsam on glass slides, after which they may be viewed under the microscope. When thus viewed by transmitted light they are seen to be most exquisitely beautiful, transparent objects, ornamented with beads, rays, fine lines, &c., traced with the greatest delicacy and arranged with the most exact mathematical symmetry. The number of lines have been reckoned at from 20,000 to 120,000 per linear inch, and to be equally distant from each other. On this account a number of species have been selected as standard tests for the resolving power of the object lenses used with microscopes. In form they are very varied, having discoid, oval, triangular, rectangular, canoe-shaped and other elongated and sometimes irregular outlines.

above sea-level. They are located at various points along the coast from Great bay, at the mouth of the Mullica river, northward to Barnegat, and in the interior on the banks of the Egg Harbor river, and also near the shore of Delaware bay.

The records of these in past annual publications of the Survey show that their depths increase quite regularly toward the southeast, and that they have all passed through a greater or less thickness of bluish clay just before finding water. For these reasons they have all been regarded as drawing their supply from the same stratum.

The wells at Beach Haven and the 554-foot horizon at Atlantic City fall into harmony with the above group with respect both to the gradual increase of depth and the occurrence of the bluish clay. The source of water for both groups may therefore be considered the same.

The relative position of these wells and their gradual increase of depth toward the southeast may be somewhat diagrammatically shown in the following manner:



Within the area designated are also a number of wells that do not entirely harmonize in depth with the above. They are located at Millville, Pleasant Mills and Harrisia (formerly Harrisville), and will be referred to again.

Since the wells at Beach Haven and those drawing from the 554-foot horizon at Atlantic City draw from an equivalent sand seam within the great diatomaceous clay bed, it follows that if the other wells, grouped above, draw from the same stratum they should show in the clays passed through, near the base of each, a similar assemblage of microscopic organisms. A tour of these wells has, therefore, been made and material obtained by sounding and otherwise, from the bottom of wells at all the localities except three—Harvey Cedars, Seven Islands and Port Norris. In each instance a similar bluish clay was found containing diatoms in abundance. From records and information verbally received, it may be stated that 65 feet of blue clay was encountered at the bottom of the well at Harvey Cedars, on Long Beach, and 125 feet of similarly-described clay at the base of the well at Seven Islands, in Great bay, the clay being entered here at the depth of 275 feet. Similarly, a blue clay was also passed through just before obtaining water, at Port Norris.

The foregoing facts demonstrate that these wells draw their supply from practically the same water-producing stratum—the upper or 554-foot horizon, at Atlantic City; that this is located near the middle of the 300-foot diatomaceous clay bed, which bed has a gentle dip toward the southeast.

Calculations of the amount of dip, based upon the depths of the different wells, have been made, and it is found that the average dip between the extremes of Weymouth and Atlantic City is 28 feet per mile, and of the wells inland, 26 feet per mile.

From around the mouth of an unfinished well at Cape May Point, having a depth of 456 feet, there was collected sand containing small particles of clay also found to be richly diatomaceous, and no doubt brought up from the lower part of the boring.

A well at Sea Isle City obtained a flow of good water between the depths of 350 and 390 feet, just underneath a series of strata described as "alternations of sand and clay." No samples of earths from this well were saved, but in view of the occurrence of diatoms at Cape May Point, these clays were almost certainly diatomaceous. Considering the trend of the strata, the average dip already established, and the southerly location of this well, it seems most probable that the flow comes either from the upper portion of the diatomaceous clay bed, or else from a stratum above the same bed. Either view indicates a water horizon higher than that of 554 feet of Atlantic City, and available for the supply of Cape May county, and possibly the southeast corner of Atlantic county.

There are at Pleasant Mills eighteen flowing wells, having a depth of 44 feet, or 34 feet below tide. Directly southwest therefrom, within two cranberry bogs, respectively three and four miles north-

northwest of Weymouth, are several wells that do not flow because on ground too high, being, according to locality, 40 and 60 feet above sea-level, their depths being about 20 and 30 feet below the same level.

Soundings were made at these several localities, and the characteristic blue clay brought up and found to contain diatoms.* These wells find water in a stratum that is probably lower than the 554-foot horizon at Atlantic City, but above that of 700 feet.

Using for the rate of dip the figures previously given, the water-bearing horizon, at the depth of 700 feet, at Atlantic City, corresponds with a stratum reached by a well at Millville, which was bored to a depth of 160 feet, entering at 120 feet a " blue clay, very hard to get through," and which proved to be about 30 feet thick—probably the base of the diatomaceous clay bed. This horizon is also probably identical with a flow opened during the drilling of a well at Harrisia, at a depth of about 190 feet, but afterwards cased off, "hoping to do better by going deeper," an expectation not realized. This horizon is immediately underneath the diatomaceous clay at Atlantic City.

The foregoing facts point to a considerable extension of the diatomaceous clay bed beneath the southern interior and towards Delaware bay. Its limit northward may be approximately placed at a point midway between Barnegat and Toms River—say in the vicinity of Forked River or Cedar Creek, since well-borings at and near Toms River do not show any diatoms, while the wells at Barnegat Landing apparently draw from the central portion of the great clay bed. Considering the thickness of this bed and the rate of dip, its broadly-upturned edge should approach the surface at about sea-level, over a belt about twelve miles in width, along the lines of the railroads crossing the State to Atlantic City, immediately eastward from Hammonton, where it might possibly be found deeply buried under the superincumbent sands and gravels that are here piled up to a height of 120 feet. The upper water-bearing horizon of Atlantic City, that at 554 feet, would approach the same level at or near Ellwood, and the middle water-bearing horizon, that at 700 feet, should correspondingly be found at or near Hammonton.

*These were not as plentiful as in the material from the former wells, but at each place they were coated with iron pyrites, rendering them opaque instead of transparent, as usual. Through the microscope, by reflected light, they look as if thinly and closely covered with gold film, and exhibit the elevations, depressions and markings of their surfaces quite plainly.

Respecting the various beds passed through in the wells at Atlantic City, underneath the great diatomaceous clay bed, more data from the future development of wells and other improvements and explorations will be needed to certainly identify them with their equivalent beds inland.

Immediately beneath the diatomaceous clay at Atlantic City, there is a succession of thin beds of sands, gravels and tough clays, containing about 85 species of shells. The forms are identically the same as those occurring near Shiloh, about eight miles slightly north of west from Bridgeton. A number of these are characteristic of deposits of this age (Miocene), and would serve to identify this bed if found in well-borings elsewhere in the State. One of these is the Perna, a shell with a pearly luster; it readily splits into numerous very thin layers, and is consequently seldom obtained entire, but generally in small fragments, which usually show a crenulated edge on the side next the hinge, thus , and which is sufficient to identify the shell when found.

Reasoning that if this shell horizon in the well and the shell-marl outcrops near Shiloh were identical, and that since diatoms were found above the shells at one place, they should occur in a corresponding position at the other, a visit was made to the marl pits near Shiloh, and diatoms found as suspected in the clays above the shell marls. Notwithstanding, however, this apparent identity of beds, they do not fall into harmony with the rate of dip established for the clay bed above them.

The difference is such that either the dip of the strata west of Hammonton decreases, or the Shiloh shell marls correspond with a still lower horizon in the wells, possibly that at 905 feet to 955 feet, where occurs a greenish, sandy, *marly clay*, showing near and at the base greensand grains and about two feet of ponderous shells; the shells were so thoroughly broken by the drill as to render their identification impossible.

Until the true relation of these beds is determined, it will be impracticable to indicate with much accuracy the westward extension and depth of the lowest of the three water horizons at Atlantic City, that at about 1,100 feet. There are some reasons, however, why it may be the equivalent of the water-bearing sands found at Winslow at a depth of 335 feet, or 215 feet below sea-level, and at Berkeley Arms, on the beach nearly opposite the mouth of Toms river, at a depth of 475 feet.

This horizon should be looked for inland at a very considerable distance under the diatomaceous clay, and at localities near the coast as much as 300 to 400 feet beneath it.

NOTE ON THE EXTENSION SOUTHWARD OF DIATOMACEOUS CLAYS AND THE OCCURRENCE THERE OF FLOWING ARTESIAN WELLS.

In view of the thickness and extent of the diatomaceous clay bed in New Jersey, its prolongation into the Southern States bordering the Atlantic should be expected. It may, perhaps, as yet be too much to say that the same identical stratum has been certainly made out in that direction. What follows, however, is strongly in favor either of the continuance of the same bed or of one closely related to it and belonging to the same series.

Outcrops of clay containing diatoms have been found at Broad creek, on the eastern side of Chesapeake bay, opposite Annapolis. Similar outcrops next appear to the southeast, on the west side of the Chesapeake, lining the shores of Herring bay, and again on the Patuxent river, north of Nottingham, at the mouth of Lyons creek. Diatomaceous earth underlies Calvert county, Maryland, and can be seen outcropping along the shores of the Chesapeake, on the eastern side of the county, and in the bluffs along the Patuxent, on the western side.

It occurs on the north side of the Potomac, at the mouth of Port Tobacco creek, near Pope's Creek Station, Maryland, and on the south side of the same river, at Nomeni cliffs, in Westmoreland county, Virginia. It has been found along the Rappahannock, about nine miles below Port Royal, and is reported to have been dug from ordinary wells in King William county, Virginia.

A rich diatomaceous deposit has long been well known as existing underneath the city of Richmond, Virginia. This has frequently been described as about twenty feet thick, but this refers to its richest portion, as the entire bed, by the writer's own measurement, is not less than sixty feet in thickness, though the remaining forty feet are quite poor in diatoms. Further south, the bed has been reliably reported at Petersburg and upon the Meherrin river, along the border line between Virginia and North Carolina.

One interesting fact in connection with these deposits is that one form of the diatoms, known as the Heliopelta, so named because of its beautiful star-shaped center, has not been found in any of the borings, and only in the outcrops at a few localities. These are at Petersburg, Virginia; Nottingham, Maryland; and Shiloh, New Jersey.

A clay bed containing diatoms has been penetrated by four artesian wells on the eastern shore, at Cambridge, Maryland, the clay being entered at a depth of 275 feet and continuing to the water-yielding sand at 360 feet.

On the western side of the Chesapeake, Prof. W. B. Rogers, in 1876, reported diatoms at a depth of 558 feet from an unsuccessful well within the walls of Fortress Monroe.

Eastward from Richmond, along the York and the James rivers, information has been received of flowing wells supplied from sand seams, probably within this same diatomaceous clay bed. Their locations are as follows:

	Feet Deep.
West Point, on York river	140
Gabel's, eighteen miles below West Point	226
Hog island, James river	330
Williamsburg, near James river, about	500
Back river, north of Fortress Monroe	1,007

Very recently a well has been finished at Lampert's Point, near Norfolk, Virginia, of which, through the courtesy of officials of the Norfolk and Western railroad, a careful record and specimen series of earths have been received by the writer. The samples, however, were taken very occasionally only and do not show any diatoms, but considering the depth, only 616 feet, and the location farther eastward with reference to the strike of the strata than any of the other wells noted, it may be that the borings did not reach the diatom bed. The interval from 407 to 526 feet is thus described: "Fine dark-gray sand, consisting of a large amount of white particles mixed with black particles." On examination, the white particles proved to be the minute shells of foraminifera and the black ones pure greensand grains. This bed, of about 120 feet in thickness, is high up in the series of strata considered in this article and probably lies under the ocean floor off the New Jersey coast, and there rests upon the extension under the sea of the water-bearing series considered above.

LIST OF ARTESIAN AND OTHER BORED WELLS IN NEW JERSEY, WITH REFERENCES TO THE ANNUAL REPORTS OF THE GEOLOGICAL SURVEY.

The following list contains references to all of the descriptions of bored and artesian wells in the State which have been given in the Annual Reports since 1878, arranged in a geographico-geological order. The location, depth, size of bore and remarks upon the volume and quality of water are stated in this tabular form. For full notes, references may be had to the Annual Reports mentioned.

In many cases the notes on the wells were republished in later reports, hence the number of references. Generally, the first reference gives the essential facts, except where the boring was continued into a second year and noted in the report for that year.

ARTESIAN AND OTHER BORED WELLS.

LOCALITY.	Depth in feet.	Bore in inches.	REMARKS.	References to Annual Reports.
Jersey City— Levi Disbrow	208	....	Bored in 1825, in granite rock. Water brackish	1885, p. 110.
Mattheisen & Wiechers	1,000	8-4	Brackish water; 50 gallons per minute	1879, p. 130. 1882, p. 138.
Andrew Clerke	215	....	In marsh, corner of Henderson and Montgomery streets. Clear water, but contained much common salt	1879, p. 131. 1882, p. 139.
Cox's Brewery	400	5	On Grove street, between Seventh and Eighth; water hard; capacity, 300 bbls. daily. In drift and sandstone	1879, p. 131. 1882, p. 139.
Limbech & Betz's Brewery	776	8	On Ninth street between Grove and Henderson; 33 gals. per minute, of soft water	1882, p. 140.
Central Stock Yard	455	8-6½	70 feet of mud; red sand rock to depth of 215 feet; then gneiss. Water brackish	1880, p. 172. 1882, p. 139.
Communipaw Coal Co.'s Dock	450	....	Water brackish and well abandoned	1888, p. 77.
Hoboken— Near south end of Grand street	400	....	1828. Probably no water. Rock at 40 feet	1879, p. 132. 1882, p. 139. 1885, p. 111.
Town of Union— Palisade Brewery	297	7	In trap rock. Pumped 250 bbls. daily, of soft water	1879, p. 132. 1882, p. 140.
Marsh west of Hoboken	250	....	Brackish water	1887, p. 27.
Newark Meadows, west of Hackensack	200	....	Four wells flowing from depth of 200 feet. Four on line of old Newark turnpike; depth unknown	1879, p. 130.
Secaucus Iron Works	600	6	Water from depth of 200-250 feet Yield on pumping, 8 gals. per minute	1879, p. 129. 1880, p. 172.
Paterson— Passaic Rolling Mill Co.	2,100	8-6-4½	In red sandstone. Bore stopped at 900 feet, whence supply is drawn —100 gals. per min. by pumping	1879, p. 128. 1882, p. 143. 1885, p. 115.
Passaic Rolling Mill Co.	900	....	From the two wells, 250 gallons pumped per minute	1885, p. 117.
Burton Brewing Co.	204	4	40,000 gals. pumped daily	1884, p. 136. 1885, p. 117.
Franklin, Essex county— Kingsland Paper Mills	400	8	180,000 gals. pumped daily. Water of satisfactory quality	1885, p. 117.
Passaic (7 wells)	40-317	....	In red sandstone. Seven wells, each yieding 300 to 1,000 gals per hour	1888, p. 88.
Hackensack— Huyler & Rutan	105½	....	Red shale at 104 feet. Intermittent flow	1879, p. 128. 1882, p. 141.

ARTESIAN AND OTHER BORED WELLS—Continued.

Locality.	Depth in feet.	Bore in inches.	Remarks.	References to Annual Reports.
Orange Water Co.'s wells, Boiling Spring, Essex Co.	1, 86 2, 90 3, 102	6 6 6	On red sandstone. Each of the three wells will yield 250,000 gals. in 24 hours	1885, p. 118. 1884, p. 132.
East Newark—Illingworth Steel Works	320	....	100 gals. per minute. 132 feet in red shale	1889, p. 83.
Newark—R. G. Solomon, foot of Wright St., on meadows	320	....	Flows 100 gals. per minute. 140 feet in red shale	1889, p. 83.
New Jersey Oil Co., near plank road	200	....	50 gals. per minute	1889, p. 83.
Lister Bros'. Works	615	8	505 feet in rock. Yielding at rate of 800,000 gals. daily	1879, p. 127. 1882, p. 142. 1885, p. 115.
Celluloid Works	250	....	Satisfactory volume of water	1879, p. 127. 1882, p. 142. 1884, p. 135. 1885, p. 115.
P. Ballantine & Sons' Brewery	450	8	350 feet in red sandstone. Yield 200 gals. per minute	1879, p. 126. 1882, p. 142. 1885, p. 115.
E. Balbach & Sons' Smelting Works	500	8	Yields at rate of 500 gals. a minute	1879, p. 126. 1882, p. 142. 1885, p. 114.
Roseville—Watchcase Factory	140	....	Excellent water, at rate of 80 gals a minute	1889, p. 83.
Verona, Essex county—J. C. Canniff	150	....	40 gals. per minute	1889, p. 83.
Short Hills—Stewart Hartshorne	180	....	Through drift to trap rock. Flowing at rate of 60 gals. per minute.	1889, p. 83.
Elizabeth—Rising Sun Brewery	300	....	In red shale and sandstone. Yield is 160 gals. a minute	1889, p. 83.
Elizabeth	50–200	....	In red sandstone	1885, p. 114.
Linden—Race Track	100	2	45 gals. per minute	1889, p. 83.
Plainfield—Finch's, Park avenue	102	2¼	42 feet in red sandstone. Ample supply	1879, p. 133.
J. B. Brown, Park avenue	107	1¼	47 feet in red sandstone. Very soft water. Ample supply	1879, p. 133. 1882, p. 147. 1885, p. 114.
Somerville—Loezer Farm, east of town	149	6	In red sandstone. Excellent water.	1885, p. 113.
New Brunswick—Raritan Landing	303	....	40,000 gals. daily. Flow 16 feet above surface. Very hard water.	1879, p. 133. 1882, p. 147. 1885, p. 113.
Bishop Place, and others	455 175–394	1½	Clear and hard water	1879, p. 133. 1882, p. 147. 1885, p. 113.

ARTESIAN AND OTHER BORED WELLS—Continued.

LOCALITY.	Depth in feet.	Bore in inches.	REMARKS.	References to Annual Reports.
New Brunswick—Johnson & Johnson	480		Moderate supply. Very hard water.	1887, p. 27.
Flemington	1, 42		1,000 gals. per hour	1889, p. 88.
	2, 150		1,000 gals. per hour	
	3, 63		1,600 gals. per hour	
Lambertville—Penn. R. R Co.'s Shops			65 feet in rock. 2,000 gals. per hour	1889, p. 88.
Perth Amboy	130		No water. An abundant flow from gravel at 18 feet	1879, p. 134-5. 1882, p. 147. 1885, p. 123.
Sayreville	80	2½	At Sayre & Fisher's brick-yard, two wells yielding an abundance of soft water	1885, p. 124.
	976	8	No water. At 300-350 feet yielded about 7 gals. per minute	1887, p. 27. 1888, p. 77.
Trenton—State Prison	52	12 feet.	Dug through gravel and decomposed gneiss. Good water	1878, p. 91. 1882, p. 184.
John A. Roebling's Sons' Works	168		Large well. Good water. Bored well a failure	1890, p. 264.
Jamesburg	431	8-6	Chalybeate water, potable, but unfit for laundry. Tube crooked and telescoped, stopping work at depth specified	1878, p. 90. 1879, p. 135. 1880, p. 165. 1882, p. 148. 1885, p. 124.
Matawan	264	8	Fine quicksand continued to fill pipe until drilling was abandoned	1885, p. 124.
Freehold	322		Good water. A little hard	1889, p. 83.
	172		Good water. A little hard	1889, p. 84.
Columbus—Rancocas Stock Farm	356		Good water. Slightly tinctured with hydrogen sulphides	1879, p. 138. 1882, p 148. 1885, p. 125.
Rancocas Stock Farm	156		Good water	
Burlington—Residence of Charles S. Taylor	200	8	No good water found	1879, p. 139. 1882, p. 148. 1885, p. 125.
Cinnaminson	46	6	Good water. Yields to pumping 400-500 gals. per minute	1889, p. 86.
Hartford—S. C. Roberts	167	6	Sand interfered with flow of water. To be deepened	1890, p. 265.
Fellowship	260		Good water at 131 feet. On boring deeper a bed of "kaolin" was entered, which closed the pipe, and well was abandoned	1889, p. 85.
Marlton	86	5⅝	Good water abundant	1884, p. 126. 1885, p. 132.

ARTESIAN AND OTHER BORED WELLS—Continued.

LOCALITY.	Depth in feet.	Bore in inches.	REMARKS.	References to Annual Reports.
Marlton—				
Farm of Joseph Evans......	380	....	No water. Pipe withdrawn to 155 feet, and good water..................	1888, p. 77.
Farm of Benjamin Cooper.	70	6	Good water..................................	1884, p. 126. 1885, p. 132.
Four or five miles southeast of Marlton......................	316	....	Satisfactory supply......................	1885, p. 133.
Medford...........	70	....	Good water. Yields to pump 1,200 gals. per hour............................	1889, p. 89.
Camden				
Cooper Hospital...............	129	6	Good, soft water. Pumped 25,000 gals. daily.........................	1885, p. 125.
Esterbrook Steel Pen Co...	130	6	Abundance of good water at 67 feet. A little rolled with clay, to avoid which well was deepened, ending in gneiss, with scanty supply of water...............	1885, p. 125. 1886, p. 213.
Mount Ephraim.................	130	....	Unfinished.......................	1879, p. 148.
	80	....	Good water....................................	1879, p. 148.
Woodbury—				
G. G. Green, No. 1...........	80	12	Good water in abundance.............	1879, p. 146.
No. 2............	163	4½	Good water; scanty......................	1879, p. 146.
No. 3............	132	4½	Good water. Yields to pumping 3,000 gals. per diem.....................	1879, p. 146.
No. 4	120	....	Never used. Pump broken...........	1879, p. 147.
Allen & Madane...............	113	2½	Good water....................................	1879, p. 147.
Louis M. Green................	142	....	Good water. 500 gals. per hour.....	1879, p. 147.
Mrs. Cooper, 1 mile north of Woodbury..................	68	4	Good water. 500 gals. per hour.....	1879, p. 147.
Sewell...................................	72	....	Good water....................................	1889, p. 86.
Vineland—				
Kimball, Prince & Co	197	....	Yields 24 gals. per minute..............	
Winslow...............................	343	....	Surface water corroded steam boiler. That from bottom good for all purposes...........................	1879, p. 139. 1880, p. 171. 1882, p. 149. 1885, p. 134.
Greenwich.............	690	4-2½	No water thus far..........................	1885, p. 131.
Bayside.................................	160	....	Only salt water obtained. Work stopped by breaking of pipe........	1889, p. 87.
Port Norris..........................	190	....	Flowing well..................................	1889, p. 98.
	210	....	Flowing well..................................	1889, p. 98. 1890, p. 268.
West Creek....	113	3	"Good water, and inexhaustible"..	1879, p. 123.
Port Monmouth	100+	....	Reported as "Flowing well over 100 feet deep," yielding a small supply of good water.................	1885, p. 124.

ARTESIAN AND OTHER BORED WELLS—Continued.

LOCALITY.	Depth in feet.	Bore in inches.	REMARKS.	References to Annual Reports.
Atlantic Highlands			Flowing well. Good water	1888, p. 73.
Normandie			Taps clay marl series. Flowing well. 55 gals. per minute. Good water	1889, p. 87.
Seabright	125 125 125 125 125 125	3 3 3 3 3 3	These six wells are all flowing, the water rising 10-12 inches above surface, and yield on pumping 35 gals. each per minute. Quality of water excellent.	1888, p. 73.
	258 258 258		Flowing wells, yielding about 40 gals. per minute at 5½ feet from surface. Probably yield 100 gals. per minute, pumped	1888, p. 73.
Red Bank	80-90	3	Good water	1884, p. 121. 1885, p. 126.
	90	6	No water at first. On raising tube a few feet good water was secured	1884, p. 121. 1885, p. 126.
	66+		Dug 15 feet diameter for 56 feet, and 5 iron pipes 3 feet diameter put down to water-bearing stratum. Water excellent	1884, p. 121. 1885, p. 126.
	230 230 230		Three tubes sunk 300-400 feet apart. Water of good quality rises to within 10 feet of surface	1889, p. 84.
Shrewsbury.	200		No water	1879, p. 139. 1882, p. 148.
Asbury Park	392-448	8	Flowing wells. 95,000 gals. in 24 hours. Good water	1883, p. 20. 1884, p. 124. 1885, p. 129.
	393		Several other wells successfully bored in 1884, 1885 and 1886 in Asbury Park and Ocean Grove	1885, p. 130. 1886, p. 211.
Ocean Grove	420	6		1883, p. 16. 1885, p. 129.
Key East			Abundant supply of pure water. Flowing	1885, p. 130.
Avon Inn	430	3	Abundant supply of pure water. Flowing	1885, p. 130.
Ocean Beach	485	3	Flowing well. Rises 34 feet. Flows 25 gals. per minute. Good water	1884, p. 124. 1885, p. 130.
	480	3	Flowing well. 50 gals. per minute. Good water	1885, p. 131.
Spring Lake	465		Abundance of good water	1885, p. 131. 1886, p. 211.
Lakewood	475		Flowing well. 17 feet head, 3½ gals. per minute. Good water	1884, p. 125. 1885, p. 131.

ARTESIAN AND OTHER BORED WELLS—Continued.

LOCALITY.	Depth in feet.	Bore in inches.	REMARKS.	References to Annual Reports.
Mantoloking	175	8	Flowing well. 35 feet head. Good water. Deepened to 790 feet in 1889	1889, p. 87.
Bay Head	710	....	Good water	1887, p. 26.
Berkeley Arms	475	....	Good water. Rises to surface but does not overflow. Pumped 60 gals. per minute	1884, p. 127. 1885, p. 133.
Barnegat	120	....	Flowing well. Good water	1887, p. 26.
Harvey Cedars, on Long Beach	240	....	Flowing well. Good water	1887, p. 25.
Harrisville	306	6	Flowed 8 feet above surface. Good water at about 180 feet, but this was shut off by tubing. Present supply scanty and impregnated with iron	1879, p. 140. 1882, p. 150. 1885, p. 135.
Pleasant Mills—Charles G. Rockwood	158	....	No satisfactory supply of water	1885, p. 138.
Pleasant Mills	48	3	Flowing well. 13 feet head. Good water	1884, p. 127.
	48	3	Eight wells bored in 1884 same depth. Head and quality of the water as the first	1885, p. 135.
	48	3	Four more wells bored in 1885, making 14 in all	1885, p. 137.
Beach Haven	430	3	Two flowing wells	1890, p. 266.
South Beach Haven	425	8-6	Flowing well. 500 bbls. per diem. Good water. 14 feet head	1886, p. 211.
Seven Islands, in Great Bay.	408	6-4½-3	Flowing well. 70 gals. per minute. Good water	1885, p. 135. 1886, p. 212.
Weymouth	42	4	Flowing well. 70 gals. per minute. Good water	1884, p. 131.
	47	5	Bored 47 feet, but tube afterward withdrawn to 38 feet. Flowing well 52 gals. per minute. Good water	1885, p. 139.
Mays Landing	150	2½	Flowing well. 7 gals. per minute. Good water	1884, p. 130.
	130	2½	Flowing well. 3 or 4 gals. per minute. Good water	1885, p. 133.
Millville	160	10	Flowing well	1890, p. 267.
Atlantic City	185	8½	Salt water	
	90	12	Potable. 24.20 grains solids to gal.	1879, p. 142. 1882, p. 150.
	118	12	Potable. 24.20 grains solids to gal.	
	1,150	8-6	Abundance of good water, rising to 5 feet above surface	1887, p. 26. 1888, p. 73. 1889, p. 89.

ARTESIAN AND OTHER BORED WELLS—Continued.

LOCALITY.	Depth in feet.	Bore in inches.	REMARKS.	References to Annual Reports.
Atlantic City	815	10	Abandoned on account of accident	1889, p. 90.
	1,400	10-8-6-4½	No water. Pipe now (1889) being withdrawn in hope of developing water-bearing strata passed through	1889, p. 90.
	578	8	Good water. Passed water-bearing strata at 328, 406, 429 and 554 feet respectively	1889, p. 90.
Sea Isle City	380	4	Good water. Yields to pumping 30 gals. per minute	1888, p. 76.
Electric Light Works	464	....	Flowed to top	1890, p. 268.
Cape May City	87-92	8	Five wells of 8-inch bore, yielding on pumping 75 gals., each, fine, fresh water	1879, p. 143.
	....	8	No water. Driven too deep	1882, p. 152.
	224	8	Salt water. Driven through the water-bearing strata	
Cape May Point	456	....	Unfinished (1885)	1885, p. 140.

NOTE.—A few artesian wells put down in 1890 are not in the above list, but are referred to in the letter of P. H. & J. Conlan, printed on pages 261-263 of this report.

DRAINAGE.

BY GEO. W. HOWELL.

PEQUEST DRAINAGE.

The results of the improvements made along the Pequest river through the Great Meadows, in Warren county, a few years ago, are very satisfactory. The actual lowering of the surface of the water in the stream has made it possible to reclaim the damaged lands of the entire district. The area of reclaimed lands is being increased year by year, and large tracts of land which formerly were utterly worthless are now producing valuable crops. Through the greater portion of the district the owners experience no difficulty in draining their lands by means of lateral ditches, the lowering of the water in the river affording a free outlet. The experience of the past few years in this locality has proved without doubt that this improvement may be looked upon as a permanent one.

Still more satisfactory results, however, may be expected if the additional improvements should be carried out which were recommended in detail in the Annual Report of the State Geologist for the year 1888. The expense of these improvements would be very moderate, the beneficial results would be greatly in excess of the cost, and the legal authority to carry them out is fully sufficient.

The sanitary condition of the district is decidedly improved. When the entire area shall have been fully reclaimed, there is no reason why this region should not be as healthy as any part of the State.

PASSAIC DRAINAGE.

Under the contract made between the Passaic River Drainage Commissioners and Alfred B. Nelson, of New Brunswick, N. J., dated July 16th, 1889, work was done amounting to a little over $4,000. Part of this was in reducing the main fall below the dam, at Little Falls, but the principal part was in blasting one of the reefs above the dam. Owing to a lack of means to properly carry out the contract, and to certain personal misfortunes, the Commissioners closed the contract with Mr. Nelson February 17th, 1890, paying him in full for all the work he had done.

Pending negotiations with other contractors, the Commissioners themselves continued the work, leasing the plant left on the ground by the former contractor. This was done in order that no stoppage might occur in the work. During this time the blasting of the lower reef was completed, though none of the rock was removed from the bed of the river.

On the 20th of August, 1890, the Commissioners entered into contract with the Morris & Cumings Dredging Company, of New York City, for all the work remaining to be done below the dam. The well-known reputation of this company, connected as they have been for many years with important municipal and government works in New York harbor and elsewhere throughout the United States, seems to be a guarantee that they will push their contract to a speedy and successful completion. By the terms of their contract they are required to have the work done by midsummer of 1891. Before that time, however, it is purposed to begin the remainder of the work yet to be contracted for, namely, the removal of the reefs above the dam, the excavation of the bar at Two Bridges and the cut-off channel at Pine Brook.

It is necessary that the work now in progress should be completed first, in order that the Commissioners may avail themselves of the advantages of their contract with the Beattie Manufacturing Company at as early a day as possible, namely, the reduction in the height of the dam and the erection of waste-gates through the dam so reduced, of sufficient capacity to carry all ordinary freshet waters. These last-mentioned improvements are to be made by the Beattie Company without expense to the Commissioners. The plans for the gates have already been made and have been approved by the Commissioners, after a thorough examination of the plans in connection with some of the best hydraulic engineers in the country. The gates will be erected as soon as the necessary preliminary work is done by the Commissioners.

No difficulty has been met in raising the funds requisite for carrying on the work by the sale of Commissioners' bonds, none of which have been sold below par. The sale of the bonds has not been pushed, as the Commissioners have not deemed it advisable to sell bonds far in advance of the necessities of the work, in order to avoid carrying a heavy interest account. Many of the bonds sold thus far have been taken by parties more or less interested in the lands to be benefited. In many instances they have been applied for by parties seeking a good and safe investment.

In a work of this magnitude delays are, to a certain extent, unavoidable. The principal part of the work below the dam can only be done at low stages of the river, high freshets rendering it absolutely impossible to prosecute the work. Taking everything into consideration, reasonable progress has been made, and as the work is now organized, the Commissioners feel assured that it will be pushed vigorously to a successful termination, and that the beneficial results arising therefrom will be eminently satisfactory.

STATISTICS OF IRON AND ZINC ORES.

IRON ORE.

The statistics of the iron mines as obtained by Mr. Nason from mine-owners and managers show a total output during the year 1890 of 552,996 tons. The aggregate tonnage of the railway and canal transportation lines from stations in the State, and the amounts used at furnaces, which do not come in the reports of these companies, make a sum total of 537,066 tons. The difference is explained by the fact that not all of the ore which is mined during the year is shipped, and this amount may represent that which accumulates as stock at the mines in excess of that of the preceding year. The tonnage of the transportation lines is, however, fairly comparable with the output as reported in preceding years, since the latter statistics also are from the returns received from these companies. Assuming the latter sum, the increase of 1890 above that of 1889 amounts to 54,897 tons, or about 11 per cent.

The statistics given in last year's report are reprinted here:

IRON ORE.

1790	10,000 tons	Morse's estimate.
1830	20,000 tons	Gordon's Gazetteer.
1855	100,000 tons	Dr. Kitchell's estimate.
1860	164,900 tons	U. S. census.
1864	226,000 tons	Annual Report State Geologist.
1867	275,067 tons	" " "
1870	362,636 tons	U. S. census.
1871	450,000 tons	Annual Report State Geologist.
1872	600,000 tons	" " "
1873	665,000 tons	" " "
1874	525,000 tons	" " "
1875	390,000 tons	" " "
1876	285,000 tons*	
1877	315,000 tons*	

* From statistics collected later.

1878	409,674 tons	Annual Report State Geologist.
1879	488,028 tons	" " "
1880	745,000 tons	" " "
1881	737,052 tons	" " "
1882	932,762 tons	" " "
1883	521,416 tons	" " "
1884	393,710 tons	" " "
1885	330,000 tons	" " "
1886	500,501 tons	" " "
1887	547,889 tons	" " "
1888	447,738 tons	" " "
1889	482,169 tons	" " "

ZINC ORE.

The production of the zinc mines of the State, as per reports from the companies carrying the ore, amounted in 1890 to 49,618 tons, a decrease of 6,536 tons as compared with that of 1889, or equivalent to 11½ per cent.

The statistics for preceding years are reprinted in the following tabular statement:

	Estimated tons.	
1868	25,000	Annual Report State Geologist.
1871	22,000	" " "
1873	17,500	" " "
1874	18,500	" " "
1878	14,467	" " "
1879	21,937	" " "
1880	28,311	" " "
1881	49,178	" " "
1882	40,138	" " "
1883	56,085	" " "
1884	40,094	" " "
1885	38,526	" " "
1886	43,877	" " "
1887	50,220	" " "
1888	46,377	" " "
1889	56,154	" " "

PUBLICATIONS OF THE SURVEY.

DISTRIBUTION OF PUBLICATIONS.

By the act of 1864 the Board of Managers of the Survey is a board of publication with power to issue and distribute the publications as they may be authorized. The Annual Reports of the State Geologist are printed by order of the Legislature as a part of the legislative documents. They are distributed largely by the members of the two houses. Extra copies are supplied to the Board of Managers of the Geological Survey and the State Geologist, who distribute them to libraries and public institutions, and as far as possible to any who may be interested in the subjects of which they treat. Several of the reports, notably those of 1868, 1873, 1876, 1879, 1880 and 1881 are out of print and can no longer be supplied by the office. The first volume of the Final Report, published in 1888, was mostly distributed during the following year, and the demand for it has been far beyond the supply. The first part of the second volume has also been distributed to the citizens and schools of the State, and to others interested in the particular subjects of which it treats. The second part of the second volume, which is the only issue of the Survey since the publication of the Annual Report for 1889, is also ready for distribution to those who have received the former volumes and those who are especially interested in the zoology of the State. The appended list makes brief mention of all the publications of the present Survey since its inception in 1864, with a statement of editions that are now out of print. The publications of the Survey are, as usual, distributed without further expense than that of transportation, except in the single instance of the maps, where a fee to cover the cost of paper and printing is charged as stated.

CATALOGUE OF PUBLICATIONS.

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

PORTFOLIO OF MAPS accompanying same, as follows:

1. Azoic and paleozoic formations, including the iron-ore and limestone districts; colored. Scale, 2 miles to an inch.
2. Triassic formation, including the red sandstone and trap rocks of Central New Jersey; colored. Scale, 2 miles to an inch.
3. Crataceous formation, including the greensand marl beds; colored. Scale, 2 miles to an inch.
4. Tertiary and recent formations of Southern New Jersey; colored. Scale, 2 miles to an inch.
5. Map of a group of iron mines in Morris county; printed in two colors. Scale, 3 inches to 1 mile.
6. Map of the Ringwood iron mines; printed in two colors. Scale, 8 inches to 1 mile.
7. Map of Oxford Furnace iron-ore veins; colored. Scale, 8 inches to 1 mile.
8. Map of the zinc mines, Sussex county; colored. Scale, 8 inches to 1 mile.

A few copies are undistributed.

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

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

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

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part I. Mineralogy. Botany. Trenton, 1889, 8vo., x. + 642 pp.

Final Report of the State Geologist. Vol. II. Part II. Zoology. Trenton, 1890, 8vo., x. + 824 pp.

Atlas of New Jersey. The complete work is made up of twenty sheets, each twenty-seven by thirty-seven inches, including margin, intended to fold once across, making the leaves of the Atlas 18½ by 27 inches. The location and number of each map are given below. Those from 1 to 17 are on the scale of one mile to an inch.

No. *1. Kittatinny Valley and Mountain*, from Hope to the State line.
No. *2. Southwestern Highlands*, with the southwest part of Kittatinny valley.
No. *3. Central Highlands*, including all of Morris county west of Boonton, and Sussex south and east of Newton.
No. *4. Northeastern Highlands*, including the country lying between Deckertown, Dover, Paterson and Suffern.
No. *5. Vicinity of Flemington*, from Somerville and Princeton westward to the Delaware.
No. *6. The Valley of the Passaic*, with the country eastward to Newark and southward to the Raritan river.
No. *7. The Counties of Bergen, Hudson and Essex*, with parts of Passaic and Union.
No. *8. Vicinity of Trenton*, from New Brunswick to Bordentown.
No. *9. Monmouth Shore*, with the interior from Metuchen to Lakewood.
No. *10. Vicinity of Salem*, from Swedesboro and Bridgeton westward to the Delaware.
No. *11. Vicinity of Camden*, to Burlington, Winslow, Elmer and Swedesboro.
No. *12. Vicinity of Mount Holly*, from Bordentown southward to Winslow and Woodmansie.
No. *13. Vicinity of Barnegat Bay*, with the greater part of Ocean county.
No. *14. Vicinity of Bridgeton*, from Allowaystown and Vineland southward to the Delaware bay shore.
No. *15. Southern Interior*, the country lying between Atco, Millville and Egg Harbor City.
No. *16. Egg Harbor and Vicinity*, including the Atlantic shore from Barnegat to Great Egg Harbor.
No. *17. Cape May*, with the country westward to Maurice river.
No. *18. New Jersey State Map*. Scale, 5 miles to an inch. Geographic.
No. *19. New Jersey Relief Map*. Scale, 5 miles to the inch. Hypsometric.
No. *20. New Jersey Geological Map*. Scale, 5 miles to the inch.

In order to meet the constantly increasing demand for these sheets, the Board of Managers of the Geological Survey have decided to allow them to be sold at the cost of paper and printing, for the uniform price of 25 cents per sheet, either singly or in lots. This amount covers all expense of postage or expressage, as the case may be. Sets of the sheets, bound in atlas form (half morocco, cloth sides, gilt title, maps mounted on muslin, and guarded), are furnished at $13.50 per copy. Application and payment, invariably in advance, should be made to Mr. Irving S. Upson, New Brunswick, N. J., who will give all orders prompt attention.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

ANNUAL REPORT of the State Geologist of New Jersey for 1883. Camden, 1883, 8vo., 188 pp.

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

ANNUAL REPORT of the State Geologist of New Jersey for 1885. Trenton, 1885, 8vo., 228 pp., with maps.

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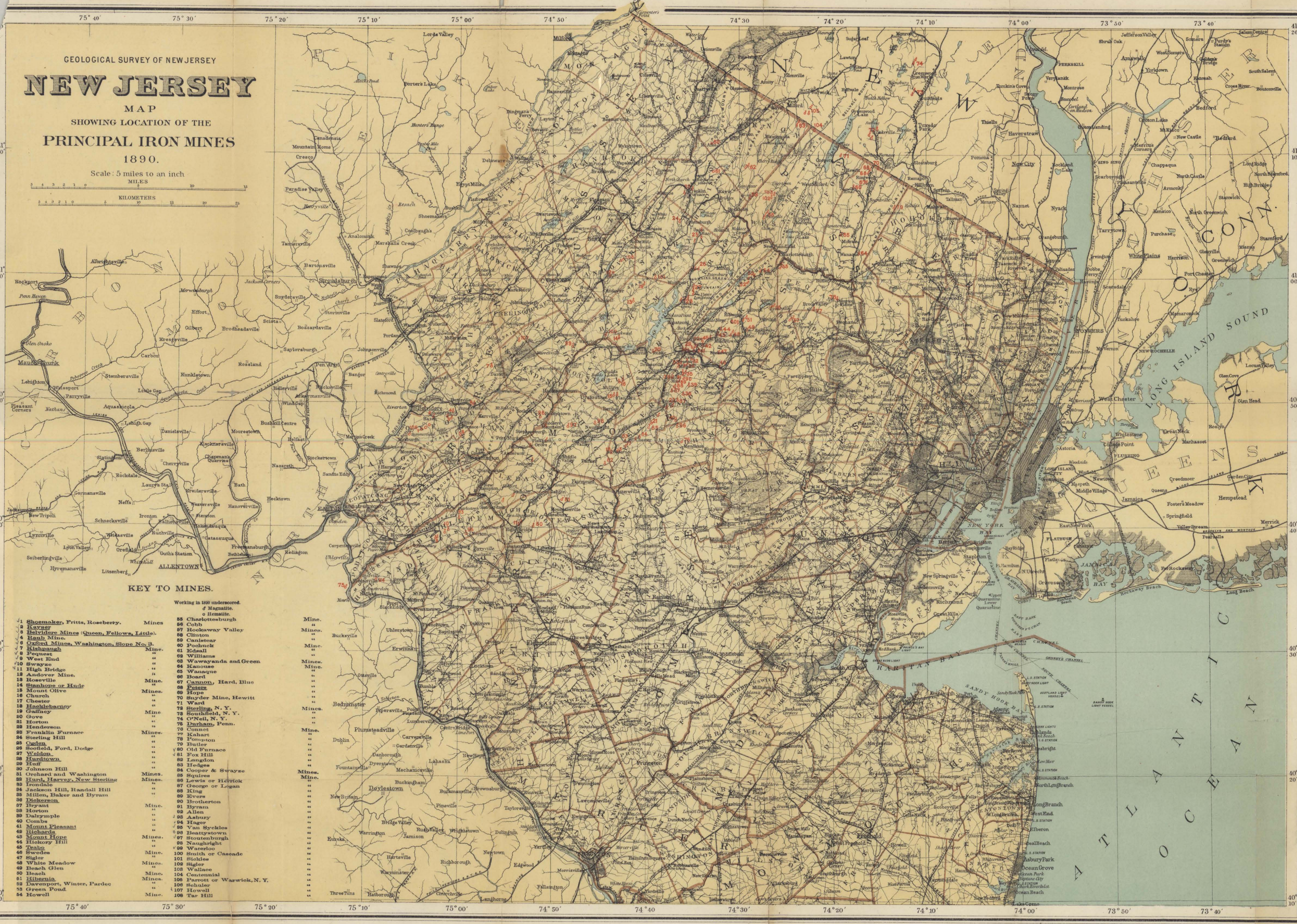
GEOLOGICAL SURVEY OF NEW JERSEY
NEW JERSEY
MAP
SHOWING LOCATION OF THE
PRINCIPAL IRON MINES
1890.
Scale: 5 miles to an inch
MILES
KILOMETERS
KEY TO MINES.
Working in 1890 underscored.
♂ Magnatite.
o Hematite.
1 Shoemaker, Fritts, Roseberry. Mines
2 Kayser
3 Belvidere Mines (Queen, Fellows, Little).
4 Raub Mine.
6 Oxford Mines, Washington, Slope No. 3.
7 Kishpaugh Mine.
8 Pequest "
9 West End "
10 Swayze "
11 High Bridge "
12 Andover Mine. "
13 Roseville Mine.
14 Stanhope or Hude "
15 Mount Olive Mines.
16 Church "
17 Chester "
18 Hacklebarney "
19 Gaffney Mine
20 Gove "
21 Horton "
22 Henderson "
23 Franklin Furnace Mines.
24 Sterling Hill "
25 Ogden "
26 Scofield, Ford, Dodge "
27 Weldon "
28 Hurdtown "
29 Huff "
30 Johnson Hill "
31 Orchard and Washington Mines.
32 Hurd, Harvey, New Sterling Mines.
33 Irondale "
34 Jackson Hill, Randall Hill "
35 Millen, Baker and Byram "
36 Dickerson
37 Bryant Mine.
38 Horton "
39 Dalrymple "
40 Combs "
41 Mount Pleasant "
42 Richards "
43 Mount Hope Mines.
44 Hickory Hill "
45 Teabo "
46 Swedes Mine.
47 Sigler "
48 White Meadow Mines.
49 Beach Glen "
50 Beach Mine.
51 Hibernia Mines.
52 Davenport, Winter, Pardee "
53 Green Pond "
54 Howell Mine.
55 Charlottesburgh Mine.
56 Cobb "
57 Rockaway Valley Mines.
58 Clinton "
59 Canistear "
60 Pochuck Mine.
61 Edsall "
62 Williams "
63 Wawayanda and Green Mines.
64 Kanouse Mine.
65 Wanaque "
66 Board "
67 Cannon, Hard, Blue "
68 Peters "
69 Hope "
70 Snyder Mine, Hewitt "
71 Ward "
72 Sterling, N. Y. Mines.
73 Southfield, N. Y. "
74 O'Neil, N. Y. "
75 Durham, Penn. "
76 Connet Mine.
77 Kahart "
78 Pompton "
79 Butler "
80 Old Furnace "
81 Fox Hill "
82 Langdon "
83 Hedges "
84 Cooper & Swayze Mines.
85 Squires Mine.
86 Lewis or Herrick "
87 George or Logan "
88 King "
89 Evers "
90 Brotherton "
91 Byram "
92 Allen "
93 Asbury "
94 Hager "
95 Van Syckles "
96 Beattystown "
97 Stoutenburgh "
98 Naughright "
99 Waterloo "
100 Smith or Cascade "
101 Sickles "
102 Sigler "
103 Wallace "
104 Centennial "
105 Parrott or Warwick, N. Y. "
106 Schuler "
107 Howell "
108 Tar Hill "
JULIUS BIEN & CO. LITH.


GEOLOGICAL SURVEY OF NEW JERSEY
J.C. SMOCK, STATE GEOLOGIST
A MAP OF
NEW JERSEY
SHOWING WATER-SHEDS.
Report on Water-Supply and Water-Power
BY
C. C. VERMEULE.
1890
Scale: 5 miles to an inch
MILES
KILOMETERS
GAUGING POINT
ATLANTIC OCEAN
DELAWARE BAY
LONG ISLAND SOUND
PASSAIC
RARITAN
HACKENSACK
WALLKILL
SOUTH RIVER
NAVESINK
MANASQUAN
METEDECONK
CROSSWICKS CR.
ASSISCUNK CR.
RANCOCAS NORTH BR.
RANCOCAS SOUTH BRANCH
CEDAR CR.
WADING RIVER
BATSTO
MULLICA
GREAT EGG HARBOR RIVER
MAURICE
SALEM CR.
RACCOON CR.
OLDMANS CR.
COHANSEY CR.
TUCKAHOE
MANUMUSKIN
MANANTICO CR.