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CHARLES D. WALCOTT, DIRECTOR

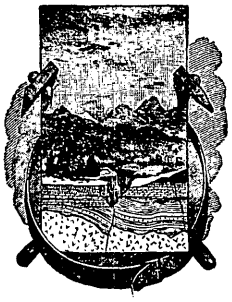
ARTESIAN WELL PROSPECTS

IN THE

ATLANTIC COASTAL PLAIN REGION

BY

NELSON HORATIO DARTON



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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., July 29, 1895.

SIR: I have the honor to submit herewith my report on "Artesian well prospects in the Atlantic Coastal Plain region," which is offered for publication as a bulletin of the Survey.

Very respectfully,

N. H. DARTON,
Assistant Geologist.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

ARTESIAN WELL PROSPECTS IN THE ATLANTIC COASTAL PLAIN REGION.

By N. H. Darton.

INTRODUCTORY.

In the Coastal Plain region of the Atlantic Slope there are no large supplies of potable surface water. The great rivers which traverse the region are either tidal estuaries or are widely bordered by swamps, and the water of their local branches is often of bad quality. The cities, situated at intervals along the western margin of the region, obtain a plentiful supply of excellent water from the rivers in the highlands to the west, but out on the Coastal Plain surface waters are mainly used. Malarial diseases prevail in varying degree over the greater part of the region, and as medical opinion is largely agreed that these diseases are taken into the system in drinking waters, the hygienic importance of pure water is very great.

Fortunately the region has a geologic structure particularly favorable to the accumulation and flowage of underground waters, and many streams of pure water are known to exist at moderate depths. These have been tapped by numerous wells, and water supplies of the very greatest economic and hygienic value have been obtained. The cities of Brooklyn, Charleston, and Savannah have wells which yield millions of gallons per day, and there are several hundred wells which supply smaller settlements and individuals.

During the past six years I have been engaged in a study of the Coastal Plain region, mainly its central portion, and have given special attention to the question of subterranean waters. Lately my observations have been extended to Long Island on the north and to eastern Georgia on the south. Although my special investigation of subterranean waters is not far advanced, it is thought that a preliminary

report would in a measure meet the great demand that exists for information as to well prospects and the general relations of the water horizons.

Notwithstanding the fairly large number of wells, the information is meager for many portions of the region. Few of the well records in the southern portion of the area and on Long Island are sufficiently definite to fully indicate the geologic relations of the water horizons and their associates, but some general features are quite clearly indicated. In New Jersey, Maryland, and Virginia there are many wells, and the geology is so relatively plain that it has been possible to definitely determine the position of many of the water-bearing horizons and to predict water almost everywhere with a fair degree of certainty.

GENERAL GEOLOGIC STRUCTURE OF THE ATLANTIC COASTAL PLAIN REGION.

It is proposed to give under this heading a brief outline of the general geologic features of the region in order that the relations of the water-bearing strata may be clearly understood. More detailed descriptions of local features will be given in subsequent chapters.

The Coastal Plain is a geographic province which extends along the

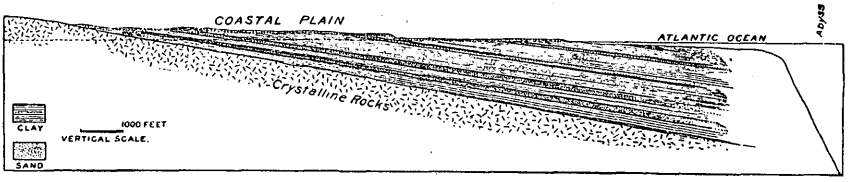


FIG. 1.—Section across the Atlantic Coastal Plain from west to east.

eastern margin of the Atlantic Slope from Long Island to Florida. Its width averages about 100 miles, exclusive of a submerged seaward extension out under the Atlantic Ocean. The surface is in greater part smooth or gently rolling, and westward it slopes up gradually to altitudes of from 300 to 400 feet in the Northern States and to heights somewhat greater toward the south. It is deeply intersected by bays and long, narrow tidal estuaries of rivers, which are surrounded by low lands near the ocean, but are flanked by moderately high plateaus and hills as the country rises inland.

The region is underlain by a series of great sheets of unconsolidated deposits, consisting mainly of sands, clays, and marls, which lie on an east-sloping floor of older rocks, predominantly granite and gneiss. These deposits constitute a great flat wedge, inclined to the east and southeast, and presenting its thin edge to the west and northwest. The underlying rocks emerge at the surface along a line which passes from New York city through Philadelphia, Baltimore, Washington,

Richmond, Weldon, and Columbia to Augusta, Ga., and thence through central Georgia and Alabama, and they extend westward up the gentle slope of the Piedmont plateau to the base of the Appalachians. To the east the crystalline floor sinks to a great depth, and it is about 2,000 feet below the surface along the ocean shore south from New Jersey. In fig. 1 a typical cross section of the Coastal Plain province is given.

The sedimentary deposits are a succession of widely extended sheets which usually thicken to the east and dip gradually to the east and southeast. In their usual relations they comprise alternating beds of coarse and fine deposits, of which the coarse materials are water-bearing and the fine materials, on account of their relatively impervious nature, serve to confine the waters in the coarse beds. The eastward inclination of the beds determines the direction of flow, and as the watersheds or surface outcrops are in the higher lands to the west, the waters often have sufficient pressure to rise above the surface from wells in the lower lands.

On the floor of crystalline rocks there appears to be an almost general occurrence of coarse water-bearing beds which are overlain by clays and fine sands. At various intervals above there are other coarse beds of greater or less extent containing water supplies for deep wells. The order and thickness of the beds vary in the different portions of the region, and present local features which will be described in the several chapters that follow this general introduction.

SOME CONDITIONS AFFECTING SUBTERRANEAN WATERS IN THE COASTAL PLAIN.

Before proceeding to the well records and to a consideration of their significance it may be well to point out some conditions which affect the occurrence of subterranean waters. I shall notice only a few points here, and those who are interested in a more extended discussion should read the paper by Prof. T. C. Chamberlin, entitled "The requisite and qualifying conditions of artesian wells."[1]

The simplest condition of underground waters is shown in section 1 of fig. 2. The water enters the coarse stratum at its outcrop over the belt, AA, and flows down the dip, being confined to the coarse stratum by impervious materials above and below. When it is tapped at B it rises to a level approximately as high as AA. On the Coastal Plain there are probably several qualifying conditions of greater or less importance. The first is shown in section 2 of the figure. This represents a diminution in the coarseness of the materials down the slope, until finally the bed becomes so fine-grained as to be impervious to the water. Under this condition a well at C would afford water, but one

[1] Fifth Ann. Rept. U. S. Geol. Survey, pp. 125–174, 1885.

at D would not. In case this fining of materials was mainly in irregular beds or in local areas, the districts underlain by water would be restricted to the areas of coarse materials.

This relation is probable throughout the Coastal Plain, for the old shore of the deposits was near A, and the fineness of materials increases offshore in most if not all of the formations. Beds which contain much water to the westward sometimes prove to be entirely fine-grained and barren of water to the east and southeast.

A third condition, which is quite widespread in Virginia from Fredericksburg southward, is shown in section 3. This represents an

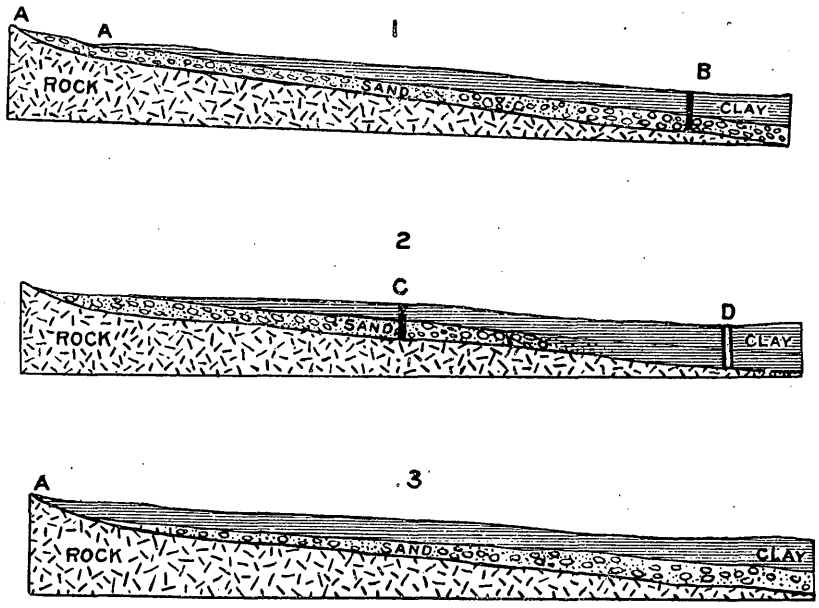


FIG. 2.—Ideal sections illustrating certain general conditions affecting underground waters.

overlap of fine materials across the catchment outcrop of the coarse beds, and this relation probably greatly diminishes the amount of water in the permeable bed. In Virginia the Pamunkey and Potomac formations are overlapped in this way by the clays of the Chesapeake and the loams of the Lafayette and the Columbia, and although they are more or less widely bared of these deposits in the river depressions, their water supplies are cut off for considerable widths on the divides.

Section 2 is introduced to illustrate the reason why some of the beds to the westward which hold water have not yielded or possibly may not yield water to the eastward.

Section 3 has a somewhat similar practical bearing, but beds which are widely overlapped by impermeable deposits in one part of the

region are often widely bared in other areas and receive ample water supply diagonally down the dip.

There are many local conditions that affect individual wells or small areas which should be illustrated here, for they are often referred to in the following pages. They are represented in the sections in fig. 3.

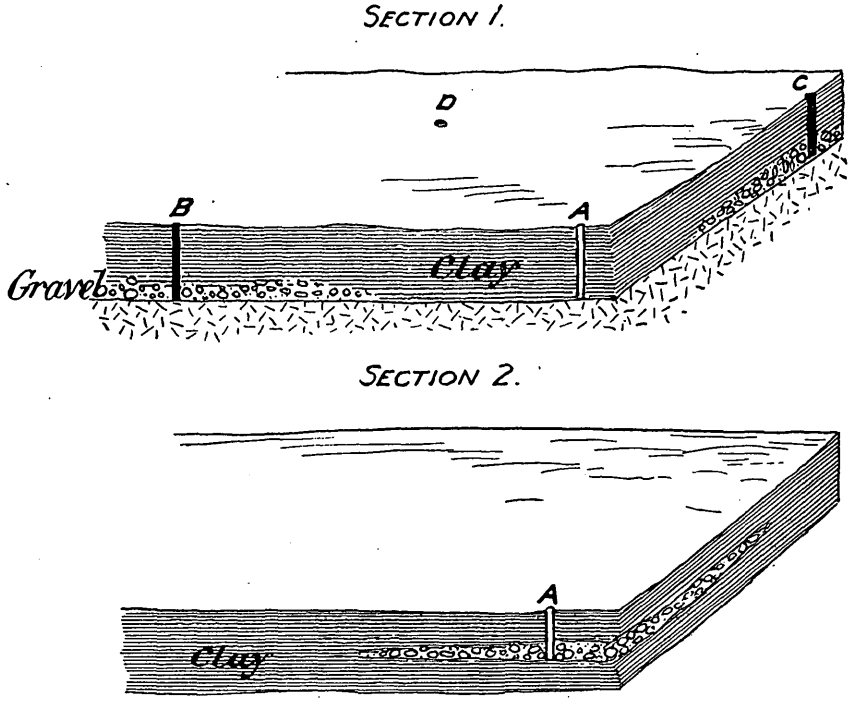


FIG. 3.—Ideal sections illustrating certain special conditions affecting well prospects.

Section 1 represents a gravel bed merging into clay or fine sand in a circumscribed area. Wells at B and C, and probably at D, would find water-bearing gravels on the crystalline rock floor, whereas at A there would be clays all the way down and no water would be obtained. In some cases at A the gravels might continue, but with a clay matrix which excludes the water.

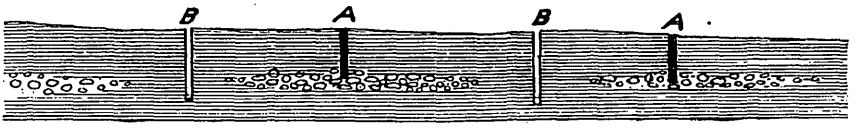


FIG. 4.—Ideal section illustrating water-bearing beds in channels.

Section 2 represents the occurrence of a gravel bed which is completely inclosed in clays, so that no water can accumulate in it, and a well at A, although finding favorable materials for water, would obtain none.

In fig. 4 a condition is illustrated which is in a measure similar to that shown in section 1, fig. 2. The water-bearing beds lie in channels, as it were, with intervening belts of nonwater-bearing materials. In this case wells at A and A would be successful, but those at B and B would not be.

Figure 5 represents a condition which is no doubt quite frequent on Long Island among the drift deposits. The conditions would appear to be favorable at A for water in the gravels between the upper clay beds, but the water does not accumulate, for it is free to flow over the edge of the clay into lower gravels, where it would be found in a deeper well, as at B.

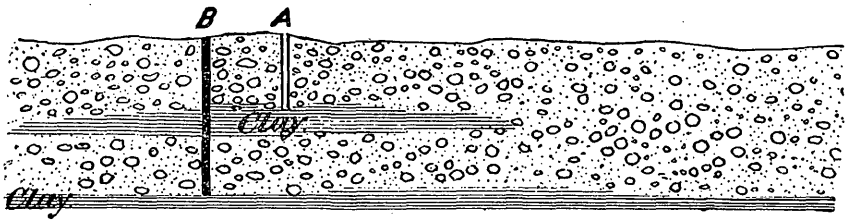


FIG. 5.—Ideal section illustrating the occurrence of local clay strata in gravels and sands.

In fig. 6 a condition is shown which is frequently met with along the western border of the Coastal Plain in Maryland and northern Virginia. The water-bearing beds lie above sea level and are cut across

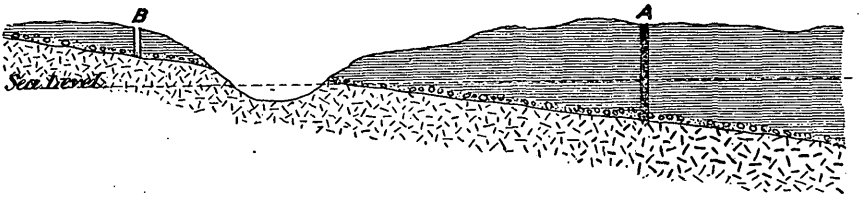


FIG. 6.—Ideal section illustrating water-bearing beds intercepted by a valley.

by a depression, so that the water may escape in springs. Accordingly, a well at B would usually find but little water, notwithstanding the fact that a well at A finds an abundant supply in the same beds.

NEW YORK.

As this report is intended to cover only the Coastal Plain region of the Atlantic Slope, in the restriction of the term to the province underlain by the Cretaceous and Tertiary deposits, this chapter should relate only to Long Island and southern Staten Island. As, however, I have incidentally obtained some data for many of the wells on New York Island, a list of these wells will also be given.

LONG ISLAND.

GENERAL GEOLOGIC RELATIONS.

Long Island consists of a great mass of glacial drift lying on Cretaceous and probably also Tertiary formations. The Cretaceous formations lie on a floor of crystalline rocks, which is deeply buried to the south, but rises gradually to the north and emerges at the surface in Long Island Sound, in Connecticut, and on the northwestern corner of Long Island. The Cretaceous formations, and probably also the Tertiary, are a succession of widely extended sheets of sands, clays, etc., which are often considerably flexed locally, but as a whole dip to the south or south-southeast. They also probably thicken and increase in number in the same direction. The drift comprises the great terminal moraine of the Second Glacial Epoch, which rises in a range of high hills extending along the center of the island, and a variety of Pleistocene deposits of which the relations have not yet been fully determined. It consists mainly of mixtures of sands, pebbles, and bowlders, and beds of sand, clay, and sandy clays, presenting considerable complexity of structure. It lies on an irregular, deeply eroded surface of the older formations, but the contour of this surface is not determined over a wide area.

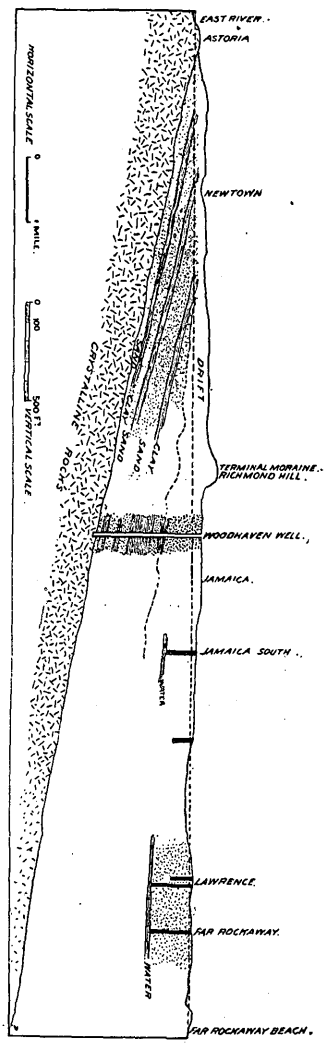


FIG. 7.—Cross section of the western end of Long Island, from Astoria to Far Rockaway Beach, looking west.

The following cross section of Long Island shows the general relations and also indicates the position and features of some of the wells.

WELLS OF LONG ISLAND.

The artesian water supplies of Brooklyn are of world-wide fame, for their amount is phenomenally large and the quality of the water is exceedingly good. The wells are of moderate depth—100 to 150 feet—and the waters do not come from any definite geologic horizon, but are simply accumulations in or under the drift deposits in localities where the physical conditions are favorable. There are other wells at various points on the island which, in the main, obtain satisfactory water supplies,

but as they are quite widely scattered and draw mainly from moderate depths, the underground waters may be said not to have been extensively explored. A fairly thorough canvass of the island was made, in part by correspondence and to some extent by a personal visit, and I have learned of the wells given in the following list:

List of deep wells on Long Island.

Location.	Depth.	Bore.	Capacity.	Height to which water rises.[a]	Remarks.
	Feet.	*Inches.*	*Gals. per min.*	*Feet.*	
Babylon	100	6		Flowed.	Milky water.
Barnum Island	386				
Bay Shore	120?	8?		Flowed.	Poor water.
Bowery Bay:					
3 wells	110	6	75 each.	One flowed 50 gallons.	
3 wells	50		500		
Brentwood	52				
Brooklyn:					
55 Pearl street			200		
Central avenue and Grove street.			300		
Brooklyn City Water Dept.:					
Gang wells:					
Spring Creek, L. I.			Pump 3333.	Flow.	
Baisley's			Pump 1350.	Flow.	
Forest Stream			Pump 2000.	Flow.	
Clear Stream			Pump 2220.	Flow.	
Jameco Park, 5 wells	130–160	8	Pump 1130.	Flow.	
Watts Pond			Pump 1080.	Flow.	
Freeport			Pump 3620.	Flow.	
Test wells:					
No. 5. Ridgewood	284		Many.	—46	
No. 4. Spring Creek	148		Many.	—2½	
Baisley's	200		Many.	To surface.	
No. 1. South of Jameco	155		Many.	—¾	
No. 2. Between Jameco and Springfield.	257		Many.	—1½	
No. 3. Between Jameco and Springfield.	277				No water below clay, 87–202 feet.
No. 8. Near Springfield	295				No water below clay, 72–211 feet.
No. 7. Near Springfield	419		2	—7	
No. 9. Just east of No. 7	271				No water below clay, 110–258 feet.
No. 12. Half mile east of No. 9.	406				No water below clay, 162–170 feet.
No. 10. Northeast of Springfield.	357				No water below clay, 248–252 feet.
No. 6 Hollis Station	406				No water below clay, 302–319 feet.
No. 11. Jamaica	198		Very many.		Blue clay, 95–190 feet.
Calvary Cemetery	582		70		182–582 feet in gneiss.
Do	50	6	230		
Clear Creek	300				

[a] —, feet below surface.

List of deep wells on Long Island—Continued.

Location.	Depth.	Bore.	Capacity.	Height to which water rises.[a]	Remarks.
	Feet.	*Inches.*	*Gals. per min.*	*Feet.*	
Cold Spring Harbor	125	.....	Flows 18.	.....	
Commac, 8 or 10 wells	75–130	.....	.....	.....	
Deer Park	136	.....	.....	—12	
Farmingdale	111	1¼	35	—104	
Farmingdale, 1 mile distant	141½	1¼	35	.....	
Far Rockaway	210	.....	40	.....	
Fenhurst, 4 wells, Queens County Water Co.	148–183	.....	.....	.....	
Freeport	285	.....	No water.	.....	Clay beds 140–152 and 278–285 feet.
Freeport, near the bay	106	1¼	Many.	.....	
Glen Head	398	5	65+	—80	Water also at 80 feet below surface.
Glen Head, 2 miles west	84	.....	"Plenty."	—60	
Glen Head, 3½ miles west	.....	.....	.....	.....	
Great Neck	100	.....	.....	.....	
Great Neck, L. I. R. R. Co	.....	.....	20	.....	
Greenlawn	175	.....	.....	.....	
Hempstead	150	.....	Small flow.	.....	
Hempstead, 6 miles south	60	.....	Small flow.	.....	
Hempstead, near ocean	300	.....	Poor water.	.....	Good water at 123 feet.
Hempstead, reservoir	360	.....	Flows 10.	.....	
Hicksville	75–85	.....	Many.	.....	
Jamaica:					
Grand street	110	.....	.....	.....	
Mill Landing	145	1¼	Flow.	.....	
Do	165	.....	Flow.	.....	
Do	200	.....	Flow.	.....	
Do	235	.....	Flow.	.....	
Jamaica, South	200	.....	Flow.	.....	
Jericho	210	.....	Plenty.	.....	Milky water at 160 feet.
Lawrence	205	.....	35	.....	Water also at 40 feet.
Do	107	6	Many.	.....	Water also at 25 feet.
Little Neck	175	.....	Fair supply.	.....	
Long Island City Gas Co	100	6	75	.....	
Lynbrook	180	.....	.....	.....	No water below 40 feet.
Merrick	83	.....	Not any.	.....	
Mineola, 4 wells	100–225	.....	.....	.....	
Mount Sinai, Crystal Brook Park.	100	.....	Many.	—80	
Northport	92	1¼	Flows 10–15.	.....	
Orient	(*b*)	.....	Not any.	.....	
Oyster Bay	64	2	Flows 9.	.....	Water also at 18–47 feet.
Do	70	1½	Flows 9.	.....	
Do	125	2	Flows 18.	.....	
Do	156	2	Flows 18.	.....	
Do	190	5	Flows 20.	.....	Under 100-foot clay bed.
Do	60	3	Flows 20.	.....	
Do	140	2	Small supply.	.....	
Do	87	2	Flows.	.....	
Port Eaton	265	3	Satisfactory.	To surface.	Brackish water to 205 feet.

a —, feet below surface. *b* Several hundred.

List of deep wells on Long Island—Continued.

Location.	Depth.	Bore.	Capacity.	Height to which water rises. *a*	Remarks.
	Feet.	*Inches.*	*Gals. per min.*	*Feet.*	
Port Jefferson, "Fairview"	120	.....	10	—114	
Riverhead	82	8	Flows 20.	Flowing.	
Rockville Center	.....	.....	.....	.....	
Roslyn	210	6	100+	.....	Water also at 74 feet.
Roslyn, 1½ miles distant	360	.....	40	.....	
Rocky Point:					
Hallock Place	125	.....	.....	—115	
L. I. R. R. bridge	125	.....	12–15	.....	
Sag Harbor	80	.....	Many.	.....	
Sag Harbor Watch Factory	179	.....	Many.	.....	
St. James	160	.....	.....	.....	
Sand Point	140	.....	.....	.....	
Sea Cliff	200?	.....	.....	.....	
Westbury	106	.....	.....	.....	
Whetley Hill	310	.....	Not any.	.....	Failed owing to quicksand.
Williamsburg, Nassau Gas Co.	102	.....	.....	.....	
Willets Point	400	.....	Not any.	.....	
Woodhaven	577	.....	Not any.	.....	556–577 feet in gneiss.
Woodsburg, several wells	90–100	.....	Many.	.....	
Woodbury	166	.....	.....	.....	

a —, feet below surface.

NOTES ON LONG ISLAND WELLS.

I have not been able to obtain records of many of the wells on Long Island, and for the greater number I can give no further information than appears in the above table. In most cases well borers have not saved or recorded the materials penetrated, and we must depend largely on that sort of data for a determination of the underground geology. Some borings have been placed on exhibition in the museum of the Long Island Historical Society, which I examined with care, but the general absence of fossils and lack of distinctive materials preclude a determination of the age of the deeper seated beds.

Brooklyn City Water Department.—I have not been able to secure extended information regarding the wells which furnish a large proportion of the water for the city of Brooklyn. They are in "gangs" sunk at a number of pumping stations along the southern side of Long Island from Spring Creek to Freeport. Their aggregate capacity is stated to be about 22,000,000 gallons per day of twenty-four hours and the water is of most satisfactory quality. The wells are nearly all flowing, but they pump down to a few feet below the surface. It is stated that when the deeper wells were sunk at Jameco the flow from a 6-inch pipe was 500 gallons per minute and the water would rise to 11 feet above the surface. In recent extended tests reported by Engineer I. M. De Varona it was found that pumping 1,000,000 gallons per day

from one well reduced the water level to about 5 feet below the surface, and pumping 3,500,000 gallons per day from four wells reduced the level to about 10 feet below the surface.

The record of one of the wells at Jameco—well No. 4*a*—is as follows:

Feet.	
0–3	muck or peat.
3–5	fine, gray gravel.
5–7	fine, white gravel.
7–21	sharp, yellow sand and gravel.
21–34	fine, white sand.
34–65	fine, yellowish sand.
65–79	coarser, yellowish sand.
79–137	blue clay.
137–144	coarse, black sand.
144–150	coarse, black sand and gravel.

During the year 1895 the water department sunk a series of twelve test wells to obtain additional light on the relations and extent of the deeper waters which are tapped by the Jameco and Baisley's wells, and the results of these investigations are embodied in a report by I. M. De Varona, water engineer, for 1895, now in course of publication. Mr. De Varona kindly furnished advance proofs of this report, from which I have obtained the following records and statement of results of the test wells, given in order from west to east:

Test well No. 5, south of Ridgewood reservoir; altitude, 61.8 feet.

Feet.	
0–16	top soil.
16–40	brown gravel and sand.
40–51	fine, yellow sand.
51–62	coarse gravel.
62–88	finer gravel.
88–131	sharp, gray sand.
131–193	brown gravel and sand.
193–200	blue clay, with traces of decayed wood.
200–216	dark gray sand.
216–280	blue clay.
280–284	gravel and black sand, with water to within 46 feet of the surface.

Test well No. 4, Spring Creek pumping station; altitude, 8.6 feet.

Feet.	
0–8	top soil (decayed vegetable matter).
8–31	coarse, brownish sand and small gravel. Water bearing.
31–64	finer, brownish sand without gravel. Water bearing.
64–74	good, sharp, yellow sand without gravel. Water bearing.
76–96	coarse, brown sand and gravel. Water bearing.
96–105	finer, brownish sand and gravel. Water bearing.
105–126	coarse, brown sand and gravel. Water to within 16 feet of the surface.
126–139	tough, dry, blue clay.
139–148	coarse, black sand, with very large gravel. Water to within 2½ feet of the surface.

Test well at Baisley's; altitude, 6.7 feet.

Feet.	
0–21.6	yellowish sand and gravel.
21.6–34.0	fine, yellow sand.
34.0–39.0	coarser, yellowish sand.
39.0–58.0	fine, yellowish sand.
58.0–77.5	gray sand and gravel.
77.5–97.5	gray sand.
97.5–104.0	yellowish sand and gravel.
104.0–107.0	yellowish sand, gravel, and clay.
107.0–139.5	blue clay.
139.5–156.0	blue clay and quicksand.
156.0–166.0	black sand and gravel.
166.0–174.0	black sand.
174.0–200.0	finer black sand. Water rises to the surface.

Test well No. 1, half mile south of Jameco pumping station; altitude, 5.5 feet.

Feet.	
0–33	yellow sand.
33–54	coarse, yellow sand, with some gravel.
54–62	fine, white sand.
62–75	coarse, white sand.
75–88	gravel and coarse, white sand.
88–141	blue clay.
141–155	gravel and coarse, black sand, with water to within 9 inches of the surface.

Test well No, 2, one-quarter mile east of test well No. 1; altitude, 7.4 feet.

Feet.	
0–2	top soil.
2–17	yellow sand, with gravel.
17–42	fine, white sand.
42–67	coarser, white sand.
67–73	gravel and coarse, white sand.
73–84	sharp, white sand, with traces of blue clay.
84–138	blue clay.
138–153	mixture of very fine sand and blue clay.
153–169	coarse, black sand and gravel.
169–208	finer, black sand, very little gravel. Water rose to within 18 inches of surface.
208–218	coarser, black sand, with gravel.
218–239	finer, black sand, with gravel. Water rose to within 2¼ feet of surface.
239–257	very fine, black sand, without gravel.

Test well No. 3, one-half mile east of test well No. 2; altitude, 9.8 feet.

Feet.	
0–1	top soil.
1–8	coarse, yellow sand, with gravel. Water bearing.
8–37	fine, yellow sand. Water bearing.
37–45	white sand. Water bearing.
45–69	fine, white sand. Water bearing.
69–87	coarse, white sand and gravel. Water bearing.
87–140	tough, dry, blue clay.

Feet.	
140–158	very fine sand and dry, blue clay.
158–161	coarse, black sand. Probably water bearing.
161–202	dry, brittle, gray clay, with fragments of wood.
202–277	dry, sharp, white sand.
	No water below the clay bed.

Test well No. 8, one-quarter mile east of test well No. 2, one-half mile west of Springfield pumping station; altitude, 10 feet.

Feet.	
0–6	fine, yellow sand.
6–28	coarse, yellow sand, with gravel.
28–59	fine, gray sand.
59–72	fine, gray sand, with wood and mica scales.
72–211	blue clay.
211–222	fine, sharp, white sand, with wood.
222–258	fine, gray sand.
258–295	coarse, white sand, large quantities of wood.
	No water below the clay bed.

Test well No. 7, one-quarter mile northwest of Springfield pumping station; altitude, 16 feet.

Feet.		
0–4	top soil.	
4–20	sharp, yellow sand, with a little gravel.	
20–32	sharp, yellow sand, with small gravel. Water bearing.	
32–45	fine, yellow sand. Water bearing.	
45–65	fine, gray sand, with small gravel. Water bearing.	
65–68	blue clay, with traces of decayed wood.	
68–78	fine, gray sand, with small gravel.	
78–176	blue clay, with traces of wood.	
176–182	coarse, brown sand, with large gravel. Water bearing.	Water to −7. Two galls. per minute.
182–197	fine, white sand. Water bearing.	
197–419	sharp, white sand, white clay, and small gravel. Water bearing.	

Test well No. 9, one-quarter mile east of Springfield pumping station; altitude, 10.3 feet.

Feet.	
0–39	sand.
39–55	fine, gray sand.
55–57	yellow clay.
57–60	greenish-gray sand.
60–65	fine, yellow sand.
65–107	fine, yellowish sand.
107–110	coarse, gray sand and gravel, with pieces of wood.
110–125	gray clay, with much wood.
125–130	gray clay, sandstone, and iron pyrites.
130–146	gray sand and much soft wood.
146–233	streaks of clay, sand and wood.
233–235	solid wood.
235–237	gray sandstone, with iron pyrites.
237–250	tough, white clay.
250–258	gray clay and sand.
258–271	white sand and particles of wood.
	No water found below the clay bed.

Test well No. 12, three-quarters of a mile east of Springfield pumping station; altitude, 18 feet.

Feet.	
0–4	dark yellow sand.
8–20	yellow sand.
20–38	fine, sharp, gray sand.
38–46	sharp, yellowish sand.
46–56	sharp, yellow sand.
56–63	yellow sand and gravel.
63–66	gray sand and gravel.
66–73	sharp, yellow sand.
73–85	sharp, yellow sand and gravel.
85–98	fine, yellowish sand.
98–130	coarse, gray sand and gravel.
130–145	gray sand, with gravel, wood, and clay of different colors.
145–162	fine, white sand, with fragments of wood and traces of clay.
162–170	gray clay, with gravel and wood.
170–205	fine, white sand, with fragments of wood and traces of clay.
205–223	gray sand, with fragments of wood and traces of clay.
223–330	fine, gray sand, with fragments of wood and traces of clay.
330–406	fine, white sand, with fragments of wood.

No water was found below the clay bed.

Test well No. 10, one mile northeast of Springfield post-office; altitude, 27 feet.

Feet.	
0–18	coarse, brown sand, with gravel.
18–28	coarse, light-brown sand, with gravel.
28–40	sharp, yellow sand.
40–54	sharp, yellowish sand.
54–59	fine, gray sand.
59–63	sharp, yellowish sand.
63–67	coarse, yellowish sand.
67–73	fine, yellowish sand.
73–80	yellow sand, with gravel.
80–89	coarse, gray sand, with gravel and wood.
89–94	blue clay.
94–102	fine, white sand.
102–114	coarse, gray sand, with wood.
114–132	sharp, white sand.
132–137	sharp, white sand, with wood.
137–139	mixture of sand, gravel, wood, and clay.
139–190	white sand, with wood.
190–212	sharp, gray sand.
212–222	coarse, gray sand, clay, and wood.
222–227	gray sand, clay, and wood.
227–229	sandstone, with iron pyrites, wood, and clay.
229–243	gray sand and wood.
243–248	gray sand, clay, and wood.
248–252	gray clay and wood.
252–325	fine, gray sand and wood.
325–357	sharp, white sand, with wood and clay.

No water found below the blue clay.

Test well No. 6; just east of Hollis station; altitude, 58.6 feet.

Feet.	
0–1	top soil.
1–13	brown sand, with gravel.
13–19	light-colored gravel.

Feet.	
19–26	brownish sand, with gravel.
26–37	sharp, yellowish sand.
37–40	brownish sand, with gravel.
40–54	light-colored gravel (rich water bearing).
54–60	brownish sand.
60–69	brownish sand, with gravel.
69–77	fine, yellow sand.
77–98	fine, light-colored yellow sand.
98–103	fine, gray sand.
103–135	sharp, yellow sand, with gravel.
135–145	fine, yellow sand.
145–157	fine, white sand.
157–186	sharp, yellow sand.
186–190	fine, gray sand.
190–196	fine, yellow sand.
196–212	sharp, yellow sand.
212–218	coarser, yellow sand.
218–225	light-colored gravel.
225–229	coarse, yellow sand.
229–244	coarse, yellowish sand.
244–295	fine, sharp, yellow sand.
295–298	fine, pinkish sand.
298–302	sharp, yellow sand.
302–319	gray clay, with wood.
319–336	fine, white sand, with wood.
336–355	very fine, white sand, with wood.
355–368	fine sand and reddish clay, with wood.
368–395	fine, white sand, with wood.
395–397	fine, gray sand, with wood.
397–401	fine, sharp, white sand, with wood.
401–403	coarse, gray sand.
403–406	fine, gray sand (powdered sandstone).
	No water below the clay bed.

Test well No. 11, one mile south of Jamaica railroad station; altitude, 19.2 feet.

Feet.	
0–2	yellow sand.
2–6	brown sand.
6–20	yellow sand, with gravel.
20–43	gray sand, with gravel.
43–65	fine, sharp, gray sand.
65–89	dark gray sand, fine and sharp.
89–95	coarser, yellowish-gray sand, with large quantities of gravel.
95–190	blue clay.
190–198	dark gray sand and gravel, containing large volumes of water, which rises to within about 9 feet of the surface.

Woodhaven.—In 1888 and 1889 a well was bored at this place to a depth of 577 feet. The gneiss was reached at 556 feet, but no useful amount of water was found. The record as given by Mr. John Bryson[1] is as follows:

Feet.	
0–113	reddish sand and gravel.
113–120	sand and coarse gravel.
120–132	pepper and salt sand.

[1] Am. Geologist, Vol. III, pp. 214–215, 1889.

Feet.	
132–144	reddish sand.
144–213	reddish sand and gravel.
213–218	tough, whitish clay.
218–246	reddish sand.
246–298	clay containing pebbles.
298–315	light-bluish clay.
315–358	clay with rootlets.
358–375	fine sand and clay.
375–385	clay, wood, and vegetable matter.
385–417	grayish sand.
417–419	light-bluish clay.
419–430	sandy clay.
430–433	bluish clay.
433–436	white clay.
436–443	light-gray sand.
443–456	dark-gray sand.
456–460	coarse white beach sand.
460–475	clay, pebbles, and beach sand intercalated.
475–480	clean gravel.
480–500	sand and gravel.
500–510	quartz, sand, and gravel.
510–515	grayish sand.
515–518	clay or marl(?).
518–540	dark clay.
540–556	gray micaceous sand.
556–577	gneiss rock.

Mr. E. Lewis, jr.,[1] gives the additional information that the well was 35.6 feet above high tide, and reports quicksand with lignite at 417 feet; 3 feet of blue clay at 436 feet; fine quicksand 7 feet, and coarse, clayey sand, 13 feet, to 456 feet; sandy clay, 460 to 470 feet; very tough, light-colored clay, 523 to 545 feet; coarse, clayey sand, 545 to 556 feet. The beds from 1 to 213 feet are regarded as Pleistocene.

Barnum Island.—This well was a quite deep one, but a satisfactory water supply was not obtained.

Samples of the borings are preserved in the museum of the Long Island Historical Society. They are as follows:

Feet.	
0–5	gravel and sand.
5	fine, light-brown sand.
15	small gravel.
22	argillaceous sand with mica.
29	coarse gravel.
29–63	sand and small gravel.
63	gravel and sand.
70	fine, light-buff sand.
74	dark-gray sand.
75	lignite fragments.
95	gray clay.
113	gray clay.
126	coarse sand and gray gravel.

[1] Am. Jour. Sci., 3d ser., Vol. XXXVII, p. 233, 1889.

Feet.
129.....coarse gravel, in part angular.
135.....gray sand.
147.....light-gray, fine sand.
168.....coarse gray sand and gravel.
170.....coarse gray sand.
175.....coarse gray sand.
180.....gray micaceous sand with lignite.
200.....much lignite.
225.....argillaceous gray sand.
243.....loose gray sand.
245.....lignite.
247–258, 260, 270 ....much lignite in gray sand.
274.....loose gray sand.
284.....lignite.
290.....gray sand.
300.....gray clay.
335.....lignite.
344.....gray sand.
350.....lignite.
352.....lignitic sand.
353.....gray micaceous sand.
360.....lignite.
365.....lignite.
368.....gray argillaceous sand.
370.....gray micaceous sand with lignite.
380.....gray clay.
383.....carbonaceous clay.

Fenhurst.—The wells of the Queens County Water Company are at the pumping station between Valley Stream and Fenhurst, on Jamaica Bay. They yield a large flow at the surface, which is elevated from 3 to 5 feet above mean high tide. The first four wells are situated within a relatively small area, but the materials penetrated vary considerably. They are as follows:

WELL NO. 1.

Feet.
0–60.....sand and gravel, reddish in color.
60–80.....blue clay.
80–96.....dark sand.
96–115.....coarse sand and gravel.
115–120.....very fine, dark sand.
120–128.....reddish, medium coarse sand.
128–142.....coarse sand, round grains.
142–152.....coarse sand and gravel.
152.....peat.

WELL NO. 2.

0–31.....coarse sand, reddish in color.
31–42.....sand and gravel, light colored.
42–54.....black, fine sand.
54–87.....blue clay.
87–100.....black sand.
100–101.....blue clay.

Feet.	
101–113	reddish sand.
113–139	coarse white sand.
139–158	white sand and gravel.
158	peat.

WELL NO. 3.

0–30	reddish sand.
30–64	white sand.
64–87	blue clay.
87–115	black sand.
115–161	white sand with some gravel (water).
161–176	peat.
176–183	sand and gravel.

WELL NO. 4.

0–10	red sand.
10–36	white sand and gravel.
36–37	blue clay.
37–50	dark or black sand.
50–88	blue clay.
88–105	black sand.
105–106	blue clay.
106–114	black sand, very fine.
114–130	reddish sand.
130–148	coarse sand and gravel (water).

Calvary Cemetery.—This well was sunk through drift and clay to and into the crystalline rocks to a depth of 582 feet. The water is soft, with only a little lime, magnesia, and chlorine in it. The yield is 70 gallons a minute.

According to Mr. Elias Lewis, jr.,[1] it had the following record:

Feet.	
1–139	surface loam and drift.
139–178	greenish earth.
178–182	white clay with red steaks.
182–582	gneiss.

The greenish earth was found to be ferruginous, and on treatment with hydrochloric acid left a residue which under the microscope was seen to consist of fragments of kaolinized feldspar, with occasional grains of quartz sand.

Nassau Gas Works, Williamsburg.—Mr. Lewis[1] also furnishes a record of the well bored at the works of this company, as follows:

Feet.	
1–3	surface loam.
3–5	quicksand (so called).
5–75	bowlder clay, somewhat sandy.
75–102	blue clay with pebbles.
	6 inches of oyster shells, underlain by a water-bearing quicksand.

[1] F. J. H. Merrill, Geology of Long Island, N. Y. Acad. Sci. Annals, Vol. III, p. 346.

Jericho.—Mr. Lewis[1] has supplied the section of the well bored at Jericho in 1878 on the premises of Mr. Jules Kunz. It is as follows:

Feet.	
0–15	surface loam.
15–51	drift.
51–132	yellow gravel.
132–147	sand.
147–151	sandy clay with a carbonized branch.
151–154	yellow clay.
154–184	blue and gray sandy clay with pyrites.
184–198½	micaceous sand.

Port Eaton.—At this locality a well has recently been sunk to a depth of 265 feet which yields a satisfactory supply of excellent water. The surface of the land is 4 feet above high tide and the water rises just to the surface. The following record was secured through the kindness of Mr. Nimmo:

Feet.	
10	quartz-gravel and sand.
20	quartz-gravel and sand.
30	fine sand mixed with clay.
40	gravel.
50	sand and fine gravel.
60	sand and fine gravel.
70	coarse gravel.
80	coarse gravel.
90	fine gravel.
100	fine gravel.
110	gravel and sand.
120	fine gravel.
130	coarse gravel.
140	fine yellow sand.
150	fine yellow sand mixed with mica.
160	lighter colored sand with mica.
170	coarser sand, no mica.
180	coarser sand, no mica.
190	fine red sand.
200	coarse, straw-colored sand.
205	very coarse sand.
210	fine light-colored sand.
215	clear gravel.
220	light coarse sand.
225	light coarse sand.
230	coarse gravel.
240	coarse gravel.
250	yellow sandy clay.
255	sharp coarse sand.
260	sand and gravel.
265	clear fine light-yellow sand.

Salt water was found at various depths down to 205 feet. The fresh-water-bearing bed was first encountered at a depth of 263 feet. The

[1] F. J. H. Merrill, Geology of Long Island, N. Y. Acad. Sci. Annals, Vol. III, p. 350.

experience of this well adds important confirmatory evidence that fresh-water supplies may be expected far below the bottom of Long Island Sound on the north shore of the island.

WATER HORIZONS AND WELL PROSPECTS ON LONG ISLAND.

Our knowledge of the underground geology of the island is not yet sufficiently far advanced for a discussion of water horizons, and no safe basis for well prognostication can be established until the geology is understood. Owing to the peculiar geologic structure of Long Island, with its great accumulations of heterogeneous glacial drift, we can not infer the underground structure from studies on the surface, and our data must come mainly from careful records of wells. As the records are so few and most of the wells so shallow the data now available are too meager to throw much light on the subject. In the opening remarks of this chapter I explained the general underground structure and showed how the south-sloping floor of crystalline rocks was overlain by a series of sheets of sands, clays, etc., which, as a whole, are thought to dip gently to the southward. It is believed that there are beds and streaks of coarse sand and gravels in this series which carry water, and I have considerable confidence that they will yield water to deep wells in wide areas on Long Island. They outcrop along the shores of the sound, and, as is shown in the cross section, lie quite far below the surface along the south shore. They proved to be fine grained and apparently nonwater-bearing in the Woodhaven well, and there is possibility that this condition exists in other areas, but the prospects for water in these lower beds is, I believe, sufficiently promising to warrant the sinking of other wells to the basal beds. The depth to these beds along the south side of the island is about 1,000 feet, and they rise gradually to the northward so as to emerge at the surface along or near the north shore. On the eastern end of the island they appear to lie somewhat deeper than they do to the west, where the underlying crystalline rocks emerge in the Long Island City region. Precise figures can not be given, for no wells have been sunk to the crystalline rocks east of Woodhaven, and we can only assume that the rate of slope is as uniform eastward as it is known to be in the region westward.

It is thought that the wells on Sands Point and Bowery Bay, and probably other deep wells along the north shore, find their waters in beds not far above the basal sands, etc., which lie on the bed-rock floor.

The higher horizons on Long Island appear to be in the drift and associated with clay beds of which the relations and distribution have not yet been ascertained. In the vicinity of Jamaica and southward the deeper waters of the Brooklyn city supply are from under a clay bed which appears to underlie an area of considerable extent.

During the past year these waters have been extensively explored by test wells by the Brooklyn City Water Department, and found to be available for large water supplies. These explorations have also

determined the southeastern limits of the water-bearing beds. They did not, however, test the availability of the still deeper horizons.

Long Island is a great reservoir of water, for the rain falling on its porous surface sinks in large proportion into the sands and spreads widely under the clay, and unless there is subterranean outflow into the ocean it should be expected to accumulate in large volumes in every porous stratum down to the rock bed. The flow-off is not so large as in many other regions, for the drift materials are sufficiently porous to hold much of the waters. There are no large surface streams on the island, and the small ones never experience any noteworthy freshets. The volume of water falling on the island, of which the area in round numbers is about 1,200 square miles, is nearly 2,200,000,000 gallons a day. Of this, from 50 to 60 per cent runs off, and some more is lost by evaporation, but it may be quite safely estimated that 500,000,000 gallons a day pass underground. This is an average for the year, and is based on a 40-inch rainfall, which has been the average for the Brooklyn region of readings extending over a half century.

STATEN ISLAND.

The southern and eastern portions of this island are underlain by Cretaceous sands and clays, which are overlain by a greater or less amount of glacial drift. In the northern section of the island the crystalline rocks, mainly serpentine, rise in high hills, and on the northwestern side there are Newark red shales and sandstones with a large intruded trap sheet. The Cretaceous beds lie on a floor of the crystalline rocks, but the depth to this floor has not been ascertained. The sands offer favorable conditions and relations for the transmission of underground waters, but I have learned of no deep wells to them. Several wells have been bored in the crystalline rocks on the northern end of the island, which yield water, and large supplies are obtained from wells in drift formations in that region.

Mr. H. Ries[1] reports a boring at Bachman's brewery in Annadale, Staten Island, in which at a depth of 200 feet a bed of yellow gravel, containing shells, was penetrated and found to be 36 feet thick. It is underlain by a 10-foot bed of whitish or bluish clay.

A well at Kreischerville is reported to have been sunk to a depth of 196 feet without finding water. The following record is given:[2]

Feet.	
0–4	gravel.
4–40	sand.
40–61	white clay.
61–91	white sand.
91–101	blue clay.
101–191	fine, white sand.
191–194	sandstone (black).
194–196	quicksand.

[1] Clay industries of New York, Bull. N. Y. State Museum, Vol. III, No. 12, p. 135, Albany, 1895.

[2] New Jersey report for 1895, p. 90.

NEW YORK CITY.

There are many deep wells on New York island which yield large volumes of water, but it appears that the greater part of the water contains either mineral or surface contaminations which greatly diminish its usefulness. The deep wells are in the granite-gneiss, mica-schist, or limestone, which are near the surface north of Fortieth street, but southward are more or less deeply buried beneath sands and clays of Pleistocene age. There are also many wells 20 to 80 feet deep in the superficial beds. Nearly all the data I have for the New York City wells were obtained through the kindness of Mr. W. d'H. Washington, of New York, who has sunk many of these wells. All those of which I have learned are listed in the following table:

List of wells in New York City.

Location.	Depth.	Size.	Capacity per minute.	Remarks.
	Feet.	*Inches.*	*Gallons.*	
Washington Building	+1,000	.....	Many.	
Manhattan Life Insurance Co	760	8	100	
Liberty and Nassau streets	720	.....	80	
New York Life Insurance Co	500	.....	.....	
Holt's well, Fulton Market	626	.....	.....	Rock at 126 feet.
West and Barclay streets	48	.....	.....	In sands.
Broadway and Houston streets	42½	.....	2,600	
Broadway and Bleecker streets	448	7	80	42 feet to rock.
Houston and Attorney streets	45	.....	.....	
Lafayette and Barnard streets	700	8	80	
West Tenth and Washington streets (7 wells)	500	6	600	
West Tenth and Washington streets (6 wells)	50	6-4	500	
West Eleventh and Greenwich streets	1,047	8	10	Rock at 40 feet.
Twenty-eighth street near Broadway	500	8	100	
Forty-seventh street and Fourth avenue	±600	8	100	
Fifty-ninth street and Eleventh avenue	700	8	100	
Dakota flats, Seventy-second street and Eighth avenue	1,200	8	8	
Hotel Savoy, Fifty-ninth street and Fifth avenue	500	.....	80	
Hoffman House	300	.....	25	
Manhattan Athletic Club, Madison avenue and Fourth street.	306	8	40	Flows.
Ringler brewery, Ninety-second street and Third avenue.	685	9	300	
One hundred and sixteenth street and First avenue (3 wells).	40–50	.....	600	
Mount Morris Park	90	.....	Many.	
One hundred and twenty-fifth street and Sixth avenue	45	.....	Many.	
One hundred and fifty-fifth street and Seventh avenue (12 wells).	50–60	.....	450	
One hundred and Forty-fifth street and Eighth avenue.	1,045	.....	120	Fine water.
One hundred and twenty-eighth street and Tenth avenue.	605	10–8	.....	

SOUTHERN NEW JERSEY.

GENERAL GEOLOGIC RELATIONS.

The portion of the State of New Jersey that lies south and east of a line extending from Trenton to near New Brunswick is underlain by a succession of great sheets of sands, clays, marls, and gravels lying on a basement of rocks which are mainly granite and gneiss. These rocks outcrop in Pennsylvania, at Trenton, and on Staten Island, but their surface slopes gradually to the southeast beneath the overlying sediments, and it is deeply buried along the ocean shore. The sheets of overlying sediments also dip to the southeast, but at a less rate, and consequently some of them thicken in that direction. In the sections on Plate III an idea is given of the structure of the region, although they do not show how deep the crystalline rocks finally sink.

The formations of southern New Jersey have been studied by the State geological surveys, and during the past few years Dr. W. B. Clark,[1] of the United States Geological Survey, has added greatly to our knowledge of them. In the following table is a list of these formations, with the names by which Dr. Clark has designated them, their thickness, and some other information, mainly from Dr. Clark's reports, but in part from the evidence of well records:

Formations of southern New Jersey.

Formations.	Monmouth Junction and New Brunswick to Asbury Park and Long Branch.	Philadelphia and Burlington to Beach Haven.	Bridgeport and Salem to Atlantic City.
Miocene:	*Feet.*	*Feet.*	*Feet.*
Chesapeake, sands and clays	100	800+	1,000+
Cretaceous:			
Shark River[2]. Upper marl	12	.....	.....
Manasquan..			
Rancocas, or Middle Marl	*a* 65	60	*f m* 90
Redbank, or red sand	20	*e* 30	*f k l m* 15
Navesink, or Lower Marl	*n* 100	*e* 90	*i k l m* 82
Matawan, or clay marls	*n* 45	*e* 43	*h k l m* 50
Raritan, sands and clays	*n* 275	*c* 220	*g h l* 220
Crystalline rocks.	*b n* 420	*d* 537	.....

a Fossil beds in Middle and Lower marls are 100 feet apart in wells at Ocean Grove and Asbury Park.
b Jamesburg well.
c Mount Holly well.
d Columbus well.
e 155 feet in Marlton well from lower beds of Middle Marl to base of Lower Marl (?).
f Glassboro and Quinton wells.
g Wenonah well; 160 feet in Woodstown well.
h Sewell well, 240 feet (?).
i Quinton well.
k 100 feet in Greenwich well.
l 336 feet in Woodstown well.
m 235 feet in Glassboro well.
n 860 feet in Monmouth Park well.

[1] Report of the State Geologist for 1892, pp. 167–245, and Report of State Geologist for 1893, pp. 329–355.

[2] Eocene?

There are also several superficial formations—the Lafayette, Columbia, and Trenton—consisting of sands, loams, and gravels, which thinly cover the lower lands and occupy certain higher regions.

CHARACTERISTICS OF THE FORMATIONS.[1]

RARITAN FORMATION.

This formation consists mainly of beds of clay and sand and admixtures of these materials lying on the floor of crystalline rocks. As the slope of this floor is quite steep, the deposits thicken rapidly to the east and southeast and a thickness of 500 feet is soon attained. The basal beds often are coarse sands and gravels or bowlders, and these coarse materials always contain an abundant water supply. In some areas finer sands and even clays extend down to the crystalline floor. Local beds of coarse sand and gravel occur interbedded among the finer sands and clays in some areas, but their distribution is not fully determined. The clays are of various colors, but red, gray, white, and buff are those most frequently observed. Ordinarily, they are in widely extended sheets, but they thin or thicken or merge into sands in a very irregular manner. Sands predominate in the upper portion of the formation. The basal beds outcrop along the Delaware River below Trenton, and in greater part extend to the Pennsylvania shore. From a few miles north of Trenton to beyond New Brunswick the formation lies on the eastern edge of the red sandstones and shales of the Newark formation.

MATAWAN FORMATION.

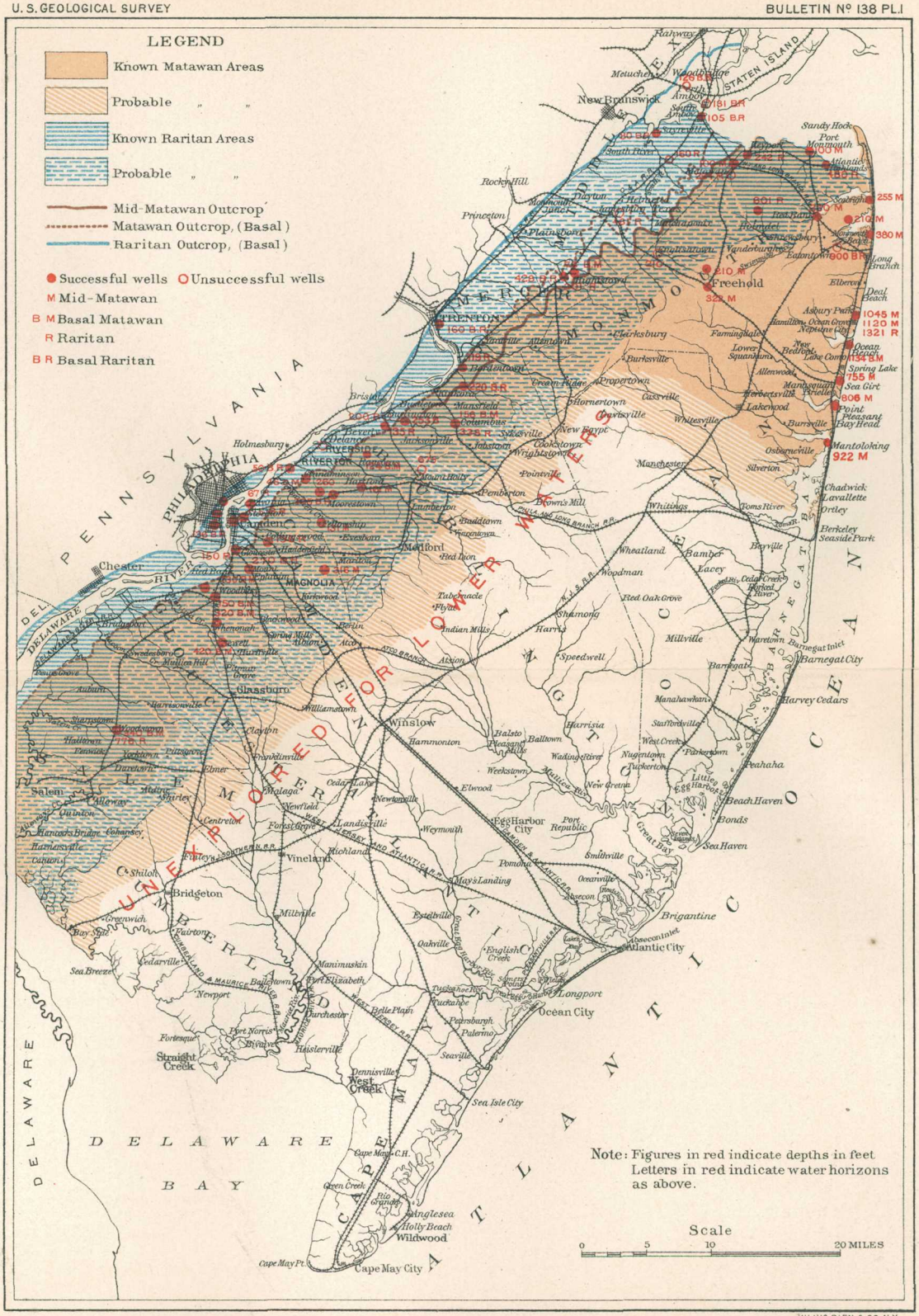
The deposits of this formation consist of dark-colored clays with intercalated beds and streaks of sand. The upper beds are predominantly sandy. The mineral glauconite, or greensand, occurs in the formation to a small extent, mainly mixed with gray sand. Fossil shells occur in some of the beds at certain localities. Dr. Clark has estimated that the formation has a thickness of about 275 feet at its outcrop, but it appears to thicken rapidly to the eastward to over 800 feet in the deepest well at Asbury Park.

In the outcrops in Middlesex and Mercer counties there appears to be no sharp break between the Matawan and the Raritan formations, but to the east and south the well borings have brought to light an intervening gravel bed which is an important source of underground water. In Maryland and Delaware the unconformity between the two formations is strongly marked, and the occurrence of this gravel bed appears to indicate the northern extension of this relation.

NAVESINK FORMATION.

This name has been applied to the Lower Marl bed, which is the next formation above the Matawan deposits and appears to merge into them. In its unweathered condition it consists of a greensand marl

[1] The data under this subheading are largely derived from the reports by Prof. W. B. Clark, in the report of the Geological Survey of New Jersey for 1893.



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AREAS UNDERLAIN BY LOWER CRETACEOUS WATER HORIZONS IN NEW JERSEY.

BY N. H. DARTON.

which is intermixed with considerable sand below and clay above. The basal beds are usually water-bearing. Fossil shells occur in greater or less abundance throughout the beds. The thickness of the formation averages about 45 feet, and is remarkably constant.

REDBANK FORMATION.

This is the "red sand" member, which lies between the Lower and the Middle Marl beds. In its unweathered condition it consists of an admixture of gray or dark sand with a moderate proportion of glauconite or greensand. Some clay admixture occurs locally, and the upper and lower beds are usually notably argillaceous. In its surface outcrop, which extends across the State along a narrow belt from Navesink Highlands to Salem, the glauconite is weathered out and the residuary sands are stained red by the iron from this mineral. The thickness of the formation averages about 90 feet, and the local variations are not large in amount. The sand is an important water bearer south of the latitude of Philadelphia, where it is mainly coarse sand of a medium-light color.

RANCOCAS FORMATION.

This, the Middle Marl bed, is considerably thinner than the Lower Marl bed, but it is a widespread and characteristic horizon. It is largely glauconitic, particularly in its lower portion. The upper beds contain much calcareous material, often to a sufficient degree to constitute an impure limestone. These beds are highly fossiliferous, and at their top carry the very distinctive layer of *Terebratula harlani*.

MANASQUAN FORMATION.

This is the lower portion of the Upper Marl bed. It consists of glauconitic marls, of which the richest beds are toward the top. The thickness has been estimated at 65 feet, but to the southward it increases somewhat.

SHARK RIVER FORMATION.

This is the upper portion of the Upper Marl bed, or the "blue marl" of local parlance. It is a highly glauconitic marl with some argillaceous admixture, and is recognized distinctly only in the area about Shark River. Its thickness there is about 12 feet.

CHESAPEAKE FORMATION.

This great series of deposits overlies unconformably the Cretaceous greensand group. To the northwest it consists largely of very coarse materials, but these gradually become finer to the south and to the east, where the principal deposits are great beds of clays with intercalated strata of water-bearing sands at various horizons. Several hundred feet of the clays are intermixed with diatom remains, which constitute a very definite horizon in the formation. The thickness of this diatomaceous clay bed has been revealed in the many deep wells

in the coastal region, and the bed has been studied with special care by Mr. Woolman. He found that it is about 300 feet thick in the Atlantic City well, 380 feet in the Ocean City well, 225 feet at Great Sedge Island, 200 feet at Waretown, 253 feet at Beach Haven, and 423 feet at Wildwood. Near its center it carries a bed of sand which is an important and widespread water bearer.

The various members of the Chesapeake formation dip at the rate of about 25 feet per mile to the southeast, and pass beneath the surface in regular succession in that direction. The various beds are given in the record of the Atlantic City well in Pl. IV, so that it is not necessary to give an account of them here.

WELLS IN SOUTHERN NEW JERSEY.

In the following list there will be given a brief statement of the location, depth, diameter, yield, and some general features of the wells, which will be followed by detailed descriptions. On the maps, Pls. I and II, the location, depth, and water horizon of the wells are indicated, and there are further data in the sections on Pl. III.

List of deep wells in the Coastal Plain region of New Jersey.

Location.	Depth.	Bore.	Capacity per minute.	Height to which water rises.[a]	Geologic horizon.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*		
Absecon, 54 wells	24	.....	Many.	.....	Post-Chesapeake	Former supply for Atlantic City.
Asbury Park	383	.....	65	.....	Lower Marl	
Do	448	.....	20	.....	In Matawan	Temperature 60°.
Do	800	.....	.....	.....	.....	
Do	1,330	.....	.....	.....	In Raritan	
Do	1,130	6	1,000	.....	In Matawan	Ferruginous water.
Do	1,045	6				
Atlantic City	960	6–4½	Pumps 200	.....	.....	
Do	1,150	8–6	.....	+50	.....	No water, 960–1120 feet.
Do	554	8	Flows 50.	.....	.....	
Do	735	6–4½	Pumps 200.	.....	Middle of diatom bed.	
Do	720	6	Pumps 250.	.....	Base of diatom bed.	
Do	780	6–4½	Flows 150.	.....	.....	
Do	763	8	Good flow.	.....	.....	
Do	809	.....	Good flow.	.....	.....	
Do. (several wells)	55–75	.....	.....	.....	Absecon horizon	
Do	1,398	10–4½	Not any.	.....	Cretaceous (?)	
Do	805	8–4½	40	.....	100 feet below diatom bed.	Pumps 125 gallons.
Do	185	.....	.....	.....	Upper Chesapeake.	
Do	90	.....	.....	.....		
Do	118	.....	.....	.....		

[a] +, feet above the surface; —, feet below the surface.

List of deep wells in the Coastal Plain Region of New Jersey—Continued.

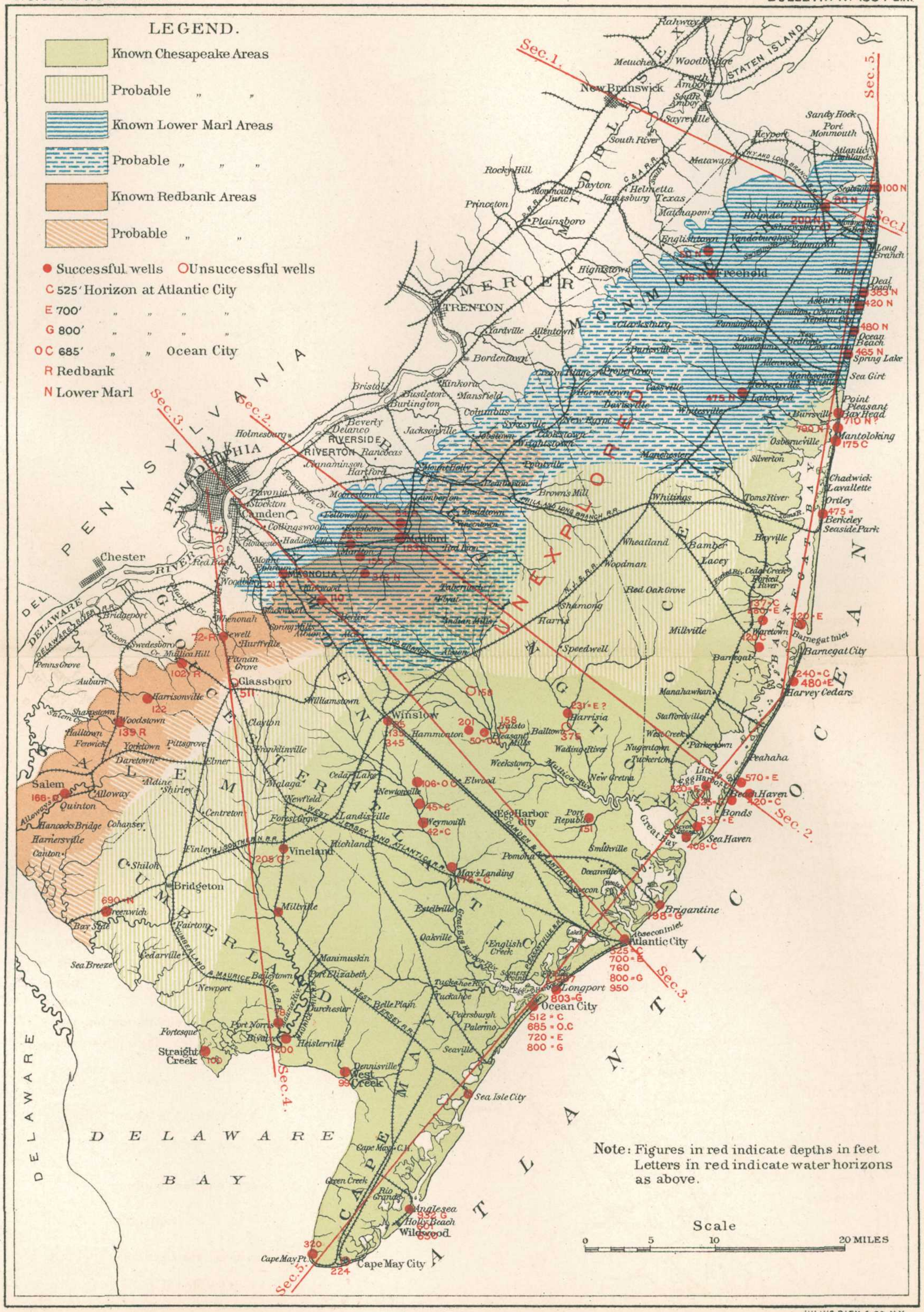
Location.	Depth.	Bore.	Capacity per minute.	Height to which water rises. *a*	Geologic horizon.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*		
Atlantic City, Brighton House.	843	6	Flows 100.	.....	.....	
Atlantic City, Cooling Co.	813	6	Flows 105. Pumps 400.	+9½	.....	Temperature 66°.
Atlantic City, Electric Light Co.	809	6	.....	.....	.....	
Atlantic Highlands:						
8 wells.....	108–112	4½	80 each.	Flow.	In Matawan.....	
1 well.....	480	4½	250	Flows.	In Raritan.....	Water somewhat ferruginous.
Barnegat Landing.	120	.....	.....	Flows.	.....	Good water.
Bayhead.....	710	.....	.....	.....	Base of Lower Marl.	
Bayside.....	190	.....	Not any.	.....	Horizon unknown.	Salt water at 100 and 140 feet.
Beach Haven.....	430	8	10	.....	"C," Atlantic City.	
	575		125	.....	"E," Atlantic City.	
Berkeley Arms....	470	.....	60	.....	960 feet at Atlantic City(?).	
Bordentown.....	119	2	Many.	.....	In Raritan.....	Ferruginous water.
Do.....	195	.....	.....	−15	Basal Raritan	Ferruginous water.
Bridgeton.....	90	.....	Not any.	.....	Post-Chesapeake .	
Brigantine.....	798	6	Flows 100.	Flows.	800 feet at Atlantic City.	Some water also at 517 and 670 feet.
Burlington	200	8	Not any.	.....	In Raritan.....	Ended in clay.
1½ miles south .	135	6	25	−40	Raritan.	
2 miles east....	253	.....	Plenty.	.....	.....do	In gravels and sand.
Camden, Esterbrook Pen Co.	62–87	6	70	−5	Basal Raritan.....	Clay particles in water.
Camden, Cooper Hospital.	129	6	16	−16	.....do.....	
Camden Ice Co., 2 wells.	152	8	150	.....	.....do	
Camden pumping station.	112	6	.....	.....	.....do	Rock at 104 feet; water at 90–98 feet.
Cape May City, 7 wells.	87–92	8	75	.....	Horizon unknown.	Salt water.
Do.....	224	8	.....	.....	Upper Chesapeake.	
Cape May Point....	360	.....	Fair supply.	.....	.....do	No water 360–450 feet;.
Cinnaminson	46	6	450	.....	Basal Matawan ...	
Clayton, 6 wells....	90–105	2–3	150 each.	−21	Post-Chesapeake?.	
Collingswood	196	.....	.....	.....	In Raritan.....	
Columbus	356	.....	Fair supply.	−45	....do	Deepened to 715 feet, but no water found.
Do.....	156	.....	10	Flows.	Basal Matawan...	Ferruginous water.
Crab Island.....	520	3	Satisfactory.	.....	.....	

a +, feet above the surface; −, feet below the surface.

List of deep wells in the Coastal Plain Region of New Jevsey—Continued.

Location.	Depth.	Bore.	Capacity per minute.	Height to which water rises. *a*	Geologic horizon.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*		
Delair	78	.....	.....	—40	In Raritan	
Englishtown	210	.....	Not any.	.....	In Matawan	Stopped in blue clay.
Fellowship	131	.....	Many.	—50	do	Water also at 260 feet.
Fifields	397	.....	Not any.	.....	Chesapeake	Water at 84 feet.
Freehold	172	.....	25	—26	Under Lower Marl	
Do	322	.....	(?)	.....	In Matawan	
Freehold, 1½ miles north, 9 wells.	50	.....	250	.....	Under Lower Marl	
Freehold, 1½ miles north, 1 well.	210	.....	Unsatisfactory.	.....	In Matawan	
Gibbsboro	71	.....	.....	—16	Middle Marl	
Glassboro, 5 wells	70–80	.....	100	.....	Post-Chesapeake	Water unsatisfactory.
Do	511	.....	Not any.	.....	In Matawan	
Gloucester	270	.....			Basal Raritan	To rock.
Gloucester, 7 wells	67–96	4½	650	+1	Basal Matawan	
Gloucester, 3 wells	149–162	4½			In Raritan	
Gloucester, 6 wells	65–102	3	100	.....	Basal Matawan	
Great Sedge Island	320	4½	100	+9	.....	Small flows at 157 175, and 252 feet.
Greenwich	690	.....	Not any.	.....	Under Lower Marl	No Redbank water found here.
Harrisia	375	6	.....	.....	.....	Good water at about 200 feet, which flowed.
Harrisonville	122	1½	Plenty.	.....	Middle Marl	
Hartford	187	.....	Not any.	.....	In Matawan	Water at 161–167 feet in Matawan.
Harvey Cedars	240	.....	.....	Flows.	"C," horizon at Atlantic City.	
Do	500	4½	Flows 100 gallons.	+12		
Hightstown	76	.....	.....	.....	In Matawan	Water at 420–480 feet.
Do	500	.....	.....	.....	.....	Crystalline rock at 482 feet.
Do	428	.....	Plenty.	.....	Basal Raritan	
Hightstown, several wells.	201	6	70	.....	In Raritan	
			12			
Holmdel	601	8-4	Not any.	.....	Low in Raritan	
Jamesburg	481	8-6	52	.....	In Raritan	
Key East	.....	.....	.....	Flow.	.....	
Keyport	242	.....	12	.....	In Raritan	
Lake Como	535	.....	.....	.....	Under Lower Marl	
Lakewood	475	.....	.....	+17	do	
Longport	803	6	Flows 180.	+14	"G," Atlantic City horizon.	Temperature 66°.
Lucaston	110	.....	.....	—10	Above Middle Marl	
Magnolia Station	91	.....	Plenty.	—36	do	
Mantoloking	175	3	.....	+35	"C," Atlantic City horizon.	
Do	790	.....	.....	.....	Under Lower Marl	

a +, feet above the surface; —, feet below the surface.



AREAS UNDERLAIN BY UPPER CRETACEOUS AND CHESAPEAKE WATER HORIZONS IN NEW JERSEY.

BY N. H. DARTON.

List of deep wells in the Coastal Plain Region of New Jersey—Continued.

Location.	Depth.	Bore.	Capacity per minute.	Height to which water rises. *a*	Geologic horizon.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*		
Mantoloking	922	.....	.....	.....	In Matawan	
Maple Shade	375	.....	.....	.....	Basal Raritan	Water also at 64–97, 103–130, and 260–300 feet.
Marlton:						
2 wells	86	5⅝	.....	.....	Redbank	Temperature, 53½°.
1 well	105	.....	.....	.....	do	
1 well	200	3	.....	−20	Matawan	
Marlton, 1½ miles south.	155	.....	20	−24	Under Lower Marl?	No water at 155–380 feet.
Marlton, 2 miles east.	70	6	Many.	−40	Redbank	Temperature, 54°.
Marlton, 3 miles southwest.	316	.....	Fair.	−22	Matawan	
Marlton, 2 miles west, 5 wells.	30	.....	Fair.	−25	Redbank	
Marlton, ¾ mile south.	114	6	Plenty.	−40	do	
Marlton, 2 miles east.	68	3	Plenty.	.....	do	
Marlton, 3 miles east-northeast.	76	6	Plenty.	−10	do	
Marlton, south	114	5	Plenty.	−10	do	
Marlton, 2 miles east-southeast.	155	5	Plenty.	.....	do	
Do	365	.....	Not any.	.....	Matawan	
Marlton, 2 miles east.	98	5	.....	−6	.....	
Marlton, 3 miles east.	102	1	Plenty.	−7	Redbank	
Matawan	100	8	.....	.....	Matawan	100–264 feet no water.
Mays Landing, 2 wells.	100–130	2½	16–7	.....	428-foot horizon, Atlantic City?	Temperature, 56°.
Do	176	6	25	.....	"C," horizon at Atlantic City?	
Mechesatankin Creek.	158	.....	Unsatisfactory.	.....	.....	
Medford	150	3	Plenty.	−18	Redbank	Water also at 17 and 90 feet.
Medford, Stoke's farm.	64–70	.....	200	.....	do	
Medford, Stoke's farm, deepened.	183	.....	Satisfactory.	−17	Under Lower Marl	
Medford, 1¾ miles northeast.	126	.....	do	−25	Redbank	Water also at 70 feet.
Millville	150–160	10	do	Flows.	.....	
Monmouth Beach	380	.....	.....	.....	In Matawan	
Monmouth Park	385	4	75	+4	do	A well 900 feet to bed rock.
Moorestown	150	.....	.....	Flows.	Basal Matawan	Water also at 118, 320, and 338 feet; no water at 338–457 feet.

a +, feet above the surface; −, feet below the surface.

List of deep wells in the Coastal Plain Region of New Jersey—Continued.

Location.	Depth.	Bore.	Capacity per minute.	Height to which water rises. *a*	Geologic horizon.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*		
Mount Ephraim	130	.....	Satisfactory.	.....	Basal Matawan	
Mount Ephraim, ¾ mile distant.	80	.....	Satisfactory.	.....	Basal Matawan?	
Mount Holly	675	.....	.....	.....	Raritan	Water not pure enough.
Mullica Hill, 1¾ miles southwest.	102	1½	.....	—35	Redbank	Ferruginous water.
Ocean Beach	485	3	25	+35	Under Lower Marl	
Do	480	3	50	Flows.	....do	
Ocean City	760	.....	.....	.....	Under Chesapeake diatom bed.	
Do	800	.....	140	+15	....do	
Ocean Grove	420	6	40	.....	Under Lower Marl	Temperature, 60°.
Do	1,134	.....	Many.	.....	Low in Matawan	
Pavonia:						
3 wells	67–82	.....	275	.....	In Raritan	
1 well	174	.....	.....	.....	Basal Raritan	
Do	112	6	.....	.....	To crystalline rock.	Water at 85 and 98 feet.
Perth Amboy	130	.....	Not any.	.....	Basal Raritan	
Do	470	.....	Not any.	.....	70–470 feet in gneiss.	
Pitman Grove, 8 wells.	60–80	.....	160	.....	Post-Chesapeake beds.	No water 80 to 130 feet.
Pleasant Mills, 14 wells.	50	.....	500	+13	658-foot horizon at Ocean City?	
Pleasant Mills, 1½ miles west.	201	.....	.....	.....	Low in Chesapeake.	Flow at 57 feet.
Pleasant Mills, 5½ miles northwest.	158	.....	Unsatisfactory.	.....		
Port Monmouth	+100	.....	Few.	Flows.	In Matawan	
Point Pleasant, Hotel Stratford.	806	.....	Flows 45.	+35	.....do	
Port Norris	78	4	1	.....	.....	
Port Norris, Bivalve, 2 wells.	200	.....	.....	.....	.....	
Port Republic	151	.....	.....	Flows.	428-foot Atlantic City horizon?	Water also at 114 feet.
Quinton, 10 wells	248–275	6	55	— 1	Redbank	
Rancocas, 1½ miles distant.	124	3	.....	—63	Basal Matawan	
Redbank:						
5 pipes	80–90	36	165	—12	Under Lower Marl	
3 pipes	230	.....	Many.	—10	In Matawan	
Richwood	65	.....	40	.....	Post-Chesapeake	
Riverside	200	.....	18	.....	.....	In bed rock 120-200 feet.
Riverside, 8 wells	45	.....	40 each.	.....	In Raritan?	
Riverton	50	.....	10	.....	In Raritan	
Rumsen Neck	210	.....	60	.....	In Matawan	
Runyon Station	160	2	Not any.	.....	.....	
Sayreville	80	2½	Many.	.....	Basal Raritan	

a +, feet above the surface; —, feet below the surface.

List of deep wells in the Coastal Plain Region of New Jersey—Continued.

Location.	Depth.	Bore.	Capacity per minute.	Height to which water rises. *a*	Geologic horizon.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*		
Sayreville	976				80–976 feet; in gneiss.	Some water at 300 feet.
Sea Girt	755	3	Flows 50.	+13	In Matawan	Temperature 65°. Water also at 570 and 694 feet.
Seabright:						
6 wells	125		210	+ 1	Under Lower Marl	
3 wells	258		120	+ 5½	In Matawan	
Seabright, Normandy Hotel.	?225		55	Flows.	do	
Sea Island City	380	4	30	—11	Just above diatom bed.	
Seven Islands	535		60	+22	"E" horizon at Atlantic City.	
Do	408	6–3	70	+15	"C" horizon at Atlantic City?	
Sewell	420	3	25		Basal Matawan	Also water in Redbank at 72 feet and in Matawan at 381–395 feet.
Shrewsbury	200		Not any.		Under Lower Marl	
South Amboy	105				Basal Raritan	
South Beach Haven	425	8–6	10?	+14	"C" horizon at Atlantic City.	
Spring Lake	465		Many.		Under Lower Marl	
Stockton:						
6 wells	116–130		875		Basal Raritan	
1 well	68				In Raritan	
Straight Creek	100		Many.	Flows.		
Trenton	60	*b* 20	Many.		Post-Chesapeake?	
Do	160				Basal Raritan	
Trenton, 3 wells	90	8	200		do	Fine water.
Vineland	205	4	20	—17½	Post-Chesapeake.	
Waretown	280	4	20	Flows.	"E" horizon at Atlantic City.	Small flows at 70 and 137 feet.
Wenonah	341		40		Basal Matawan	
Wenonah, 2 wells	196	3		— 6	In Matawan	
West Creek	99	3	Many.	— 1		
Weymouth	42	4	70	Flows.	"C" horizon at Atlantic City?	
Do	42	5	52	+ 8		
Weymouth, 4 miles north.	96–106			— 2	650-foot horizon at Ocean City?	
Weymouth, 2 miles north.	45				"C" horizon at Atlantic City?	
Wildwood	215		Unsatisfactory.	No flow.	In upper Chesapeake.	Water also at 46–78 feet.
Do	931		Flows 10.	+ 7	240 feet below great diatom bed.	1,244 feet deep; small flows also at 625, 750, and 843 feet, and salt-water flow at 1,185 feet. Temperature 67°.

a +, feet above the surface; —, feet below the surface.

b Feet.

List of deep wells in the Coastal Plain Region of New Jersey—Continued.

Location.	Depth.	Bore.	Capacity per minute.	Height to which water rises.[a]	Geologic horizon.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*		
Wildwood	655		Flows 300.	Flows.	In great diatom bed.	Temperature 63°.
Winslow	135-145		40	—40	Chesapeake	
Do	85		20	—40	Chesapeake	
Do	345				960-foot Atlantic City horizon.?	
Woodbury	80		Fair supply.		In Matawan	
Do	163	4½	Few		Basal Matawan ?	
Do	132	4½	2		do	
Do	113	2½	Fair supply.	—19	do	
Do	142		8	—50		
Woodbury, 1 mile north.	68	4	8	—10	Basal Matawan	
Woodbury, 2 miles south.	120				In Matawan	
Woodstown	340				Basal Matawan	No water at base of Lower Marl.
Woodstown, 6 wells	139-149	6	360	+ 1	Redbank	
Woodstown, 1 well.	776			—18	In Raritan	Do.

[a] +, feet above the surface; —, feet below the surface.

NOTES ON THE WELLS OF SOUTHERN NEW JERSEY.

Much of the information regarding the wells in southern New Jersey has been obtained from the reports of the geological survey of the State, and particularly from the admirable contributions by Mr. Woolman in these reports. Considerable additional data have been supplied by various persons, mainly well borers. The material from the New Jersey reports has been condensed as far as practicable, and in some cases has been modified in the light of more recent well experience or geologic investigation.

I shall indicate in footnotes the source of information when it is taken from the New Jersey reports, but can not in every case indicate modifications or additional comments which I have made.

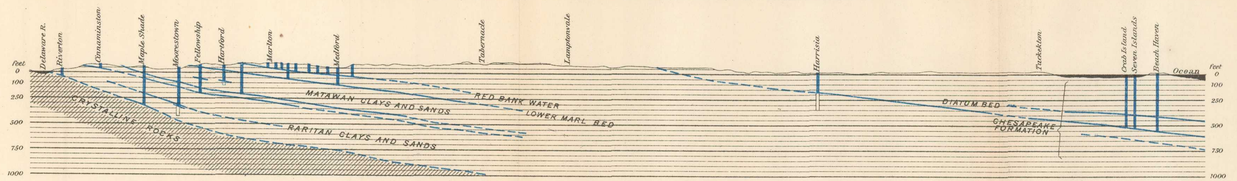
Absecon,[1] *Atlantic County.*—The earlier water supply for Atlantic City was derived from a series of shallow wells on the mainland near the shore road, midway between Absecon and Pleasantville. The wells are 54 in number and 24 feet deep. They are on low ground, near tide level, and flow into two large basins. The records of the borings are as follows:

Feet.
0-9.....heavy white gravel, with fossiliferous pebbles.
9-18.....bluish clay, containing marine diatoms of recent age.
18-24.....coarse sand, with water of excellent quality.

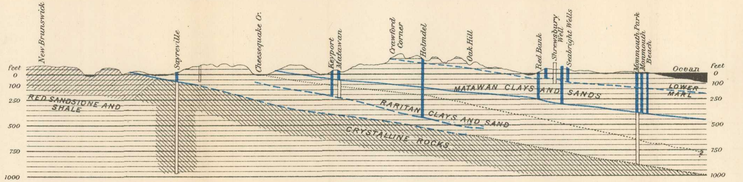
Mr. Woolman has discovered a similar bed of diatomaceous clay, overlain by gravels with fossiliferous pebbles, on the shores of Great

[1] L. Woolman, in New Jersey report for 1892, pp. 283-285.

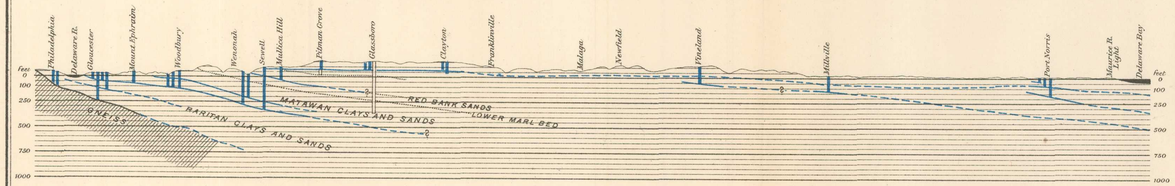
SECTION 2: DELAWARE RIVER AT RIVERTON, TO BEACH HAVEN.



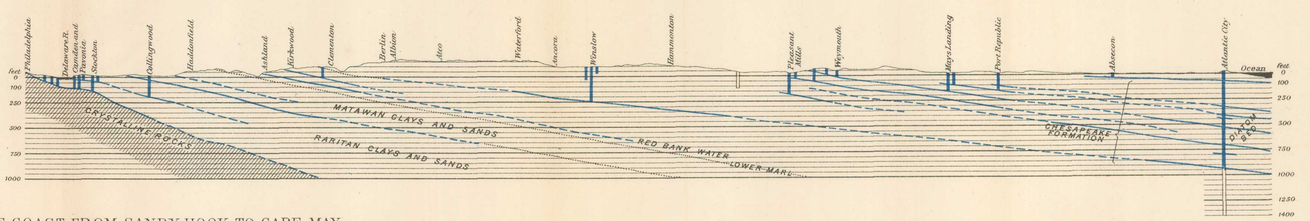
SECTION 1: NEW BRUNSWICK TO MONMOUTH BEACH.



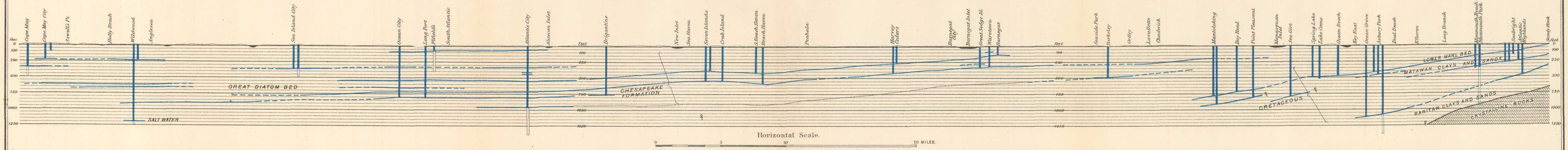
SECTION 4: PHILADELPHIA TO MOUTH OF MAURICE R. ALONG W. J. R.R.



SECTION 3: PHILADELPHIA TO ATLANTIC CITY.



SECTION 5: ALONG THE COAST FROM SANDY HOOK TO CAPE MAY.



Horizontal Scale.

0 5 10 20 MILES.

JULIUS BIEN & COMPANY N.Y.

SECTIONS ACROSS SOUTHERN NEW JERSEY.

Egg Harbor River, near Mays Landing, and believes it to be the same as that at the Absecon wells. Other outcrops are at Long Branch and Bridgeton. Its dip was found to be 6 feet per mile. From a careful study of the diatoms and the relations of the beds Mr. Woolman considers the clay and gravels at 58 to 63 feet and 72 to 75 feet in the Atlantic City wells to belong to this series. They were also found in the well at Fifields at 84 feet, and in other wells along the southern shore of New Jersey.

Asbury Park, Monmouth County.—The first well is situated on the land of Mr. Uriah White, 3,276 feet northeast from the Ocean Grove well. The materials penetrated were the same in this well as in that at Ocean Grove. The layer of shells containing *Terebratula harlani*, which is near the top of the Middle Marl bed, was found at 270 feet, and continued 7 feet. It has a considerable body of greensand below it. At 365 feet there were sands containing fragments of *Belemnitella mucronata, Exogyra costata, Gryphæa convexa*, and *Ostrea falcata* of the Lower Marl bed or Navesink formation. The water is in sands at the base of this formation at a depth of 383 feet. The capacity of the well proved to be about 95,000 gallons a day.

Another well was bored in 1884 to a depth of 448 feet, to a sand bed at the top of the Matawan formation, which yields about 20 gallons a minute.[1]

In the past few years several deeper wells have been sunk to obtain increased water supplies and discovered very important water-bearing beds. Three borings attained depths of 1,045, 1,130, and 1,350 feet respectively. The deepest of these was damaged by an accident and abandoned, but the other two yield nearly 1,500,000 gallons of water per day by the air-lift process. The water contains considerable iron, but aëration and filtration render it satisfactory for use.

Mr. Woolman[2] has recently given a detailed account of the formations penetrated by these deep borings, which throws much interesting light on the geology. Below the Lower Marl at 380 feet are alternating clays and sands mainly of light color. Gray sand with water was reported at 380 to 430 feet, several water-bearing sands from 500 to 630 feet, glauconitic clays 630 to 954 feet, water-bearing fine sands 954 to 1,000 feet, and coarse gray sands with the main water supply at 1,083 to 1,135 feet. Below 1,135 feet were dark clays and sandy clays in which no water was obtained. Molluscan remains reported at 1,195 feet included an Exogyra, which would indicate Matawan beds. If the depth is correct, this would indicate an unlooked-for expansion of the Matawan formation to a thickness of at least 800 feet—400 to 1,200 feet in the boring—and it is the opinion of Mr. Woolman that it extends to the bottom of the deepest boring.

Atlantic City.—The underground waters of southern New Jersey

[1] New Jersey reports for 1883 and 1884.

[2] New Jersey report for 1895, pp. 72–74.

have been extensively developed at this locality, and a number of wells sunk to various depths have thrown most important light on the water horizons. The deepest well attained a depth of approximately 1,400 feet, and there are many which have a depth of over 700 feet. The first boring of which I have learned was made in 1858. It found a good supply of water at 185 feet.[1] In 1874 the gas and water company sunk two wells to 90 and 118 feet,[1] respectively, but no data appear to be on record as to the result.

The deeper borings were begun in 1887 for the Consumers' Water Company, and one well reached the depth of 1,400 feet. The principal water horizons revealed by these wells were at about 525, 700, and 960 feet, but several others were also found. Mr. Lewis Woolman, of Philadelphia, received samples of the borings from several of these wells, and he made a detailed report[2] on them, which is a most valuable contribution to our knowledge of Coastal Plain geology. He also reported on later borings and studied the extension of the beds in other wells.

In Pl. IV, I have reproduced Mr. Woolman's columnar section of the Atlantic City wells, with a blue overprint for the water-bearing beds. The relations of the beds are so clearly shown in this section that further description of them is not necessary. The geologic correlations are based on careful studies of the fossil shells and diatoms by Mr. Woolman and others, and they represent the best information now obtainable. The lowest beds are regarded by Mr. Woolman as probably Pamunkey and Severn.[3]

In the earlier reports on the wells of Atlantic City it was stated that a water horizon had been found at a depth of 1,120 feet, but it has since been ascertained that the water came from a break in the pipe at 960 feet below the surface. The 800-foot horizon was not fully tested until 1893, when it was found to be a great water bearer both at Atlantic City and Ocean City. In 1895–'96 several wells were sunk to it and all found large supplies. The waters from the several horizons between 115 and 328 feet appear to be saline, and it is reported that the water from 300 feet is quite strongly ferruginous. Mr. Woolman gives the following list of approximate depths of the principal water horizons at Atlantic City:[4]

1. At about 328
2. 406 and 430 ..sands above the diatom bed.
3. 525....middle of diatom bed.
5. 700 to 720....base of the diatom bed.
6. 760
7. 800 ..below the diatom bed.
8. 958

[1] New Jersey report for 1875, pp. 27–28.

[2] Artesian wells, Atlantic City, N. J., Report of State Geologist for 1889, pp. 89–99; Geology of the artesian wells at Atlantic City, N. J., Proc. Acad. Nat. Sci., Phila., 1890, pp. 132–147; and papers in New Jersey reports for 1890–1894.

[3] New Jersey report for 1894, p. 180.

[4] New Jersey report for 1893, p. 390.

The two upper horizons are not utilized. There is also a water-bearing bed about midway between the 525-foot and the 700-foot horizon at Ocean City, but it has not been found at Atlantic City. The sizes, depths, and yields of the Atlantic City wells, from data in the New Jersey reports, are given in the table on pages 42–43.

An analysis of the water from the first deep well at Atlantic City, at 960 feet, by Messrs. Austin and Wilbur, March 14, 1888, is as follows:[1]

Analysis of water from deep well at Atlantic City.

	Grains per gallon.
Silica	0.24
Sesquioxide of iron and alumina	0.10
Lime	1.08
Magnesia	1.02
Potash	1.49
Soda	31.24
Sulphuric acid in sulphates	2.64
Chlorine in chlorides	19.30
Total solids determined	57.11
Volatile constituents	7.22
Total solids at 212°	64.33
Temporary hardness, equivalent to calcium carbonate	3.809
Permanent hardness, equivalent to calcium carbonate	0.326
Oxygen requisite to oxidize organic matter	0.003

Color.....colorless.
Taste.....none.
Smell.....none.
Reaction.....faintly alkaline.
General appearance.....exceedingly clear and attractive.

Atlantic Highlands, Monmouth County.—There are 9 wells at this place, which are 4½ inches in diameter. Eight of them are 108–112 feet deep, and the other is 480 feet deep. The shallower wells flow and pump about 80 gallons per minute each. The deep well pumps 250 gallons per minute. The deep water is ferruginous, but is said to be satisfactory after filtration. The 108–112-foot water is from a sand bed in the Matawan formation, about 160 feet below the top of the formation. The lower formation is in sands in the medial beds of the Raritan formation.

Barnegat Landing, Ocean County.—At this place there is a flowing well with a depth of 120 feet. The horizon has been correlated by Mr. Woolman[2] with the 525-foot horizon of Atlantic City and the water at 137 feet at Waretown, which I believe to be correct.

Bayhead, Ocean County.—Excellent water is obtained at 710 feet, apparently from the base of the Lower Marl series,[3] or the same horizon

[1] New Jersey report for 1888, pp. 72–73.
[2] New Jersey report for 1890, p. 271.
[3] New Jersey report for 1887, p. 26.

as that at 383 feet at Asbury Park, 480 feet at Ocean Beach, and 465 feet at Spring Lake.

Bayside, Cumberland County.—The American Oil and Refinery Company has bored a well at this place. At 100 feet below the surface a salt spring was penetrated from which the water flowed to 18 inches above the level of the surrounding marsh, and it was not affected by the rise or fall of the tide. At 140 feet other water was found which was very salt, but cold and clear. The first 33 feet was mud, underlain by about 18 inches of hard clay. At a depth of 160 feet a hard clay was encountered, and the work was stopped by the breaking of the pipe.[1]

In the report for 1894[2] it is further stated by Mr. Woolman that all the beds below 33 feet to a depth of 190 feet were hard clays of the great diatomaceous clay bed in the Chesapeake formation.

Beach Haven, Ocean County.—The first two wells were bored to a depth of 430 feet. They yielded about 10 gallons a minute. Another well was sunk in 1893 to a depth of 575 feet. It has a diameter of 8 inches, and yields a supply of 125 gallons per minute. The record is as follows:

Feet.	
0–17	beach sands.
17–18	mud, with roots.
18–55	gray sands, with shells and recent marine diatoms.
55–65	gray sand.
65–90	white clay and gravel.
90–95	fine white clay.
95–115	white sand, a few fossiliferous pebbles.
115–1[illegible]	fine white sands.
135–150	alternations of sand and clay, both yellow.
150–160	coarse gray sand.
160–165	black clay.
165–170	fine white sand.
170–180	fine yellow sand.
180–200	medium fine, white sand.
200–205	medium coarse, yellow sand.
205–215	white sand.
215–250	yellow sand.
250–280	gray sand.
280–290	greenish sand and clay mixed.
290–365	greenish, marly clay, containing diatoms.
365–410	dark marly clay, containing diatoms.
410–429	fine sand, with water.
429–450	coarse sand, with water.
450–476	tough diatomaceous clay.
476–543	alternations of sandy clays and clayey sands, all diatomaceous.
543–575	gray sharp sand, with water.

The equivalent of the diatom bed from 18 to 55 feet was found at depths of 9 to 18 feet in wells at Atlantic City and on the mainland at Absecon, and it is the same, in all probability, as the bed exposed at

[1] New Jersey report for 1889, p. 87.

[2] Pages 191–192.

STRATA	Feet	SECTION	SUBDIVISIONS	
Surface sand.	30		45 Ft. Beach sand with recent shells	
Blue mud, shells.	15		45 feet	
Coarse gravel and large stones.	10		220 Ft.	
Light, fine sand.	14		Whitish sand,	QUATERNARY
Gravel, medium to coarse Water	15		Coarse gravel with	
Coarse gravel, petrified shells.	15		fossiliferous pebbles	
with seams of clay.	15			
Coarse gravel. Water	8			
Thin alternate layers of sand & sandy clay.	16		Yellow sand, clays	
Yellow gravel.	5			
Yellow sand.	6		and gravels.	
Light clay.	7			
Dark, hard clay.	12		White and gray	
Clay - various colors.	10			
Sandy clay.	30		sand and gravel.	
White clean sand.	5			
Dark, slushy sand.	13			
Coarse gravel. Water	3			
White sand.	33			
Coarse gravel. Conglomerate.	3		265 feet	
White, coarse sand. Water	2		118 Ft.	
Dark clay.	17			
Dark quick-sand.	6		Reddish brown	MIOCENE
Green clay.	26		sand with two	
Iron seam. (Water 328)	5		or more thin clay-beds.	
Red sand.	44		Fragments of wood	
Dark sand.	6		throughout.	
Dark, fine quick-sand.	12		383 feet	
Greenish clay.	14		275 Ft.	
Clean gray sand. Water	2		406	
Dark greenish clay. (Water 406) (Water 429)	31		430 Diatomaceous clays,	
Dark, fine sand. Green clay or marl, minute fragments of shells	55		rich in diatoms, (382 – 406,	
Dark, slushy sand, and clay	25		480 510 510 – 535, 609 – 632)	
Green clay.	25		535	
Sandy clay.	25		Foraminifera,	
Clean gray sand. (Water 554 to 565)	10			
Sandy clay.	30		comminuted shells,	
Dark brown clay.	20		609 and diatoms.	
Dark brown and very hard clay.	8			
Dark brown soft clay.	10		632 (430 – 480, 632 – 658)	
Chocolate colored clay.	20		658 feet	
Dark brown clay, slightly diatomaceous.	19		103 Ft.	
Green marl, full of shells.	5			
Sandy clay - Sharks-teeth	8			MIOCENE
Light sand, shells.	10		Equivalent of	
Coarse sand and gravel. Water	8			
Quick-sand.	6		Shiloh marls.	
Dark colored clay. (Water 720)	12			
Dark sandy marl, full of shells.	4		Perna maxillata.	
Dark greenish marl.	27			
Tough clay and gravel. Water	4		761 feet	
Reddish brown sand.	40		83 Ft. Reddish brown sand.	
Light, brown sand. Water	30			
Quick-sand.	13		844 Micaceous sand.	
Dark clay. Chocolate colored clay.	2		111 Ft.	
Sandy clay.	4			
Dark clay.	6		Dark chocolate	
Dark hard clay.	20		clay.	
Dark, clay, softer.	9			
White clay.	15		Green marl.	
Green marl.	5			
Yellow loam and sand. Water	50		955 Ostrea (sp?) in lower 2 feet	
Yellow sand.	5		140 Ft.	
Greenish sand.	12			
Yellow sand with streaks of loam.	3		Greenish-yellow sand with streaks of loam.	
Coarse, gray, clean sand. (Yel. loam 1 ft.)	93		Barnacles throughout.	
Coarse gray sand	8			
Yellow loam and sand.	9		1095 feet	
Dark green or gray marl or clay.	10		130 Ft.	
Dark green marl.	31		Dark greenish-gray	
Dark green or gray marl.	20		clay, abundance	
Dark marl, a few shells at 1180.	24		of Foraminifera.	
Slate colored clay.	55		1225 feet	
Dark, hard clay.	25		173 Ft. Light and dark slate colored clays.	
Light clay, shelly.	55		Abundance of Foraminifera throughout.	
(White clay at 1398 ft.)	93		Placocyathus. (coral.)	
			1398 feet	

JULIUS BIEN & CO. N.Y.

By Lewis Woolman

COLUMNAR SECTION OF ARTESIAN WELLS AT ATLANTIC CITY, NEW JERSEY

Scale of 100 feet to 1 inch

Long Branch by the storms, for both contain the same forms. The 575-foot water horizon is thought to be the same as the one at Seven Islands at 510–535 feet and at Atlantic City at 700–720 feet. The water at 425 feet is apparently the 525-foot Atlantic City horizon, but it is in somewhat coarser sand. The beds at 410 feet are richly diatomaceous and contain *Coscinodiscus excavatus*, a form which occurs at Atlantic City at a depth of 500–525 feet, just above the water horizon.[1]

Berkeley Arms, Ocean County.—The wells are on the beach opposite the mouth of the Toms River. The water was found at 475 feet. It rises to the surface, but does not flow, and is said to have yielded 60 gallons per minute.[2]

The water horizon is far down in the Chesapeake formation, as will be seen in section 5, Pl. III, and may be the same as the water horizon at 950 feet in the Atlantic City well, and at 335 feet at Winslow, as suggested by Woolman.[3]

Analysis of water from well at Berkeley Arms, New Jersey, by Messrs. Austin and Wilber.

	Grains per gallon.
Sodium chloride	0.769
Sodium sulphate	0.764
Sodium carbonate	0.619
Potassium sulphate	0.635
Calcium bicarbonate	1.300
Magnesium	0.571
Silica	1.032
Sesquioxide of iron and alumina	0.052
Total solids	11.742

The water is pure and wholesome. It is remarkable for the quantity of carbonate of soda which it contains.

Bordentown, Burlington County.—The well at the Aquatic Club House, on the banks of the Delaware River, obtains an excellent supply of somewhat ferruginous water from a depth of 119 feet. The following record was kindly furnished by Mr. Wiese, of Bordentown:

Feet.	
0–3	mud.
3–11	sand.
11–21	clay.
21–30	fine white sand.
30–34	coarse sand with ironstone streaks.
34–52½	white clay and fine sand.
52½–54	blue clay.

[1] L. Woolman, in New Jersey report for 1890, pp. 266–267, and report for 1893, pp. 395–396.

[2] New Jersey report for 1884, p. 187.

[3] New Jersey report for 1890, p. 274.

[4] New Jersey report for 1888, p. 133.

Feet.	
54–68	blue sand with wood fragments, much irony water.
68–76	white sand and white clay.
76–90	coarse gravel in very white clay.
90–90½	clay.
90½–103½	fine white sand mixed with clay.
103½–110	coarse gravel with white clay, considerable irony water.
110–114	sandstone and hard sand.
114–119	sand and gravel with much water.

The horizon is in the Raritan formation, about 125 feet below its top.

In another well in Bordentown, which was sunk to a depth of over 220 feet, a good supply of ferruginous water was found at 195 feet and the crystalline bedrock at 220 feet. The water is in basal sands of the Raritan formation underlying 65 feet of red clay, and it rises to about tide level.[1]

Bridgeton, Cumberland County.—The well at East Bridgeton is at an altitude of about 40 feet. It was bored at a depth of 90 feet, but yielded no water supply. The record is as follows:

Feet.	
21–22	clay.
22–62	light-gray quicksand.
62–63	sandstone.
63–64	white clay.
64–66	sand.
66–69	quicksand.
69–77	coarse sand.
77–79	quicksand.
79–80	sand with small amount of water.
80–82	hard stiff yellow clay.
82–84	sand.
84–85	reddish clay.
85–89	sand.
89–90	dark clay.

This record is given by Mr. Woolman,[2] who states that the beds are probably all post-Miocene (post-Chesapeake) in age.

Brigantine.—In the summer of 1895 a 798-foot well was completed at this place. It flows over 100 gallons per minute and undoubtedly draws from the 800-foot horizon at Atlantic City. Very small flows were noted at 517 to 525 feet and at 670 feet. The main flow is from sands at 728 to 798 feet. The diatom clay series extended from 389 to 670 feet. The detailed record is given by Mr. L. Woolman in New Jersey report for 1895.[3]

Burlington, Burlington County.—A well at the residence of C. S. Taylor, near Burlington, was sunk 200 feet in the dark clays of the lower part of the Matawan formation and the upper part of the Raritan clays, and ended in a light-colored clay. No good supply of water was obtained.[4]

[1] L. Woolman in New Jersey report for 1895, p. 71.
[2] New Jersey report for 1893, pp. 418–419.
[3] Pages 78–79.
[4] New Jersey report for 1879, p. 139.

The well sunk for Mr. Ezra Bowen, 2 miles east of Burlington, had the following record:[1]

	Feet.	
Matawan.	0–6	soil.
	6–59	black mud or marl.
	59–103	green marl.
	103–120	gray sand with wood, no water.
Raritan.	120–124	white clay.
	124–145	red-mottled clay.
	145–150	dry, dark lead-colored clay.
	150–154	sand and hard crusts.

At 253 medium-fine to coarse sand and gravel.

A well 1½ miles south of Burlington obtains an excellent water supply from a depth of 128 feet. The following record is given:[2]

Feet.	
0–8	sand.
8–10	sandy crust.
10–13	gravel and quicksand.
13–69	green marl.
69–76	red and white clay.
76–85	white clayey sand.
86–106	red clay.
106–110	gravel and red sand.
110–126	white clay.
126–132	white sand and water.
132–135	heavy yellow gravel and water.

Camden, Camden County.—The well at Esterbrook Steel Pen Works yields 40,000 gallons in ten hours. The diameter is 6 inches, and the first boring was 66½ feet deep. The water stood at about high-tide level, or 5 to 6 feet below the surface. It was at first clear, but finally carried particles of clay. It was deepened in 1886 and water was found at 87 feet, but not in sufficient amount. The record was as follows:[3]

Feet.	
0–20	muck and some gravel.
20–23	gray mud.
23–25	sand.
25–30	potters' clay.
30–33	yellow sand.
33–60	coarse gravel with some yellow sand.
60–62	fine, smooth, yellow clay.
62–66½	coarse sand with green specks.
67–77	yellow gravel and stones.
77–87	fine white sand and gravel.

The boring was farther deepened to 100 feet, where a soft micaceous rock was encountered, and continued 30 feet into the rock, but the supply of water was not increased.[3]

[1] New Jersey report for 1892, p. 310.
[2] L. Woolman in New Jersey report for 1895, p. 70.
[3] New Jersey report for 1885, p. 126.

The well at Cooper Hospital was sunk in 1885 and a supply of water was obtained at 129 feet. It is a 6-inch pipe and the water rises to within 16 feet of the surface. It is estimated to yield 25,000 gallons per day. The following analysis is given:[1]

Analysis of water from well at Cooper Hospital, Camden, N. J.

	Grains per gallon.
Sulphate of lime	1.76
Carbonate of lime	0.77
Carbonate of magnesia	0.83
Chloride of sodium	0.30
Sesquioxide of iron and alumina	0.07
Silica	0.54
Organic and volatile matter	0.46
Total solids	4.73

It is a soft and good water.

The following materials are penetrated:[1]

Feet.	
0–4	sand and soil.
4–10	molding clay and sand.
10–12	white gravel with water.
12–20	sand.
20–26	soft clay.
26–28	soft ironstone.
28–30	potters' clay.
30–34	black clay and mud, with fragments of wood.
34–40	soft pink clay.
40–68	white sand, white gravel (large stone).
68–78	white gravel.
78–80	red gravel.
80–95	yellow gravel and sand (water).
95–120	white sand and gravel.
120–123	red gravel, with 3 inches of white clay.
123–126	red gravel, with 1 or 2 inches of white clay.
126–129	white gravel.

The water horizon is in or near the basal beds of the Raritan formation, apparently the same as that which supplies the well at 174 feet at Pavonia, 130 feet at Stockton, and the deep well at Gloucester.

A 6-inch well was recently bored at the Camden pumping station, on the Delaware River, near the foot of Fulton street. It is on tide meadow, and considerably below the wells above described. Its record is given by Mr. Woolman[2] as follows:

Feet.	
0–39	black river mud.
39–49	yellow and red mottled plastic clay.
49–72	red clay.

[1] New Jersey report for 1885, p. 125.

[2] New Jersey report for 1894, pp. 197–198.

Feet.	
72–78	white sand.
78–83	large coarse gravel.
83–85	white sand, with water, which rises to within 1½ inches of the surface.
85–89	gravel and sand.
89–90	white clay.
90–98	large gravel, with water, which rises to within 34 feet of the surface.
98–104	gravel, clay, and sand.
104–112	soft rock.
112	hard rock, in which boring was discontinued.

Cape May City, Cape May County.—There were seven 8-inch wells bored here to depths varying from 87 to 92 feet. They tap a stratum of fine, fresh water, and yield about 75 gallons per minute. Driven wells to from 25 to 30 feet yield from 7 to 10 gallons per minute.[1]

Cape May Point, Cape May County.—A well at this locality found a fair supply of water at 320 to 360 feet, in sands containing thin beds of clay and broken shells. The boring was deepened in 1890, and Mr. Woolman found diatom remains in materials from 456 feet in this well.[2]

Another well sunk to 224 feet obtained salt water.

Cinnaminson, Burlington County.—A 6-inch well bored by A. C. Wood a quarter of a mile east of the post-office passed through the following strata:[3]

Feet.	
0–6	earth.
6–7	shells.
7–27	yellow sand.
27–30	fine white gravel.
30–32	yellow clay.
32–42	whitish sand.
42–46	coarse white gravel.

The well yields 400 to 500 gallons per minute, and the water has a temperature of 52°.

The water appears to be from the basal Matawan horizon.

Clayton, Gloucester County.—Three 2-inch and three 3-inch wells have been bored at this place. They all found water in a coarse gravel at 80 to 105 feet from the surface, of which the elevation is about 140 feet. The water rises to within 21 feet of the surface, and each well has yielded 150 gallons per minute without being lowered. The water is thought to be in superficial sands and gravels, probably not far from Miocene (Chesapeake) clays.[4] A series of four wells for the water company, reported by Mr. Woolman in 1895,[5] range in depth from 86 to 93 feet. Miocene blue clay is reported at 105 feet.

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[1] New Jersey report for 1879, p. 144.

[2] New Jersey report for 1890, p. 272. In the New Jersey report for 1894, pp. 157–158, Mr. Woolman gives some additional data regarding the shells and other materials from this well.

[3] New Jersey report for 1889, p. 86.

[4] Woolman, New Jersey report for 1893, p. 419.

[5] New Jersey report for 1895, p. 89.

Collingswood, Camden County.—The record of the well at this place is as follows:[1]

	Feet.	
Matawan.	0–8	surface sand.
	40–48	marly clay of dark color.
	48–71	sandy clay of lighter color.
	71–96	gray clay.
	96–105	greenish marly clay, with sand and gravel mixed.
	105–125	same, but lighter in color, with large white pebbles.
	125–141	whitish sand.
Raritan.	141–143	white clay.
	143–170	red clay.
	170–184	reddish sand.
	184–196	white clay.
	196	coarse yellowish-white gravel, with large pebbles, and water.

The water horizon is thought to be about 200 feet above the base of the Raritan formation. The coarse materials at 105–125 feet appear to be the basal Matawan beds, which yield water at various wells in the surrounding region, but no water was reported at this horizon in the Collingswood well.

Columbus, Burlington County.—In the deep well of the Rancocas stock farm of Pierre Lorillard the record is as follows:

	Feet.	
Matawan.	0–14	yellowish loams and sands, water bearing.
	14–48	fine sand, water bearing.
	48–72	stiff black sandy clay.
	72–73	fine sand, muddy, and water bearing.
	73–82	stiff black sandy clay.
	82–116	fine sand, water bearing; containing scattering layers of sandstone on clay or shell rock from 3 to 5 inches thick.
	116–117	black sandy clay.
	117–124	fine sand, water bearing.
	124–125	black sandy clay.
	125–128	fine sand, water bearing.
	128–178	dark sandy clay, containing scattered layers of sandstone and shell rock, 3 to 5 inches thick.
Raritan.	178–306	dark sandy clay, changeable to more sandy, with scattering layers of sandstone, shell rock, shells, and wood.
	306–314	fine sand, some gravel, sand crusts and floating brown clay lumps, water.
	314–338	red and white variegated clay.
	338–356	sand and sandrock alternately, from 5 inches to 2 feet thick, with some thin clay veins and considerable wood.
	356–367	?
	367–370	fine sand.
	370–387	coarse sand with small amount of water.
	387–390	coarse gravel.
	390–395	fine sand.
	395–400	white clay.
	400–410	white clay and some coarse gravel.
	410–432	fine white sand.
	432–440	dark sand, full of mica; looks like rotten rock.

[1] New Jersey report for 1892, p. 302.

	Feet.	
Raritan.	440–451	pieces of stone clay.
	451–459	coarse dark sand, mixed with red clay.
	459–479	fine white sand.
	479–483	dark clay.
	483–495	white and red clay.
	495–497	sand.
	497–508	thin white clay.
	508–514	dark clay.
	514–516	thin white clay and a little gravel intermixed.
	516–534	white and red clay mixed.
	534–538	soft light-colored clay.
	538–550	alternations of tough red and white clay.
	550–575	dark clay.
	575–588	sand.
	588–600	thin sand layer on coarse white sand and some streaks of clay.
	600–603	coarse sand and gravel.
	603–619	fine sand.
	619–625	clay.
	625–636	clay with wood.
	636–644	mostly dark clay.
	644–651	sand.
	651–664	white clay.
	664–679	sand.
	679–681	white clay.
	681–690	gravel and coarse sand.
	690–715	red and white clay on sand.

A fair supply of ferruginous water was obtained at 338–356 feet, which rose to within 45 feet of the surface. The well was deepened to 715 feet without finding a further supply, and was then abandoned.

In another well a slightly ferruginous water was obtained at 156 feet in the basal Matawan beds, which flows about 10 gallons a minute.[1]

The deep well was unfortunately abandoned in beds not far above the base of the Raritan formation, so that it did not determine whether the basal beds of this formation are water bearing in this region.

Delair.—The well at this place has a depth of 78 feet and draws an excellent water supply from a gravel bed in the Raritan formation. The following record is given:[2]

Feet.	
0–25	not given.
25–55	dry coarse sand.
55–73	stiff white clay.
73–78	coarse and heavy gravel.

Fellowship, Burlington County.—Well on the farm of J. G. Wilson, a quarter of a mile north of the village, entered a layer of coarse white gravel at a depth of 131 feet, from which a good volume of water rose to within 50 feet of the surface. Under the gravel a bed of marl with fine quicksand was driven through down to 192 feet, and then 8 feet of gravel, to 200 feet. The boring was continued to a depth of 260

[1] New Jersey reports for 1879, pp. 137–139, and for 1892, p. 306.

[2] L. Woolman in New Jersey report for 1895, pp. 70–71.

feet and through a bed of "kaolin" which was troublesome in pumping and at last closed the pipes. The marl bed passed through at 20 feet below the surface is the Lower Marl.[1]

The water at 131 feet is from a mid-Matawan horizon, and the gravel at 200 feet is probably near the base of the Matawan formation.

Fifield's, Great Egg Harbor Bay.—This well is on Ladd's Hummocks in Great Egg Harbor Bay, opposite Longport. It was bored in 1891 to a depth of 397 feet and then abandoned. The following record is given:

Feet.	
0–40	beach sand.
40–50	mud, with some shells.
50–58	coarse gravel.
58–60	white clay.
60–66	coarse gravel and sand.
66–70	dark clay.
70–84	coarse gravel.
84	water.
84–160	gray sand.
160–164	gray sand, with wood.
164–275	gray sand.
275–294	greenish clay.
294–346	coarse sand and fine gravel.
346–397	greenish blue clay; solid.

From 294 feet down, the beds are considered Chesapeake, of which the lower 25 to 50 feet are probably part of the great diatomaceous clay bed. The mud at the depth of 40 feet and the 4 feet of dark clay at 66 to 70 feet were also noted at Atlantic City. The coarse water-bearing gravels from 70 to 84 feet are almost certainly the equivalent of the diatomaceous clay and water-bearing gravel found in the Absecon wells.[2]

The coarse sand and fine gravel at 294–346 feet appears to represent the 328-foot water horizons at Atlantic City and Ocean City, but it was not reported to contain water in the Fifield well.

Freehold, Monmouth County.—Two wells were bored in Freehold in 1889 for the village water supply. The borings were not studied satisfactorily. The first stratum of water-bearing sand was struck at 135 feet. At 172 feet a black clay was found, which was penetrated to 208 feet, but whether it extended to a greater depth is not stated. At 255 feet white sand with fragments of wood was found, and the boring was continued to a depth of 322 feet. The water rose to within 62 feet of the surface. The following record is given:

Feet.	
40	green sand marl.
58	black "marl" or clay, with sand.
96–102	light-gray clay.

[1] New Jersey report for 1879, p. 85.

[2] L. Woolman, in New Jersey report for 1892, pp. 281–282.

Feet.
102–105.....hard layer.
105–107.....green "marl."
108–119.....black and hard material.
114.....seam of gray "marl" with small shells.
120.....black deposit.
127.....layer of fine gravel or coarse sand.
136.....fine sand mixed with blue clay.
148.....water-bearing sand.

The capacity of the well in November, 1889, with a hand pump, was found to be equivalent to a supply of 25 gallons per minute, or 36,000 gallons per day. The water rose to within 26 feet of the surface, when the pumping was discontinued. An analysis of the water made by Prof. F. A. Wilber showed that it contained 8.607 grains of total solids per gallon, comprising:

Analysis of water from well at Freehold, N. J.

	Grains per gallon.
Silica	0.776
Sesquioxides of iron and alumina	0.017
Lime	3.084
Magnesia	0.303
Potash	0.116
Soda	0.349
Sulphuric acid in sulphates	0.245
Chlorine in chlorides	0.321
Total solids determined	5.211
Volatile and undetermined	3.396
Total solids	8.607
Hardness (equivalent to calcium carbonate)	5.479

The water is clear, tasteless, without odor, and neutral with reagents.

The present water supply of the village is from wells about 1½ miles north of the court-house, at a point 100 feet above sea level and 78 feet below the court-house steps. The first well was bored to 210 feet, into what is generally known as the second stratum of water-bearing sand, but no good supply of water was obtained. The second well was bored to 50 feet. The marl extended from the surface to 40 feet, and was underlain by from 8 to 10 feet of coarse sand containing much water. Eight more wells were bored to this horizon, and their total yield is about 250 gallons per minute.[1]

The upper waters found in these wells are in the horizon at the base of the Lower Marl bed, and the "second stratum" is in the Matawan horizon, which yields water at Seabright, Monmouth Beach, Monmouth Park, Matawan, the deeper Red Bank well, and others.

[1]New Jersey report for 1889, p. 84, and for 1890, pp. 64–65.

Gibbsboro, Camden County.—A well 71 feet deep, at the residence of J. Lucas, obtains a water supply from beds between the Limesand and Middle Marl. The record is given by Mr. Woolman in New Jersey report for 1895.[1]

Glassboro, Gloucester County.—The well bored for the New Jersey Packing Company reached a depth of 511 feet, but did not obtain a satisfactory water supply. The record was as follows:

	Feet.	
	0–8	white sand with pebbles.
Chesapeake.	72–80	fine yellow sticky sand.
	80–90	black sandy clay and sand with lignite.
	90–145	dark-blue clay with *Turritella æquistriata*, *Cardita granulata*, and coccoliths.
Upper marl.	145–190	black sand marl with *O. bryani*, foraminifera and large Nodosaria.
Middle marl.	190–240	blue clay, lighter than overlying marl.
Red sand.(?)	240–255	conglomerate with ponderous shells.
Lower marl.	255–335	light-blue clay.(?)
	335–380	green and white sands intermixed. Belemnitella and other shells.
Matawan.	380–395	clay with while quartz and greensand grains, mixed.
	395–410	yellowish sand.
	410–511	micaceous, marly sandy clay.

From a study which Mr. Woolman made of the fragments of shells, and the general relations, it is thought that the Middle Marl was penetrated at 250 feet and the Lower Marl at 350 feet. The Chesapeake was clearly recognized.[2]

The five shallow wells bored at this locality by the West Jersey Railroad Company obtain a supply of water in a sand at from 73 to 80 feet. They have the following record:

Feet.	
0–20	clay.
20–23	sand and gravel.
23–70	yellow quicksand.
70–73	yellow clay.
73–80	sand with water.
80–86	light, fine gravel.
86–88	black sand.
	Green marly clay.

The water is in the basal portion of the Chesapeake formation.

Gloucester.—Several borings have been made at this locality to various depths. A test well was sunk to the rock at the waterworks, which are on Newtown Creek, directly west of the station of the New Jersey Railroad. Its record was as follows:

	Feet.	
Matawan.	0–15	gravel and meadow muck.
	15–35	yellow clay.
	35–42	indigo-blue clay.
	42–54	blue-gray sand, with wood.
	54–75	coarse bluish-white sand and fine gravel.
	75–85	blue and white gravel, with large pebbles. Water.

[1] Pages 66–67.

[2] L. Woolman, New Jersey report for 1893, pp. 407–408.

Raritan.	85–113	alternations of sandy clays and water-bearing sands.
	113–120	reddish clay.
	120–129	white sandy clay.
	129–139	coarse yellowish sand, with small pebbles. Water.
	139–155	alternations of white sands and clays.
	155–169	gravel. Water.
	169–195	red clay.
	195–226	clay.
	226–242	sand, slightly red.
	242–276	clay and water-bearing sand and gravel. Water at 270 feet.
	276–290	greenish micaceous rock clay, evidently decomposed rock.
	290	solid rock.

Eleven 4½-inch wells were sunk a short distance east of the New Jersey Railroad station. Nine of these wells have yielded from 700,000 to 1,000,000 gallons per twenty-four hours. The water rises about a foot above the tide level and pulsates a few inches with each rise and fall of the tide.

Three of the wells are in beds from 67 to 79 feet, four of the wells are in beds from 83 to 96 feet, and three of the wells are in beds from 149 to 162 feet. One well is at 270 feet.

There are six 3-inch wells at the Gloucester Gingham Works, near the Delaware River, about half a mile southwest of the waterworks well. They have depths of 65 and 102 feet, and each well yields about 100 gallons a minute on pumping.[1]

Great Sedge Island,[2] *Barnegat Bay.*—This island is near to and north of Barnegat Inlet. The well was bored in 1892 to a depth of 320 feet with a 4½-inch bore. The yield is 10 gallons per minute. The record is as follows:

Feet.	
0–2	sedge.
2–5	blue mud.
5–36	white sand with a 1-foot hard crust in middle and shells below.
36–40	sand and marly clay.
40–45	marly green clay, very tough, with gravel.
45–50	green marl or clay, with small shells.
50–57	white sand.
57–58	ginger-colored clay, with bits of wood.
58–77	gray clay.
77–80	green clay.
80–90	gray and black sand.
90–94	gray clay and rotten wood.
94–100	chocolate-colored clay.
100–120	gray and black sand.
120–150	brown and gray clay, with small quartz fragments.
150–151	hard sand crust of white sand.
151–160	white sand, coarse gravel, and rotten wood; water at rate of 1 gallon per minute at 158 feet.
160–180	fine white sand and many flecks like mica; water, 2 gallons per minute at 170 feet.

[1] L. Woolman, New Jersey report for 1893, pp. 404–406.

[2] L. Woolman in New Jersey report for 1892, pp. 290–293.

Feet.
180–188.....black mud, white and black sand, mica, and vermilion sand.
188–200.....fine and coarse white and black sand and mica.
200–225.....fine white and black sand and very coarse white quartz.
225–244.....coarse sands and fine gravel.
244–245.....gray clay, tough.
245–252.....coarse sand and fine gravel; water, 2 gallons per minute.
252–260.....gray clayey marl, medium gravel and quartz, and rotten stone.
260–270.....brownish-gray clay and bits of rotten wood.
270–280.....fine and coarse sands, some like opals; bits of wood.
280–290.....hard sandy brown clay.
290–293.....hard muddy brown clay.
293–320.....coarse and fine white and gray sand and some mica.

The small flows of water at 157 and 175 feet appear to represent the horizons of 525–550 feet at Atlantic City, on the calculation of the dip at 25 feet per mile. The small flow at 252 feet probably represents some water-bearing sands in the lower part of the same clay bed, a horizon not reported at Atlantic City, but noticed at Ocean City, and believed to be stratigraphically the same as that supplying the wells at Pleasant Mills. The horizon at 300–320 feet is equivalent to that at the depth of 700 feet at Atlantic City, being the first water-bearing sands fairly below and out of the diatom clay bed. On pumping this well for an hour it supplied 100 gallons without perceptible lowering of the water level. The water will rise 9 feet above the level of the bay.

Two analyses of the water have been made at a year's interval. Both are said to be fairly accordant as to the relative amounts of the ingredients, but the total amount of mineral matter increased from 4.633 grains per gallon to 8.694 grains. The later analysis was made by Dr. Henry Leffman, and is as follows:

Analysis of water from well at Great Sedge Island, New Jersey.

	Grains per gallon.
Calcium carbonate	0.937
Silica	1.624
Potassium sulphate	0.691
Sodium sulphate	0.274
Sodium chloride	0.466
Sodium carbonate	0.266
Magnesium	0.207
Iron	0.168
Total	4.633
Nitrogen as nitrites	None.
Nitrogen as nitrates	Trace.
Nitrogen as ammonium	0.0005
Nitrogen as permanganates	0.0034

Greenwich, Cumberland County.—Mr. Job Bacon bored a well 690 feet deep at this locality, but found no water.

The following partial record of this boring was given by Mr. Woolman, and is based on samples preserved in the State Museum at Trenton.[1]

	Feet.	
Middle marl.	0–360	no sample.
	360–400	sandy clay.
	400–450	clay, containing Textularia and other foraminifera.
	450–525	micaceous, sandy clay.
	525–550	greensand, with Gryphea and foraminifera.
	550–600	green and white sand, with Textularia and coccoliths.
Lower marl.	600–625	greenish sand, coccoliths, Textularia, and greensand grains.
	625–642	greensand, with Gryphea shell.
	642–650	greensand.
	650–690	black, micaceous, sandy clay.
	690	sandy clay, somewhat lighter in color; contains coccoliths.

If the boring of this well was properly managed and no waters were passed by oversight, it probably demonstrates the absence of the Red bank and Lower Marl water horizons in western Cumberland County.

Harrisonville, Gloucester County.—This well is a small boring on the farm of Mr. Joseph Cheeseman, a mile east of the village, at an elevation of 120 feet. Mr. Woolman gives the following record:

Feet.	
0–18	superficial gravel, with streaks of yellow clay at bottom.
18–55	bluish clay.
55–80	"bluish green, muddy, marly clay."
80–90?	white quartzose sand, with greensand grains.
90–118	alternations of lime sand and lime rock, composed largely of bryozoans and foraminifera.
118–122	quartzose sand, with water.

The beds from 37 to 80 feet are regarded as Chesapeake. The water-bearing sand is in the middle of the Rancocas formation, between the lime sands and the Middle Marl bed.[2]

Harrisia,[3] *Burlington County.*—A well was sunk at this place in 1866 to a depth of 306 feet, with a bore of 6 inches. Gravel and blue and gray clay were passed through to 180 feet, where mud, sand, and what appeared to be decayed wood were encountered. Farther down a gravel bed was penetrated and water flowed to a level 8 feet above the surface. The well was unfortunately deepened to 375 feet, where, without increase in volume, the water became strongly ferruginous and the well was abandoned.

The record of this well is as follows:

Feet.	
0–77	surface sand.
77–85	sand.
85–98	blue mud.
98–108	clay, with pyrite.
108–124	marly mud.

[1] New Jersey report for 1894, p. 131.

[2] Loc. cit., pp. 195–196.

[3] L. Woolman, in New Jersey report for 1892, pp. 288–289.

Feet.	
124–131	strata with old wood.
131–146	mud and shells.
146–196	hard rock layer.
196–231	sand and water.
231–245	dark slushy sand.
245–261	yellow sand.
261–306	coarse red sand.
306–318	dark sand.
318–331	white clay.
331–368	green marl, ferruginous water.
368–375	slate stone. (?)

The beds from 85 to 146 feet are regarded by Mr. Woolman as the representatives of the great Chesapeake diatom clays. Those from 146 to 231 feet are regarded as the base of the diatomaceous series, and the nondiatomaceous beds below are correlated with the water horizon of 700 to 720 feet at Atlantic City. The beds from 231 to 375 are thought to represent the Perna marl, brown sands, chocolate clay, and green Shiloh marl of the Atlantic City wells. The record is considered similar to that of the Winslow well, and it is suggested that if drilling had been continued through the marl or marly clay to an additional distance of 75 to 80 feet there would have been found the same water horizon that supplies the deep well at Winslow, and which is probably the equivalent of that at 960 feet at Atlantic City. This would indicate a dip of 25 feet per mile. Some large oyster shells were taken out of this well, but the species were not identified.[1]

Hartford,[2] *Burlington County.*—The well is on the farm of S. C. Roberts, about 1¼ miles north of Hartford, at an elevation of 70 feet above tide. Water was found at 161–167 feet, which rose nearly to the surface, but it was filled with fine sand. The well was deepened to 187 feet, but was abandoned just above the water horizon that occurs at the base of the Matawan formation. The record is as follows:

	Feet.	
	0–39	yellow sand. Laminated sands.
Clay marls.	39–46	micaceous, sandy clay; light chocolate color.
	46–100	black mud, or clay marl.
	100–117	green marl.
	117–157	clay marl.
	157–163	sandy clay.
	163–168	sand; fine, whitish gray.
	168–175	sand; darker gray.
Lower sands of clay marls.	175–181	coarse white sand and gravel, with some mica.
	181–187	slightly coarser sand, bluish gray in color.

Hightstown, Mercer County.—The record of the well at this place was supplied by Messrs. I. S. Cassin & Son, of Philadelphia, who bored it:

Feet.	
0–4	top soil.
4–39	black-clay mud.
39–66	fine white sand (yielding 30 gallons a minute).

[1] Woolman, in New Jersey report for 1892, pp. 288–289.

[2] Loc. cit., pp. 304–305.

Feet.	
66–75	blue clay.
75–172	coarse white sand with iron water.
172–180	white clay.
180–201	coarse white sand lying on white clay.

The well yields 70 gallons per minute of very satisfactory water. Dr. Henry Leffman has kindly sent the information that it contains three parts per million of iron, a small amount of carbonate of lime, and very little chlorides.

According to Mr. Woolman[1] there are three wells at the Peddie Institute. One of these has a depth of 76 feet, the others which were bored in 1894 have a depth of 428 and 500 feet, respectively. The deeper boring reached crystalline rocks at a depth of about 482 feet, and the 428-foot well found a water supply in coarse gravels and sands in the basal beds of the Raritan formation. It is stated that some coarse sand and gravel were found at a depth of about 200 feet—near the base of the Matawan formation—and between the depth of 240 and 255 feet, and still coarser gravel and sand from 385 to 435 feet. Lignite is reported at 175 feet. The crystalline rock yielded much white quartz, some mica, and a few small garnets. Four additional 6-inch wells have recently been sunk to depths averaging 200 feet.

Holmdel, Monmouth County.—The well on the Gidean & Daly stock farm is 601 feet deep, and obtains about 12 gallons a minute from a horizon low in the Raritan formation, probably the same as the Keyport and Atlantic Highlands wells.

Jamesburg, Middlesex County.—At the State Reform School a well has been bored to a depth of 481 feet. For the first 285 feet the diameter was 8 inches, the remainder 6 inches. The record is as follows:

Feet.	
0–9	yellow sand.
9–13	yellow sand and gravel.
13–43	black clay, containing very little sand.
43–52	dark sand, containing a little clay; 6 inches of sand rock at base.
52–64	dark and greenish sand, containing a little clay.
64–65½	black clay.
65½–70½	dark and greenish sand, containing some clay, rock, and thin sand crusts; 6-inch layer of sandstone at base.
70½–92½	black clay, with a few thin, sandy layers.
92½–93½	hard dry whitish clay.
93½–108½	black clay, with thin layers of white sand.
108½–110	stiff black sand.
110–133½	fine beach sand.
133½–134½	black clay.
134½–147	fine sand.
147–150½	black sandy clay, with thin layers.
150½–164	fine sand.
164–183	brown clay; very compact and solid above, more sandy below.
183–191½	fine sand.

[1] New Jersey report for 1894, pp. 200–201.

Feet.	
191½–192	dark clay.
192–203	coarse sand, with 3 inches of bluish clay at base.
203–204	sharp sand; water.
204–204¾	fine bluish clay.
204¾–217½	sharp clean sand; water-bearing; has 3 inches of wood at base.
217½–218¼	coarse sand and fine gravel, with lumps of white clay.
218¼–224	sharp sand, with lumps of bluish clay and a streak of iron pyrites crust.
224–231	fine beach sand.
231–233½	sharp sand; coarser, with 3 inches whitish clay at base.
233½–236	sharp sand, with scattering, whitish clay lumps.
236–237	coarse sand and fine gravel, with white clay lumps.
237–238	fine lively sand.
238–240	coarse sand and fine gravel, with white clay lumps and 3 inches of whitish clay at bottom.
240–241	sharp sand, with 3 inches of whitish clay below.
241–251	fine beach sand.
251–256	coarse sand.
256–316	dark-blue clay.
316–333	sandstone.
333–341	dark-blue clay.
341–345	quicksand.
345–365	very fine sand.
365–383	sand not so fine as the last.
383–395	quicksand.
395–401	blue clay.
401–405	coarse sand and wood.
405–409	blue clay and pyrites.
409–424	coarse sand.
424–428	very coarse sand.
428–431	fine sand.
431–435	blue clay.
435–438	quicksand.
438–443	red clay, sand, and pyrites.
443–448	quicksand.
448–452	fine sand and wood.
452–455	fine, white sand.
455–456	white clay.
456–462	coarse sand.
462–466	white sand.
466–472	coarse sand and gravel.
472–481	coarse sand, white clay, and gravel.

Owing to an accident, the well was bored no farther, and as the water which it contained was somewhat ferruginous it was abandoned.[1] The first 60 feet are in the lower portion of the Matawan formation, and the remainder is in the Raritan formation. Probably within the next 100 feet the basal Raritan beds would have been reached and possibly a supply of water found in them.

Key East, Monmouth County.—Just north of Shark River are two artesian wells, both of which yield an abundant supply of pure water,

[1] New Jersey report for 1880, pp. 166–168.

The one at the Avon Hotel flows into the building and is distributed by pipes. It has a 3-inch bore, and was found to yield 52 gallons per minute.[1]

Keyport, Monmouth County.—In this well water was found at 242 feet. The record was as follows:[2]

	Feet.	
	0–16	sand and gravel.
Matawan	16–21	blue clay.
Raritan	21–27	fine sand.
	27–44	white clay.
	44–64	gray quicksand.
	64–86	white clay.
	86–101	fine sand.
	101–138	blue and white clays.
	138–153	fine sand.
	153–190	red and white clay.
	190–242	sand and water.

The water in the well is at a horizon about the middle of the Raritan formation, apparently the same as the one which furnishes water to the 489-foot boring at Atlantic Highlands.

Lake Como.—Two or more wells have been bored at this place. One has a depth of 535 feet and obtains a water supply from below the Lower Marl bed. It is stated that the Miocene clay or "rotten stone" extends from 40 to 120 feet.[3]

Lakewood, Ocean County.—The well for the Laurel Hotel was bored to a depth of 475 feet. The mouth is 50 feet above tide level, and the water rises about 17 feet above the surface. The flow was $3\frac{1}{2}$ gallons per minute, and by pumping, 12 gallons per minute have been obtained. The water is clear and sparkling and free from organic matter.[4]

Analysis of water in well at Lakewood, N. J.[4]

	Grains per gallon.
Sodium chloride	0.478
Sodium carbonate	0.968
Potassium carbonate	0.624
Potassium sulphate	0.898
Calcium bicarbonate	3.446
Magnesium bicarbonate	0.915
Silica	1.499
Oxides of iron and alumina	0.046
Total	8.874
Hardness equivalent to calcium carbonate	3.52

[1] New Jersey report for 1885, p. 130.
[2] L. Woolman, in New Jersey report for 1893, p. 414.
[3] L. Woolman, in New Jersey report for 1895, p. 75.
[4] New Jersey report for 1884, p. 125.

The water horizon is apparently at the base of the Lower Marl bed, and the same as that of Spring Lake, Asbury Park (at 383 feet), Ocean Beach, Ocean Grove, Red Bank (at 80-90 feet), and others.

Longport.—The well at Longport was sunk in 1895. Its depth is 803 feet, diameter 6 inches, and flow 180 gallons per minute. The water horizon is the one which occurs at about the same depth at Atlantic City, where it supplies many wells. The record is given by Mr. Woolman in the New Jersey report for 1895.[1]

Magnolia Station, Camden County.—This place is 8 miles east of Camden on the Reading route to Atlantic City. The following record was reported by Mr. Woolman:[2]

Feet.	
0–4	yellow clay and sand.
4–36	blue marl.
36–41	coarse, white sand, with water.
41–56	coarse, white gravel, with water.
56–59	hard stratum with shells.
59–74	black sand with marl grains.
74–84	gray sand and shells cemented together.
84–91	very dark gray sand with plenty of water.

The horizon is thought to be Lower Marl.

Mantoloking, Ocean County.—The first well at this place obtained a fair supply of water at 175 feet, which rose 35 feet above the surface. The horizon is at the base of the great diatom bed of the Chesapeake formation, and probably the same as that at 700 feet at Atlantic City (see section 5, Pl. III). A deeper boring was made to 790 feet, which reaches the Lower Marl Horizon, and another boring to a depth of 922 feet obtains a supply from sands in the Matawan formation. No definite data have been obtained regarding the results of the deeper borings, but I have understood that they are satisfactory.

Maple Shade, Burlington County.—This place is 2¾ miles south of west from Moorestown Station on the Burlington County Railroad. Water was found at about 95, 125, 280, and 370 feet. The following record is given:[3]

	Feet.	
	0–5	surface gravel.
Matawan.	5–13	yellow clay.
	13–17	ferriferous clay and ironstone crust.
	17–20	black sand, containing ammonites, scaphites, baculites, etc.
	20–64	black clay.
	64–97	gray sands, fine above, coarse and pebbly at bottom; water.
	97–103	greensand marl.
	103–130	fine gray sand and coarse gravel; water.

[1] Pages 83–85.

[2] New Jersey report for 1894, p. 197.

[3] L. Woolman in New Jersey report for 1893, pp. 410–411.

	Feet.	
Raritan.	130–230	white clay.
	230–240	red clay.
	240–260	alternations of sand and clay, in part reddish.
	260–300	white sand; water.
	300–315	white sand, fine, with streaks of clay.
	315–330	white sand, coarse.
	330–350	white sand, medium coarse.
	350–370	white gravel, coarser below.
	370–375	white gravel, very coarse, with large pebbles and bowlders.

This well has thrown important light on the water horizons for the western corner of Burlington County. The waters are in the mid-Matawan beds at 80 feet, in the basal Matawan beds at 125 feet, in the mid-Potomac beds at 280 feet, and apparently in the basal Potomac beds at 370 feet. Excepting the deepest, these waters are also found in the Moorestown well, and they also occur in the other wells, as shown in section 2, Pl. III.

Marlton region, Burlington County.—There are many wells in the vicinity of Marlton, and the greater number of them draw an abundant water supply from the Redbank horizon. They are described in considerable detail in the New Jersey reports, and especially by Mr. Woolman in the report for 1894, where their relations are also shown in a detailed cross section. The following notes are condensed from these reports:

A bored well at the house of Mr. Joseph Evans, 1½ miles south of Marlton, has a depth of 155 feet and yields 20 gallons per minute. The water rises to within 40 feet of the surface and is of good quality, and from the fossils found it is judged to come from the sand bed underlying the Lower Marl bed. The well was first sunk to a depth of 380 feet without getting water, as it was driven through this sand layer without proper testing and into beds of upper Matawan clay marls, which have usually failed to yield a supply of good water.[1]

A well was bored in 1884 in Marlton for C. B. Chew. Its depth is 86 feet and its diameter 5⅝ inches. It is sunk through the Middle Marl bed into a sandy layer of the Redbank formation. The following record is given:

Feet.	
0–20	loam and gravel.
20–26	black marl.
26–46	greensand marl.
46–59	chocolate marl, with a thin, strong crust near its middle and at its base.
59–83	hard black sand, which gradually becomes white below.
83–86	hard rock or bowlder.

The water rose to within 24 feet of the surface. Quality is good. Temperature, 52½°.[1]

Two miles west of Marlton, on the farm of Mr. Ellwood Evans, there are several wells with depths of about 30 feet, which obtain water supplies from the Redbank sands.

[1] New Jersey report for 1888, p. 77.

At the residence of Mr. Henry Brick there is a well 86 feet deep, and at the residence of Mr. Samuel Lippencott one 105 feet deep, which reach the Redbank sands.

On the farm of S. J. Eves, three-fourths of a mile south of Marlton, water was obtained at a depth of 114 feet; on the farm of J. W. Barr, 2 miles east of Marlton, at 68 feet; on the farm of Josiah Ballenger, 3 miles east-northeast of Marlton, at 76 feet; on the farm of Amos Evans, near Marlton, at 83 feet; on the farm of W. J. Evans, at 121 feet; at the residence of B. S. Lippencott, at 105 feet; at Levi Ballenger's, at 82 feet; on the farm of Joseph Evans, 2 miles east-southeast of Marlton, at 98 feet; and on the Davis Rogers farm, 3 miles east of Marlton, at 102 feet.

On the farm of Mr. Benjamin Cooper, 2 miles east of Marlton, there is a well which yields a large supply of "exceptionally good water." The following record is given:

Feet.	
0–28	top soil.
28–31	ironstone.
31–32	greensand marl.
32–33	ironstone.
33–52	greensand marl, black and chocolate marl.
52–66	clean black sand, with white specks.
66–70	open coarse sand, with belemnites.

The well is 6 inches in diameter. The water rose to within 5 feet 7 inches of the surface; after pumping, it rose to 3 feet 10 inches from the surface. The temperature is 54°.[1]

It was suggested that this water was from over the Middle Marl, but it is much more probable that it is from the Redbank horizon, which furnishes water to other wells in the region.

A well 3 miles southwest of Marlton, on property of Mrs. John Wilkins, has a depth of 316 feet, and yields a satisfactory supply of water on pumping.[2]

A well bored in 1895 at the residence of H. B. Dunphey, in Marlton, is reported to have the following record:[3]

Feet.	
0–18	soil, yellow loam and gravel.
18–32	black marl.
32–41	green marl.
41–70	chocolate marl, with probable *Gryphea*.
70–82	gray sand, irony water.
82–122	black sand.
122–194	black clay.
194–200	fine white sand, with good water to within 28 feet of surface.

The horizon is low in the Matawan formation. The irony water horizon at 82 feet is just below the Lower Marl, which supplies several wells in the neighborhood.

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[1] New Jersey report for 1884, pp. 126–127.

[2] New Jersey report for 1885, p. 133, and for 1894, pp. 207–208.

[3] L. Woolman in New Jersey report for 1895, p. 69.

Matawan, Monmouth County.—A boring at this place passed through about 100 feet of bluish clay with marl grains, and then into fine sand with an abundance of water. Unfortunately, this water carried too much fine sand in suspension and was not available. The boring was continued in the sand to 264 feet without finding gravel or sand coarse enough to keep the lower end of the pipe clean, and the work was suspended.[1]

The water at 100 feet is in the mid-Matawan horizon, which is satisfactory in wells at Redbank, Monmouth Park, Monmouth Beach, Seabright, etc. With proper treatment, this well could no doubt have been made a success at 100 feet, or it could have been deepened to the mid-Raritan or basal Raritan horizons with good prospects for finding other water-bearing beds.

Mays Landing, Atlantic County.—Two wells here furnished a moderate supply of water through a 2½-inch tube. They are at an elevation of about 8 feet above high water. The record was as follows:

Feet.	
0–20	coarse gravel.
20–60	quicksand.
60–90	beach sand, with clay layers, perhaps 1 foot thick.
90–96	fine black or blue tough clay underlain by some water.
96–136	glass sand and no clay.
136–150	Sand, with no increase in water.

The supply from the first well was 12 gallons per minute at first, but it finally decreased to 7 gallons. The second well was sunk to 130 feet, and yields 3 to 4 gallons per minute. The temperature of the water is 57°. The solid matter in the water at 110° was 7.69 grains. It contains only a trace of iron and is slightly alkaline.[2]

A 6-inch well was sunk in 1891 to a depth of 176 feet which yielded 25 gallons per minute. The temperature of the water was 56°.

The section, according to Mr. Woolman, is as follows:

Feet.	
0–22	gray sand, granular.
22–54	gray sand, finer.
54–72	bluish-gray, clayey sand, considerable wood.
72–98	bluish clay, diatomaceous.
98–112	clayey sand, diatomaceous.
112–116	sand, bluish when wet.
116–125	alternations of sand and diatomaceous clay.
125–132	sand, water.
132–142	sandy clay, diatomaceous.
142–149	bluish clay, diatomaceous.
149–151	sand, water.
151–165	alternations of sand and diatomaceous clay.
165–172	blue clay, richly diatomaceous.
172–176	sand, water bearing.

The clays below 100 feet contain Miocene diatoms. The water horizon of the 130-foot and 176-foot wells at this place is identical with that

[1] New Jersey report for 1885, p. 124.
[2] New Jersey report for 1884, pp. 130–131.

at Weymouth at a depth of 40 feet. The distance between the two places is 5 miles, which is nearly directly across the line of strike. This horizon is thought to be the same as that in the Atlantic City wells at 525 feet, in the central portion of the diatom clays.[1]

Mechesatankin Creek, Atlantic County.—A well bored for C. G. Rockwood about 4 miles from Atsion and 5 or 6 miles northwest of Pleasant Mills passed through 158 feet of sandy clays and sand but did not obtain a satisfactory supply of water.[2]

Medford, Burlington County.—A boring to 70 feet yielded 20 gallons a minute on pumping. It was deepened to 183 feet in 1892. The following record is given:

Feet.	
0–15	sand and earth.
15–45	marl.
60–64	shelly layer.
64–70	coarse gray sand.
70–85	green marl.
85–110	black quicksand.
110–122	marl.
122–157	quicksand.
157–170	marl.
170–175	sand, some clay.
175–177	sand, some clay, and good water.
177–183	sand.

The water is stated to be first class and to rise within 17 feet of the surface, which is 78 feet above tide level.[3]

A well on the farm of Mr. J. S. Mills, about $1\frac{3}{4}$ miles northeast of Medford Station, had the following record:

Feet.	
0–2	soil.
2–5	clay, yellow sand.
5–15	fine gray sand with greensand grains.
15–23	coarse gray sand with greensand grains.
30	olive-colored marl.
35	dark-green marl, thought to be bottom of Upper Marl bed.
50	limesand with Foraminifera, Bryozoa, etc.
70	greensand marl with Gryphea and Terebratula, Middle Marl bed.
76	pure greensand, dark color.
80	pure greensand, light color.
91	pure greensand, dark color.
104	pure greensand, chocolate color.
120	pure greensand, dark green.
124	gray sand with greensand grains, Exogyra, and Belemnites.
126	gray sand and water.

The elevation of the boring is 63 feet. From a comparison of the records it appears that the 70-foot horizon in the first well is the same as that at 126 feet in the other[4] or in the Redbank beds. The water at a depth of 183 feet in the well at Medford is probably in the horizon at the base of the Lower Marl bed.

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[1] New Jersey report for 1892, pp. 287–288.

[2] New Jersey report for 1885, p. 138.

[3] New Jersey reports for 1889, p. 89, and for 1892, p. 302.

[4] Woolman, in New Jersey report for 1893, pp. 417–418.

Millville, Cumberland County.—The well at this place is at an elevation of 10 feet above tide, and the water flows from it. The following record is given:

Feet.	
0–120	sand, more or less coarse, but always sharp.
120–150	thick blue clay, very hard to penetrate.
150–160	fine white sand.

This water is regarded by Mr. Woolman as equivalent to the 525-foot horizon at Atlantic City.[1]

A well in Medford, at the residence of Joseph Hinchman, obtains water from a depth of 140 feet. The following record is given:[2]

Feet.	
0–12	soil and gravel.
12–17	clay (Miocene?).
17–52	marl (Upper Marl).
52–57	blue clay.
57–73	lime sand.
73–150	alternations of sands, marls, gravels, etc., with Belemnites near base.

Water was found at 17, 90, and 140 feet.

Monmouth Beach, Monmouth County.—Nothing further was learned regarding the well at this place than its depth (380 feet) and that it was satisfactory. The horizon from which the water is obtained is in the Matawan formation, in beds about 100 feet above its base, the same as that at Monmouth Park, the deeper wells at Redbank and Seabright, and the 108-foot well at Atlantic Highlands.

Monmouth Park, Monmouth County.—The three wells here are 385 feet deep and 4 inches in diameter. The water flows 4 feet above the surface, which is 10 feet above tide level, and yields 75 gallons a minute on pumping. The horizon is the same as that in the Monmouth Beach well. It is reported that a trial boring was made to a depth of 900 feet to rock which was thought to be the granite or "bed rock."

Moorestown, Burlington County.—The well at this place is on the Pensauken, 1¼ miles south of the village, and at an elevation of 10 feet above tide. It was bored for the Moorestown Water Company, and has a depth of 457 feet. Water that flowed above the surface in considerable quantity was found at 118, 136, 320, and 338 feet. The record was as follows:

	Feet.	
	0–6	mud and muck.
Matawan.	6–12	white quicksand.
	12–93	blue clay or black mud.
	93–118	coarse sand, almost gravel, blue gray in color. Water.
	118–121	white clay.
	121–129	sand, some water.
	129–131	white clay.
	131–162	coarse sand and flinty gravel, blue gray in color. Water.

[1] New Jersey report for 1890, pp. 267, 273.

[2] New Jersey report for 1894, p. 218.

	Feet.	
Raritan.	162–212	white and red clays.
	212–250	fine white sand and large gravel, yellowish in color. Water.
	250–310	sand, coarse gravel, and clay mixed.
	310–320	white clay.
	320–344	sand and gravel, blue gray in color. Water.
	344–350	blue clay.
	350–358	white clay.
	358–418	red clay.
	418–451	red clay and quicksand.
	451–457	red clay and cobblestone. No water.

The tubing was withdrawn to 136 feet and the well finished at 150 feet in the gravels of the base of the Matawan formation. This water was also noted in the Maple Shade and other wells. It is suggested that if the boring had been continued a short distance farther the water-bearing coarse beds at the base of the Raritan formation would have been reached and a further supply of water found in them.[1]

Mount Ephraim, Camden County.—A well was bored near this place for Mr. Joseph Warrington to a depth of 130 feet. The following record is given:

Feet.	
0–10	clay.
10–110	marl or blue mud.
110–130	clay, gravel, and sand mixed.

Sharks' teeth were found at from 116 to 129 feet, and magnolia roots at 130 feet.

Three-fourths of a mile from this well there is another, which furnishes water from a depth of 80 feet.[2]

The water in the Warrington well is apparently from the basal Matawan beds which supply water at Woodbury, Wenonah, Sewell, and other places, as shown on section 4, Pl. III.

Mount Holly, Burlington County.—The well at the Dunlap Carpet Works was bored to a depth of 675 feet, and although several horizons of water were found, none were of sufficient purity for use in dyeing yarns. The record was as follows:[3]

	Feet.	
	0–43	dark muck.
Matawan.	43–46	sand and gravel, with small flow of water.
	46–107	dark muck.
	107–111	fine sand.
	111–245	dark muck or clay.
	245–250	sand, gray.
	250–262	dark sandy clay.
Raritan.	262–273	red clay.
	273–274	white clay.
	274–294	brown sandy clay.

[1] Woolman, in New Jersey report for 1893, pp. 413–414.

[2] New Jersey report for 1879, p. 148.

[3] New Jersey report for 1892, pp. 303–304.

	Feet.	
Raritan.	294–296	white clay.
	296–365	light sandy clay.
	365–367	red clay.
	367–410	light sandy clay.
	410–412	red clay.
	412–430	brown (?) clay.
	430–436	red clay.
	436–442	light sandy clay.
	442–457	fine sand, gray; small flow of water.
	457–509	light sand and clay and sand.
	509–546	light sandy clay.
	546–560	red clay.
	560–608	sandy clay and fine sand.
	608–611	yellow clay.
	611–620	brown clay.
	620–660	red clay.
	660–667	fine sand and a little brown clay mixed; a small flow of water.
	667–675	fine and coarse sand and some gravel.

As this well penetrated over 400 feet of the Raritan formation, it was no doubt near the basal beds when boring was discontinued. It is probable that these basal beds would have furnished a water supply, but until a well is sunk to the bed rock in this region no definite prediction can be made.

Mullica Hill, Gloucester County.—The well is on the Borton farm, $1\frac{3}{4}$ miles due southwest of Mullica Hill, at an elevation of 100 feet. The depth is 102 feet and the diameter $1\frac{1}{2}$ inches. The water rises to within 35 feet of the top. It is irony, and in ample supply for farm use. The water is in a gray sand, which is thought by Mr. Woolman to be the equivalent of the red sand below the middle marl, the same horizon as at Quinton and at Woodstown.

Ocean Beach, Monmouth County.—The well is on the property of Mr. E. C. Jayne, at the corner of Ocean and Sixth avenues, about 400 feet from the ocean. It has a depth of 485 feet and a bore of 3 inches. The flow at the surface was 25 gallons per minute, or 36,000 gallons per day. The water rises to 34 feet above the ground, or about 50 feet above low-tide level. It is clear and colorless, but is a little hard and contains a trace of iron. The record was similar to the records of Ocean Grove and Asbury Park, and the water is found in a sandy layer under the Lower Marl bed.[1]

A second well at Ocean Beach, between Second and Third avenues, and one block from the ocean, only a few hundred feet from the first well, was bored in 1885. It is 480 feet deep, 3 inches in bore, and flows 50 gallons per minute at the surface.[2]

Ocean City, Cape May County.—In the summer of 1892 a well was

[1] New Jersey report for 1884, pp. 123–124.

[2] New Jersey report for 1885, p. 131.

bored to a depth of 760 feet for the Ocean City waterworks. The following record is by Mr. L. Woolman:

Feet.	
0–30	beach sands, with recent shells at the base.
30–115	sand.
115–175	sand, with thin clay seams.
175–185	sandy clay.
185–278	fine gravel and sand, with streaks of clay.
278–318	bluish, sandy clay, solid.
318–334	sand, with water.
334–366	bluish, sandy clay, with small shells.
366–371	sand, with water.
371–400	gray sand, with small shells.
400–512	bluish, sandy clay, diatomaceous.
512–528	gray sand, with water.
528–600	bluish, sandy clay, diatomaceous.
600–655	brownish, sandy clay, hard, with shells and diatoms.
655–660	brownish clay, with crusts.
660–680	gray sand, with many small shells in considerable variety, some diatoms.
680–685	clayey sands, with diatoms.
685–690	sand, with wood, shells, and water.
690–700	coarse gravel, sand, shell, and thin clay seams.

From 400 to 685 feet is the great diatomaceous clay bed, which occurs at from 380 to 680 feet at Atlantic City, but it is here somewhat more sandy. The beds from 278 to 371 feet in the Ocean City well contain more clay than at Atlantic City, where the corresponding interval shows mostly sand. The gravels which terminate at 278 feet terminate at 265 feet at Atlantic City. As at Atlantic City, the beds here from 695 to 760 feet are nondiatomaceous. The following comparison of the water horizons is given:

	Atlantic City.	Ocean City.
	Feet.	*Feet.*
In sands above the diatomaceous clays	270–328	334 and 366
In central sands of diatomaceous clays	525	512 and 528
In lower sands of diatomaceous clays	Not known.	685
In sands below diatomaceous clays	700–720	720

Although this well is 10½ miles from Atlantic City, it is only about one-half mile southeast of the line of strike of the beds; hence the close correspondence of the records. The water from the Ocean City well was taken at 720 feet.[1]

Another well was bored in 1893 to a depth of 800 feet, where, in a coarse brown sand, water was found which rises in the casing 15 feet above the surface and flows 140 gallons a minute. It is the same horizon as that at the Knickerbocker Ice Works in Atlantic City.

[1] L. Woolman, in New Jersey report for 1892, pp. 279–281.

Additional data for the record are as follows:

Feet.	
700–716	fine gravel, sand, shell, and thin clay seams.
716–736	alternations of clay, gravel, sand, and shell, and thin clay seams. Water at 720 feet, 25 gallons per minute.
736–755	brownish sand with wood.
755–800	coarse brown sand and water.[2]

Ocean Grove, Monmouth County.—The first well was 6 inches in diameter and yielded a supply of 60,000 or 70,000 gallons daily of sparkling, pure, and wholesome water. The following beds were penetrated:

Feet.	
18	sand and gravelly earth.
30	black clay for 12 feet.
69	black clay and grains of greensand, 10 feet; black clay, 34 feet.
82	lighter colored clay and grains of greensand.
92	light-colored clay, 4 feet, and pure greensand grains.
102	light-colored clay, 2 feet, and fine-grained stone, light colored.
110	clay, light colored and plastic.
132	clay, ash colored and flaky.
146	clay, ash colored with fragments of light-colored stone.
155	light ash-colored clay.
177	darker ash-colored clay.
185	black clay, coarse and free from mica.
195	black clay, micaceous.
210	black clay, micaceous, fine.
229	black clay, micaceous, fine.
241	black clay, micaceous, coarse and rough.
268	sand, compact and greenish.
280	broken shells and fragments of *Terebratula harlani*=Middle Marl.
300	grains of greensand and few shells.
303	dark greenish clay, compact.
322	dark greenish clay, sandy.
337	dark greenish clay, sandy.
360	greensand and calcareous earth.
382	greensand grains, open sand, and *Belemnitella mucronata.*
397	petrified stratum, 1 foot thick.
404	clay for the last 6 feet.
420	open sand for the last 16 feet.

But little water was found until a depth of 382 feet was attained, when the water rose to a height of 18 or 20 feet above the surface. At this depth a 4-inch pipe was placed in the well so as to hinder loss by leakage and to shut out surface water, which might otherwise find its way down the outside of the pipe. Then the drilling was resumed and the well deepened 38 feet. The flow was increased in quantity and the water rose to a height of 28 feet above the surface. The temperature of the water was 60°. It is clear and colorless, and contains 8.5 cubic inches of carbonic acid to the gallon. An analysis of the water made

[2] L. Woolman, in New Jersey report for 1893, pp. 398–399.

by Prof. F. A. Wilber shows it to contain 8.19 grains of solid matter to the gallon, of which the following are the component parts:

Analysis of water of artesian well at Ocean Grove, N. J.

	Grains per gallon.
Sodium	0.274
Potassium	.519
Calcium	1.520
Magnesium	.286
Silica	.682
Alumina and oxide of iron	.402
Chlorine	.449
Sulphuric acid (SO_3)	1.540
Oxygen in calcium sulphate	.205
Oxygen in calcium carbonate	.404
Oxygen in magnesium carbonate	.186
Oxygen in potassium sulphate	.104
Carbonic acid in calcium carbonate	1.115
Carbonic acid in magnesium carbonate	.512
Total solids found	8.189
These constituents are probably combined as—	
Sodium chloride	.706
Potassium sulphate	1.138
Sulphate of lime	1.728
Carbonate of lime	2.530
Carbonate of magnesia	.976
Magnesium chloride	.029
Silica	.682
Alumina and sesquioxide of iron	.402

No organic matter was found.

The *Belemnitella mucronata* is characteristic of the Lower Marl bed and the *Terebratula harlani* in the Middle Marl bed. The dip indicated by the Lower Marl bed in this well is 36.6 feet per mile from Middletown, and by the Middle Marl bed 37 feet from Big or Crawfords Hill.[1]

Other wells have been sunk which add to the supply. The water is from the basal beds of the Lower Marl, the same as at Asbury Park (at 383 feet), Spring Lake, and many other wells, as shown on the right-hand end of sections 1 and 5, Pl. III.

In 1894 a well was bored at Ocean City to a depth of 1,134 feet. A heavy bed of coarse white gravel and sand was found at 1,083 to 1,130 feet, which yields a large water supply. The horizon is low in the Matawan formation, as in the deep wells at Asbury Park. A record from 0 to 553 feet is given by Mr. Woolman in New Jersey report for 1895.[2]

[1] New Jersey report for 1883, pp. 17–19.

[2] Page 74.

Pavonia, Camden County.—At the shops of the Pennsylvania Railroad Company there are three wells which have yielded a supply of water for years. The wells are 67, 60, and 82 feet deep. They are a short distance from the wells of the Stockton Water Company, but on somewhat higher ground. Several years ago an attempt was made to obtain water from a greater depth and the record of this deeper well is as follows:

Feet.	
0–6	gravel.
6–16	white clay.
16–35	sand.
35–58	gravel, water-bearing.
58–80	fine sand.
80–85	red clay.
85–95	fine sand.
95–115	yellow clay.
115–126	yellow sand.
126–132	coarse sand.
132–164	gravel.
164–174	large pebbles.

A large amount of water was found, but the higher horizon appears to have been preferred. The supply is 275 gallons per minute. The water is very pure. It is thought that the water from the 67 to 82-foot wells represents the 64 to 78 foot horizon which supplies one of the Stockton wells. The abandoned well had probably reached the 121-foot horizon of the Stockton wells, and is probably the same as is drawn from by the wells in the southern part of Philadelphia and by a well at the Cooper Hospital at Camden at a depth of 129 feet.[1]

Perth Amboy, Middlesex County.—A well bored for the Easton and Amboy Railroad was sunk through Cretaceous clays to a depth of 130 feet, but no water was obtained. Water was found in abundance at a depth of about 24 feet.

A 12-inch boring was made at this place which found no water. The following record is given:[2]

Feet.	
0–55	black clay.
55–61	red and white clay, a little kaolin, and 1 inch of white sand.
61–70	red shale and sandstone.
70–85	soft granite or gneissic rock.
85–470	hard granite or gneissic rock.

Pitman Grove, Gloucester County.—There are at this place eight wells, ranging from 60 to 80 feet in depth, all above the marl, and each one yielding from 1,000 to 2,000 gallons per hour.

The marl was found at 96 feet and was prospected to a depth of 130 feet to conglomerate, when the work was stopped and the water was

[1] New Jersey report for 1892, pp. 308-309.

[2] New Jersey report for 1885, p. 111.

taken from the stratum above the marl.[1] This marl is regarded by Mr. Woolman as Miocene (Chesapeake) in age.[2]

Pleasant Mills, Atlantic County.—Between 1873 and 1885, 14 wells were sunk at this locality which yield a large supply of very pure water. The record was as follows:

Feet.	
0–40	yellow and white sand and pebbles.
40–48	tough, hard, dry blue and blue-black clay.

Below the clay was the water-bearing stratum, from which the water rose 13 feet above the level of the ground. The yield from the first eight wells was 300 gallons per minute. The water contains 28.41 grains of solid matter per gallon. Its temperature was 55°.[3]

A well at Barge's cranberry bog, about one-half mile west of Pleasant Mills, is at an elevation of 20 feet. It reached a depth of 201 feet, but was not deemed successful because it did not overflow. A flow of water reported at 57 feet is thought by Mr. Woolman to be the Pleasant Mills water stratum, which belongs to the lower part of the great diatom clay bed, a horizon which yields water at 658 feet at Ocean City. He regards the water in the bottom of the well as the representative of the 760-foot horizon in the Atlantic City wells.[4]

A well at Rockwood's bog, 5½ miles northwest of Pleasant Mills, is at an elevation of 45 feet. It was sunk to a depth of 158 feet, but yielded no satisfactory supply of water. The following record is given:

Feet.	
0–13	sands.
13–21	sand.
21–30	sand and clay, milky water.
30–48	quicksand.
48–57	quicksand and clay.
57–66	black clay.
66–98	coarse gravel full of iron.
98–115	mud or muck.
115–158	sand, gravel, and more iron.

It is suggested by Mr. Woolman that the lower portion of this boring must have entered the clays and marls met with at 844 feet at Atlantic City, and that they are the same unsatisfactory beds in which the boring at Harrisia was discontinued. Had the boring been continued it would probably have reached the horizon tapped by the well at Winslow at a depth of 335 feet, and which is probably equivalent to the 950-foot horizon at Atlantic City.[5]

Point Pleasant, Ocean County.—The artesian well is at the Hotel

[1] New Jersey report for 1891, p. 220.
[2] New Jersey report for 1893, p. 409.
[3] New Jersey report for 1884, pp. 127–129.
[4] New Jersey report for 1892, p. 296.
[5] Loc. cit., p. 297.

Stratford, on the beach. Its depth is about 800 feet and the yield is 30 gallons a minute. It is said to rise 35 feet above the surface. The water horizon is probably in the Matawan formation, the same as at Monmouth Beach, Monmouth Park, Seabright at 258 feet, Atlantic Highlands at 108 feet, Asbury Park at 550 feet, Mantoloking at 922 feet, and other wells.

Port Monmouth, Monmouth County.—There is said to be a flowing well at this place, near the terminus of the New Jersey Southern Railway. It is over 100 feet in depth and yields a small supply of good water, which probably comes from the beds in the Matawan formation.

Port Norris, Cumberland County.—The principal well has a depth of 78 feet, and was bored through sand and clay. The water flows about 1 gallon a minute, and is of good quality, with a slightly ferruginous taste. There is also a flowing well, which has a depth of 37 feet. Mr. Woolman suggests that the water at 78 feet may be in sands which yield water at Atlantic City at a depth of 328 feet.[1]

There are also two wells at Bivalve, one on either side of the Maurice River. The following record is from the memory of the driller:

Feet.
0–20.....salt mud.
20–70.....white quicksand, like glass sand.
70–76.....blue clay.
76–200.....alternations of sand and blue clay, with 18-inch layer of shells at bottom.

Mr. Woolman found diatoms in materials near the bottom, and regards the water horizon as equivalent to the one in the upper diatom clay at 406 and 430 feet in Atlantic City wells, which would indicate a dip of 25 feet per mile in that direction.[2]

Port Republic, Atlantic County.—In the spring of 1892 a 2½-inch well was bored for E. W. French at Port Republic. Water was obtained at a depth of 114 feet, at the base of black sand 33 feet thick, but it was cased off and the boring continued. Farther down 13 feet of bluish clay were penetrated, and water was found in a bed of coarse gravel at 151 feet.[3] The blue clay is thought by Mr. Woolman to represent the great diatomaceous clay bed, and the water horizon at 151 feet to be the probable equivalent of the water which occurs in the upper part of that clay bed at 406 feet at Atlantic City. It is suggested that the water at 114 feet may possibly belong in the sands above the diatom clays and represent the group of water horizons, one of which occurs at the depth of 328 feet at Atlantic City.

Quinton, Salem County.—A 6-inch well was bored at this place in 1892 for the Salem Water Company. Nine more 6-inch wells have since been bored. The elevation is 10 feet above tide and the water rises to

[1] New Jersey report for 1891, p. 222.
[2] New Jersey report for 1890, p. 262, and for 1892, p. 286.
[3] New Jersey report for 1892, p. 285.

within a foot of the surface. The yield is stated to be 55 gallons a minute. The following record is given:

Feet.	
0–4	surface soil and gravel. Recent.
4–30	clay with shells of several Miocene species.
30–38	green and white sandy, clayey marl. Lower layer of Upper Marl.
38–146	alternations of lime sand and lime rock. Lime sand.
146–148	clay.
148–162	greensand marl and shells. Middle Marl.
162–166	clay.
166–248	gray quartzose sand with water. Redbank.

The 108 feet of limy beds from 38 to 146 feet reveal an unexpected thickness of the upper member of the Middle Marl, which is only 25 feet thick in its outcrop. The Middle Marl is quite definitely recognized from 148 to 162 feet. The lower beds correspond with those in the Woodstown well, and the water in both wells is from 80 feet of pure clean sand, which is regarded as the Redbank horizon.[1] This horizon has also been opened in the well near Mullica Hill and at other places.

Rancocas.—A well at A. Hansell's, a mile and a half west of Rancocas, had the following record:[2]

Feet.	
0–3	loam.
3–13	reddish gravel.
13–15	red clay.
15–121	black clay.
121–124	white sand.

The horizon is at or near the base of the Matawan formation.

Red Bank, Monmouth County.—Water was found here at a depth of between 80 and 90 feet, at the base of the Lower Marl. The first well was 8 inches in diameter, and on pumping was found to yield about 40,000 gallons a day. The water rose to within 6 to 8 feet of the surface, but did not overflow. Another well, 6 inches in diameter, reached water at the same depth. Later an excavation was made 15 feet in diameter to within 10 feet of the water, and five 3-foot pipes were sunk within this to the water. Marl was found at 29 feet; at 40 feet and at intervals to 48 feet large lumps of hard marl were encountered; and from 48 to 52 feet the excavation was through a hard seamy marl, closely compacted with shells. The water supply from the well is about 250,000 gallons per day, and the water rises to within 12 feet of the surface.

The water is free from any organic matter, and three different samples afforded in solid matter per gallon 6.8, 6.9, and 5.6 grains respectively. It contains a mere trace of iron, and the solid matter is mainly carbonate and sulphate of lime.[3]

An additional water supply has since been discovered in a sand bed 230 feet below the surface and 160 feet below that from which the first

[1] L. Woolman, in New Jersey report for 1893, pp. 415–416.
[2] L. Woolman, in New Jersey report for 1895, p. 70.
[3] New Jersey report for 1884, pp. 122–124.

supply was obtained. The stratum is a fine white sand in which there are embedded logs of wood. Three pipes were sunk at intervals of 300 or 400 feet, and the water rose in each to within 10 feet of the surface. The water is pure and delicious. The well is thought to prove the existence of water-bearing layers in the Matawan marls.[1] The horizon is about 100 feet above the base of the formation, and is the same that yields water in the Monmouth Beach, Monmouth Park, deeper Seabright, and several other wells.

Richwood, Gloucester County.—This well is 65 feet deep, and was sunk for the public school. The water is in red gravel, and the well furnished 2,500 gallons per hour. According to Mr. Woolman the Miocene (Chesapeake) marl was found at 78 feet in a test boring at this place.[2]

Riverside, Burlington County.—The water company at this place has 8 wells, from 40 to 45 feet deep, which yield about 40 gallons each a minute. The materials penetrated were sands, containing a bed of clay extending from 10 to 23 feet. In a test boring made to a depth of 90 feet the bed rock was found at 50 feet. The following analysis of the water has been furnished:

Partial analysis of water from well at Riverside, N. J.

	Parts per 1,000,000.
Total solids	54.50
Transient hardness	10.00
Permanent hardness	38.46
Chlorine	11.40
Sulphuric oxide	5.93
Nitrogen (as ammonia)	0.12
Nitrogen (albumenoid)	0.09

At the Philadelphia Watch Case Company's works a well was sunk to a depth of 200 feet, of which 80 feet were into the "mica rock." A flow of water, amounting to 50 gallons a minute, was found at 40 feet, but it contained considerable fine sand in suspension. Only 18 to 20 gallons of water per minute were found in the mica rock. The following analysis of the water from this well was kindly furnished by the superintendent of the works:

	Parts per 100,000.
Matter insoluble or made insoluble by heating	5.6
Readily soluble solid matter	4.8
Total solids	10.4

Or the small amount of 6.06 grains to a gallon.

[1] New Jersey report for 1889, p. 85.

[2] New Jersey report for 1891, p. 220, and for 1893, p. 409.

There are considerable carbonates, some sulphates, and but very little chlorides, associated with lime, magnesia, soda, and potash, combined, as indicated by the analysis, in the form of lime carbonate, magnesia carbonate, soda sulphate, soda carbonate, potash sulphate, soda chloride (slight). There were also some iron oxide, a little siliceous and aluminous matter, and a trace of ammonia. The water was somewhat alkaline. Scale matter is mostly lime and magnesia carbonate, with some iron oxide and silica and a little aluminous matter, which exists largely as clay in suspension in the water.

Riverton, Burlington County.—I have no further data for this well than are given in the table, page 46.

Rumson Neck,[1] *Monmouth County.*—The well bored in 1890 on Rumson Neck is near the corner of the Ridge road and Bellevue avenue. The beds penetrated are as follows:

Feet.	
0–31	top earth.
31–86	marl.
86–92	shells and sand.
92–95	hard stratum.
95–100	gray sand.
100–150	marl or clay.
150–190	sand.
190–210	clay, with thin sand seams.

Beds from 31 to 95 feet are glauconitic.

The water is from a sand bed in the Matawan series, probably the same horizon as in the deeper Seabright and Redbank wells. The pumping capacity of the well is 60 gallons a minute.

Sayreville, Middlesex County.—At Sayre & Fisher's brickyards two wells, 2½ inches in diameter and 80 feet deep, furnish an abundant supply of water. They are in clay to near the bottom, where sand and gravel were found. The water is soft and does not corrode steam boilers. It is slightly ferruginous.[2] The water horizon is in basal beds of the Raritan formation.

A deep boring has also been made at this locality to a depth of 976 feet, in which the gneiss was entered at 70 feet. No water was found in this well except at 300 to 350 feet, where about 7 gallons a minute was obtained.

Seabright, Monmouth County.—Nine wells are reported, of which 6 are down 125 feet, and yield on pumping 35 gallons each per minute, the water rising 10 or 12 inches above the surface. All are 3 inches in diameter except one, which is 6 inches, but yields no more water than the others. Three others have been sunk to 258 feet, and stopped in fine white sand which yields fresh water of good quality. From each of these three wells there is a flow of about 40 gallons per minute at 5½ feet above the surface. It is thought that this yield could be

[1] New Jersey report for 1891, p. 219.

[2] New Jersey report for 1885, p. 124.

increased by pumping, to 100 gallons per minute. The upper beds penetrated are as follows:

Feet.	
0–18	sand.
18–24	yellow clay.
24–70	marl. Lower marl bed.
70–110	black clay.

At 258 feet is the thick bed of fine white sand containing water.[1]

At the Normandy Hotel near Seabright there are wells from which the water is good, but hard. The water-bearing sand is 120 feet below the lower marl bed, and is 40 feet thick. It is very fine, and is underlain by a black clay. The pipe is bored with five-eighth inch holes and sheathed with wire gauze for the 40 feet of its length in the fine sand. The flow of water is at the rate of 55 gallons per minute.[2]

The water horizon at Seabright is at the base of the Lower Marl, or the same that supplies the shallow wells at Red Bank, and the Asbury Park (383 feet), Ocean Grove, Ocean Beach, Spring Lake, Lakewood, and many other wells. The lower waters are from the Matawan beds, which yield water to the deeper Redbank, Monmouth Beach, Monmouth Park, deep Atlantic Highlands, and other wells.

Sea Girt.—Early in 1885 a well was completed at the Beach House, which reached a depth of 755 feet. A flow of 50 gallons per minute was obtained, and the water rises to 13 feet above the surface, or 24 feet above tide level. The beds penetrated are reported in detail by Mr. Woolman in the New Jersey report for 1895.[3]

The Lower Marl was passed through at 489 to 570 feet and water-bearing sands were reported at 570 to 620, 694 to 720, and 735 to 755 feet, with intervening clays. These waters represent the Lower Marl, Matawan, and probably the basal Matawan horizons.

Sea Island City, Cape May County.—A well bored to a depth of 380 feet furnishes a moderate supply of water through a 4-inch pipe. It is reported that the water rises to within 11 feet of the surface, and yields 30 gallons per minute. The following beds were penetrated:

Feet.	
0–16	sand.
16–25	black mud.
25–35	sand.
35–45	mud.
45–53	sand.
53–63	coarse gravel and shells.
63–98	clay.
98–125	coarse sand and gravel in layers.
125–137	clay.
137–150	coarse sand and gravel.
150–173	fine sand.
173–200	coarse sand.
200–217	fine dark sand.

[1] New Jersey report for 1888, p. 73.
[2] New Jersey report for 1889, p. 87.
[3] Pages 75–76.

Feet.	
217–232	clay.
232–308	coarse sand.
308–380	fine dark sand and water.[1]

The well at the electric-light works obtains water from the same beds. Its record has been reported as follows:[2]

Feet.	
0–6	beach sand.
6–8	marsh clay.
8–50	fine white sand, with one or two thin streaks of clay.
50–60	coarse gravels, with cobbles, some as large as hens' eggs.
60–250	whitish sand with a few clay streaks.
250–256	dark-blue or drab clay.
256–300	whitish sand, coarser than the other.
300–350	blue clay.
350–390	very fine quicksand, dark blue gray in color, with white shells.
390–464	green or gray marl.

The water horizons appear to be the same as the horizon at 328 feet at Ocean City and Atlantic City.

Seven Islands, in Great Bay, Burlington County.—The well was bored on the eastern side of the most northerly of the islands by Joseph Wharton. It is 408 feet deep—188 feet of 6-inch pipe, 147 feet of 4½-inch pipe, and 69 feet of 3-inch pipe. The record is as follows:

Feet.	
0–279	sand with salt water.
279–284	tough clay.
284–285	white pebbly sand.
285–335	clay with seams of sand.
335–380	dark-blue clay.
380–395	sand and gravel.
395–408	compact dark-brown clay.
	Sand and fresh, pure water.

The water flows at the rate of 70 gallons a minute and rises to a height of 15 feet above the surrounding tide meadows. Analysis showed the water to contain only 6.88 grains of solid matter to the gallon. Its temperature was 60°. The analysis, by Austin and Wilbur, is as follows:

Analysis of water from well at Seven Islands, N. J.

	Grains per gallon.
Silica	1.557
Sesquioxide of iron and alumina	.140
Lime	.379
Magnesia	.221
Soda	.968
Potash	.157
Sulphuric acid (SO_3) as sulphates	.408
Chlorine as chlorides	.408
Mineral matter	4.238

[1] New Jersey report for 1888, p. 77.

[2] New Jersey report for 1890, pp. 268, 269.

Permanent hardness, equivalent to grains of calcium carbonate, 1.394; temporary hardness, trace; organic matter, very small amount. The water is perfectly clear and odorless.[1]

A well was bored in 1893 on Crab Island of this group to a depth of 535 feet. It is one-half mile southwest of the first well. It yields 60 gallons per minute and the water rises 22 feet above tide level. The record is as follows:

Feet.	
0–58	mud and large gravel.
58–133	white and yellow sand.
133–135	hard crust.
135–172	dark bluish-green clay, hard.
172–272	sand.
272–380	marly clay and wood.
380–392	coarse sand, small flow of water.
392–510	lighter-colored, soft bluish clay.
510–535	coarse sand and gravel with water from 510–535 feet.

The water at 380 to 392 feet is thought to be the horizon at 525 feet at Atlantic City and at 425 feet at Beach Haven. The water at 510–535 feet belongs to the 700-foot stratum at Atlantic City, and 543–575 feet at Beach Haven.[2]

Sewell, Camden County.—The well here was bored for F. J. Anspach on Chew's Hill, east of the Mantua road. A good supply of water was obtained at 72 feet at the horizon in the Redbank underlying the Lower Marl bed. The water was found to be ferruginous and the well was deepened to 420 feet, where an abundant supply of pure, fresh, soft water was obtained. The bore is 3 inches and the yield is stated to be 1,500 gallons per hour. The record is as follows:

Feet.	
0–17	yellow gravel, yellowish sand, and yellow ochery sandy clay.
17–24	green marl.
24–30	very dark green marl.
30–43	reddish-yellow sand rock with casts of shells.
43–56	yellowish sand with greensand grains.
56–72	yellowish sand, lighter in color, with greensand grains.
72–104	water-bearing sand continued.
104–284	tough, fine, blue clays and blue sandy clays. Exogyra at 180 feet. Layer of sand at 264 feet. Very sandy clay with large pebbles at 276 feet.
284–335	greenish sand with streaks of clay at base.
335–342	fine, clean, gray sand.
342–351	coarse sandy gravel, angular grains. Yielded a little water
351–352	stiff white clay.
352–375	fine gray sand with streaks of clay and considerable lignite.
375–381	layers of white sand and white clay.
381–395	white angular gravel, coarse and gritty. Great abundance of good water.
395–405	white angular gravel, extra coarse.
405–408	fine white sand.
408–415	fine sand and coarse gravel, mixed.
415–420	very coarse angular gravel with bowlders and cobbles.[3]

[1] New Jersey report for 1886, pp. 212–213.

[2] L. Woolman, in New Jersey report for 1893, pp. 396–397.

[3] New Jersey report for 1891, pp. 230–231.

The water horizon is in the basal Matawan beds, which yield water in the Woodbury, Wenonah, and other wells. The water at 381–395 feet is in the mid-Matawan horizon, which is widespread in southern New Jersey.

Shrewsbury, Monmouth County.—A well at the residence of Dr. Van Buren was bored through several strata of the marl formation to a depth of 200 feet, but no water was found.[1]

As this well penetrated to and below the base of the lower marl, it is difficult to understand why it did not obtain the water which is found at that horizon in many wells in the surrounding region.

South Amboy, Middlesex County.—A well recently sunk by the Pennsylvania Railroad is reported to have the following record:[2]

Feet.
0–2.....dark sand.
2–7.....yellow gravel.
7–16.....red sand.
16–22.....blue clay.
22–49.....red, firm sand.
49–105.....black clay.

South Beach Haven, on Long Beach, Ocean County.[3]—A well was bored at this locality for James Holgate in 1886. An 8-inch pipe was sunk to a depth of 318 feet, of which the lower 8 feet were in clay; a 6-inch pipe was then sunk 107 feet farther, and a flow of excellent water was obtained. The quantity flowing was said to be 500 barrels a day, which is about 10 gallons a minute. It rises in a tube to a height of 14 feet above the surface. The horizon is doubtless the same as that from which the water is obtained at Seven Islands at 403 feet, and at Atlantic City at about 525 feet.

Spring Lake, Monmouth County.—The well has a depth of 405 feet, and taps the horizon at the base of the lower marl bed which supplies Ocean Beach, Ocean Grove, Asbury Park (at 383 feet), Seabright, Redbank, and many other places.

Stockton, Camden County.—There are seven wells at this locality for the Stockton Water Company. Some of their features are as follows:

Well.	Depth.	Distance beneath surface to which water rises.
	Feet.	*Inches.*
1	68	12
2	116	18
3	119	18
4	124	*a* 8½
5	130	*a* 13
6	121	18
7	117	18

a Feet.

[1] New Jersey report for 1879, p. 139.
[2] L. Woolman, in New Jersey report for 1894, p. 201.
[3] New Jersey report for 1886, pp. 211–212.

Excepting No. 1, they all draw from the same water stratum, reached at the same level, the differences in depths being due to differences in altitude of the wells. The record is as follows:

Feet.	
0–5	sand.
5–13	marsh mud.
13–16	white clay.
16–25	red clay.
25–45	white sand.
45–64	white clay.
64–78	white sand, water horizon of well No. 1.
78–94	yellow clay.
94–121	coarse sand and gravel, water horizon of wells Nos. 2–7.

The total yield from the seven wells averages about 875 gallons per minute. The water is excellent, pure, and soft.[1] The deeper wells appear to draw from basal Raritan beds, and the shallower ones from the mid-Raritan horizon.

Straight Creek, Cumberland County.—The well in tide meadows near False Egg Island Point is about 100 feet deep. It is a flowing well of good water.[2] The horizon is probably in the lower portion of the Chesapeake series, but no definite correlation is now practicable.

Trenton.—Two large wells have been sunk at the wire works of Roebling's Sons' Company. One near the corner of South Clinton and Mott streets was dug through 60 feet of gravel and sand to the clay. It is 20 feet in diameter and yields a large supply of water. A boring in its bottom passed through 68 feet of clay, then through gravelly clay and seams of clay to the bedrock at 160 feet below the surface.[3]

Vineland, Cumberland County.[4]—A well 4 inches in diameter has been bored at this locality to a depth of 205 feet, which supplies 20 gallons per minute. A portion of the borings were obtained by Mr. Lewis Woolman, who reports on them as follows:

Feet.	
52 or 57	black clay.
116–126	white and blue clay in layers and containing considerable wood.
197	greenish clay from the base of the bed.
197–205	brownish and reddish-brown sand in which the water was found.

The water rises to within 17½ feet of the surface. This well is thought not to have reached the Chesapeake formation,[4] but I am inclined to believe that it has, and I have so represented it on section 4, Pl. III.

Waretown, Ocean County.—In 1891 a 4-inch well was bored at this place which yields a flow of about 20 gallons of water a minute from a

[1] New Jersey report 1892, pp. 309–310.
[2] New Jersey report for 1891, p. 222.
[3] New Jersey report for 1890, p. 264.
[4] New Jersey report for 1892, p. 294.

depth of 280 feet. It is located on a bank facing Barnegat Bay, at about 10 feet above tide level. The record was as follows:

Feet.	
0–10	gravel and sand.
10–30	brownish clay.
30–70	blue clay.
70–280	alternations of black mud and black sand, changing near the bottom to gravel and white sand.

At 70 feet there was a small flow of water which rose 6 or 8 feet above the surface, and at 137 feet there was another small flow which rose but 2 feet above the surface. An examination of the sands by Mr. Woolman revealed the presence of diatoms of the great diatom clay bed, and this bed is thought by Mr. Woolman[1] to comprise the strata from 10 or certainly from 30 feet to 255 feet in this well, a thickness of over 200 feet. The lower 25 feet are thought to represent the water-bearing stratum found below the great diatom bed at 700 feet at Atlantic City.

Wenonah, Gloucester County.—A well at the hotel at this place obtains a supply of 40 gallons a minute from between 320 and 341 feet. The following section is given:

Feet.	
0–32	loam.
32–52	gravel.
52–245	black clay, with *Exogyra costata* at 115 feet.
245–280	gravel in streaks.
280–318	lighter-colored clay.
318–341	coarse sand and gravel with water.

The horizon is thought to be the same as the one at Sewell at 395 to 420 feet, or at the base of the Matawan formation. The dip indicated is 38 feet per mile.[2]

Two wells were bored in 1894 to supply the waterworks at Wenonah.[3] They are located about one-half mile northwest of the hotel well and on ground elevated only about 10 feet above tide level. Their depth is 196 feet and they obtain water from a bluish-gray coarse sand which is thought to be the equivalent of the gravel in streaks reported at from 245 to 280 feet in the hotel well.

West Creek, Cape May County.—A well for Kirby & Smith is situated on the marsh within 300 feet of the bay shore. The following record is given:

Feet.	
0–18	salt mud.
18–21	blue clay.
21–24	yellow clay.
24–27	pink clay.
27–72	quicksand.
72–99	sand and clay in layers about 6 inches apart.

[1] New Jersey report for 1892, pp. 293, 294.

[2] L. Woolman, in New Jersey report for 1893, pp. 406, 407.

[3] L. Woolman, in New Jersey report for 1894, pp. 196, 197.

Water is good and in large supply. The water flow rises nearly to the top of the well. The bore is 3 inches. The horizon can not be definitely correlated, but is probably a bed above the great Chesapeake diatom bed.

Weymouth, Atlantic County.—The first well was bored in 1877 and was altogether successful. It is 4 inches in diameter and 42 feet deep. It flows at the surface and yields 70 gallons per minute.

A second well, at the old mill, was 5 inches in diameter and has a uniform flow of 52 gallons per minute. The water has sufficient pressure to rise 8 or 10 feet above the surface. The record is as follows:

Feet.	
0–2	old cinders.
2–5	yellow sand.
5–8	coarse quicksand with a stony crust at its base.
8–16	coarse sand and a little gravel.
16–18	clay.
18–30	sand.
30–36	clay.
36–45	sand lying on clay.

The water-bearing horizon is thought to be the same as at Mays Landing, and the difference in depth is due to the dip to the southeast. The rate indicated is 16 feet per mile on the assumption that the Weymouth well is 25 feet above tide.[1]

At Horner's cranberry bog, 4 miles north of Weymouth, at an elevation of 50 feet, two wells were bored to 96 and 106 feet, respectively The records were as follows:

Feet.	
0–4	white sand.
4–6	yellow hardpan.
6–12	white clay.
12–77	quicksand and gravel.
77–95	blue clay and pebbles.
95–106	white gravel.

The water rose to within about 2 feet of the surface. It is thought by Mr. Woolman that this well was in the great Chesapeake diatom bed, and that the water was in the horizon which occurs in the lower part of this bed—"a horizon not recognized at Atlantic City, but probably the one passed in a boring at Ocean City at a depth of 685 feet" and the same as the one at the Pleasant Mills wells.[2]

At the Atlantic Company's cranberry bogs, 2 miles north of Weymouth, two wells were bored at an elevation of 40 feet, but as they did not overflow so as to afford a supply for flooding the bogs they were abandoned. The record was as follows:

Feet.	
0–6	white clay.
6–14	iron crust.
14–45	diatomaceous sandy clay.

[1] New Jersey report for 1884, pp. 131–132.
[2] New Jersey report for 1892, pp. 295–296.

The water-bearing stratum is regarded by Mr. Woolman as the same as that at Weymouth and Mays Landing, and at 525 feet in the Atlantic City wells.[1]

Wildwood, Cape May County.—The first well at this place was bored to a depth of 215 feet, but the water was unsatisfactory. Another well was bored in 1894 to a depth of 1,244 feet, which obtains a satisfactory water supply at a depth of 887 to 931 feet. Mr. Woolman has made an extended report[2] on the geology and paleontology of the well, and the following statements are condensed from that report.

Small flows of water, some fresh and others salt, were found at various depths, but the principal water-bearing sand extends from 887 to 931 feet. The water from this bed flows over the surface and will rise above it 7 feet. A strong overflow of salty water was met with at 1,185 feet. The great Chesapeake diatom bed was found to extend from 370 to 793 feet, and a series of glauconitic sands extends from 1,104 to 1,244 feet, which is regarded as probably Pamunkey (Eocene) in age. The following section is given:

Feet.	
0–3	black mud.
3–29	beach sand.
29–46	bluish, muddy, sandy clay.
46–78	beach sand, fine on top, coarser below; water at 75 feet.
78–102	bluish clay.
102–106	sand, with salt water.
106–135	blue clay.
135–145	gray sand.
145–179	bluish, clayey sand.
179–181	black mud.
181–215	white sand and gravel, with salt water.
215–294	whitish sand.
294–309	bluish clay.
309–328	coarse sand and fine gravel, mixed.
328–389	dark-bluish clay, with seams of fine sand; shell 370 to 389 feet; diatoms from 370 to 389 feet.
389–655	dark-blue, diatomaceous clay, with four thin rock strata, some shells, thin sand streaks, and small flow of water just above 625 feet.
655–705	dark-brown clay.
705–713	gray sand.
713–744	dark-brown clay, with shells.
744–750	gray sand, with small flow of water.
750–793	dark-bluish clay; base of great diatomaceous bed.
793–799	rock stratum.
799–887	dark, sandy clay, with sand and gravel 820–832 feet and rock from 832–837 feet; small flow of water at 843; shells plenty.
887–931	gray sand, water bearing.
931–1,030	dark-colored, sticky clay, with two thin rock strata near bottom.
1,030–1,098	dark-colored, tough clay, with lower Chesapeake diatoms 1,040–1,060 feet.
1,098–1,104	rock stratum.
1,104–1,244	dark olive-green, clayey sand, containing much glauconite, a few feet of sand at about 1,185 feet yielded a strong flow of salt water; age Pamunkey(?).

[1] New Jersey report for 1892, p. 295. [2] New Jersey report for 1894, pp. 159–180, Pl. V.

In a third well, sunk in 1895, a good supply of fresh water is obtained in beds from 580 to 655 feet, a horizon which was not fully tested by the deep well. Details of beds penetrated are given by Mr. Woolman in New Jersey report for 1895.[1]

Winslow, Camden County.—A well bored many years ago for water for the gas works had the following record:[2]

Feet.
0–15.....surface earth.
15–30.....blue and black clay.
30–125.....glass sand, described as quicksand.
125–160.....Miocene clay, described as hard black clay.
160–267.....Micaceous sand.
267–310.....brown clay; a gum log 1 foot in diameter found here.
310–330.....greensand marl, with white shells, teeth, etc.
330–345.....pure greensand; no fossils.

Water rose from the bottom of the greensand. The following analysis is given:[3]

Analysis of water from well at Winslow, N. J.

	Grains per gallon.
Silica	0.816
Chlorine	.012
Sulphuric acid	.157
Carbonic acid	3.030
Peroxide of iron	.175
Lime	1.177
Magnesia	.460
Potash	.583
Soda	3.230
Total solid matter	9.640

This water has much excess of carbonic acid, which keeps in solution the alkaline earths as bicarbonates. The well was bored to obtain a supply of water which would not corrode a steam boiler, and the result was entirely satisfactory.

In 1881 two more wells were bored at this place, one at the hotel, to a depth of 145 feet, and the other for Mr. George Cochran, to a depth of about 130 feet. The following record is given:

Feet.
0–2.....surface soil.
2–12.....fine clay.
12–30.....fine sand.
30–38.....yellow clay.
38–45.....sand.
45–125.....sand, with water.
125–135.....black clay, Miocene (Chesapeake).
135–138.....blue sand, Miocene.
138–141.....blue clay, Miocene.
141–145.....red gravel, Miocene.

[1] Pages 86–88.
[2] New Jersey report for 1879, p. 140.
[3] Geology of New Jersey, 1868, p. 706.

The water rises to within 40 feet of the surface, which is 130 feet above tide, and yields about 20 gallons a minute. The black and blue clays and sands are recognized by Mr. Woolman to be of Miocene age (Chesapeake formation) and to occupy a position near the base of that formation. The water horizon is thought to be that at 760 feet at Atlantic City. The well to 335 feet at Winslow, bored in about the year 1853, is thought to reach the water horizon of the 950-foot level at Atlantic City.[1]

Woodbury, Gloucester County.—Well of G. G. Green, on Main street, about 300 feet from Woodbury Creek, supplies good soft water from a depth of 80 feet. The first 10 feet were yellow clay; next, 65 feet of green or bluish colored clay, oily and very tough; the balance, gravel.

Well at G. G. Green's residence is 163 feet deep and cased with 4½-inch pipe. The following beds were penetrated:

Feet.	
0–14	yellow clay and sand.
14–104	blue and greenish colored clay.
104–163	coarse sand or gravel containing water, but not in large supply.

Another well, situated 600 feet away, is 132 feet deep and of the same bore. It supplies about 3,000 gallons of water per day.

There is a well 120 feet in depth about 2 miles south of Woodbury. The first 15 feet were clay and the 105 feet below are in marl.

Allen & Madane had a well bored in 1875 to a depth of 113 feet which yields a satisfactory water supply from a 2½-inch pipe. Water rises to within 19 feet of the surface. Record is as follows:

Feet.	
0–10	sand and clay.
10–50	blue mud or marl.
50–100	coarse sand containing shells.
100–113	sand and gravel intermixed; hard crust at bottom 1 foot thick.

L. M. Green has a well at his residence on Main street. Its depth is 142 feet, and the water rises to within 50 feet of the surface. It is expected to furnish 500 gallons per hour. The record is as follows:

Feet.	
0–12	yellow clay.
12–120	blue and green marl.
120–134	sand and gravel.
134–138	loose sand, with two logs.
138–142	hard clay and sand mixed with shells.

A well at the home of Mrs. Deborah Cooper, about 1 mile north of Woodbury, on the Redbank road, is 68 feet deep. The record is as follows:

Feet.	
0–10	sand and clay.
10–60	blue mud or marl.
60–68	gravel and sand.

[1] New Jersey report for 1892, p. 298.

The water comes to within 10 feet of the surface, and 500 gallons per hour have been pumped from the well.[1]

The well at the skating park obtains water in a gravel bed at a depth of 130 to 136 feet. The record is as follows:[2]

Feet.	
0–30	sand.
30	thin blue clay.
30–118	black clay marl.
118–130	sand.
130–136	gravel.

The Matawan horizon furnishes the water for these wells. Those in Woodbury at from 130 to 163 feet are from the basal Matawan beds, and those at 80 and 113 feet are from the higher Matawan horizon. The well 2 miles south of Woodbury at 120 feet is probably also in this higher Matawan horizon. The well a mile north of Woodbury probably reaches the basal Matawan beds, for they rise quite rapidly to the north.

Woodstown, Salem County.—A well was bored at this place in December, 1891. The site is on low ground near the creek, where the surface is about 30 feet above tide level and near the outcropping Middle Marl bed. The record of the boring is as follows:

Feet.	
0–4	meadow earth.
4–16	gravel and limestone.
16–56	greensand marl, with shells near bottom.
56–126	gray coarse sand, no water.
126–186	quicksand, with flakes of mica.
186–246	black sand marl.
246–276	black muddy quicksand.
276–296	blue clay, hard and tough.
296–340	white sand, with lignite, water bearing, underlain by white clay and red clay in succession.

The limestone at 16 feet belongs to the Middle Marl bed. The coarse, gray sands and quicksands are identified as the Redbank sand bed, though of increased thickness. The micaceous quicksand corresponds to the clay, which occurs over the lower marl bed at many localities. The black sand marl, 60 feet thick, also appears to be abnormally thick if it be the Lower Marl bed, but it is probable that the lower part of this black sand marl and the black muddy quicksand represent the Matawan clay marls which underlie the marl bed. The white sand corresponds to the Laminated sand. At the bottom the red clay is recognized as the top of the Raritan series.[3]

In the first well at this place no water was found in the sand bed from 61 to 131 feet, but subsequent borings have developed a large supply from that depth. The wells are six in number and 6 inches in

[1] The preceding is condensed from the New Jersey report for 1879, pp. 146, 147.
[2] L. Woolman, New Jersey report for 1895, p. 68.
[3] Condensed from New Jersey report for 1891, pp. 221, 222.

diameter, ranging in depth from 136 to 149 feet. The following record is given:

	Feet.	
Middle marl.	0–8	muck.
	8–16	limesand.
	16–50	green marl, with shells.
	50–54	cemented limesand and shell.
Redbank sand	80–134	fine gray sand and water.

The water rises to about 1 foot above the surface, which is about 20 feet above tide. The average flow of each well is 60 gallons per minute and the temperature is 58°.

The results of some prospecting in the old well is reported by Mr. Woolman. The boring continued through alternations of sands and white and red clays to a depth of 776 feet, where water was found which rose to within 18 feet of the surface.[1]

This well and the one at Quinton indicate that the Redbank formation in the lower part of the State is a clear gray, medium coarse sand, 80 feet thick, with abundance of good water. It is just below the Middle Marl, from which it is separated by a few feet of impervious strata.

WATER-BEARING HORIZONS IN SOUTHERN NEW JERSEY.

There are in southern New Jersey twelve well-defined water-bearing horizons which underlie extensive areas. There are also several horizons which have been recognized in restricted areas.

The lowest horizon is on the floor of crystalline rocks, which rises to the surface along a line passing through or near Wilmington, Chester, Philadelphia, Trenton, and New Brunswick. It dips quite steeply to the east-southeast and is probably at least 2,000 feet below the surface along the Atlantic coast, southward. It underlies all of southern New Jersey, and may contain water throughout the area. It has, however, been reached only by wells in or near the Delaware Valley, but to all of these it has yielded a large amount of excellent water. The other higher horizons pass beneath the surface in regular succession to the southeastward and occur at vertical intervals varying from 300 to 60 feet. They incline gently southeastward at various low angles, the lower beds, as a rule, having the greater degree of inclination. They are not fully explored as yet, and the deeper horizons are not reached by the more eastern and southern wells. For the purpose of reviewing them it will be more convenient to discuss these horizons in groups which are entitled the Lower Cretaceous, the Upper Cretaceous, and the Chesapeake.

LOWER CRETACEOUS HORIZONS.

There are four horizons comprised under this heading, namely:

1. In the Matawan beds.
2. At the base of the Matawan formation.

[1] New Jersey report for 1892, p. 302, 303.

3. In the Raritan beds.
4. At the base of the Raritan formation.

Basal Raritan.—The water horizon at the base of the Raritan formation is in the coarse sands, gravels, etc., which lie on the east-sloping floor of crystalline rocks. These coarse materials appear to be a general feature over wide areas, and they are always water bearing. In some areas clays, either pure or including sand and gravel in an impervious matrix, lie directly on the crystalline rocks, but this feature is probably local. It is to be expected that to the eastward, out under central-southern New Jersey, the Raritan basal sediments gradually become finer grained and finally become too impervious to carry water supplies, but they are known to be coarse and to contain water over a wide belt parallel to the Delaware River and a line from Trenton to New Brunswick and Woodbridge. The area of this belt is indicated by a distinctive pattern in Pl. I, on which wells to the basal Raritan beds have the letters BR in red after the figures indicating the depth in feet.

The horizon is reached by the following wells at the depths indicated:

Locality.	Depth.	Remarks.
	Feet.	
Camden, Esterbrook well	87	Fair supply.
Camden, Cooper Hospital	129	25,000 gallons per day.
Camden, pumping station	90–98	Not known.
Pavonia	174	Large supply.
Stockton, deeper wells	125	500 gallons per minute.
Gloucester, deeper wells	270	Fair supply.
Woodstown	776	Satisfactory.
Riverton (horizon doubtful)	50	10 gallons per minute.
Maple Shade	375	Plenty of water.
Riverside	120	No water.
Trenton	160	Not known.
Hightstown	428	Satisfactory.
Bordentown	195	
Burlington (horizon doubtful)	253	Plenty of water.
Sayreville	80	Not known; quality excellent.
Perth Amboy	61	No water.
South Amboy	105	Not known.
Monmouth Park	900	No water.

The many wells in the southern portion of the city of Philadelphia obtain a large supply of water from this horizon at depths averaging 130 feet. The well at Moorestown, which ended at 457 feet in red clay and cobbles, with no water, was probably not far above the basal beds, and if it had been continued into them would no doubt have obtained a supply of water. The same is the case with the deep wells at Mount Holly, Jamesburg, and Columbus, and wells to more moderate depths at various points. The greater number of the wells obtained water from higher horizons, and there is, perhaps, no need for deepening them, but the Mount Holly and Jamesburg wells would have to be deepened to the basal beds of the Raritan formation to obtain water. The

absence of water in the Monmouth Park deep well probably indicates that no water exists in basal Raritan beds in that immediate region.

The rate of dip of the basal beds is difficult to establish definitely over a wide area, because the wells which reach them are mainly along the strike of the formation and near its western margin. In the sections on Pl. III all available data on the subject are presented, and in the discussion of prospects in the various counties, on pages 108–115, some estimates are made for depths to the beds in the various regions.

Beds in the Raritan formation (higher than basal beds).—The Raritan formation is, as before explained, somewhat heterogeneous in composition, and no general subdivision of its components has been made. Alternating strata of fine sands and clays predominate, and some beds contain deposits of coarse sands and gravel which are water bearing. Whether these beds are widespread and at the same horizon or horizons is not known, but it is probable that they are not. Some wells in the middle and upper Raritan beds have yielded waters and others have not been successful. My judgment would be that the occurrence of individual water-bearing beds is irregular and restricted, but throughout the area there is a fair chance for finding water at one depth or another in the Raritan formation. As the thickness of the formation is not great, the safest plan will always be to prepare to sink to the basal beds, but if water is found above, further sinking may not be necessary. The following wells appear to obtain water from middle and upper Raritan beds:

Locality.	Depth.	Remarks.
	Feet.	
Pavonia, 3 shallower wells	67–82	275 gallons per minute.
Stockton, shallower wells	68	125 gallons per minute.
Camden, hospital	80–95	Supply is from a deeper horizon.
Camden, pen works	67	Clay particles in water.
Collingswood	195	Good supply.
Delair	78	
Riverton (horizon doubtful)	50	10 gallons per minute.
Riverside	40	Large amount.
Maple Shade	260-300	Excellent water.
Moorestown	212–250 320–344	Do.
Gloucester, 3 wells	149–162	200 gallons per minute.
Burlington:		
2 miles east	253	Satisfactory.
1½ miles south	135	25 gallons per minute.
Mount Holly	442–457 660	Small flow of water.
Hightstown	201	Satisfactory.
Columbus	338–356	Fair supply; ferruginous water.
Holmdel	601	12 gallons per minute.
Keyport	242	Satisfactory.
Matawan	264	No water.
Asbury Park	1,045–1,120	Satisfactory.
Jamesburg	472–481	Unsatisfactory water.

Although the occurrences of water in these wells are not thought to be at uniform horizons, the Stockton and Pavonia, and probably also the Camden wells, all appear to draw from the same bed, but these wells are relatively near together. The bed consists of coarse sand and gravel, sometimes with bowlders, and it contains a fairly large supply of water. The failure of the mid-Raritan horizon to furnish a satisfactory water supply at Mount Holly, Columbus, and Jamesburg appears to indicate the existence of an area in which the deposits are too fine to carry much water or are completely inclosed by fine materials. If these wells had been bored to the crystalline rock, a short distance below the depth at which they were abandoned, there is some chance that plenty of good water would have been found in the basal Raritan beds. The Keyport well clearly obtains its water from beds considerably above the base of the formation and indicates the presence of a water-bearing stratum at about the same horizon as that in the region near Camden. The same horizon, or one near to it, furnishes a water supply at 601 feet at Holmdel, and at 480 feet at Atlantic Highlands. Its absence in the boring to 264 feet at Matawan would seem to indicate that the horizon was of very restricted extent in the Keyport region, unless by mishap it was "passed" in the Matawan well. As I do not know precisely the relative altitudes of the two wells and the dip of the beds, it seems also possible that the well at Matawan did not penetrate sufficiently deep to reach the horizon of the Keyport water.

No attempt has been made to represent separately on the map the area underlain by the waters in the Raritan formation, for it is practically the same as that underlain by the water in the basal beds. Some of the relations of the Raritan waters are shown on the cross sections on Pl. III, and the wells which obtain water from the horizon have an R after them on the map, Pl. I.

Base of the Matawan formation.—In the region east and south of Philadelphia there are many wells which supply a large amount of fine water from this horizon. In that region there appears to be a nearly general sheet of coarse gray sands and pebbly beds lying on the surface of, or constituting a transition series into, the Raritan formation, which may be relied upon for water over a wide area. The following wells have penetrated to the horizon:

Locality.	Depth to horizon.	Remarks.
	Feet.	
Cinnaminson	46	450 gallons per minute.
Woodbury, 1 mile north	68	8 gallons per minute.
Woodbury village; several wells	104–163	Variable amounts.
Wenonah	320–341	40 gallons per minute.
Sewell	420	25 gallons per minute.
Woodstown	340	Fair supply.
Gloucester	64–102	13 wells; large supply.

Locality.	Depth to horizon.	Remarks.
	Feet.	
Moorestown	136	Flowing well.
Collingswood	105	Water not reported.
Maple Shade	130	Considerable.
Keyport	21	Water not reported.
Holmdel	.....	Do.
Mount Holly	262	No water.
Sea Girt	755?	Satisfactory supply.
Jamesburg	60	No water.
Columbus	156	12 gallons per minute; ferruginous water.
Hightstown	76	Not known.
Rancocas	124	

These records indicate the general presence of this important water horizon over a wide area east and south of Camden, and that it appears to die out to the northeastward. In the Mount Holly, Jamesburg, and Columbus areas there are no signs of the coarse sands and gravel and no water was found in the wells, excepting a small amount of ferruginous water at Columbus. In Delaware and Maryland the Matawan formation is represented by the lower portion of the Severn formation, which is separated from the Raritan and Potomac beds by a general unconformity. It is suggested that this unconformity extends into New Jersey to beyond the latitude of Philadelphia and is marked by the presence of coarse deposits in the basal beds of the Matawan. According to Dr. W. B. Clark, no unconformity appears to exist in the area which he studied in Monmouth County, so in that region there probably are beds of passage from Matawan to Raritan formations.

The known distribution and probable extension of the water-bearing beds at the base of the Matawan formation are represented on the map, Pl. I, and in some measure also in the sections 2, 3, and 4 of Pl. III. The rate of dip to the east averages about 35 feet per mile east of Philadelphia, but there are some local variations of small amount.

Beds in the Matawan formation (higher than basal beds).—A number of wells derive a moderately large amount of water from certain coarse beds some distance above the base of the Matawan formation. It is possible that the coarse beds are not at the same horizon throughout; and at present the evidence as to this is not complete. This horizon is about 160 to 200 feet below the top of the formation, varying slightly in different sections, and in the Asbury Park region, where the formation thickens, there are several other horizons down to depths over 1,100 feet.

The following wells have reached the horizon at the depths indicated:

Locality.	Depth.	Remarks.
	Feet.	
Asbury Park	448–1,083	500 gallons per minute.
Ocean Grove	1,134	
Atlantic Highlands	108–112	
Fellowship	131	Fair supply.
Freehold	322	Not very satisfactory
Freehold, 1½ miles north	210	Do.
Glassboro	511	Do.
Hartford	161–167	Too much fine sand.
Matawan	100	Do.
Port Monmouth (?)	100	Flows.
Red Bank	230	Large.
Rumson Neck	210	60 gallons per minute.
Maple Shade	64–97	Considerable.
Seabright, 3 wells	258	120 gallons per minute.
Seabright, Hotel Normandy	190?	Flows.
Monmouth Beach	380	Satisfactory supply.
Sea Girt	694	Not utilized?
Point Pleasant	800	Satisfactory supply.
Mantoloking	922	
Woodbury	80	Fair supply.
Woodbury, 2 miles south	120	Satisfactory.
3 miles southwest of Marlton	316?	Do.
Marlton	200	Water to −28 feet.
Sewell	342–351	Small amount.
Wenonah waterworks	196	Satisfactory.

No water at these horizons was reported in wells at Woodstown, Marlton, Mount Holly, Columbus, and Holmdel.

The region from Matawan to Asbury Park, and probably to Mount Pleasant, appears to be underlain by a continuous stratum of the upper water-bearing horizon containing a good supply of water, with the possible exception of the Holmdel area. In the Asbury Park region and southward there are also several lower horizons.

In the region east and southeast of Camden the upper horizon was found to yield some water, notably at Woodbury, and possibly in the well 3 miles southwest of Marlton; but basal Matawan and deeper beds furnish a more satisfactory supply. In the Hartford well there was plenty of water at this horizon, but it was mixed with much fine sand. The Redbank and Seabright wells are the greatest producers from the upper horizon, and the Asbury Park and Ocean Grove wells obtain large supplies from lower horizons. The areas known to be underlain by these waters and that of the basal Matawan horizon are represented by one pattern on the map, Pl. II, and some of the relations are shown in the cross sections in Pl. III.

UPPER CRETACEOUS HORIZONS.

These are mainly in the Lower Marl and Redbank formations. A well at Harrisonville and another at Gibbsboro draws from a bed of sand in the Rancocas formation.

Under the lower marl or in the base of the Navesink formation.—Many of the most satisfactory wells in southern New Jersey are at this horizon, and only a few wells which have penetrated it have failed to obtain water. Many of the wells flow above the surface. It is particularly well adapted for the supply of the Monmouth County ocean resorts. As it is underlain, probably throughout, by lower water horizons, there are several chances for finding water at successive depths within its area. The wells which have penetrated the Lower Marl are as follows:

Locality.	Depth.	Remarks.
	Feet.	
Red Bank, 5 pipes	80–90	165 gallons per minute.
Ocean Beach	480	Flows.
Do	485	Flows 35 feet above surface.
Asbury Park	383	65 gallons per minute.
Rumsen Neck	210?	60 gallons per minute.
Ocean Grove	420	40 gallons per minute.
Key East	.....	
Lake Como	535	
Sea Girt	570	Not utilized?
Mantoloking	790	Satisfactory.
Bay Head	710	
Spring Lake	465	Much.
Freehold	148–172	25 gallons per minute.
Freehold, 1½ miles north	50	250 gallons per minute.
Lakewood	475	Satisfactory supply.
Greenwich	690	No water.
Magnolia	91	Satisfactory.
Medford	183	Satisfactory supply.
Marlton, 1½ miles south	155	Do.
Seabright, 6 wells	125	210-gallon flow.
Shrewsbury	200	No water.

No water was found, or at least reported, from this horizon at Glassboro, Sewell, and Wenonah. The failure of the wells at Glassboro may indicate that the water-bearing conditions at this horizon do not extend in that direction, or possibly the water may have been passed. The Lower Marl fossils are reported from 650 and the boring extended to 690 feet. It is also possible that the water horizon is here a few feet farther below the marl than usual, and would have been found a short distance below the point at which boring was discontinued. The areas underlain by this water horizon are shown in the map, Pl. II, and in sections on Pl. III. The rate of dip is indicated in the sections.

In Redbank formation.—This formation has proved to be a water bearer over a considerable area, south of the latitude of Philadelphia, which is indicated on the map, Pl. II. Possibly it may continue for some distance to the northeastward, but no explorations have been made between Medford and Lakewood which would throw light on this question. Its relations in the Medford to Marlton region have been discussed in detail by Mr. Woolman, who has ascertained that it has a

dip of 37 feet per mile to the southeast.[1] The following wells appear to derive water from the Redbank horizon at the depths stated:

Locality.	Depth.	Remarks.
	Feet.	
Woodstown	139–149	360 gallons per minute.
Quinton	166–248	55 gallons per minute.
Sewell	72	
Mullica Hill, 1¾ miles southwest	102	Satisfactory.
Medford	64–70	20 gallons per minute.
Medford, 1¾ miles northeast	126	Satisfactory.
Marlton	86–105	Do.
Marlton, 2 miles east	70	
Marlton, several wells in vicinity	80–150	

No water was reported from this horizon in the wells at Glassboro and Greenwich, but there is the usual possibility, or even a probability, that the borings at these points passed the Redbank waters without revealing them, particularly in the case of the Glassboro well. Further explorations should be made for this water throughout the area shown on the map (Pl. II) to be probably underlain by it, and also in the region to the east and southeast for at least several miles. A small overflow from this horizon was reported in the new deep well at Asbury Park at a depth of 280 feet.

The materials in which the Redbank waters occur are moderately coarse gray sands, and as they are quite thick the amount of water they contain is large.

CHESAPEAKE HORIZONS.

The water-bearing horizons in the Chesapeake formation are at least eight or nine in number, and they underlie nearly all of the southeastern portion of "South Jersey." They have been studied with special care by Mr. Lewis Woolman, who has been able to identify the various New Jersey members of the Chesapeake formation in many of the wells. He gives the following table of the Chesapeake water horizons which are represented in the wells at Atlantic City or Ocean City:

	Horizon.	Depth at Atlantic City.	Depth at Ocean City.
		Feet.	*Feet.*
1	Sands above diatom bed	328	334, 366
2		406, 430	.....
C 3	Middle of diatom bed	525–560	512, 528
4	Lower part of diatom bed	.....	685
E 5	At base of diatom bed	700–720	720
6		760	
G 7	Below diatom bed	800	800
8		*a* 950	

a About.

[1] New Jersey report for 1894, pp. 203–218, and cross section, Pl. X.

The principal horizons at Atlantic City are those near 525, 700, and 800 feet, and these I have designated in the table and on the maps and sections by the letters C, E, and G, respectively. They are widespread, clearly defined in relations, and yield large amounts of waters to many wells. The deposits consist of coarse sands intercalated between beds of clay, and their stratigraphic relations and intervals appear to be fairly constant over a wide area.

In the following table there is given a list of the wells which have penetrated the Chesapeake beds, with indications of their equivalence with Atlantic City horizons:

Locality.	Depth.	Depth to Atlantic City horizons.			Remarks.
	Feet.	*Feet.*			
Atlantic City	.....	525–560	700	800	
Asbury Park	.....	.....	93	.....	No water reported.
Mantoloking	175	.....	175?	.....	
Berkeley Arms	470	.....	.....	470?	60 gallons per minute.
Great Sedge Island	320	157	320	.....	100 gallons at 320 feet; waters also at 157, 175, and 252 feet.
Waretown	280	137	280	.....	20 gallons at 280 feet; small amount at 137 feet.
Barnegat Landing	120	120	.....	.....	Good supply.
Harvey Cedars	.....	240	480	.....	Do.
Beach Haven	575	425	575	.....	Good supply at both.
South Beach Haven	425	425	.....	.....	Good supply.
Crab Island	520	.....	520	.....	Do.
Seven Islands	408	408	.....	.....	70 gallons a minute.
Seven Islands, ½ mile southwest	535	392	535	.....	60 gallons at 535 feet; small amount at 392 feet.
Harrisia	306	.....	196?	.....	Flow at 196 feet; no water at 306 feet.
Port Republic	151	151?	.....	.....	Good supply at 151 feet; some at 114 feet.
Pleasant Mills	50	.....	50	.....	300 gallons from 8 wells.
Pleasant Mills, ½ mile west	201	.....	57	.....	Flow at 57 feet; no flow at 201 feet.
Pleasant Mills, 5½ miles northwest	158	.....	.....	.....	Unsatisfactory supply.
Winslow	85	.....	85?	.....	20-gallon flow.
Do	135	.....	.....	.....	Do.
Do	145	.....	.....	.....	Do.
Do	345	.....	.....	.....	Satisfactory.
Weymouth	45	45	.....	.....	70 gallons per minute.
Weymouth, 4 miles north	96, 106	.....	.....	.....	
Weymouth, 2 miles north	45	45	.....	.....	Nonflowing.
Mays Landing	176	176	.....	.....	25 gallons per minute.
Do	130	130	.....	.....	
Quinton	.....	.....	.....	.....	Basal Chesapeake 4 to 30 feet; no water.
Vineland	205	.....	.....	.....	20 gallons per minute.
Glassboro	.....	.....	.....	.....	Chesapeake 80 to 145 feet; no water.
Pitman Grove	130	.....	.....	.....	Marl at 96 feet; no water.
Millville	160	.....	160	.....	Satisfactory supply.

Locality.	Depth.	Depth to Atlantic City horizons.	Remarks.
	Feet.	*Feet.*	
Brigantine	798	517 670 798	100-gallon flow.
Fifields	397	....	Unsatisfactory supply.
Longport	800	 803	
Ocean City	760	512, 528 720	25-gallon flow.
Do	800	....	140-gallon flow.
Sea Isle City	380	....	30 gallons per minute.
Wildwood	1,244	580 887	300 gallons at 580 to 655 feet.
Cape May Point	456+	....	Water at 360 feet.
Cape May City	224	....	Salt water.
West Creek	99	....	Good supply.
Port Norris	78	....	
Bivalve	200	..... 200?	
Strait Creek	100	..... 100?	Flowing well.

The 685-foot horizon in the Ocean City well is not represented in the wells at Atlantic City. Mr. Woolman suggests that it supplies the water in one of the deepest Weymouth wells and in the Pleasant Mills well, and, as this seems reasonable, I have so shown it on section 3, Pl. III. The two upper horizons at Atlantic City are not known to be extensive in area. It has been suggested by Mr. Woolman that the well at Bivalve is in the 406-foot Atlantic City horizon at a depth of 200 feet, on the evidence of the occurrence of diatoms, and that the well to 78 feet at Port Norris, near by, is in the 328-foot horizon, but the evidence is not conclusive. The waters at 114 feet and 151 feet in the well at Port Republic are also thought by Mr. Woolman to be possibly from the 328-foot and the 406-foot horizons at Atlantic City. The water horizon at Cape May at 320 to 360 feet and at Sea Isle City can not be definitely correlated from data now on hand, but there is a fair degree of possibility that it is the 334-foot Ocean City horizon. In regard to the areal extensions of horizons deeper than the "E," or 700-foot Atlantic City water, we have relatively little reliable information. The "G," or 800-foot water, was also found in large supply at Ocean City, Longport, and Brigantine, and the well at Wildwood found a good water supply at 931 feet, undoubtedly from this horizon. The well to 470 feet at Berkeley Arms may possibly be in this horizon, but as it is far below the great diatom bed, there is greater probability that it is deeper than the 960-foot Atlantic City horizon. The water at 175 feet at Mantoloking is clearly higher than the Berkeley Arms water, and as it is just below the great diatom bed, it is probably equivalent to the 700-foot horizon of Atlantic City, found at 320 feet at Great Sedge Island, near Barnegat Inlet. The Harrisia well found water in fair amount at 190 feet, in all probability at the "E," or 700-foot horizon, as suggested by Mr. Woolman, but when it was depeened did not go to a sufficient depth to reach the deeper waters which no doubt underlie the region and are reached by the deepest well at Winslow.

The well at the glass works at Winslow, which was sunk to a depth of 345 feet, is thought by Mr. Woolman to have reached water of the 950-foot horizon at Atlantic City, which would indicate a wide extension of that horizon and a dip of 23 feet per mile.

POST-CHESAPEAKE HORIZONS.

There are a number of bored wells in southern New Jersey which yield satisfactory water supplies from beds more recent in age than the Chesapeake formation. They are relatively shallow, and their waters are in some degree liable to surface contamination. Owing to our lack of knowledge of the relations of the younger formations in southern New Jersey, it has not always been possible to determine the age of some of the shallower water-bearing beds.

WELL PROSPECTS IN THE VARIOUS COUNTIES OF SOUTHERN NEW JERSEY.

ATLANTIC COUNTY.

The many wells in this county and the wide range in their depths afford very satisfactory data as to the prospects for additional wells. The entire county is underlain by water-bearing beds of the Chesapeake formation, which increase in number to eight in the eastern end of the county. I believe that a clear idea of the relations of these beds will be obtained from sections 3 and 5 in Pl. III. There is considerable probability, also, that the waters of the Cretaceous beds extend to the western edge of the county, as suggested in the map, Pl. II, but as there are other waters at higher horizons it may never be necessary to go to the deeper ones for water supply.

The principal water horizons in the county are those which occur at about 525, 700, and 800 feet at Atlantic City, and at approximately the same depths at Ocean City. The 525-foot horizon is only 50 feet below the surface about Weymouth, and it probably outcrops under the superficial deposits along the western border of the county. It is thought that the 950-foot horizon of the Atlantic City wells furnishes water at Winslow at a depth of 335 feet, and if this is the case, three horizons of water may be expected throughout the western portion of the county between the depths of 50 and 400 feet in the vicinity of Weymouth, Richland, Elwood, and Pleasant Mills. They dip almost due southeast at the rate of 22 feet per mile. In the eastern portion of the county the waters found in the wells at Atlantic City and Ocean City may be expected at depths which diminish at the rate of 22 feet to the mile to the northwest.

CAPE MAY COUNTY.

The experience of the Ocean City well indicates that the great water horizons of Atlantic City may be expected to extend at least for some distance under Cape May County, and it is probable that some of them

will be found to underlie the entire county. This expectation has been realized in the deeper wells at Wildwood, which found an abundant supply at 887 to 931 feet, probably from either the 800-foot or the 950-foot Atlantic City horizons, and a very great flow of water at 580 to 655 feet in the middle of the great Chesapeake diatom bed. The water at 320 feet at Cape May, at 99 feet at West Creek, and at 380 feet at Sea Isle City appear to indicate a southward extension of the water horizons which occur just above the diatom bed at Ocean City and Atlantic City. The water at 215 feet at Wildwood indicates a still higher horizon, possibly the one which yielded salt water at 224 feet at Cape May City.

EASTERN CUMBERLAND COUNTY.

There is a sufficient number of wells in this section to indicate a general extension of waters in Chesapeake beds at moderate depths. The Millville well found the 700-foot Atlantic City horizon at 160 feet, and there is a fair degree of probability that this water will be found to the east and southeast. Its relations are quite fully suggested on the map, Pl. II, and in section 4 in Pl. III. The wells at Bivalve and Port Norris are in higher horizons, of which the relations and extent are not as yet fully determined, but they give assurance that water-bearing beds underlie the southeastern corner of the county at moderate depths.

EASTERN BURLINGTON COUNTY.

There have been relatively few wells sunk in this section, and their results were not altogether satisfactory. The well at Harrisia obtained a fair prospect of water at 190 feet, apparently from the horizon which is at a depth of 700 feet at Atlantic City, but when it was deepened to 306 feet it was not quite deep enough to reach the 800-foot or the 960-foot horizons, which may be expected to underlie the region. South of Harrisia there should be found the waters which occur in the Port Republic wells at 114 and 151 feet, and also the waters found at Beach Haven and Seven Islands. For the region north of Harrisia to 3 miles beyond the New Jersey Southern Railroad no definite predictions can be made. There is fair possibility of finding waters in the lowest Chesapeake beds, and other chances in the Redbank sands a short distance below. A well to the depth of 500 feet at Atsion, Harris, or Shamong would pass through the lower Chesapeake beds in the first 300 feet and reach this lower horizon. Whether it would prove to be water-bearing can not now be safely predicted.

SOUTHERN AND EASTERN OCEAN COUNTY.

The wells in this county are along or near the ocean shore, and they are at such frequent intervals that the water horizons are located with a fair degree of definiteness. In section 5, Pl. III, these water horizons are represented, and their relations and bearings are quite apparent.

From Mantoloking, Waretown, and Seven Islands southward the 525-foot and 700-foot horizons of the Atlantic City wells have been tapped, and at Berkeley Arms the deeper-seated waters have been found. These deeper waters probably extend southward, but the wells between Berkeley and Atlantic City have not reached them. The water at 790 feet at Mantoloking is from the beds at the base of the Lower Marl, and as no waters were reported between 175 and 790 feet in this well, it would appear that other upper Cretaceous waters do not extend under that portion of the county. The water at 922 feet in the deepest well at Mantoloking indicates the presence of the Matawan waters. The southern extension of the Mantoloking waters and of the water of lower horizons has not been determined.

MONMOUTH COUNTY.

This county appears to be underlain by several water horizons which furnish water to many wells at various depths. The horizon which has been best explored is in the basal sands of the Lower Marl bed, and the evidence is so satisfactory that I feel confident that there is a continuous sheet of water in this bed in the portion of the county which it underlies. This comprises nearly the entire county, for the Lower Marl outcrop lies only about 2 miles east of the western boundary line for the greater part of its course. The depths to this water horizon are 383 feet at Asbury Park, 420 feet at Ocean Grove, 475 feet at Lakewood, 135 feet at Freehold (village), 80 feet at Red Bank, 480 feet at Ocean Beach, 125 feet at Seabright, 465 feet at Spring Lake, 535 feet at Lake Como, and 570 feet at Sea Girt, but not there utilized. The dip is to the southeast, at a rate of 25 feet to the mile in the northeastern corner of the county and about 28 feet per mile in the Spring Lake region. From these data it will be very easy to calculate the position of the Lower Marl water horizon for any point, taking care in every case to make due allowance for differences in elevation above tide level. The water in the various wells which draw from this horizon is of excellent quality and of sufficient amount to rise, with pressure enough, considerably above tide level. The only boring of which I have learned that did not find water at the base of the Lower Marl was at Shrewsbury, but as there are successful wells in the surrounding region, I am of the opinion that the Shrewsbury boring passed the water by oversight. It was not reported at Point Pleasant.

From 150 to 200 feet below the Lower Marl horizon there is another water-bearing bed in the Matawan formation, which has proved to be very widespread and may underlie the entire area of the county. It has not, however, been as thoroughly explored as the higher horizons. At Red Bank it is 160 feet bow the Lower Marl, and is a large water producer. At Port Monmouth and at Matawan it is 100 feet below the surface; at Seabright it is 190 feet below the Lower Marl, or 258 feet below the surface; at Monmouth Beach and at Monmouth Park it is

380 feet below the surface, at Asbury Park 550 feet below the surface, at Point Pleasant 922 feet. At Freehold it is 165 feet below the Lower Marl; but here the water does not appear to be satisfactory. The dip of this water-bearing bed is about the same as that of the Lower Marl bed, or 25 to 28 feet per mile, and the direction of maximum slope appears to be nearly due southeast.

Waters have been found in the Raritan beds in the northern part of the county, but there are very few data as to their extent. They sink very rapidly to the southeast. The deep boring at Monmouth Park, it is claimed, reached the crystalline rocks and found no water below the Matawan horizon. The well at Keyport obtains water from a mid-Raritan horizon at a depth of 242 feet, and the deeper boring (480 feet deep) at Atlantic Highlands and the well to 601 feet at Holmdel probably are to the same bed of water-bearing sands. The deeper wells at Sea Girt, Asbury Park, and Ocean Grove are thought to be in middle and lower beds of the Matawan formation which thicken to the southward and carry several water horizons. The basal Matawan horizon, which is so important to the northward, probably extends across the southwestern corner of the county, and even along its southern margin, but, as indicated by the well at Asbury Park, it rapidly increases in depth.

EASTERN MIDDLESEX COUNTY.

This county lies across the border of the Coastal Plain region, to the west of which rise the red sandstones and shales of the Newark formation. Near the junction line of the Coastal Plain deposits and the Newark formation the crystalline rocks extend near to the surface in a narrow underground ridge, which reaches the surface at Trenton and Staten Island. This feature is shown in section 1 on Pl. III. In the basal beds of the Raritan series there are water-bearing materials in some areas, but their distribution is irregular. Their extent has not been very fully explored. One of the wells at Sayreville obtains a good supply of water from this horizon; but as this is one of the very few wells that meet with success, I can not base a very far-reaching prediction on it. The Perth Amboy wells obtained no water in the beds lying on the crystalline rocks, but found a good supply in superficial beds above. A recent boring at South Amboy found water at 105 feet in beds low in the Raritan formation. The unsuccessful Jamesburg well was no doubt bored near to the basal beds of the Raritan formation, but as the underlying rocks were not reached, the test is not conclusive. In the eastern part of Madison Township there is good prospect for water in the beds which furnish water at Matawan and Keyport in the adjoining county. The relations of these beds are shown in section 1, Pl. III.

EASTERN MERCER COUNTY.

The geologic relations in this county are similar to those in Middlesex County, as described above. The only wells in the central portion

of the county of which I have learned, are in Trenton, and the geologic data are not sufficiently definite for water prediction outside of the vicinity of these wells. The success of the wells at Hightstown indicates that water may be expected in the basal and higher Raritan beds and at the base of the Matawan at some localities, if not throughout the region. The waters in the Trenton wells appear to be in part from the base of the Raritan formation, but probably in part also from the superficial Trenton and Columbia gravels. They afford a large supply of water, and no doubt the area of the water-bearing beds is considerable in the Trenton region.

WESTERN BURLINGTON COUNTY.

This region has been quite extensively explored for water, and there are several wells which yield a large supply. The basal Raritan waters have been found in the Maple Shade well at a depth of 375 feet, in the deeper well at Bordentown at a depth of 195 feet, and possibly also in the Riverton well at a depth of 50 feet. The Riverside well passed through the horizon into the crystalline rocks and reported no water in the basal Raritan beds, although an abundant supply was found in higher beds at a depth of 45 feet.

The well at Burlington, which obtained no water down to the depth of 200 feet, did not reach the basal beds, nor did the deep well at Mount Holly. The Columbus well, at a depth of 715 feet, and the Moorestown well, at 457 feet, were probably very near the basal beds, but evidently not in them. From this evidence it is not possible to make a prediction as to the general extension of the basal Raritan waters in the western portion of the county, but I believe that they will be found to be widespread. The waters at 260 to 300 feet in the Maple Shade well, at 253 feet in the well east of Burlington, at 212 to 250 and at 320 and 344 feet at Moorestown, at 45 feet at Riverside, at 442 to 457 feet at Mount Holly, at 128 feet 1½ miles south of Burlington, and at 338 to 356 feet at Columbus, indicate a wide extension of horizons within the Raritan formation above its base. The waters in the Mount Holly and Columbus wells were, however, only in small amount, and they were ferruginous. The supplies from the other wells are reported not to be large.

The basal Matawan water horizon appears to extend only a short distance into the southwestern corner of the county. It has proved very satisfactory at a depth of 130 feet at Moorestown, 124 feet near Rancocas, 46 feet at Cinnaminson, and probably at 316 feet near Marlton, and was noted at 136 feet in the Maple Shade well. At Fellowship it promised to yield a supply at 200 feet, but this was not utilized. At Columbus, at 156 feet, it yields a fair supply of ferruginous water, but at Mount Holly no water was reported. In the Collingwood well the gravel was reported at 125 feet, but no water was obtained from it. The Hartford well stopped in dry beds about 50 feet above the horizon. I am quite confident that this water may be expected throughout

the region south of Rancocas Creek, east of the line of the Burlington and Camden turnpike. Its relations, dip, etc., are shown in the western end of section 2, Pl. III.

In the Maple Shade well at 64–97 feet, in the Fellowship well at 131 feet, in the Marlton well at 200 feet, and in the Hartford well at 161–167 feet was found the water of the horizon in the lower half of the Matawan beds, but it does not appear to have been utilized. It was not reported in the other wells which were bored into the basal Matawan or the Raritan beds. The water in the base of the Lower Marl bed was found in the wells at Medford at 183 feet, at the well 1½ miles south of Marlton at 155 feet, and probably at the well 4 or 5 miles southeast of Marlton at 316 feet. As the supply is large I am confident that the horizon extends far to the eastward of the Lower Marl outcrop, as shown on the map, Pl. II, and in section 2, Pl. III.

The extent of the Redbank water horizon in the county is not yet fully determined, and it may be found to be widespread. The wells in the Medford region at depths of 70–150 feet found in it a supply of 200 gallons per minute, and a large supply was found in the wells at Marlton at a depth of 86 feet, at the well 1¾ miles northeast of Medford at 125 feet, at 70 feet in the well 2 miles east of Marlton, and others. These are the only wells that I have heard of which touch the horizon, and I shall await with great interest to hear that wells have been sunk to the southeast and east where the water horizon may be expected to extend, at least under the area shown on the map, Pl. II, and with the relations shown in section 2, Pl. III. The general occurrence of this water in wells in the counties to the southwest gives much encouragement that it may be expected to extend at least some distance to the northeast.

WESTERN CAMDEN COUNTY.

Only the lower water horizons have been tested in this region so far as I know, and they have proved entirely satisfactory in all cases. The waters at the base of the lower marl bed and the Redbank horizons have not been reached, but there is every reason for believing that they extend across the county, as shown in map, Pl. II, and in section 3, Pl. III.

The basal Raritan waters are at depths from 62 to 129 feet in wells in Camden, the depth increasing quite rapidly to the east, to 174 feet at Pavonia and 270 feet at Gloucester. A higher Raritan horizon has been found to be very satisfactory at a depth of 149–162 feet at Gloucester, at 67–82 feet at Pavonia, and at 196 feet at Collingwood. The Gloucester wells at 65–102 feet obtain a large supply of water in the basal Matawan beds, according to Mr. Woolman, and this same horizon is tapped at 130 feet at Mount Ephraim, and also, probably, at 80 feet, three-fourths of a mile from Mount Ephraim. The relations of these waters and their extent are indicated on the map, Pl. I, and in section 3, Pl. III.

GLOUCESTER COUNTY.

The many wells sunk along the line of the West Jersey Railroad have thrown much light on the distribution of underground waters in this county, and they produce a large supply of fine water. The relations of all these wells and their water horizons are shown on the western end of section 4, Pl. III, so that there is no need for an extended discussion of them. The Mullica Hill well, which is some distance off the line of the section, has been projected on to it. This well clearly draws its water supply from the Redbank horizon. The failure to obtain water from the Redbank horizon in the well at Glassboro probably indicates that the water does not extend that far to the eastward, but it is possible that the water was passed. The basal Matawan water has been found in every well which has been sunk to the requisite depth to reach the beds, and no doubt they would have been found at Glassboro in the next 150 feet. The water in beds about 60 feet above the base of the Matawan formation made a good showing at Sewell at 380 feet, and in some of the shallower Woodbury wells. It was not reported at Wenonah. The basal Raritan and mid-Raritan water horizons have not been explored east of Gloucester, but there is every reason to believe that they may yield water to at least as far east as Sewell, possibly much farther. The Pitman Grove, Clayton, and shallower Glassboro wells appear to obtain their waters from the base of the superficial capping of post-Chesapeake formations. The water horizons found in the wells along the main line of the West Jersey Railroad undoubtedly extend to the west and southwest in Gloucester County, with practically the same relations as shown on section 4, Pl. III, and on the map, Pl. II.

SALEM COUNTY.

The waters above described in Gloucester County appear to underlie Salem County with about the same relations. They have not been extensively explored, but the wells at Woodstown and Quinton give much confirmatory evidence. The Redbank horizon has proved to be very satisfactory at Quinton, where it was found at a depth of 170 feet, and at Woodstown it yields an enormous supply at a depth of 140 feet. A well at Woodstown also found water in the basal beds of the Matawan formation at a depth of 340 feet, and in beds low down in the Raritan formation at a depth of 776 feet.

WESTERN CUMBERLAND COUNTY.

There are less reliable data for this locality than for any other in the region, and no predictions can be offered with any degree of confidence until further well boring has been done. The failure of the deep well to 690 feet at Greenwich to obtain water would appear to indicate that the Redbank horizon, which yields so much water to the west and north, does not extend so far as we might expect, but it should be borne in

mind that this water horizon may have been carelessly passed in boring, an occurrence, I may repeat, which is by no means rare.

The unsuccessful attempts to obtain water at Bayside and at Bridgeton add confirmatory evidence that no waters may be expected in the higher horizons in the western part of the county. To the eastward the prospect is more encouraging, for the Vineland, Millville, Port Norris, Bivalve, West Creek, and Straight Creek wells all obtain good supplies of excellent water at depths from about 80 to 200 feet. The horizons of these waters are not definitely known, but they appear in the main to be those in the Chesapeake beds which occur at intervals of from 334 to 700 feet at Atlantic City. Some of the relations of these beds are shown in section 4, Pl. III.

PENNSYLVANIA.

PHILADELPHIA REGION.

The eastern portion of this city is underlain by Coastal Plain formations, consisting of the lower beds of the Raritan-Potomac deposits. These beds are water bearers and have been tapped by a number of wells in the city. Besides these wells quite a number of others have been sunk in the crystalline rocks which rise from beneath the Raritan Potomac beds in the center of the city and to the westward. Mr. Thomas B. Harper, of Jenkintown, has bored many of these wells, and he has given some data regarding their depth and yield.

List of wells in the Philadelphia region.

Location.	Depth.	Size.	Capacity per minute.
	Feet.	*Inches.*	*Gallons.*
Fairmount Co. Ice Works, 2401 Green street	300	8	120
Schimm's Brewery, Twentieth and Poplar streets	252	8	*a*60
J. Bower & Co. packing house. Twenty-fourth and Brown streets	495	6	60
Thirteenth and Mount Vernon streets	2,031	8	*b*50
Brewery, 1707 North Twelfth street	350	8	100
Seventh street and Callowhill	452	8	150
Brewery, 1729 Mervine street	340	8	75
Prospect Brewery, corner Eleventh and Oxford streets	350	8	*a*75
Crown and Willow streets	1,000	10	100
Ice works, 23 North Eleventh street	250	8	300
Wall paper, 2228 North Tenth street	210	8	100
Fifteenth and Market streets	500	8	100
Woolen mills, Ninth and Dauphin streets	272	6	30
Carpet works, Eleventh and Cambria streets	200	6	50
Dye works, 4520 Worth street, Frankford	335	6	250
Continental Hotel, corner Ninth and Chestnut streets	240	8	40
Hotel, Eleventh and Pine streets	250	5	*c*40
Hotel, 108 South Broad street	484	8	60
Hotel, Broad street below Locust	525	8	70
Turkish bath, 1104 Walnut street	265	8	110

a Flowing wells. *b* Water not good in boilers. *c* Lime and iron water.

List of wells in the Philadelphia region—Continued.

Location.	Depth.	Size.	Capacity per minute.
	Feet.	*Inches.*	*Gallons.*
Machine shop, Fifty-second street and Lancaster avenue	100	6	200
Morocco works, Frankford and Junction streets	500	6	500
Do	322	6	500
Do	252	6	500
Children's Home, 170 feet above tide, west of George's Hill	364	8	*a*60
Angora Cotton Factory	252	8	*a*60
Vicker residence, Clifton Heights	30	5	100
Ambler Chemical Works, 2 wells	500	6	250
Overbrook Waterworks, 3 wells	150	6	*a*500
Bryn Mawr Waterworks	600	6	120
Jenkintown Waterworks	376	6	350
Do	310	6	350
Residence, Sandy Hill, Norristown	200	6	40
Wayne Waterworks	200	6	1,000

a Flowing wells.

NOTES ON SOME WELLS IN PHILADELPHIA.

South from Christian street, near the Delaware, there are many wells for sugar refineries, salt works, and ice factories. They penetrate the red, white, yellow, and other clays of the Potomac-Raritan clay series, to the basal gravels. Seven wells were bored for one sugar refinery at Morris and Otsego streets. The record from the memory of the well borer, according to Mr. Woolman,[1] is as follows:

Feet.	
0–25	alluvium on fine yellow sand.
25–65	mottled red and white clay.
65–75	white potter's clay mixed with gravel.
75–90	fine sand of light-gray color.
90–94	fine white clay, no gravel.
94–109	white coarse sand.
109–125	coarse white gravel, with pebbles and small cobbles, containing water in large amount.

One boring was made through to the rock at 140 feet.

N. & G. Taylor's well, in the southeastern part of the city, is 12 inches in diameter. Water found in heavy gravel at 130 feet was cased off. The first water obtained in the rock was at 400 feet, but the boring was continued to 670 feet. The yield is 250 gallons a minute. The record is as follows:[2]

Feet.	
0–27	black muck (river alluvium).
27–44	coarse gravel.
44–45	yellow clay.
45–75	red clay.

[1] New Jersey report for 1891.

[2] New Jersey report for 1892, pp. 307, 308.

Feet.	
75–93	yellow clay.
93–103	blue clay mixed with yellow clay.
103–130	coarse sand and gravel, with some clay and a few large cobbles, containing plenty of water.
130–136	yellow clay.
136–165	soft mica rock.
165–670	hard rock.

Several wells in the southern part of the city draw water from the 103–130-foot horizon.

A well bored at the corner of Laurel and Beach streets is reported to have had the following record:[1]

Feet.	
0–58	coarse gravel and sand.
58–74	red clay.
74–78	gravel.
78–80	rock clay (disintegrated rock).
80–308	solid rock.

DELAWARE.

GEOLOGIC RELATIONS.

This State lies almost entirely on the Coastal Plain, across which it extends diagonally to the Atlantic Ocean. The crystalline rocks emerge at the surface in the extreme northern portion of the State, but are deeply buried under the Coastal Plain deposits to the southeast. The general structure is shown in section 1, Pl. VI. The topography of the State is relatively simple, consisting of a general terrace plain averaging about 50 feet in altitude and a small area of higher rolling hills north and west of Wilmington. The principal knowledge of the geology of the State is derived from the studies of Booth over a half century ago and the more recent observations by Prof. F. D. Chester.[2] The geologic formations are as follows:

Formation.	Characteristics.	Age.
Columbia	Sands, loams, and gravel	Pleistocene.
Chesapeake	Sands, clays, infusorial earth, and marl	Miocene.
Pamunkey	Brown sand and marl	Eocene.
Rancocas	Middle marl	Later Cretaceous.
Redbank	Sands and marl	Do.
Navesink	Lower marl	Do.
Matawan	Clay marl and sand	Do.
Raritan and Potomac	Clays and sands	Early Cretaceous.
Crystalline rocks	Granite, gneiss, gabbro, limestone, and quartzite	

[1] New Jersey report for 1894, p. 198.

[2] Preliminary notes on the geology of Delaware. Academy Nat. Sciences of Philadelphia, Proceedings for 1884, pp. 237–259, map.

CHARACTERISTICS OF THE FORMATIONS.

RARITAN AND POTOMAC.

The basal members of the Coastal Plain series in Delaware comprise the upper portion of the Potomac formation below and more or less of the southward extension of the Raritan beds above, but they appear not to be clearly separable. The deposits consist of clays and sands interbedded and intermingled in various relations. According to Chester, red clays predominate above and fire clays and sands below. The basal beds appear to consist largely of coarse sands, which lie on the steeply east-dipping floor of crystalline rocks and contain water available for wells. It is probable that this basal series was penetrated in the well at Middletown, in which rock was reported at a depth of 552 feet. The Raritan beds are overlain by white and buff sands with more or less clay and marl intermixture to the eastward, which are probably the representatives of the Magothy formation of Maryland, but a careful study of this question has not yet been made.

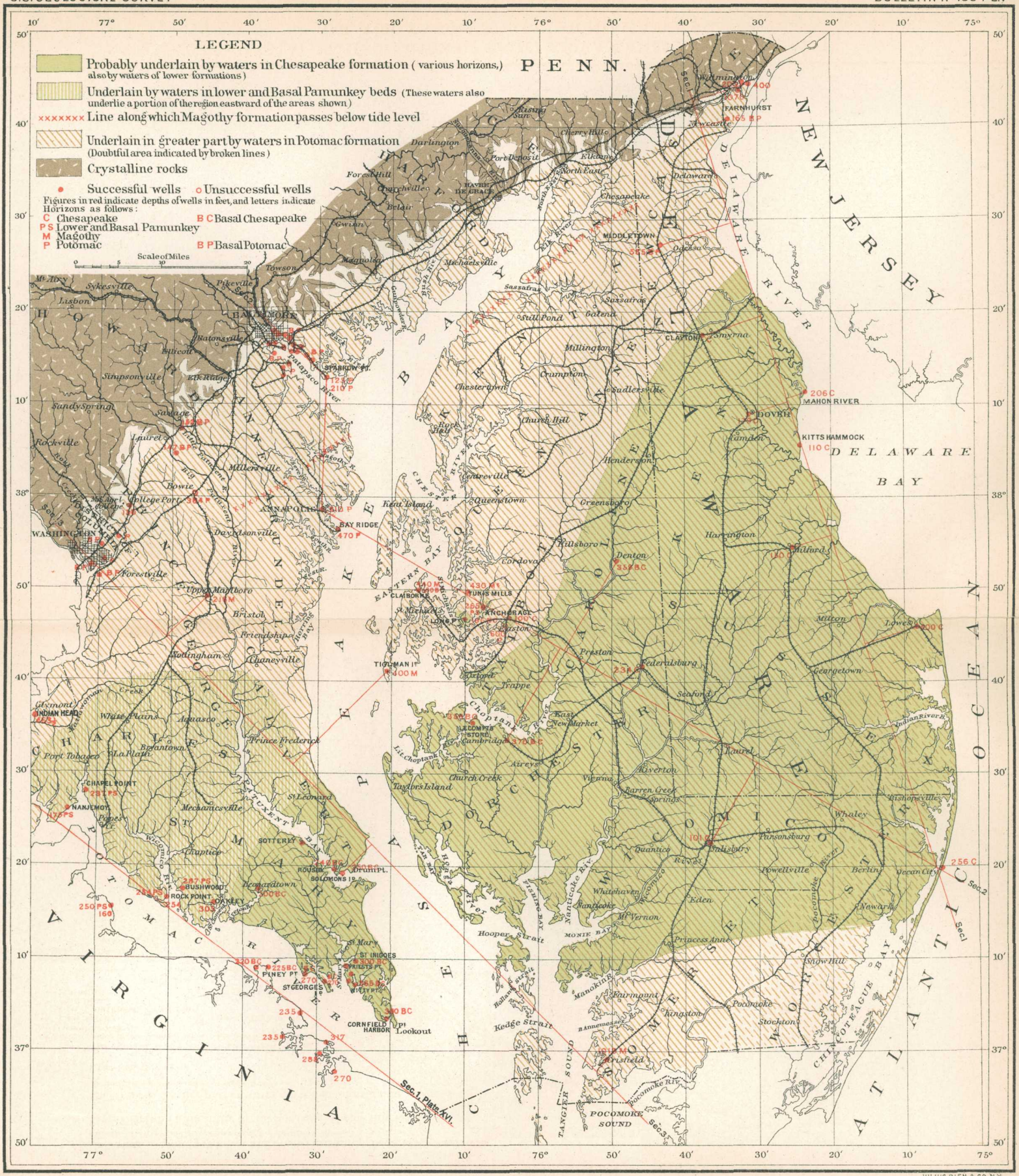
CRETACEOUS MARL SERIES.

The middle and lower marl beds of New Jersey and their associated beds extend across Delaware in a belt averaging about 8 miles wide, of which the greater part lies between Middletown and Delaware City. They are extensively exhibited along the Delaware and Chesapeake Canal. In the vicinity of this canal they dip south 30° east at a rate of 45 feet per mile, according to Chester, but the rate decreases southward. The following beds are recognized by Chester:

Formation.	Division.	Material.	Thickness.
			Feet.
Middle marl	Yellow sand	Contains some greensand	.....
	Shell layer	Shells of Rancocas age	.....
	Greensand layer	Dry, pure greensand; no clay	3–10
Redbank	Indurated greensand	Lumpy, dark-colored rich marl, with some clay	.....
	Red sand	Soft, yellowish-red sand	
Lower marl	Black marl	Mainly a black, micaceous acid clay	*a* 32
	Shell layer	Shells in black, earthy marl	3
	Cretoidal marl	Tough, bluish-black marl, with some clay	*a* 25

a About.

These subdivisions present notable differences from the New Jersey marl series, particularly in the case of the Redbank, which changes from a coarse water-bearing sand to a marl bed above and a fine yellowish sand below. This change continues southward into Maryland, where the subdivisions are not so strikingly marked and the formations have been consolidated into one, known as the Severn formation.



THE COASTAL PLAIN REGION OF MARYLAND AND DELAWARE, SHOWING RELATIONS OF UNDERGROUND WATERS.

BY N. H. DARTON

JULIUS BIEN & CO. N.Y.

PAMUNKEY FORMATION.

The weathered brown sands of this formation, a few feet in thickness, extend only a short distance into the western side of the State, but it is probable that the formation thickens to the south and east under the Chesapeake beds, for it outcrops over a wide area in the adjacent Maryland region.

CHESAPEAKE FORMATION.

All of central and southern Delaware is underlain by this formation, of which the edge extends to within about 2 miles south of Middletown. On the southern border of the State the formation probably has a thickness of about 1,200 feet. It consists mainly of clays and fine sands of the same character as those in southern New Jersey. The great diatomaceous clay bed, which is over 300 feet thick in the Atlantic City, Ocean City, and Wildwood wells, continues southward across Delaware, apparently with slightly increased thickness. It appears to be associated with similar water-bearing sands, but as few wells have been sunk in Delaware these sands have not been so definitely located as in New Jersey.

COLUMBIA FORMATION.

This formation covers all of the State south of the Baltimore and Ohio Railroad. It is a mantle of gravels, sands, and loams which caps the terrace plain to a thickness of from 10 to 30 feet, the amount increasing somewhat southward.

DEEP WELLS IN DELAWARE.

There are only a few deep wells in the State, but they are all successful and nearly all furnish large supplies of water. In the following list are given all those of which I was able to learn. Their location and horizons are indicated on the map, Pl. V:

List of deep wells in Delaware.

Locality.	Depth.	Diameter.	Capacity per minute.	Height to which water rises.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Dover	196	10	Flows 35 Pumps 218	+ 6	Water also at 157 feet.
Clayton	35	6	30	+20	No water at 85–150 feet.
Do	60	.....	.....	.....	
Do	85	.....	Moderate.	.....	Water also at 40 and 60 feet; rock at 211 feet.
Farnhurst	165	.....	.....	.....	
Kitts Hummock	110	1½	Much.	— 2½	
Lewes	400	6	15	To surface.	
Mahon River	206	.....	Much.	.....	
Middletown	535	10–8	330	—50	Fine quality of water; much water also at 475 and 540 feet.

List of deep wells in Delaware—Continued.

Locality.	Depth.	Diameter.	Capacity per minute.	Height to which water rises.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Middletown	90	(?)	(?)	(?)	
Milford	160	4	60	+ 2	
Do	150	4	60	+ 3	
Do	34	4	50	.....	
Wilmington (Stoekle Brewery).	400	8	15–18	.....	In granite.
Wilmington (H. & F. Brewery).	1,077	.....	10	—25	In granite, 96–1,077 feet.
Wilmington (Hart & Bros.).	200	6	75	.....	In granite, 36–200 feet.

DESCRIPTIVE NOTES ON WELLS IN DELAWARE.

For the notes on the wells at Dover, Milford, Kitts Hummock, Mahon River, Lewes, and Clayton I am indebted to Mr. Lewis Woolman, of Philadelphia,[1] who has carefully studied the records and has correlated the waters with water horizons in New Jersey. The very important data for the wells at Middletown and Farnhurst were furnished by Mr. J. H. K. Shannahan, of Easton, the borer, and the information regarding the wells in Wilmington was given by their owners. The general structural relations of all these wells are shown in section 1, Pl. VI.

Middletown, Newcastle County.—The well recently sunk at this place has proved to be a great success. Its depth is 535 feet and it furnishes 240 gallons a minute. A somewhat larger amount was obtained on a special trial with a more powerful pump. The following partial record was furnished by the driller:

Feet.
0–76.....sand with streaks of gravel and ironstone; water.
76–96.....hard green clay with black, rounded sand grains in some beds.
425–475.....tough red clay.
475–497.....fine white sand yielding 40 gallons of water per minute.
497–516.....red clay.
516–535.....fine sand filled with large supply of water.
535–537.....white clay.
537–552.....sand with large supply of water.
552.....pretty hard rock.

The boring was begun on the middle marl bed, but as no record was saved of the beds from 96 to 425 feet, the well furnishes no new light on the thickness of the various members of the marl series. It is probable that the rock at 552 is "granite" or bed rock, as suggested in section 1, Pl. VI, and if this is the case the waters are in basal sands of the Potomac formation. These sands are reported to have a thickness of 36 feet and to include a 2-foot bed of white clay near their middle, which divides the water into two horizons.

[1] Report of geologist of New Jersey for 1891, p. 227; for 1893, pp. 401–404.

Farnhurst, Newcastle County.—This well draws its waters from coarse gravel and sand at a depth of 165 feet, but additional supplies are also obtained at 55 to 63 feet and at 40 feet. The following partial record was furnished:

Feet.	
85	yellow clay.
95	mottled red clay.
99	thin bed of ironstone with some gravel below.
99–140	red clay.
165	coarse sand with pebbles up to one-half inch in diameter.
211	bed rock.

The boring was entirely in the Potomac formation, and the water at 165 feet is in the basal member.

Dover.[1]—A 12-inch well for the Dover waterworks was bored in 1893 to a depth of 196 feet. The water rises to about 12 feet above tide level, or 6 feet above the surface, and the natural flow is 35½ gallons a minute; 218 gallons per minute have been pumped from it. A 4-inch well previously bored found water at 157 feet, but this horizon was cased off in the later well. The two horizons are thought by Mr. Woolman to represent the 720-foot and 760-foot horizons at Atlantic City, and it is predicted that the 60-foot bed of coarse, water-bearing sands of the 800-foot horizon at Atlantic City and Ocean City would be found at Dover at about 50 to 75 feet below the bottom of the 196-foot well, but from the structural evidence presented in section 1, Pl. VI, a higher horizon is indicated.

The record of the Dover well is as follows:

Feet.	
0–7	yellow gravel.
11	deep orange-colored sand and clay.
26	medium orange-colored sand; coarse.
42	light orange-colored sand; finer.
54	sandy clay, with a few marine diatoms.
62	sand and marly clay.
71	sand.
83	brownish clay and sand, with marine diatoms.
90	sand and comminuted shell, with marine diatoms and sponge spicules.
94	sand.
100	sand and broken shell.
109	"marl."
117	micaceous marly sand; some reddish sand grains.
120	sand, with bad water; comminuted shells, diatoms, and coccoliths.
128	sandy clay, with diatoms.
147	clay, with diatoms.
150	sand, shell, and diatoms.
155	clay, with a few diatoms.
157	sand, with good water.
157–167	clay, with pyrite-covered diatoms.
167–196	dark sand, some grains large as peas; good water.

[1] Report of geologist of New Jersey for 1893, pp. 402–403.

Clayton, Kent County.—Water is obtained here in large supply from wells to 35, 60, and 85 feet in the Chesapeake formation, probably at the same horizon as at Dover and Mahon River. The diatom bed below was penetrated to a depth of 150 feet in a trial boring, which was abandoned at that depth.

Milford, Kent County.—Three 6-inch wells were bored at this place in 1891, near tide level. One at 160 feet furnishes 4,000 gallons an hour, and the water rises 2 feet above the surface; another furnishes the same amount from 150 feet, with slightly greater pressure; and the third furnishes 3,000 gallons an hour from a depth of 34 feet. The record given by Mr. Woolman is as follows:[1]

Feet.	
0–11	gravel.
11–25	blue-gray gravel.
25–44	fine gray sand, with water at 34 feet, which rises to the surface.
44–60	blue-gray clay.
60–68	fine gray sand, with wood fragments at 65 feet.
68–73	blue clay.
73–90	fine gray sand, with gravel and shells at 85 feet.
90–118	fine gray sand, containing shells.
118–121	blue clay.
121–137	fine gray sand.
137–140	greenish clay.
140–160	fine blue-gray sand.

Arca, Astarte, Natica, and two forms of Turritella were recognized by Mr. Woolman among the shell fragments. The water horizon is thought to be somewhat above the 300-foot diatomaceous clay bed.

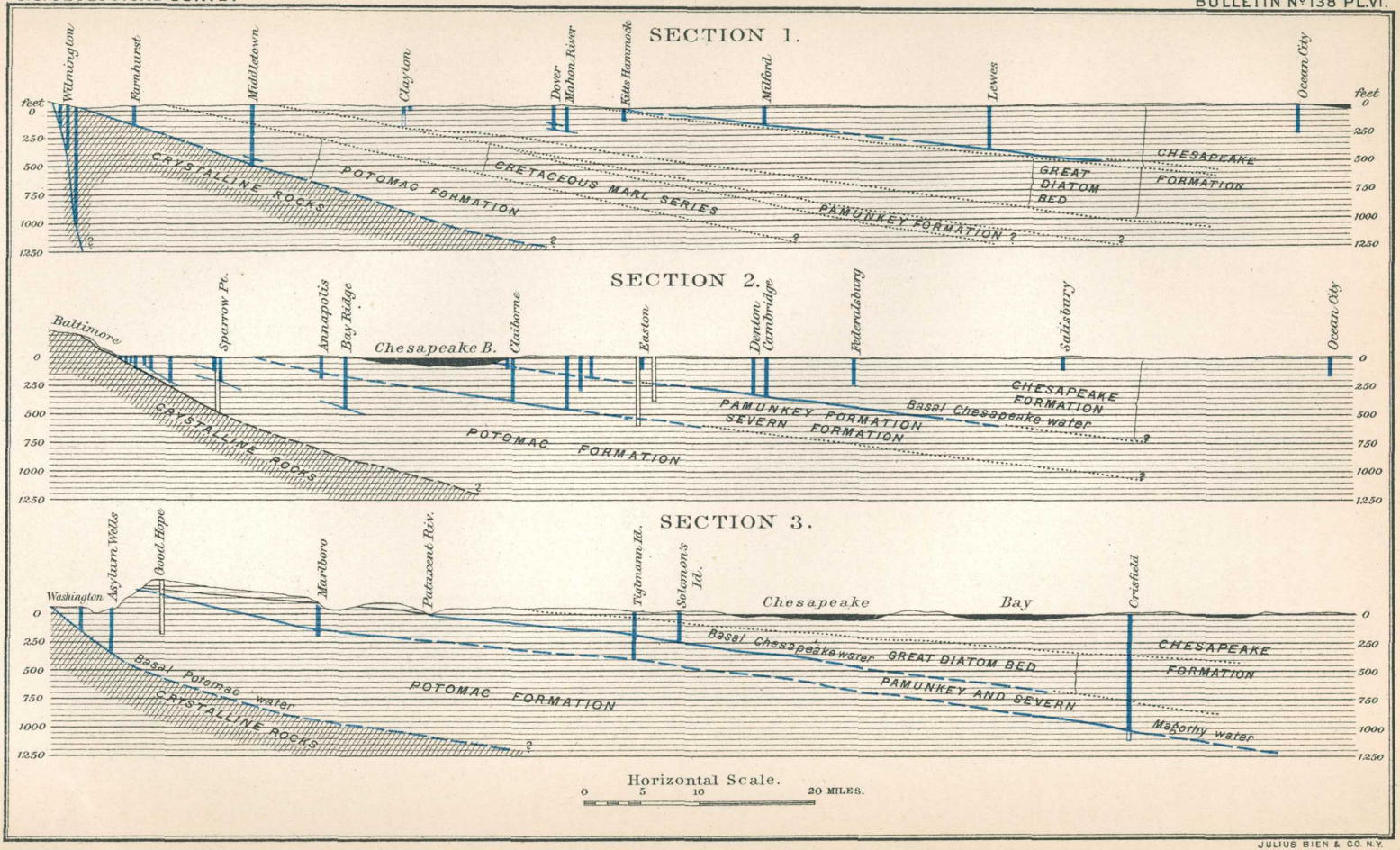
Mahon River, Kent County.—This well was sunk in 1893. It is on the meadow at the landing just north of Mahon River light and 6 miles east of Dover. The following record is given:

Feet.	
0–35	blue marl and mud.
35–75	blue sand and mud.
75–110	blue sand.
110–113	hard blue sand rock.
113–148	blue sand and chalk.
148–154	fine white hard sand.
154–193	white sand mixed with a substance resembling magnesia.
193–198	very fine white sand mixed with fine black sand.
198–206	coarse white sand mixed with gravel, and yielding an abundance of cool, fresh water.

The water horizon appears to be the same as that at Dover at 196 feet.

Kitts Hummock, Kent County.—This well is 7 miles south of the Mahon River well. It is 110 feet in depth, has a diameter of 1½ inches, and the water rises to within 2½ feet of the surface. The water is from a coarse gravel which appears to be in the great Chesapeake diatom bed, possibly at the 525-foot horizon at Atlantic City.

[1] Report of geologist of New Jersey for 1891, pp. 227–229.



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SECTIONS, MARYLAND AND DELAWARE.

Lewes, Sussex County.—This well was bored in 1892 at the quarantine station, at an elevation of about 7 feet. Its bore is 6 inches and its depth 400 feet. The water rises to about the surface. In one day 22,000 gallons were pumped, lowering the water level 55 feet, but it soon rose again when the pump was stopped. The following record is given:

Feet.	
0–90	ordinary beach sand.
90–100	yellowish gravel, medium coarse.
100–300	gray sands and sandy clays, with a fragment of cedar at 200 feet.
300–330	blue tenacious clay, mixed with about 30 per cent of pebbles.
330–392	similar blue clay and alternations of sand.
392–400	sand and water lying on rock.

The beds are Chesapeake below the yellowish gravel, and are thought to be above the great diatomaceous bed.[1] It is probable that the horizon is the same as that at Milford at 150 and 160 feet, as suggested in section 1, Pl. VI.

Wilmington.—The deep wells in Wilmington are bored in the crystalline rocks, and the water supplies appear to be satisfactory.

WATER HORIZONS IN DELAWARE.

As relatively few deep wells have been bored in Delaware, the water horizons have not been fully explored over a very wide area. The well at Middletown has obtained a fine supply of water from the Potomac formation, apparently in the basal beds, and it is probable that this water sheet will be found to extend from Wilmington past Middletown far to the southward. At Farnhurst it yields a moderate supply. The dip of the horizon to the south-southeast is about 30 feet to the mile, which carries it from the tide level at Wilmington to a depth of 165 feet at Farnhurst and 535 feet at Middletown. Water horizons above the lower beds of the Potomac formation and in the Matawan, Redbank, and Lower Marl that occur in New Jersey were not reported in the Middletown well, which probably indicates that these waters do not extend into Delaware. The principal Chesapeake horizons appear to be represented in Delaware, although the evidence in regard to their correlation is not conclusive. The basal Chesapeake water, so important in Maryland, has not been reached by the wells. The water from sands in the great diatom bed (the 525-foot horizon at Atlantic City) probably supplies the Dover and Mahon River wells with their large yields, while Milford and Lewes apparently obtain their waters from just above the diatom bed. As the Kitts Hummock well draws from a bed about 125 feet above the Dover and Mahon waters, its horizon can not be definitely correlated with any of those at Atlantic City. The Ocean City well in Maryland is a high Chesapeake horizon which probably extends into the southern edge of Delaware, but no wells have yet been sunk to it in that State.

[1] Woolman, report of geologist of New Jersey for 1893, p. 404.

WELL PROSPECTS IN DELAWARE.

From the evidence of wells now yielding water supplies, it appears probable that the entire Coastal Plain area of Delaware is underlain by waters, and in the map, Pl. V, it is so represented. About Middletown and northward the Potomac waters are to be expected at depths which decrease at the rate of 30 feet per mile nearly to Wilmington, where the Potomac beds come to the surface. These waters may extend down the dip south from Middletown for many miles, but as no wells have been bored to them in that direction no positive prediction can now be made. At Dover they should be expected at about 1,000 feet below the surface, of the dip continues south at a uniform rate.

The Chesapeake waters begin a couple of miles north of Clayton and extend to the southern border of the State. The basal Chesapeake waters, which are important sources of supply in Maryland and southward, have not been tested by any wells in Delaware, but I should expect them to extend over a wide area. The Clayton boring to 150 feet nearly reached this horizon, and it lies about 450 feet below the surface at Dover. The Dover waters no doubt are widespread, for they are probably the same as those found at 234 feet at Federalsburg. The water horizon which appears to extend from Milford to Lewes probably also underlies all of eastern Sussex County, but it is not reported in any of the Maryland wells. In both Kent and Sussex counties there are almost certain prospects for Chesapeake waters at one horizon or another within 500 feet of the surface. The sections 1 and 2, Pl. VI, show the conditions so far as there are any data to present concerning them.

MARYLAND.

GEOLOGIC RELATIONS.

The Coastal Plain region in Eastern Maryland presents the usual general structural relations, but certain local features are conspicuous. The Raritan formation merges down into the Potomac formation; the upper marl of the marine Cretaceous thins and changes to more clayey beds, and only the middle and lower members continue southward, where they have been designated the Severn formation; the Pamunkey greensand marls come in, and the plateau areas capped by the Lafayette formation become characteristic features. The general structural relations are shown in sections 2 and 3, Pl. VII. The formations are as follows:

	Formation.	Characteristics.	Age.
Pleistocene.	Columbia.	Loams, sands, and gravels on terraces.	
Neocene.	Lafayette.	Gravels, sands, and loams.	Pliocene?
	Chesapeake.	Sands, clays, infusorial earth, and marl.	Miocene.

	Formation.	Characteristics.	Age.
Eocene.	Pamunkey.	Glauconitic marls and sands.	Eocene.
Cretaceous.	Severn.	Black argillaceous, carbonaceous sands.	Cretaceous.
	Magothy.	White sands and brown sandstones.	Cretaceous.
	Potomac.	Clay, sands, and gravels.	Early Cretaceous.

THE POTOMAC FORMATION.

This, the great basal member of the Coastal Plain series, lies directly on the floor of crystalline rocks. In Maryland it consists mainly of clay with interbedded fine sands, but it also contains beds of water-bearing coarse sands and gravels, especially toward its base and lying on the crystalline rocks. Some features and relations of these basal beds are shown in Pl. IX. The thickness of the formation is about 600 feet east of Washington and of Baltimore. Its thickness and components out under the later Cretaceous and Tertiary deposits are not known, for it does not appear to have been pierced by any of the eastern wells. The gravels and sands of the Potomac formation, notably those lying on or near the surface of the crystalline rocks, contain a large supply of water, and a number of wells in and near Baltimore and Washington draw from this horizon. I have great confidence in the extension of this water stratum eastward, but it has been explored by wells in only a relatively narrow belt.

MAGOTHY FORMATION.

This is a thin series of coarse white sands with sandstone streaks which overlie the Potomac formation in eastern Maryland. It is a water bearer. In Pl. X are exhibited its relations to the Severn formation.

SEVERN FORMATION.

This overlies the Magothy formation in Maryland. It is the southern extension of the middle and lower beds of the great greensand marl series of New Jersey, and terminates at the surface near Washington, D. C. It consists of dark, carbonaceous, sandy clay below, merging into fine gray and brown sands above. The thickness in Maryland is 150 feet on the eastern shore, 80 feet near Annapolis, and from 3 to 8 feet east of Washington. The formation does not appear to be a water bearer in Maryland.

PAMUNKEY FORMATION.

This overlies the Severn deposits in Maryland. It outcrops in a considerable area southeast of Baltimore and east of Washington. It consists mainly of glauconitic sands and marls, which are in greater part fine grained. It usually contains less water than the Chesapeake sands, but it furnishes a moderate supply to certain wells. The formation, which attains a thickness of about 150 feet in surface outcrops, appears to thicken gradually to the east and south, but its precise thickness in those directions is not known. Some of its relations are shown in the two lower sections of Pl. VII.

CHESAPEAKE FORMATION.

This is a conspicuous member of the Coastal Plain series in Maryland, although it is overlain in greater part by thin sheets of Columbia or Lafayette deposits. Its western edge extends to the crystalline rocks at a few points, and the formation thickens rapidly eastward to over 1,000 feet at the coast line. It consists of a series of beds of sand and clay which dip gently eastward at a rate of about 15 feet per mile in Maryland and Delaware. These beds rise to the surface in succession on the dip, and outcrop diagonally across the Coastal Plain with a northeast-southwest strike. Clays predominate, and the sands are in greater part of impalpably fine grain. The lower clay members contain a large proportion of diatom remains, and this diatomaceous series is a characteristic member of the formation over nearly its entire area. Interbedded with the clay and fine sands there are, at various horizons, beds of coarser water-bearing sands, some of which underlie wide areas and contain much water. At the base of the Chesapeake formation there usually are gravelly sands, of greater or less thickness, underlying the diatomaceous clays. These basal beds are generally water bearing.

LAFAYETTE FORMATION.

This is a thin sheet of gravels and loams which covers the plateau region of the "ridges" of the southern counties of the Western shore. It has been widely removed north of the latitude of Washington and from the area of the Eastern shore. It generally has water-bearing gravels at its base, and this water supplies all the shallow wells in the higher lands of St. Mary, Calvert, Charles, and southern Prince George counties. The water, however, is similar to that of the Columbia formation in being subject to surface contamination.

COLUMBIA FORMATION.

This occupies terraces along the tidal estuaries and the entire area of the region east of the Chesapeake Bay which is known as the "Eastern Shore." It is in greater part a thin sheet of loam merging downward into a gravel bed, and its total thickness rarely exceeds 25 feet. The basal gravel contains water in moderate amount, and is the general source of supply for dug wells in the lower lands of the region. The water is usually of good quality, but in thickly settled districts and where surface drainage is defective it is subject to contamination. It is probable, also, that it is not sufficiently protected from surface water ever to be free from malarial germs.

WELLS IN MARYLAND.

Except in Baltimore, where there are many wells, the wells in Maryland are relatively few in number and mainly in widely scattered groups. They have been generally successful in obtaining large water

supplies, although in some instances the quality of the water has not been satisfactory. In these instances I find that purer waters could probably be obtained from greater depths, for nearly every portion of the Coastal Plain region in the State is underlain by several horizons of water, and usually only the one nearest the surface has been drawn on.

Data for wells in Maryland have been obtained largely from Mr. J. H. K. Shannahan, of Easton, who has sunk many of the wells. Mr. L. Rude, of Sharps Wharf, Va., has sunk wells in St. Mary and Calvert counties and supplied the information regarding them. Data for the Baltimore wells have been obtained mainly by personal canvass, and my information regarding them has been derived from many persons.

The locations of wells in Maryland are shown on Pl. V, and some of the relations are shown in sections 2 and 3 of Pl. VI and section 1 of Pl. XII. The following is a list of the wells, excepting those in Baltimore, which are given on page 137:

List of deep wells in Maryland.

Locality.	Depth.	Diameter.	Capacity per minute.	Height to which water rises. *a*	Horizon.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*		
Agricultural College.	150	4	5	.....	Basal Potomac....	Ferruginous water.
Annapolis	201	1½	.....	Flows.	Magothy	
Bay Ridge.....	470	6-4½	20	—20	Mid-Potomac	Sulphurous, irony water.
Bowie	384	.....	None.	.....	In Potomac.....	Unfinished.
Bushwood	287	2	.....	+14	Low in Pamunkey.	
Cambridge, 6 wells.	370	8-3	Flow 250 to 160 each.	+15	Basal Chesapeake.	
Chapel Point	237	3	.....	— 6	Basal Pamunkey..	
Claiborne, 1 well...	440	6	Many.	—10	Magothy	Alk. water at 380.
Claiborne, 3 wells..	100	1½	Many.	— 5.	In Pamunkey.....	
Cornfield Harbor, at wharf.	360	1½	.....	+ 7	Basal Chesapeake.	
On farm	240	.....	.....	.....	Chesapeake.....	
Do.....	370	.....	.....	.....	Basal Chasapeake.	
Crisfield, Ice Co ...	1,018	3	200, flows 40	.....	} Magothy	
Do.....	1,033	4½	Flows 130	.....		
Do.....	1,090	6	.....	.....	Potomac	Unfin. June, 1895.
Denton	359	3	30	— 4	.....	
Easton, 6 wells	98-102	4	75 each.	+10	Low in Chesapeake.	
Easton, Barber well.	366	.....	None.	.....	Into Pamunkey...	} No water below 100 feet.
Easton, south of waterworks.	600	3	None.	.....	Low in Severn?...	
Federalsburg.....	234	3	Flows 20	+16	In Chesapeake....	
Indian Head.....	463½	6	11½	+10	In Potomac.....	
Laurel.....	148½	.....	10	—80	Basal Potomac....	
Le Compt's store ..	358	2½-1½	4	16½	Basal Chesapeake.	

a +, feet above surface; —, feet below surface.

List of deep wells in Maryland—Continued.

Locality.	Depth.	Diameter.	Capacity per minute.	Height to which water rises.[a]	Horizon.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*		
Leonardtown	300	1½	Flows 2	+20	Basal Chesapeake.	Water also at 170 feet.
Marlboro	222	6	25	+13	Magothy?	Water at 215 feet.
Miles River Neck "Anchorage."	265	3	15	To surface.	In Pamunkey	
Miles River Neck, Long Point.	195	3	5	To surface.	Basal Chesapeake.	
Miles River (see Tunis Mills).						
Nanjemoy (Landing).	175		Flows 1	+24	Basal Pamunkey	
Oakley, 3 wells	305	1½	Flows 7		Low in Pamunkey.	
Ocean City	256	6	Flows 130	+ 6	High in Chesapeake.	
Patuxent River at B. & O. R. R.	152	6	20		Basal Potomac?	Under red clay.
Piney Point	270	1½	5?	+12	Basal Chesapeake.	
Rousby on Patuxent.	240		Many.	+ 3	do	Fine water.
Rock Point, Charles County.	254		Flows 3	+24	do	
St. George Island, 25 wells.	270	1½	2–5 each.	+12	do	
St. Inigoes, 10 wells.	300	1½	2 each.	+12	do	
"Jutland"	365	1½	1	3½	do	Alkaline water.
Salisbury	101	6	Flows 350	Flows.	High in Chesapeake.	Water unsatisfactory.
Salisbury, 15 wells.	18–75	6	200 in all.	— 2		City supply.
Solomons Island, 2 wells.	252	1½	150 each.	+ 4	Basal Chesapeake.	
Do	258	1½	60 each.	+ 2	do	
Do	256	1½	10		do	
Sotterly					do	
Tilghman Island, 4 wells.	400		Many.		Magothy?	
Tunis Mills, on Miles River Neck.	430	2½	Flows 6 and pumps 100	+ 2	do	Strongly alkaline.

[a] +, feet above surface; —, feet below surface.

DESCRIPTIVE NOTES ON WELLS.

Crisfield, Somerset County.—This place is in the southern corner of the Eastern Shore. Two deep wells have been sunk to 1,018 and 1,033 feet, and a third is now in progress, which had reached a depth of 1,090 feet on June 15, 1895. The principal water supply now utilized is at 1,018–1,033 feet, from which the flow was 130 gallons a minute and the water pressure 20 pounds to the square inch. The wells throw most important light on the geology and water prospects of the region, and fortunately, through the kindness of J. H. Buxton, former president of the water company at Crisfield, I was supplied with samples of borings at frequent intervals down to the depth of 950 feet. Some deeper

samples were subsequently obtained down to the depth of 1,052 feet. The principal features in the record are as follows:

Feet.	
0–13	sands and loams with gravels at base.
13–100	buff and gray sandy clays with shell fragments.
100–110	dark-gray sandy clay; few shell fragments and small pebbles.
120	gray clay.
130	gray clay; many shells.
135	clay, light greenish gray.
140	clay; shells and siliceous concretions.
147	sand, very fine grained; greenish gray; glauconitic.
150	tough clay, light greenish gray.
160	sandy clay, greenish gray.
170	clay, lead gray.
177	glauconitic sands, loose, greenish; shell fragments.
185	glauconitic sands, loose, greenish; fragments of Perna.
190	glauconitic sands, moderately coarse; shells.
230	shells in sand.
235	sand, dark greenish gray; shell fragments.
240	argillaceous sand, gray.
240–268	clay, greenish gray, with siliceous concretions and lignite fragments.
268–270	siliceous concretion.
280	clay, dark gray.
285	clay, tough, greenish gray; shells.
290	clay, light greenish, with siliceous concretions.
310	clay, dark olive; lignite, ferruginous crusts, and shell fragments.
340	clay, light greenish.
345	sand with shell fragments.
350–360	argillaceous sand, light green, with fragments of *Pecten madisonius*.
370	fine sand, greenish gray; fragments of *Pecten jeffersonius*.
380–385	clay, greenish gray; sandy below.
390–420	sand, light greenish gray, moderately fine.
420–430	clay, light greenish gray.
460	clay, very sandy, light greenish gray; shell fragments.
465	sand, very fine, dark greenish gray, micaceous.
466–467	sandy clay, dark greenish gray.
469	clay, dark greenish gray; shell fragments.
473–480	clay, sandy, greenish gray, lighter below.
485	clay, bright greenish gray.
490	sand, fine, greenish gray.
495–510	clay, light greenish.
515	clay, very light greenish tint; very diatomaceous.
520–530	similar to 495–510.
535	clay, light greenish; diatomaceous.
545	clay, dark gray.
555	clay, greenish gray; diatomaceous.
565	sand, argillaceous; shell fragments, *Turritella plebia*.
575	sandy clay, greenish gray.
585–595	clay, brownish gray.
600–605	clay, light gray; diatomaceous; Anomia.
610	sand, fine, greenish gray; shell fragments; glauconite.

Fee..
620.....sand, fine, greenish gray.
630.....clay, sandy; shell fragments.
640–650.....clay, light gray; diatomaceous.
660.....clay, light brownish gray; diatomaceous; Anomia.
670.....clay, very sandy, dark greenish gray.
675–690.....clay, light greenish gray; diatomaceous.
700.....clay, gray, sandy.
710.....clay, light gray; diatomaceous.
720.....sand, fine, greenish gray; large glauconite grains.
740.....diatomaceous clay, dark buff.
750.....diatomaceous clay, light gray.
760.....diatomaceous clay, darker.
770.....sand, fine, greenish gray; some glauconite.
771–775.....rock, with large grains of glauconite.
780–850.....argillaceous sand, dark olive green, with large proportion of glauconite; coarser grained at 820; finer at 800; few small quartz pebbles and a shell fragment (oyster) at 810.
855–950.....clay, very light greenish gray; shell (sp?) at 932.
955.....clay, slightly micaceous.
960.....clay, more sandy, more micaceous.
961–963.....clay, brownish gray, sandy, micaceous, with plant fragments of Severn aspect.
965.....sand, fine, gray, some mica.
970.....clay, black, with pyrite fragments.
971–972.....clay, very compact, light gray.
974–1,005.....sand, fine, micaceous, coarser below; lignite at 990.
1,005–1,015.....clay, brownish gray, tough.
1,015–1,025.....sand, fine, gray.
1,025.....sand, moderately fine, gray, micaceous.
1,033–1,040.....clay, bluish gray, with reddish streaks.
1,042–1,052.....sand, moderately coarse, gray, with some mica; water.
1,052–1,064.....clay and sands, gray, sandy, with reddish streaks.
1,064.....clay, light gray, very compact.

The upper members in this record are typical Chesapeake deposits, but the lower members are not clearly identified. Dr. Wm. H. Dall examined the shell fragments, and states that from 60 to 230 feet the St. Mary's fauna of the Chesapeake formation is well characterized. The diatomaceous beds begin at about 380 feet below the surface and extend to 760 feet. The rock at 771–775 feet appears to be at the base of the Chesapeake formation, as it occurs in wells and outcrops to the north and west, and the highly glauconitic sands or marls below are probably Pamunkey in age. The shell at 932 feet was a worn fragment of which the species could not be determined by Mr. T. W. Stanton, who kindly studied it for me. I received a large mass of clay from 961 to 963 feet, brought up in the valve space of the sand bucket, and as it showed fragments of plant remains I requested Mr. L. F. Ward, of the Geological Survey, to examine it. He found the organic materials too fragmentary for identification, and could give no opinion as to its age. From the aspect of the clay I am strongly inclined to refer it to the Severn formation, of which also the black pyritiferous clay at 970 feet would be quite characteristic. The water-bearing sands which extend from 974 to 1,033 feet are thought to be the Magothy formation.

The sands and clays below would then be of Potomac age. It is greatly to be regretted that the evidence is not more definite in regard to the formations in this well.[1]

A chemical analysis of the water from a depth of 957 feet, by H. J. Patterson, is as follows:

Analysis of water from artesian well at Crisfield, Md.

	Parts per million.
Silica	6.00
Oxide of iron and alumina	1.50
Calcium carbonate	10.50
Magnesium sulphate	5.50
Sodium and potassium, carbonates, chlorides, and sulphates	1,434.00
Total chlorine	97.40
Total sulphuric acid as SO_3	70.00
Nitrogen in ammonia compounds	0.20
Nitrogen in albuminoid compounds	Trace.
Oxygen-consuming power	1.00
Reaction, alkaline (100 c. c. = 18.8 c. c. $\frac{n}{10}$ H_2SO_4)	
Total solids at 100° C	1,457.5

Salisbury, Wicomico County.—The water supply for this place is derived from a gang of 15 driven 6-inch wells to depths of from 18 to 75 feet. They yield in all about 200 gallons a minute.

A deeper boring was made to 101 feet for lower waters, but the result was not satisfactory, because the water was strongly impregnated with mineral matters. The following analyses are given of the water from this well and of the water from the shallower wells which afford the present supply. The analyses were made at the Maryland Agricultural College:

Partial analysis of waters from wells at Salisbury, Md.

	Parts per million.	
	City supply.	101-foot well.
Total solids	171.0000	88.000
Inorganic solids	126.0000	65.000
Nitrogen in free ammonia	.0074	.045
Nitrogen in nitrates (=32.8 N_2O_5)	8.4000	.000
Nitrogen in albuminoid ammonia	.0092	.029
Chlorine	24.0000	5.000
Iron		7.000

[1] Mr. L. Woolman has recently published some additional data regarding the diatoms and other organic remains from the Crisfield wells in New Jersey report for 1894, pp. 181–189, Pl. VII. He states that from 930 to 933 feet there is a glauconitic bed containing a Nodosaria identical with the form occurring in strata immediately over the Middle Marl (Middle Cretaceous or Severn) of New Jersey.

The 101-foot well flowed about 300 gallons a minute, but carried much fine sand. The following condensed record is given:

Feet.	
1–65	sand and gravel.
65–86	sticky blue clay.
86–101	fine, water-bearing sand.

Cambridge, Dorchester County.—This place is on Choptank River, about 40 miles north-northeast of Crisfield. There are six flowing wells reaching a depth of 366 feet and furnishing a large supply of water of excellent quality. The water occurs in sands underlying 100 feet of the diatomaceous clays of the Chesapeake formation, and probably near or at the base of this formation. Rock strata are reported from 75–82 and from 342–344 feet, and one 22 inches thick occurs at 366 feet, just above the water-bearing sand. Sixteen feet of sands above this 22-inch rock stratum are reported to also contain a water supply. At Le Compt's store, 6 miles west of Cambridge, water is obtained from the Cambridge horizon at a depth of 358 feet.

Federalsburg, Caroline County.—This place is 20 miles northeast of Cambridge, in the central-southern portion of the Eastern shore and only 14 feet above tide level. The well is 234 feet deep and the water rises to 30 feet above tide level. From an outlet at 15 feet above tide it flows 600 gallons an hour. The water-bearing stratum is a loose sand, containing glauconitic grains, and overlain by clays. I have not been able to obtain the record. The horizon is well within the Chesapeake formation and is probably the same as that at Lewes and Milford, Del.

Denton, Caroline County.—This place is 15 miles north-northwest of Federalsburg and near tide level. The well is 358 feet deep, through green clay containing shells. The water is of excellent quality and in fair supply. Judging from the statement of the driller, the well is in green clay all the way down to water, and if this is the case the water horizon is probably at the base of the Chesapeake formation, or the same as that at Cambridge and vicinity and in St. Mary and Calvert counties. This would indicate an inclination of the beds of 15 feet per mile in this region.

Claiborne, Talbot County.—This well is on the bay shore, on the western side of the peninsula, nearly opposite Annapolis. The depth is 440 feet, and the water is good and in considerable quantity. The boring is in clay, with black sand grains, from 120 to 380 feet, then "coral rock" for 40 feet, with plenty of strongly alkaline water (16 grains to the gallon); then 10 feet of sand and a crust of sand rock, under which the water occurs. The horizon is probably in the Magothy formation, as at Crisfield. I have not seen the borings. The three wells to 100 feet appear to be in the upper beds of the Pamunkey formation, but may obtain their irony water from the basal Chesapeake beds.

Ocean City, Worcester County.—This is a resort on the Atlantic coast of Maryland a few miles south of the Delaware line. Its well, 256 feet deep, passes through green clays to a sand which yields 130 gallons

per minute of good water. This sand is high in the Chesapeake formation, and probably comes to the surface east of the other wells in Maryland and Delaware.

Easton, Talbot County.—There are six 4-inch wells at Easton, reaching a depth of from 98 to 102 feet, which yield about half a million gallons a day. The horizon is about the same as at Federalsburg. A stratum of rock is reported at 97 feet in these wells. A boring 366 feet deep near Easton is reported to have passed through a rock stratum at 220 feet, which is undoubtedly the rock at the base of the Chesapeake formation, with which water-bearing beds are associated at Cambridge, Denton, and on the Western shore. In another deep-test boring, made some time ago just south of the water company's wells, a depth of 600 feet was attained, but no water was found below 100 feet. The well ended in a mixture of bowlders and clay with ironstone streaks, probably not far above the horizon which yields water at Claiborne and Crisfield.

Miles River Neck, Talbot County.—One well on the Shipley property, "The Anchorage," near the bridge, found water at 265 feet. The supply is 15 gallons a minute and the water rises to the surface. The driller reports hard rock strata at 140 and 223 feet, the latter being a foot thick and probably indicating the base of the Chesapeake formation. Another well is about a mile due west, at Long Point, on Miles River. Its depth is 195 feet and the water-bearing sand lies on a rock stratum, which is probably at the base of the Chesapeake formation. The water rises to the surface at the rate of about 5 gallons a minute.

There is a well at Tunis Mills which is 430 feet deep. The water supply is large, but the water is strongly alkaline. It is in sand which overlies a "coral rock" similar to that reported in the well at Claiborne. The horizon is apparently in the Pamunkey formation, and the well is the only one of which I have heard on the eastern shore which has found water in these beds.

Centerville, Queen Anne County.—An attempt to bore a well was made at this place many years ago, but for some reason it was not a success. Nothing was learned as to its depth or record.

Bay Ridge, Anne Arundel County.—The well at this place was sunk to 470 feet to a gravel bed which yields sulphurous and ferruginous water at the rate of about 20 gallons a minute.

Hawkins Point, Anne Arundel County.—A well bored in 1895 has the following record:

Feet.	
0–60	pink clay.
60–100	pink sandy clay.
100–120	fine buff sand.
120	white and buff mottled clay.
136	white and buff mottled clay.
137	water in bed of sand between clay beds.

Bowie, Prince George County.—At Bowie Station, 18 miles northeast of Washington, a well is in process of boring for the Philadelphia,

Wilmington and Baltimore Railroad Company, and I have received samples of the borings through the courtesy of Mr. E. T. Brooks, superintendent. They are as follows:

Feet.	
114	sand, light brownish-gray, fine.
120	clay, buff and yellow, mottled.
135	clay, buff, with white streakings.
140	clay, light buffish gray.
165	sandy clay, pink and buff variegated and ocher-yellow.
202	sand, fine, loose, buff-gray.
215	clay, bright pink, with white streakings, and layer of brown sandstone.
233	sand, fine gray, with few buff grains.
265	sand, pink-brown, moderately fine.
280	sand, light gray-brown.
300	clay, rich brown-pink tint.
314	clay, light pinkish-buff.
333	sand, coarse gray, with some pink and yellow grains.
335–345	sandstone, red-brown, with fragment of lignite.
345–355	sand, very fine, light reddish-brown.
355–384	sand, very fine, buff, containing a large pebble of quartz.

This boring is in the Potomac formation, and probably to within about 150 to 200 feet from the basal beds, where it is expected that abundant water will be found.

Marlboro, Prince George County.—The Marlboro well has a depth of 222 feet, and yields a flow of excellent water, apparently from the Magothy formation. The water is stated to rise 13 feet above the surface, which is elevated about 30 feet above tide-water level. At a depth 3 feet below the surface the well supplies 25 gallons per minute. The following record is based upon statements and samples furnished by Mr. R. A. Baker, the well driller:

Feet.	
0–185	green sand marl with Pamunkey fossils.
185–190	hard rock strata.
190–215	gray micaceous clays, with Severn fossils at a depth not precisely indicated.
215–222	white, water-bearing sand, with fragments of lignite and silicified coarse sand.

Indian Head.—At the naval proving grounds a well was sunk which yields a moderate but satisfactory water supply. It is near the Potomac River, at an altitude of about 100 feet above low-water level. Its depth is 463½ feet, and is cased with 459.1 feet of 6-inch iron pipe. The water rises to about 10 feet above low-tide level, and has to be pumped to the surface of the terrace. Its yield is 11.68 gallons per minute. These facts and the following record and analysis were furnished by the Bureau of Ordnance, Department of the Navy:

Feet.	
0–15	soil, with light sand.
15–18	cobblestone and clay.
18–22	red clay and gravel.
22–27	sand and gravel.

Feet.	
27–34	red clay, with water.
34–42	dark marl.
42–54	red clay and sand mixed.
54–72	hard, tough, sandy clay.
72–87	red, tough clay.
87–95	hard, sandy clay.
95–110	red, hard clay.
110–112	rock.
112–122	hard, sandy clay.
122–125	very dark, sandy clay.
125–134	dark clay and sand.
134–142	mixed red sand and clay.
142–160	dark, sandy clay.
160–170	blue, hard, sandy clay.
170–220	gray sand and clay.
220–230	dark-blue sand and sandy clay.
230–260	hard clay and sand.
260–285	very fine, gray, sandy clay, with little gravel.
285–302	light-gray, sandy clay.
302–313	clay and sand.
313–328	gray, sandy clay.
328–340	clay and sand.
340–346	clay and sand, with little dark-red gravel.
346–353	sand, mixed with red clay.
353–358	part red and part gray clay.
358–360	soft rock.
360–365	red clay.
365–368	hard, red beds.
368–376	hard, red beds, with blue intercalations
376–387	blue and red beds.
387–392	blue beds and sand.
392–400	clay, mixed with sand.
400–409	sandy clay and rock.
409–424	gray rock.
424–435	mixed sand and sandy clay.
435–442	?
442–445	blue, sandy clay and sand.
445–456	sandy clay and sand.
456–463.5	hard sand, with gravel.

The upper beds are earlier Columbia and Pamunkey formation. The Potomac formation was entered at about 42 feet and the boring stopped in the lower portion of the formation. The basal beds lie about 150 feet deeper and probably would have afforded a larger water supply. An analysis of the water by Joseph Westerson, dated December 24, 1895, gave 23.8 grains per gallon of solid matter, consisting exclusively of chloride of sodium. Free ammonia was reported as 0.008 milligram per liter, and albuminoid ammonia as 0.09 milligram per liter.

Laurel, Prince George County.—A well on the farm of Mrs. J. D. Taylor, 3 miles southeast of Laurel, was recently bored to a depth of 148½ feet. It pumps 10 gallons per minute, but appears to be capable of yielding a much larger supply. The water was found in sand and gravel underlying 147 feet of red clay. It rises to within 80 feet of the surface.

Solomons Island, Calvert County.—There are four flowing wells on this island, and another at Rousby on the mainland just north. They average about 250 feet in depth and furnish good supplies of excellent water. The water horizon is the basal Chesapeake beds, the same as in the St. Mary County wells, and at Denton and Cambridge on the Eastern shore.

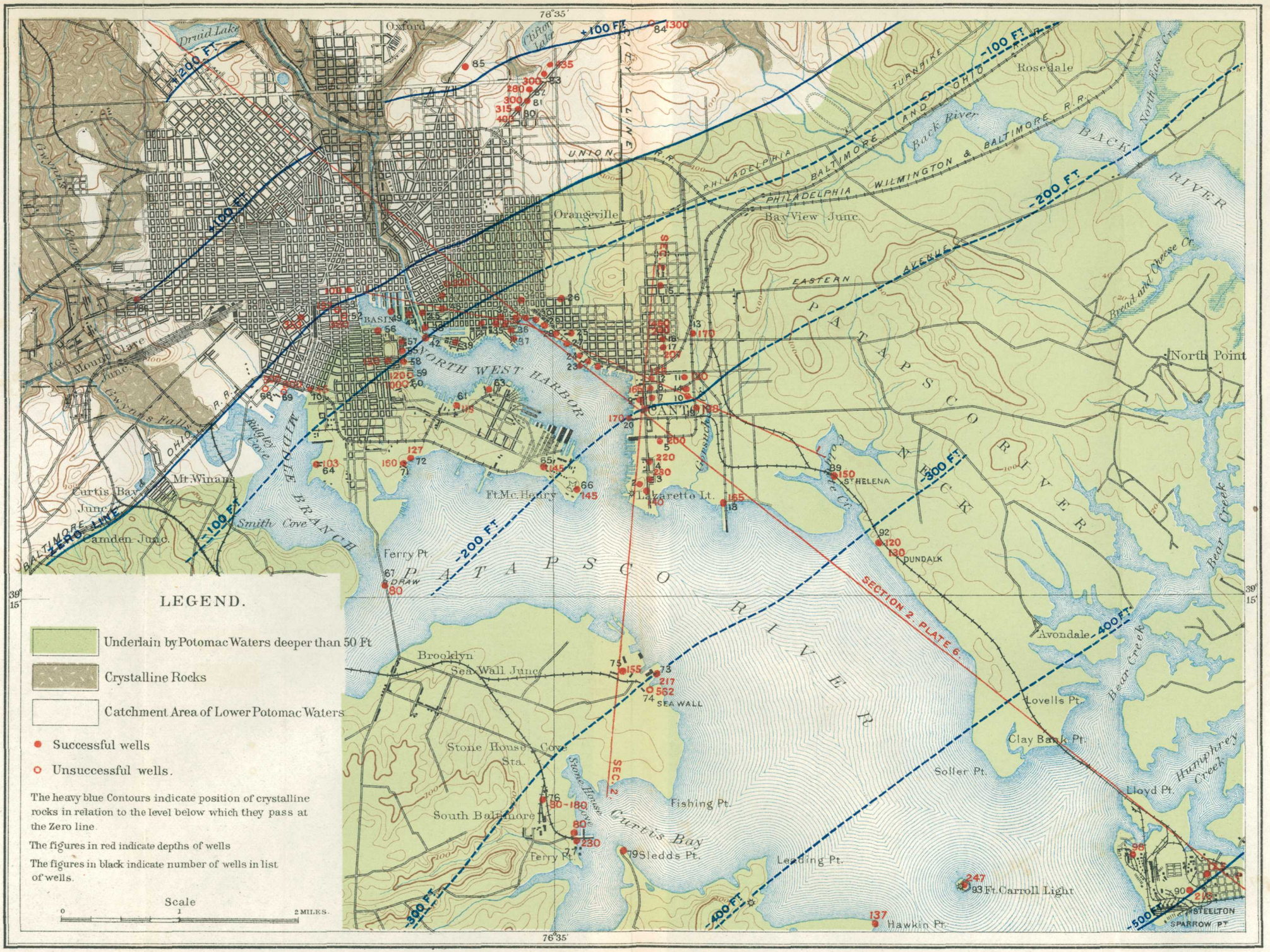
St. Mary County.—The wells at Leonardtown, Piney Point, St. George Island, and about St. Inigoes are all sunk to the basal Chesapeake horizon, which furnishes water in the group of wells across the river in Virginia. The relations of all these wells are shown in section 1, Pl. XII.

Chapel Point, Charles County.—This place is on Port Tobacco River, near its mouth. The well is 237 feet deep, and is said to have a large water supply which rises to near the surface. The record, unfortunately, could not be obtained. It is probable that the water horizon is at the base of the Pamunkey formation, or the same as in the deeper wells at Colonial Beach, across in Virginia.

THE BALTIMORE REGION.

GEOLOGY OF BALTIMORE.

Baltimore lies in the zone in which the crystalline rocks emerge from beneath the Coastal Plain deposits. Although the greater part of the city is built on the Potomac formation, the depressions of Jones and Gwynns falls are excavated to the crystalline rocks, and these rocks rise rapidly to constitute the surface in the region north and west. The Potomac formation consists of its usual materials, in which predominate clays of various colors and fine sands. Toward its base there are intercalated beds of coarse sands and gravels, and at the base an almost general occurrence of these materials, lying on a floor of crystalline rocks. Some features and relations of these basal beds are shown in Pl. IX. The coarse materials contain widely extended sheets of water, which have been tapped by many well borings of moderate depth. The rock floor slopes quite steeply eastward, at a rate averaging about 65 feet per mile, but the rate appears to increase locally to 100 feet along by the Basin. The basal gravels pass beneath tide water along a line extending from the lower Baltimore and Ohio Railroad bridge over Gwynns Falls to the Fayette street bridge over Jones Falls, and thence due east-northeastward, as shown by the blue zero line on the map, Pl. VII. The principal water supplies are to the south of this line, for to the northward the waters are free to flow laterally into the depression of Jones and Gwynns falls. The basal gravels emerge in the northern portion of the city, although in some areas they are overlain by a thin cap of gravels and loams of earlier Columbia age. They cap the Druid Hill Park region, the ridges for some distance out Charles street, Roland avenue, and York, Harford,



MAP OF BALTIMORE REGION ILLUSTRATING FEATURES OF UNDERGROUND WATERS, BY N.H.DARTON.

and Belair roads, and the high region about Catonsville. In these outlying extensions the basal gravels constitute a capping on the crystalline rocks which averages from 10 to 30 feet in thickness. The superficial distribution of the crystalline rocks and the contour of the floor on which the Potomac formation lies are represented in Pl. VII. The principal structural relations are shown in the sections on Pl. VIII. On Patapsco River Neck the Potomac formation rapidly thickens as the crystalline rock floor descends to the eastward, and at Sparrow Point the thickness was found to be 500 feet. The higher ridge which extends along the northern portion of this neck is capped by a thin mantle of earlier Columbia gravels and loams, and the lower terraces consist of later Columbia loams and sands, with some gravel in the lower beds. These formations, however, are not involved in the question of the deeper water supply.

The crystalline rocks present considerable variety of materials, but gneiss and granite, or "gray stone," and the "nigger head," or gabbro, are the most conspicuous varieties. They are all considerably fissured and often deeply decomposed along fissures or veins of moderate width and extent. The fissures or veins are usually nearly vertical and extend from northeast to southwest. They are water-bearers in greater or less measure, but their distribution and extent have not been determined, except in the case of the one along Belair road, which has been tested for a short distance.

List of deep wells in Baltimore.

Locality.	Depth.	Diameter.	Capacity per minute.	Height to which water rises. *a*	Remarks.
Canton.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
1. Maryland Fertilizer Co., Clinton and Eleventh streets, 3 wells.	140	2½ and 1½	15	— 8	
2. Stickney Iron Co., Clinton and Eleventh streets.	130	1½	30	— 2?	
	175	.....	.....	— 3	
	226	.....	.....	.....	
3. Lazaretto Fertilizer Co., Clinton and Tenth streets.	220	6	Many.	—22	Water also at 155 feet.
	220	3			
4. Baltimore Guano Co., Clinton and Ninth streets.	170	3	Many.	.....	
	125	12			
	80	3			
5. Susquehanna Fertilizer Co., First street and Seventh avenue.	±200	10	Many.	—20	Water also at 120 feet.
6. Griffith & Boyd, Clinton and Fifth streets.	90	12	Many.	.....	
	190	10	Many.	.....	
7. Orient Distilling Co., First street and Third avenue, 2 wells.	210	.....	65–80	.....	
	185	.....			
Orient Distilling Co., First street and Third avenue, 3 wells.	125	.....	.....	.....	Poor water.

a —, feet below surface.

List of deep wells in Baltimore—Continued.

Locality.	Depth.	Diameter.	Capacity per minute.	Height to which water rises. *a*	Remarks.
Canton—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
8. Baltimore Copper Co., First street and Third avenue, 8 wells.	50	Small.	10 each.	.....	
	114	8	75	.....	
	165	.....	45	.....	To rock at 212 feet,
9. Copper works, Clinton and Third streets, 3 wells.	87–90	4	20 each.	—16	
	160	.....	Many.	.....	
10. Electric Refining Co., Eighth street and Fourth avenue, 4 wells.	50–120	3–6	160 in all.	.....	
	129	10	120	.....	
	216	8	+150	—38	Rock at 216 feet.
11. Standard Oil Co., First avenue and Eighth street.	130	20	400	—40	Air pumps.
12. Standard Oil Co., Second avenue and Second street.	195	12	550	—20	Do.
13. Monumental Distilling Co., O'Donnell street.	170	.....	Many.	—12	
	190	.....	Many.	.....	
14. Davidson Acid Works, Second avenue and Eighth street.	196	4½–3	+ 40	—26	
15. Schluderberg Packing Co., Third and Bank streets.	160	.....	150	—98	Rock at 230 feet; water also at 216 and 135 feet. No water 216–408 feet.
16. National Brewing Co., O'Donnell and Third streets.	240	10	200	.....	Air pumps.
	450	6			
17. Gunther's brewery, O'Donnell and Third streets.	207	6	50–60	.....	Air pump.
	208	6	120	—56	
18. Northern Central R. R. wharf, foot of Thirteenth street.	165	16	+150	.....	
19. Power house, Canton, Tenth street and Fifth avenue.	198	8	100	.....	
20. Northern Central R. R., elevator No. 1, foot of Sixth avenue.	170	4?	70	.....	
From Canton to the Basin.					
21. Fait & Slagle Co., foot of Streeper street.	93	9	Many.	.....	
	112	10			
22. Tunis Lumber Co., foot of Chesapeake street.	148	1½	20	.....	
23. McGrath & Co., foot of Patapsco street.	114	2	20	— 2	
24. Chipman & Son, Patapsco and Boston streets.	123	6	Many.	.....	
25. Norton Tin Co., Boston and Luzerne streets, 5 wells.	50–60	12	35–60 each.	.....	
	120	8	Many.	.....	
26. Gas works, Eastern and Patapsco streets.	.....	.....	.....	.....	
27. G. G. Tyler, Boston and Luzerne streets, 2 wells.	225	4	Many.	— 6?	
	120	6	+ 40	.....	
28. Farren & Co., Boston and Hudson streets.	.....	.....	Many.	.....	
29. Wagner & Co., Boston and Concord streets, 2 wells.	100	6	50	— 7	
	100	1½	30	— 7	
30. Gibbs Preserving Co., Boston and Leakin streets.	100	8	Many.	.....	

a —, feet below surface.

List of deep wells in Baltimore—Continued.

Locality.	Depth.	Diameter.	Capacity per minute.	Height to which water rises. *a*	Remarks.
From Canton to the Basin—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
31. Old sugar refinery, foot of Chester street.	112	.....	Many.	.....	
32. Sheppard & Co., Eastern avenue and Chester street.	80	12	500	—20½	
33. Booth Packing Co., foot of Washington street.	94	10–6	200	— 4	
34. Davidson & Co., Wolfe and Lancaster streets.	.....	8	Many.	— 3 to —10	
35. Public pump, Wolfe street near Lancaster.	.....	.....	Many.	.....	
35. Public pump, Ann street near Lancaster.	.....	.....	Many.	.....	
36. Winebrenner Bros., Wolfe and Thames streets.	85	4	50	— 1	Rock at 90–95 feet.?
37. Ice works, Wolfe and Fell streets, 2 wells.	157 317	8	300 each.	—15	Much water at 97 feet. 157–317 feet in rock.
38. Smith's distillery	132	.....	.....	.....	To black rock.
39. Chrome works, 1348 Block street.	72	.....	.....	.....	Saline water.
40. Corner Lancaster and Caroline streets.	.....	.....	.....	.....	
41. Iron works, Broadway and Thames.	.....	.....	.....	.....	
42. Maltby property, Block and Albemarle streets.	900	.....	Satisfactory.	.....	In rock.
43. Alice Anna and West Falls streets.	70	3	.....	.....	Poor quality of water; rock at 112 feet; no water 70–112 feet.
45. Duker & Co., President street and Canton avenue.	90	.....	.....	.....	Formerly a large supply; very little now.
46. Potteries, Canton and Central avenues, 7 wells.	45	.....	Many.	.....	
47. Public well, Central and Eastern avenues.	50?	.....	Many.	.....	
48. Bartholomay Brewing Co., Central avenue and Gough street.	320	8	None.	.....	Stopped in quicksand.
49. Flour mills, foot of Smiths wharf, 3 wells.	.....	.....	.....	.....	Old wells; water scaled boilers badly.
From the Basin and Locust Point to Spring Garden.					
50. Maltby House	100	10–12	40	.....	
51. Cold Storage Co., 409–411 West Conway street.	353	8–6	100	.....	50–353 feet in rock.
52. Gail & Ax, Charles and Barre streets.	380	6	None.	.....	Mica gneiss.
53. Globe Brewing Co	197	6	10	.....	Do.
54. Jones's paper mill, on Federal Hill.	150	.....	75	—75	Low Potomac; rock 180–402 feet, no water.
55. Moore & Brady, foot of Montgomery street.	53½	8	Many.	—10	Low Potomac; rock 85–135 feet, no water below 53 feet.

a —, feet below surface.

List of deep wells in Baltimore—Continued.

Locality.	Depth.	Diameter.	Capacity per minute.	Height to which water rises. *a*	Remarks.
From the Basin and Locust Point to Spring Garden—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
56. Marble works, Lee and Johnson streets.	60	2½	Few.	.....	Brackish water.
	200	6	Few.	.....	
57. Dunnington & Co., foot of Hughes street.	65	4	Fair.	— 6	
58. Beacham & Bro., foot of Warren street.	58	1½	Fair.	—18	
59. Skinner's shipyard, foot of West street.	72	2½	Many.	.....	
60. Numsen Can Co., Jackson and West streets.	100	.....	.....	—10	Water also at 60 feet.
61. Woodhall & Co., Marriott and Allen streets.	115	8	16	— 8	Fine water.
62. Pearson & Co	102	.....	.....	.....	
63. Ferry landing, Locust Point	.....	.....	Many.	.....	Do.
64. Thomsen Chemical Works, Winder and Leadenhall sts.	103	6	30	—30	
65. Warren Manufacturing Co., near Fort McHenry.	148	4	50	.....	
66. Fort McHenry	145	.....	.....	.....	
67. Light Street bridge	180	1½	Many.	Flowed.	Iron water; corrosive.
68. Spring Garden Brewery	500	.....	None.	.....	Rock 30–500 feet.
69. Hannis Distilling Co., Ostend and Warner streets.	800	.....	.....	.....	20 gallons on top of rock at 200 feet.
Hannis Distillery Co., Ostend and Warner streets, 2 wells.	42	144	70	— 6	
70. Hilgartner & Sons, Sharp and Ostend streets.	44	4	Many.	.....	
71. Horner & Co., Covington and Donaldson streets.	160	10	250	—10	
72. Chesapeake Guano Co., foot of East Winder street.	54	1½	150	.....	Bad water.
	68	1½	175	.....	
	117	2	100	.....	Good water.
	122	2	100	.....	
	127	2	100	.....	
Brooklyn to Curtis Bay region, etc.					
73. Rasin Fertilizer Co., Seawall	217	4½	Many.	— 5	
74. Baltimore chrome works, Seawall.	155	4	10–15	— 2	
	562	.....	None.	.....	
75. Monumental acid works, Seawall.	155	4	10–15	Flows(?)	
76. Curtis Bay Water Co., 8 wells	80–180	3–8	Many.	—25	
77. Sugar refinery, Curtis Bay	80	6	Many.	—10	
	230	4?	Many.		
78. Car shops, Curtis Bay	65	.....	Many.	—20	
Baltimore Yacht Club	.....	.....	.....	.....	
79. Hawkins Point	137	.....	.....	.....	
Northeastern section.					
80. Bauernschmidt brewery, Gay and East Federal streets.	315	.....	31	.....	
Do	400	.....	25	.....	

a —, feet below surface.

List of deep wells in Baltimore—Continued.

Locality.	Depth.	Diameter.	Capacity per minute.	Height to which water rises. *a*	Remarks.
Northeastern section—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
81. Wiessner brewery, Gay and East Lanvale streets.	300	.....	20?	.....	Dry 300–600 feet.
82. Standard brewery, Gay and East Townsend streets.	286	6	15	.....	In rock. Ferruginous water.
83. Van Der Horst brewery, Gay street and North avenue.	300	10	120	.....	Rock at 36 feet.
Do	435	8	120	.....	Rock at 36 feet.
84. Brehm's brewery	1,300	.....	Dry.	.....	In rock.
85. Darley Park brewery	.....	.....	.....	.....	
Western section.					
86. Lipp soap works, Hollands and Calverton Road.	200	.....	35	—65	In granite below 28 feet.
Do	350	.....	35	—65	
87. Sheep butchers' abattoir, Calverton.	.....	.....	60	.....	
88. Adler's brewery, Calverton	.....	.....	.....	.....	
St. Agnes, Wilkins avenue	800	.....	.....	.....	
Wells on Patapsco River Neck, below Canton.					
89. St. Helena	156	6	50	.....	
90. Sparrow Point Lumber Co., 2 wells.	98	4	Flows 20	.....	Strong iron.
Sparrow Point Iron Co., etc.:					
40 wells	125	4, 6, and 8	Flow. Pump 100 to 200 each.	+?	
1 well	210	4	100	+?	
Do	495	.....	.....	.....	To granite rock. No water below 210 feet.
91. Distillery on Colgate Creek, 2 wells.	150	2	35 each.	+3	In 10 feet of gravel under hard red clay 0–140 feet.
92. McShane's foundry at Dundalk.	120	8	Many.	—40	
	230	8	Many.	—40	
93. Fort Carroll	247	.....	.....	.....	

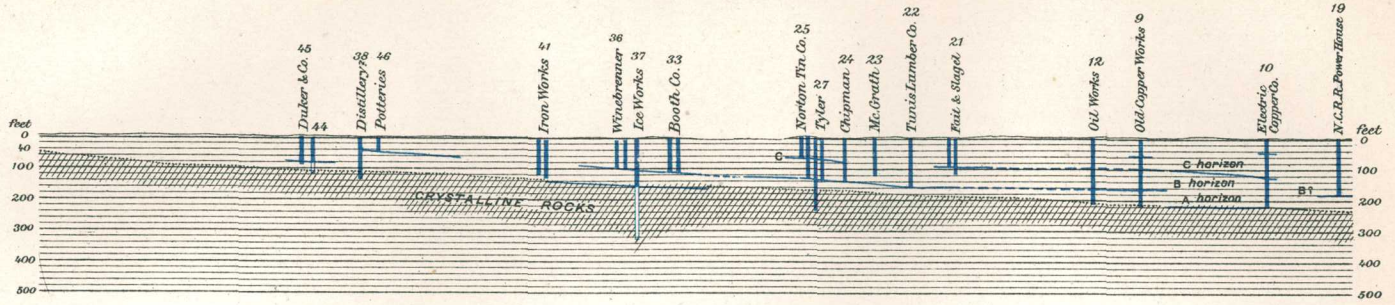
a—, feet below surface; + feet above surface.

WATER HORIZONS, WELLS, AND WELL PROSPECTS IN THE BALTIMORE REGION.

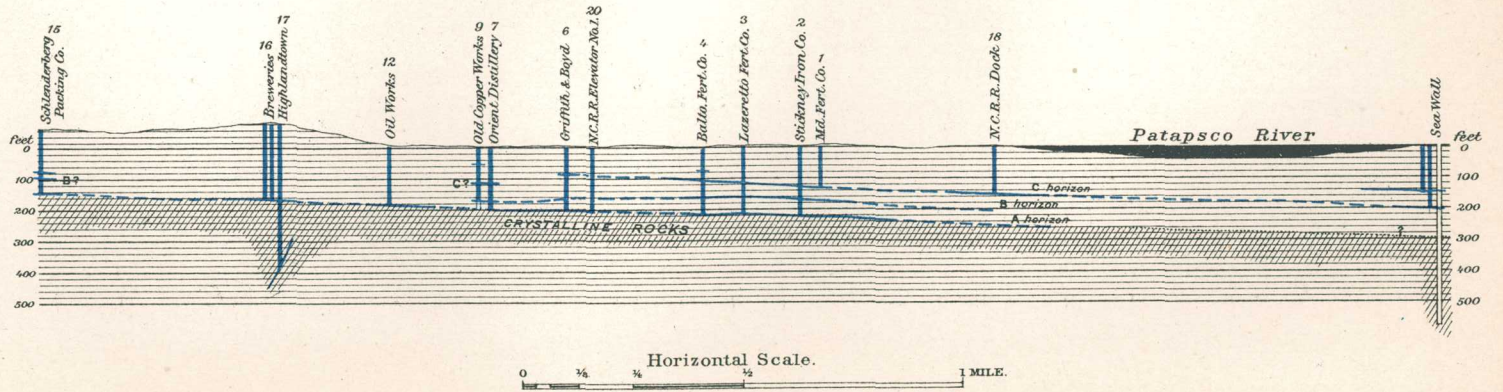
As very few well records or descriptive data were obtained in Baltimore, and the wells are in groups of which the general relations are significant in their bearing on water horizons and prospects, I shall combine the discussion of these questions and include incidental notes on some of the wells. In most cases all the information that could be obtained regarding depth, yield, etc., of the wells is given in the tables, pages 137 to 141. The location of the wells is shown on the map, Pl. VII, and the relation of nearly all are shown in sections 1 and 2 on Pl. VIII. The numbers in black on these plates are for reference to the list of wells on pages 137 to 141.

Canton.—The many wells in Canton have afforded a fairly definite idea of the distribution of underground waters in that section. The wells are mainly in the vicinity of Clinton street, but there are others farther eastward, and some in Highlandtown. They indicate the presence of several widely extended sheets of water-bearing gravelly deposits, the upper beds of which are intercalated between sheets of clay and fine sand, the lower bed lying on the floor of crystalline rocks. The dip is to the southeast at a very uniform rate of 60 feet per mile. In the map, Pl. VII, an attempt has been made to represent the underground contour of the lowest beds, and in the sections in Pl. VIII some of the relations are shown. The first section is along and near Clinton street, from Highlandtown to Thirteenth avenue, and across the Patapsco River to Seawall. This section indicates three principal water horizons, which I have lettered A, B, and C, respectively. They are at intervals which average 40 feet from the bed rock up. The most extensive sheet of water-bearing materials is B, which appears to average from 30 to 50 feet above the crystalline rock floor, and it supplies large amounts of excellent waters at the copper works, Northern Central power house, the Standard Oil Company's well at First avenue and Seventh street, and at many other places. Water generally occurs in large volume in the gravels and sands lying on the crystalline rock floor (Horizon A), and many wells draw from this source, notably those at the Electric Copper Works, the breweries at Highlandtown, the deeper wells on Lazaretto Point, the 210-foot well of the Orient Distillery, the well at Northern Central Railroad Elevator No. 1, and the 195-foot well at the oil works on Second street, near Second avenue. No water was reported below 160 feet at the old copper works; the deep well at Seawall found no water on top of the crystalline rocks, and the basal and lower Potomac waters are all absent at Sparrow Point if the record of the 495-foot well is to be relied on. It is probable, however, that to the south and east these water horizons rise from the crystalline rocks. In wells between Third and Eleventh avenues there is a general occurrence of a water horizon, which I have designated C, which lies about 100 feet above the basal beds or crystalline rock floor. It

SECTION 1.



SECTION 2.



Horizontal Scale.

0 ⅛ ¼ ½ 1 MILE.

JULIUS BIEN & CO. N.Y.

SECTIONS, BALTIMORE REGION.

appears to extend to Seawall, South Baltimore (Curtis Bay), and Colgate Creek, and is probably the source of water in the Northern Central Elevator well (foot of Thirteenth street) and of the water at 100–114 feet in the copper works wells. The following analysis is given of the water of this horizon from the well at the old copper works from a depth of 100 feet. In this well there is probably some surface contamination, for the soil is deeply saturated with acid.

Analysis of water in well at copper works.

	Grains per gallon.
Chlorine	0.62
Sodium	0.41
Magnesium	0.64
Calcium	0.35
Sulphuric acid	0.00
Total	2.02
Reaction distinctly acid.	

Another horizon, D, about 40 feet higher, is found at the old Copper Works, the Electric Copper Works, the Baltimore Guano Works, and possibly in other wells, but it has not been well explored, and I understand that the water is subject to surface contaminations to the northward, where it lies only 50 feet deep.

The only well record which I obtained for the Canton region is a partial one for the well 198 feet deep at the Northern Central Railroad power house at Tenth street and Fifth avenue. It is as follows:

Feet.
0–18.....sand.
18–19.....gravel.
19–45.....sand.
45–47.....clay.
47–67.....sand, with slight admixture of clay.
67–69.....coarse sand and gravel, with water.
69.....thin bed of compact sand underlain by thin bed of clay.
69–170.....fine sand, with occasional very thin gravel beds.
170–? .....thin clay bed, 2 feet of gravel with slight water yield, three feet of very hard clay.
198.....clean coarse gravel, yielding 100 gallons of water per minute.

The last is probably the basal gravel of the Potomac formation, or Horizon A.

There are several wells in the upper portion of Canton, known as Highlandtown, which yield large water supplies. At the National Brewery there are two wells to 240 and 450 feet, and at Gunther's Brewery two wells to 207 and 208 feet. No records of these wells could be obtained, but it was stated that rock was noted at 240 feet. The waters at 207 and 240 feet are probably in basal Potomac beds, or Horizon A, as shown in section 1, Pl. VIII. At Schluderberg's Packing House, seven blocks north of these breweries, a well was bored to

over 408 feet which yields 100 gallons a minute. Sand rock was reported at 216 feet, "granite" at about 230 feet, limestone from 360 to 385 feet, and then the "granite" again to 408 feet. Water was found at 135, 160, and 210 feet, and the 160-foot, or B horizon, was tested to 150 gallons a minute. The identification of the sand rock and of the top of granite in the boring is too unreliable to positively determine the location of the basal beds of the Potomac formation, but they probably carry the water found at 210 feet.

Southern Baltimore, from Canton to the Basin.—These wells are mainly along or near Boston street and on the eastern side of Fells Point. There are only a few in the vicinity of Jones Falls, and they are not very successful. From the foot of Patuxent street to Ann street there are 25 wells, nearly all of which are large producers of excellent water. Some are very old and others have been recently bored. The average depth is between 80 and 120 feet, and the principal water horizon is B of the Canton region, but A and C also are found. Locations of wells and contour of the lower water horizon are shown in the map, Pl. VII. Section 2 of Pl. VIII illustrates the principal relations. This section is from the Basin across Fells Point and eastward along or near Boston street to East avenue and thence to the Electric Copper Works, looking north.

The wells at the ice works on South Wolfe street, near Fell, form an interesting group which quite clearly exhibits the relations in the region. The well borer kindly furnished me with data regarding them, including the following record:

Feet.	
0–25	filling.
25–30	black mud.
35–42	pinkish clay.
42–47	sand and gray gravel, with brackish water.
47–95	clay of various colors: pink, gray, red, yellow, etc.
95–97	sand and gravel, with large supply of good water.
97–155	clay of various colors and a few sandy streaks.
155–157	gravel and sand, with large supply of good water.
157	hard black rock, which was penetrated to 317 feet without finding water.

The large water supply found in the basal Potomac beds, Horizon A, appears to extend to the north and west, but it was not reported in the Tyler well, half a mile southeast. The greater number of the wells in this district find abundance of water in the B horizon about 40 feet above the basal beds. This water has yielded a large supply at the ice works wells at a depth of 97 feet and in several wells in that vicinity, but it has not been traced to the westward. In the 60-foot well at the Norton Tin Works and in the 93-foot well at Fait & Slagel's a higher water horizon was found, which appears to be the C horizon of the Canton region. It was not, however, reported in wells lying between these two localities, nor in the wells to the westward. Possibly the C horizon is the one that yields water at the potteries, corner of Canton and Central avenues, at a depth of 45 feet. The several wells

at this locality yield a largeamount of excellent water, which does not appear to contain surface contamination. The following record is given for one of the wells at the potteries:

Feet.	
0–20	black mud.
20–30	yellow loam.
at 30	gravel; full of water.
30–41	yellow clay.
41–45	hard "kaolin."
45–50	white gravel, full of water.

The well on West Falls avenue, near Alice Anna street, obtains water from sands about 42 feet above bed rock, no doubt in the B horizon; and the Duker wells, a few blocks northeast, have a depth of 90 feet, probably to about the same horizon. The water of the first is brackish, and that of the latter, although formerly in large supply, is now greatly decreased in amount. In the region immediately adjoining Jones Falls and for some distance to the westward on the north side of the Basin deep wells do not yield satisfactory water supplies, on account of proximity of the basal and lower Potomac beds to the surface. Several wells have penetrated the crystalline rocks, notably the one at the old Maltby property, at the foot of President street. This well was bored to a depth over 900 feet, and found, I understand, a fair supply of satisfactory water. The Tyler well, at the foot of Luzerne street, appears to have penetrated the rock for some distance, and it furnishes a large supply of water, but I could not ascertain whether the water came from the rocks or the overlying beds.

A recent boring at the Bartholomay Brewing Company's building on Central avenue, near Gough street, encountered "quicksand" at 320 feet, which could not be penetrated with the means at hand. This boring was in the crystalline rocks from 250 feet down.

Region between the basin and harbor and the Middle Branch.—There are several wells along the north side of Locust Point to Fort McHenry. which yield satisfactory water supplies from the Potomac horizons, The wells at the marble works at the south end of the basin reach basal Potomac beds at 160 feet, and extend into the bed rock to 200 feet, but they do not yield much water. Wells less than 100 feet deep at Dunnington's, Moore & Brady's, and Beacham's shipyard draw from a horizon about 30 feet above bed rock, and this same horizon is reached at 150 feet in the well at the paper mill on top of Federal Hill. At this mill the rock was found at a depth of 180 feet, and penetrated to 402 feet without yielding additional water.

At Moore & Brady's Packing House, foot of Montgomery street. there is a well 53 feet 7 inches deep which yields a large supply of pure water. It is reported that sand extended from the surface to 30 feet, and clay from 30 to 53 feet. The water is in a gravel and sand bed of which I could not learn the thickness. The well borer stated that the rock was found under blue clay at 85 feet, and that it was penetrated to 135 feet without finding additional water.

The water horizon is found at a depth of 100 feet at the Numsen Can Company, near the foot of West street, and probably the same water is found in the 115-foot well at Woodhall's, at the foot of Allen street, where it is reported to be in gravel under white clay. At the packing establishment of C. H. Pearson & Co. water is obtained in sands from 80 to 102 feet below the surface, at a somewhat higher horizon, probably, than the one that yields water at 60 feet at the Numsen Can Company, on West street. The record of the Pearson well is as follows:

Feet.	
0–8	shells.
8–15	mud.
15–22	mud with shells and gravel.
22–30	red clay.
30–45	white clay.
45–60	sandy white clay.
60–65	sand-rock.
65–80	white impervious clay.
80–102	water-bearing white sand.

This water is also found at the works of the Warren Company, near the foot of Fort avenue, and in the well at Fort McHenry, all at a depth of 145 feet. It is probably the C horizon found on the other side of the harbor, at about the same depth, in the well at the Maryland Fertilizer Works.

Probably the B and C horizons underlie all of the Locust Point region, and the A horizon in the basal beds may possibly occur at some localities to the southeastward of the Federal Hill region.

On the Ferry Point peninsula there are a few widely scattered wells, which, however, indicate that the favorable conditions in Canton and on Locust Point continue to the westward. The group of wells near old Fort Covington, at the eastern foot of Donaldson street, obtain abundant waters at three main horizons, 55, 122, and 160 feet below the surface, apparently in the C, B, and A horizons. The waters from 54 to 69 feet prove to be unsatisfactory in quality, as they did also at the roundhouse of the Baltimore and Ohio Railroad, a few blocks northwest. The deeper waters give no scale in the boiler and are in large supply. The well of the Thompson Chemical Works, at the west foot of Wincer street, on the opposite side of the peninsula, obtains abundant water supply at a depth of 103 feet, probably from the B horizon. The well on the Light street drawbridge has a depth of 180 feet and furnished much water, but it was unsatisfactory for boilers, and the well is now abandoned. The water was probably from the A or basal Potomac horizon.

Basal Potomac waters are found in wells 45 feet deep on the corner of Ostend and Sharp streets, and also at the Hannis distillery, where the quantity is large and the quality apparently good, but probably there is some surface contamination in these shallow wells.

Between the Basin and Ridgeley Cove a number of attempts have been made to obtain water from the crystalline rocks with varying

POTOMAC GRAVELS ON CRYSTALLINE ROCKS, NORTH CHARLES STREET, BALTIMORE; LOOKING NORTH.

degrees of success. At the cold-storage warehouse, 408 West Conway street, a well 353 feet deep obtains a large supply of water that answers for condensing, and the Maltby House obtains water for closets, etc., at a depth of 100 feet.

At Gail & Ax's building, corner of Charles and Barre streets, a boring to 380 feet was made in a mica-gneiss, and at the Globe Brewery, two squares northwest, there is a boring to 197 feet, neither of which found water. At the Hannis distillery, on Ostend street, near Warner, a well was bored over 800 feet into the rock and only a very small amount of water obtained, while no water at all was found in a boring to a depth of over 500 feet at the Spring Garden Brewery, a couple of squares west. Our knowledge of the occurrence of water in the crystalline rocks about Baltimore is at present too uncertain and too largely negative for predictions to be made.

Region from Brooklyn to Curtis Bay.—The successful group of wells at Seawall and at South Baltimore (Curtis Bay) indicates a wide and general extension of the Potomac waters under the Curtis Bay-Patapsco peninsula. The Seawall water at 217 feet appears to represent the C horizon. The 562-foot boring at Seawall no doubt demonstrates the absence of water in the basal Potomac, or A horizon, in that vicinity, and also in the underlying crystalline rocks.

Region southeast of Canton to Sparrow Point.—The wells of St. Helena, Dundalk, and Sparrow Point are included under this heading. Their relations are shown in section 2, Pl. V. The wells at St. Helena are probably in the C horizon, and the water at 230 feet at Dundalk is thought to be in the B horizon, which probably would have been found at 200 feet at St. Helena. The 120-foot water at Dundalk I can not correlate with any other, but possibly it is the deepest water of Sparrow Point.

The Sparrow Point wells are a most satisfactory group of water producers. The principal supply is obtained from a depth of 125 feet in a horizon that is high in the Potomac formation, for a well to 495 feet just reached the granite bed rock. In this deep well no water was found below 210 feet, which indicates that the lower water horizons do not extend far to the eastward in this region. The one well which draws 100 gallons a minute from a depth of 210 feet is in a horizon which can not be definitely correlated with those to the northwestward.

Northeastern Baltimore.—Several breweries in this section of the city have deep wells, some of which yield satisfactory water supplies. They all penetrate the crystalline rocks and obtain water from fissures or decomposed portions of these rocks. The water is found mainly at a depth of from 300 to 400 feet in the wells near the junction of Belair road and North avenue, and the wells are along the northeast-southwest strike of the rocks. Probably there is one large vein having a width of, approximately, 200 feet, and it may extend along the Belair road and Gay street far beyond the present line of wells. At the Wiessner brewery the water was found at 300 feet below the surface, and

in fair supply, but when wells were sunk to 315 and 400 feet at the Bauernschmidt brewery, a block southwest, the supply at once diminished to a very small amount. The well at the Brehm brewery, which is some distance east of the Belair road, and several squares beyond North avenue, was sunk in the rock to a depth of 1,300 feet without finding water, but it is considerably east of the line of the other wells.

The Darley Park Brewery well, on the Harford road, three squares north of North avenue, is west of the Belair-Gay street line of wells. The waters from these wells differ considerably in character, but in greater part they are satisfactory for boilers and drinking. An analysis of the water of a well at Von Der Horst's brewery is as follows:

Analysis of water from well at Von der Horst's brewery.

	Grains per gallon.
Sodium chloride	3.25
Sulphate of lime	1.33
Carbonate of lime	8.44
Carbonate of magnesia	3.55
Total	16.57

The water from the wells at the Standard brewery is too ferruginous for general use.

Western part of Baltimore.—Excepting the well at the Lipp Soap Works, at Holland and Calverton streets, I have no specific data for borings in the western part of Baltimore. The soap works wells are in crystalline rocks, and reached a vein or fissure which yields a good supply or water of excellent quality.

THE WATER HORIZONS OF MARYLAND.[1]

It is now satisfactorily established that the entire Coastal Plain region of eastern Maryland is underlain by subterranean waters, and that there are several horizons of water-bearing beds under the greater part of the area. On the map in Pl. V, and in the cross sections of Pl. VI, the distribution of wells and water horizons is represented, and it will not be necessary to supplement these illustrations with an extended discussion.

The water horizons in the gravels and sands of the basal beds of the Potomac formation, which lie on or near the floor of crystalline rocks, are the principal source from which waters are to be expected in the western portion of the area. How far southeastward this water horizon may extend has not been determined, but probably it will yield water in many areas nearly to the shores of the ocean. This last consideration is, however, not particularly important, for to the east and south the dip of the Potomac horizon carries it to a great depth, and there

[1] See also under Baltimore, pp. 135–148.

are several strata of water in higher beds in the Potomac, and in other formations at more moderate depths. The easternmost successful wells which have reached the base of the Potomac formation are those in the southeastern portion of the Baltimore region, in the District of Columbia, and at Middletown, in Delaware, all of which are only a few miles from the outcrop of the formation, so that the eastern extension of the basal Potomac waters is not known over a very great breadth of territory. The failure of the well at Sparrow Point to find water in the basal beds indicates also that the sheet of water is not general at this horizon.

The water horizons at various distances above the basal beds, but lying within the Potomac formation, have been extensively explored in the vicinity of Washington and Baltimore, where they appear to be widespread and satisfactorily productive. They have also been reached in the Marlboro well at a depth of 216 feet, and in the Indian Head well at 459 feet. The well at Bowie found no satisfactory supply of water to within about 200 feet of the base of the formation, nor was the well on Spesutie Island a success, though it appears to have penetrated the Potomac beds to a considerable distance. The sands of the Magothy formation, which underlie the Potomac formation, appear to be water bearers over a wide area on the Eastern Shore of Maryland, as probably indicated by the wells at Claiborne, Tilghman Island, and Crisfield, and possibly also at Tunis Mills. They underlie the central area of the Western Shore southeast of a line from Bowie to the mouth of the Patapsco River, but do not appear to yield water in Marlboro, Annapolis, and Bay Ridge wells. The boring to 600 feet at Easton, unfortunately, probably did not thoroughly test this horizon, otherwise we might have had some important evidence for that portion of the Eastern Shore region. The 265-foot well on Miles River Neck appears to draw its water from a horizon in the Pamunkey formation, but this well is the only indication of a water horizon in these formations in the Eastern Shore region. In the wells at Colonial Beach, Va., and in the wells at Nanjemoy, Chapel Point, and Rock Point, in Charles County, the basal Pamunkey beds yield water which probably underlies much of southern Maryland southeast of a line from Herring Bay to Liverpool Point.

The basal Chesapeake water horizon, which is well explored in Virginia, yields water over a wide area in the southern counties of the western shore at depths from 200 to 300 feet, as in the wells at Solomons Island, Leonardtown, Piney Point, St. Inigoes, and St. Georges Island. At Cornfield Harbor it is 365 feet. This horizon also furnishes large water supplies at Denton, Cambridge, and LeCompts Store, and possibly in the well to 195 feet on Miles River Neck, on the Eastern Shore. It was not found at Crisfield, nor in the deeper boring at Easton, although the asscoiated sandstone bed was reported at Easton. Its probable area is shown on the map (Pl. V) by a separate color, which comprises also the higher Chesapeake horizons to the south and east. These higher Chesapeake horizons are important in New Jersey and

Delaware, and although not extensively tested in southern Maryland they probably underlie a considerable area of the Eastern Shore. At Easton the large water supply in wells 100 feet deep is from a horizon in the Chesapeake formation about 150 feet above its base, and the Federalsburg water from a depth of 234 feet is either in the same horizon or in one not a great distance above. The small showing of water at 160 feet at Leonardtown appears to be a local occurrence, for it was not reported in other wells to the eastward. The unsatisfactory water at Salisbury is from a much higher horizon, and the flow of fine water at Ocean City is still farther up in the Chesapeake formation. In the wells at and near Cambridge and at Crisfield no waters were reported above the basal Chespeake beds; so we must conclude that the higher waters do not extend in that direction.

PROSPECTS, BY COUNTIES, IN EASTERN AND SOUTHERN MARYLAND.[1]

ANNE ARUNDEL COUNTY.

In the northern portion of this county water may be found at moderate depth in the various beds in the middle and lower portion of the Potomac formation. The wells at Seawall found Potomac water at a depth of about 200 feet, or about 80 feet above the base of the formation. The depths increase rapidly to the eastward; and along a line extending from Bodkin Point, at the mouth of the Patapsco River, by the heads of the Magothy and Severn rivers and Millersville to the forks of the Patuxent River, the base of the formation is about 600 feet below tide-water level. Water may also be looked for in the southern extension of the formation as far as the southern edge of the county, where the basal beds sink to about 1,300 feet below tide-level. There are prospects for water in beds at various horizons in the lower half of the formation, but as yet they can not be definitely predicted. At Bay Ridge a mid-Potomac horizon was found at a depth of 470 feet, which may extend widely to the westward. In the vicinity of Annapolis water may be expected in the same horizon as that which is tapped by the 208-foot well at Annapolis. This water probably underlies all the lower portion of the neck between the Magothy and Severn rivers, at a somewhat less depth than at Annapolis, for the beds rise to the north and west. The same waters may probably be expected in the Davidsonville region, in the Patuxent Valley, about West and Rhode rivers, and near Herring Bay, at a depth which increases at the rate of 25 feet per mile to the southeastward.

CALVERT COUNTY.

This county is probably underlain throughout by the water which is obtained in the wells at Solomons Island, at the base of the Chesapeake formation, at a depth of about 250 feet. The depth decreases at the rate of about 9 or 10 feet per mile northward from Drum Point, and

[1] Exclusive of Baltimore County, which is treated on pages 142–148.

the water-bearing beds rise from below tide-water level along a line from Nottingham to Herring Bay. This water may be expected to flow several feet above tide level, but of course it will be far below the surface on the higher lands back from the bay or river. There are probably other water horizons below the one just described, notably the Magothy horizon, which may be expected at moderate depths (300 to 400 feet) below tide level in the northern part of the county. It is not known whether the Pamunkey or basal Pamunkey waters underlie the county, but if they do they should be looked for midway between the basal Chesapeake and Magothy horizons.

ST. MARY COUNTY.

The conditions in this county are almost precisely similar to those in Calvert County, except that the water horizons are from 75 to 100 feet deeper at Point Lookout than at Drum Point. The wells at Leonardtown found the basal Chesapeake waters at a depth of about 200 feet, and at Piney Point and St. George Island they are 270 feet below tide level. The dip to the southeast carries the water 30 feet deeper at St. Inigoes. The well at "Jutland" is said to be 365 feet deep and one at Cornfield Harbor is 360 feet. The water found at 237 feet at Chapel Point in Charles County may extend into St. Mary, but no wells have yet been sunk to it.

CHARLES COUNTY.

In the western portion of the county waters may be expected in the basal beds of the Potomac formation at a depth of about 500 feet below tide level. The well at Quantico, on the west side of the Potomac River, obtained a good supply from this horizon at a depth of 210 feet, and the water rose considerably above tide-level. There also are waters at higher horizons in the Potomac formation, as indicated by the successful well at Barrow, in Virginia, which reached them at a depth of 143 feet, and the well at Indian Head at 459 feet. In the extreme eastern and southern portions of the county this water is at a depth of about 500 feet, and the water in the basal Potomac is about 300 feet deeper. The water found at Nanjemoy at 175 feet, at Chapel Point at a depth of 237 feet, and at Rock Point Landing at 275 feet probably extends widely under the central and eastern portions of the county, but its extent is not yet fully determined. The waters in basal Chesapeake beds may be expected at a depth of about 100 feet near the eastern border of the county, but they were not in useful amount in the well at Rock Point Landing.

PRINCE GEORGE COUNTY.

In the northern portion of this county the water at the base of the Potomac formation will be found to be available over a wide area. Along the line of the Baltimore and Ohio Railroad this water horizon is about at tide level, and along the line of the Baltimore and Potomac Railroad it is about 350 feet lower. The well at Bowie, which was

started at an elevation of about 150 feet, was sunk 384 feet before it was abandoned, and would in all probability have found water within the next 200 feet.

The basal Potomac waters may also be expected along the Potomac Valley in this county at a fairly uniform depth of 500 feet. Other waters will probably be found in higher beds of this formation at less depths, for these waters are obtained in some of the wells in the District of Columbia, and at Barrow, in Virginia. The new Marlboro well found a fine supply of water at a depth of 215 feet, with considerable head in sands which are either in the Magothy beds at the base of the Severn formation, or near the top of the Potomac formation. This same horizon may be expected to furnish water over the entire southeastern section of the county at depths which increase at the rate of about 12 feet per mile to the south of Marlboro and decrease at the same rate to the north and west. There is a fair degree of probability that the basal Potomac waters will also be found in the same section at about 500 feet below the horizon of the Marlboro water.

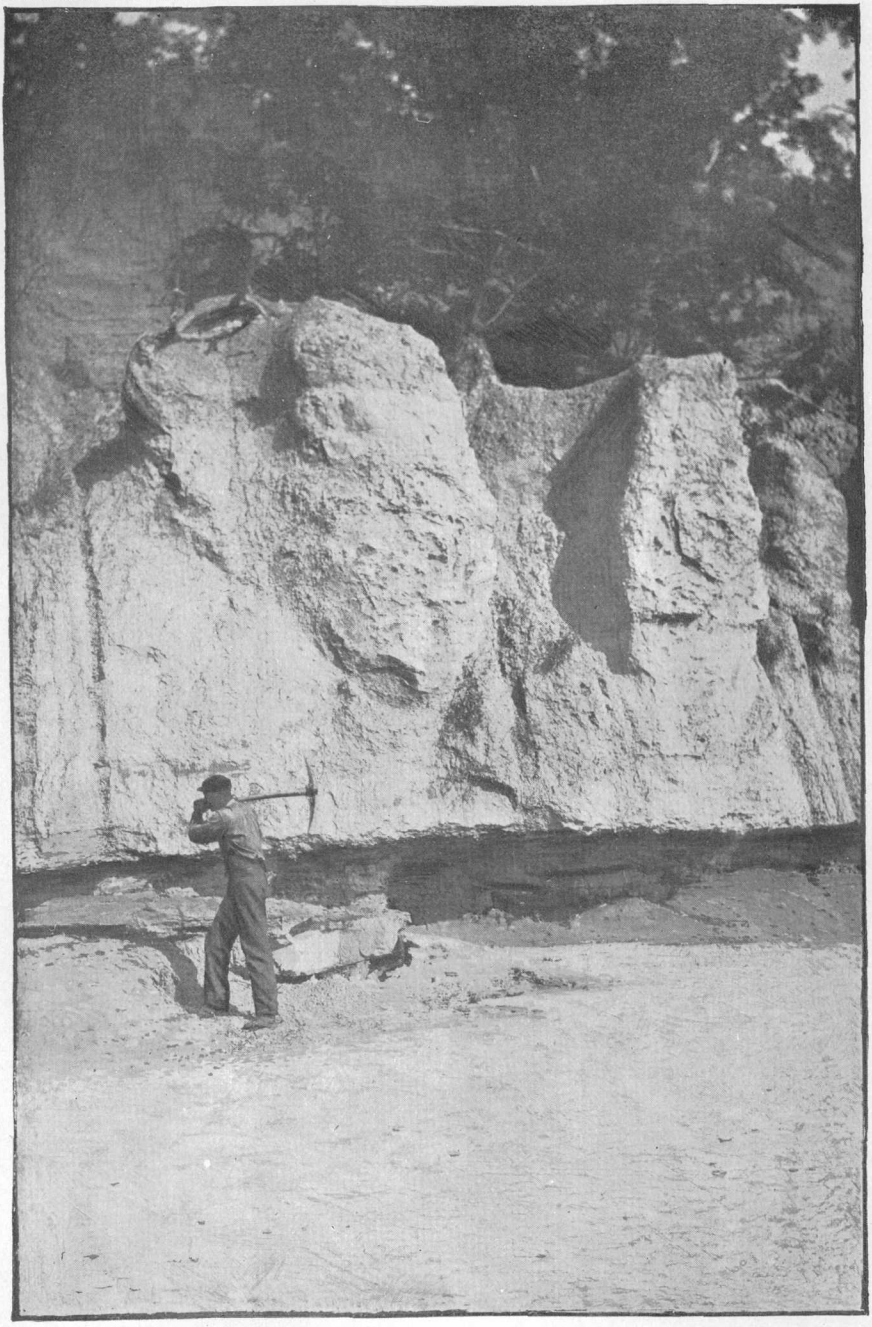
In the extreme southeastern corner of the county water may be expected at depths of from 75 to 100 feet in basal Chesapeake beds, and possibly also 250 feet deeper in basal Pamunkey beds.

HARFORD COUNTY.

The southern portion of this county, adjoining the bay, is underlain by the Potomac formation, at or near the base of which a large supply of water may probably be expected. The area is included in the wide, low neck lying between Bush River and the head of the bay. The depth to the basal waters at Michaelsville is about 250 feet. Possibly waters may also occur at higher horizons in the formation, as they do in Baltimore and vicinity, but of this we have no definite knowledge at present.

CECIL COUNTY.

The basal Potomac waters underlie the portion of this county south of the Philadelphia, Wilmington and Baltimore Railroad. These basal beds are at tide level at Elkton and at Northeast, and dip to the southeast at the rate of about 45 feet per mile. This dip carries them to a depth of about 250 feet at Chesapeake City, 500 feet on the middle portion of Bohemia River, and over 600 feet in the southeastern corner of the county. They were found at Middletown, Del., at 535 to 552 feet. Water may also be looked for in higher Potomac beds at a less depth, but these horizons are less trustworthy. The Magothy formation, which passes beneath the surface along a line extending from Grove Point to Chesapeake City, is a water bearer which may be expected to furnish water east of that line. Its dip is to the southeast at a rate of about 20 feet per mile, which carries it to a depth of 150 feet in the southeastern corner of the county. It furnishes water in many of the dug wells of Sassafras and Bohemia Neck regions. (See Pl. X.)



SEVERN CLAYS ON MAGOTHY SANDS, SHORE OF CHESAPEAKE BAY, 1 MILE NORTH OF GROVE POINT, CECIL COUNTY, MARYLAND; LOOKING EAST.

KENT COUNTY.

This county is underlain by the Magothy sands, which may be expected to yield water throughout the area. The depth of this water is about 250 feet along the Chester River and along a line from Crumpton to Galena. From 300 to 400 feet below the Magothy water begin the Potomac waters, which may be expected at a depth of about 650 feet along the bay shore.

QUEEN ANNE COUNTY.

Although no successful wells appear to have been sunk in this county and its immediate vicinity, the geologic conditions are so clearly indicated that good prospects for water may be predicted with some confidence. The Potomac and Magothy waters probably underlie the county at depths which gradually increase southeastward from those given above for Kent County at a rate of about 10 feet per mile. I should expect to find the Bay Ridge waters at a depth of 600 feet on Kent Island, and to have a fair prospect for obtaining water in Magothy sands 250 feet above. Along the eastern half of the county there is an excellent prospect for the basal Chesapeake waters, which are tapped at Denton, in the adjoining county, at a depth of 359 feet. The depth would of course be less, for the beds gradually rise to the northwest.

TALBOT COUNTY.

The many wells in the western portion of this county have located the underground waters in that section, and in all probability they extend throughout the county. Section 2 of Pl. V shows the relations of the waters.

The Claiborne, Tunis Mills, and Tilghman Island wells probably reached the Magothy waters, which I believe extend from Kent County to Crisfield. The deep boring to over 600 feet at Easton did not go quite deep enough for the lower Potomac beds, but if it was so managed as to properly test the various formations, the Magothy, basal Chesapeake, and Pamunkey waters are absent in this section. The 366-foot well also failed to find water, and it appears to have penetrated the bed of siliceous rock at the base of the Chesapeake formation. The higher Chesapeake water area appears not to extend far beyond Easton. The 265-foot well on Miles River Neck appears to obtain water from the Pamunkey formation, and the well to 195 feet probably draws from the basal Chesapeake horizon, the same as at Denton and about Cambridge, and possibly also in the shallower wells at Claiborne. Probably along the Choptank River this basal Chesapeake horizon may be depended on for water, even though it was neither found at Easton nor reported at Tilghman Island. The Magothy water is probably about 700 feet below the surface in this portion of the county. Probably below the Magothy beds water will also be found in the Potomac formation.

CAROLINE COUNTY.

The Denton well to 359 feet and the Federalsburg well to 234 feet indicate two Chesapeake horizons in this county. The first is in basal Chesapeake beds, in which waters probably underlie the entire county at depths of from 350 to 450 feet, for they are tapped at Cambridge to the southwest at 370 feet. The impure water of the deeper Federalsburg well is in a higher horizon, which was not reported at Denton, but may extend across to the 100-foot wells at Easton. The Magothy horizon lies about 400 feet below the basal Chesapeake water, and no doubt underlies Caroline County. As to the deeper horizon nothing can now be predicted for the southern counties of the Eastern Shore.

DORCHESTER COUNTY.

The basal Chesapeake waters which are so satisfactory at Cambridge and LeCompt's store probably underlie all of this county at depths which increase to 500 feet in the southern section. As the horizon is not a water bearer at Crisfield, it may end in southern Dorchester County, so that we can not be confident of its continuation far south of Cambridge. A well sunk to the Magothy beds in any portion of the county will probably find the same water as at Crisfield. The higher Chesapeake horizons can not be predicted widely in the county, as they were not reported at Cambridge or Crisfield, but they probably extend at least a few miles from Federalsburg, and they may be found to be widespread.

WICOMICO COUNTY.

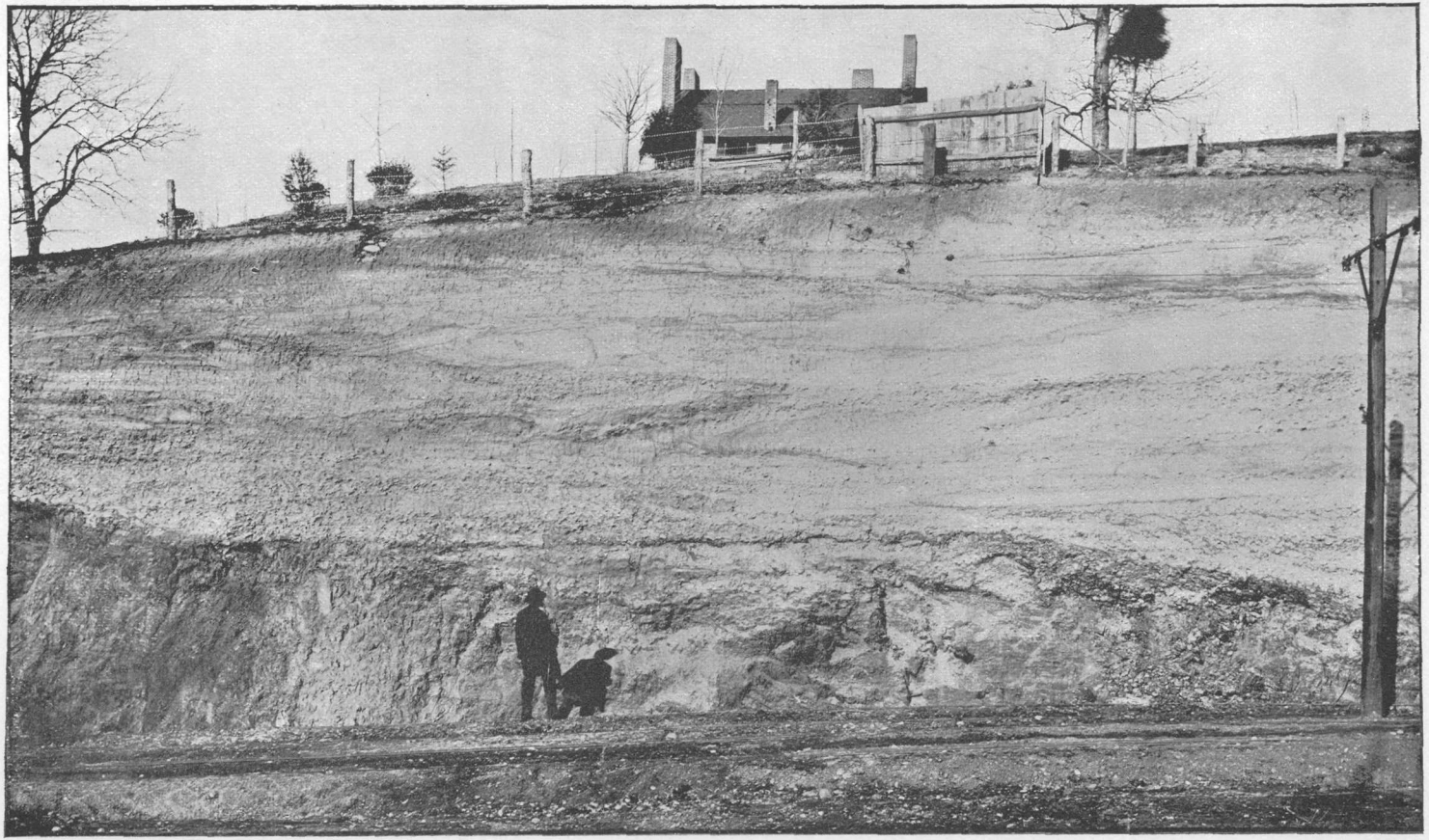
The unsatisfactory water at 101 feet at Salisbury is not a fair test of the resources of this county for underground waters. It would appear, however, from the experiences of the Crisfield well, that only the deeper horizons continue into the county, and my only prediction would be for the Crisfield water at depths near 1,000 feet. Possibly the basal Chesapeake waters, or even higher Chesapeake waters, may extend into the county, but this can only be suggested as a possibility. It is, I believe, worth testing.

SOMERSET COUNTY.

The Crisfield wells prove the existence of large supplies of water, but so far they have been too saline for general usefulness. These waters probably underlie the entire county at depths near 1,000 feet, for the county lies along the strike of the water-bearing beds. Still deeper, in the Potomac formation, there may possibly be waters at intervals down to the crystalline rocks, or the bed rock, which I should expect to find at about 1,500 feet.

WORCESTER COUNTY.

The Ocean City well obtains water from upper Chesapeake beds, in which there may be water under all of the county, or at least its eastern



POTOMAC GRAVELLY SANDS ON CRYSTALLINE ROCKS, QUARRY ROAD, NEAR ZOOLOGICAL PARK, WASHINGTON, D. C.; LOOKING NORTH.

portion. No prediction can be made as to the extent of these waters or the possible southward extension of higher Chesapeake waters on account of entire lack of definite data. There is a fair chance that the Crisfield waters underlie the county at depths near 1,200 feet, but this can be surely determined only by a boring.

DISTRICT OF COLUMBIA.

GEOLOGIC RELATIONS.

The District of Columbia extends across the zone in which the crystalline rocks emerge from beneath the Coastal Plain deposits and rise into the Piedmont Plateau to the west. The contact line crosses the Potomac River at Washington, passes through the western portion of the city, and to the northward extends along the east side of Rock Creek valley. The formation that lies on the crystalline rocks is the Potomac, which consists mainly of water-bearing sands and gravels below and of clay and fine sands above. Some features and relations of the basal beds are shown in Pls. XI and XII. The formation has in all a thickness of about 700 feet, and outcrops in a belt from 7 to 8 miles wide, which extends to the eastward high up the slopes on the east side of Anacostia River. In these slopes it is surmounted by younger formations, consisting of a succession of the thin western edges of the dark sandy clays of the Severn formation, the impure marl of the Pamunkey, the gray clays of the Chesapeake, and the gravels of the Lafayette. Washington is situated on a series of broad, low terraces cut in the Potomac sands and clays and across the edge of this formation on the crystalline rocks.

This series of terraces, and its extension along all the lower land of the District, is capped by from 20 to 35 feet of gravelly sands and loams of the Columbia formations. In the three sections in Pl. XIV a fairly clear representation is given of the structure of the Washington region, and in the map, Pl. XIII, is shown the relative distribution of the crystalline rocks and the Potomac formation. It is in Good Hope Hill that the Potomac formation passes under the Severn, Pamunkey, Chesapeake, and Lafayette formations, as shown in section 2, but there are also small outlying areas of the Chesapeake and Lafayette formations on the high lands of Soldiers' Home Park and the ridge which extends to Tenley.

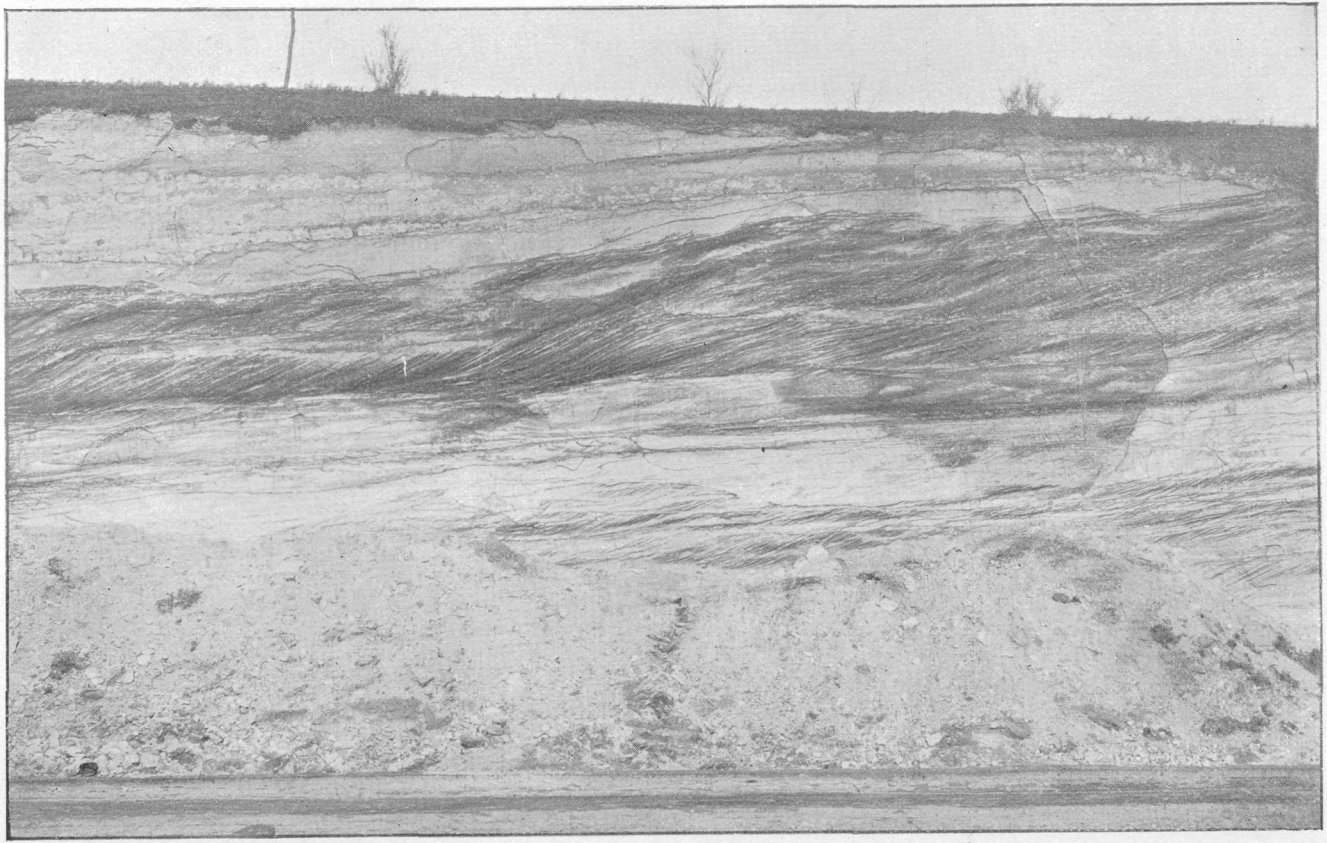
The Potomac formation is the only member in the District that contains underground waters of any importance, for the water in the Columbia and Lafayette cappings are of local surface origin.

DEEP WELLS IN THE DISTRICT OF COLUMBIA.

There are quite a number of deep wells in the District, and they have been so satisfactory that plans have been made for sinking many others. The following list is thought to be nearly complete:

List of deep wells in District of Colnmbia.

Location.	Depth.	Capacity per minute.	Remarks.
	Feet.	*Gallons.*	
Reform School	270	60	Low in Potomac.
Eckington power house	159	65	Basal Potomac.
Ice Works, Fifteenth and E streets NE.	150	Many.	Low in Potomac.
Do	90	30	In Potomac.
Do	320	15	Basal Potomac.
Metropolitan Railroad power house, Four-and-a-half and O streets SW.	208	20	Do.
St. Elizabeth Asylum:			
Twenty or more small wells	240–350	130 in all.	Low and basal Potomac beds.
Two 6-inch wells	350 and 380	65 each.	Basal Potomac beds. Flowing wells.
Anacostia stables	170	Many.	
Heurich's Brewery, Twentieth and M streets NW.	900	7	In crystalline rocks.
Storage warehouse, Fifteenth and M streets NW.	97	40	Basal Potomac. Rock at 97 feet.
"The Cairo," Q and Sixteenth streets NW.	70	15	70–312 feet, in crystalline rock. Water is at base of Columbia.
"Mount Vernon," Ninth street and New York avenue NW.	183	40	133–183 feet, in crystalline rocks. No water above.
The Shoreham, Fifteenth and H streets	.....	.....	25 gallons per minute were found in gravel on top of crystalline rocks at 110 feet.
312 Pennsylvania avenue	93	Many.	
E, between Twenty-first and Twenty-second streets NW.	132	(?)	In crystalline rocks.
Lafayette Square Opera House	70	16	Basal Potomac.
Riggs House	558	None.	In crystalline rocks.
Fifteenth street, near M street NW	97	Many.	Do.
Palais Royal, Eleventh and G streets NW.	97	35	Basal Potomac beds.
Brightwood	146	20?	In crystalline rocks.
J. P. Clark, Conduit road	100	15	Do.
W. H. Bolton, Somerset Heights	60	20	Do.
Bethesda Park	67	10?	Do.
Good Hope Hill	380	.....	Unfinished.
Hotel at North Takoma	251	20	In crystalline rocks.
National Brewery, Fourteenth and D streets SE.	310	120	Basal Potomac.
Washington Brewery, Fourth and F streets NE.	300	75	Do.
Do	275	100	Do.
Highland Station, 5-inch well	96	Many.	Low in Potomac.
Gas Works, Twelfth street SE.	290	.....	Do.



ARKOSIC SANDS OF POTOMAC FORMATION, SIXTEENTH STREET, JUST NORTH OF FLORIDA AVENUE, WASHINGTON, D. C.; LOOKING EAST.

NOTES ON WELLS IN THE DISTRICT OF COLUMBIA.

I have not been able to obtain as complete data for the wells as I could desire, but a number of well records and special details have been contributed by various persons, which it is important to preserve. Mr. Emig, of the Star Drilling Company, has supplied all the records except those of the Ice Works and Reform School.

Insane Asylum.—The group of wells which supply water for St. Elizabeth's are perhaps the most important in the District, for their output is large and the water is very pure. The wells are situated on the banks of the Anacostia River only a few feet above tide level. The first well flowed over the surface, but after several years of active pumping the level was lowered to 18 feet below the surface. The first well was sunk in 1883 to a depth of 350 feet, and 18 half-inch wells were soon after sunk, which yielded 150,000 gallons a day. Then some 2-inch wells were added, and for nearly twelve years the supply was 200,000 gallons a day. Two 6-inch wells, 50 feet apart, were recently sunk by the Star Drilling Company to 350 and 380 feet respectively, and they supply 100,000 gallons a day. The deeper wells draw from a bed of sand and gravel, which extends from 350 to 400 feet and lies on the crystalline rocks.

No accurate record of borings was preserved, but Mr. Emig reports the following items:

Feet.	
0–20 (approximately)	clay and sand.
20–60 (approximately)	clay.
60–80 (approximately)	sand.
80–378 (approximately)	alternate layers of sand and clay to gravels, the clay ending at 350 feet.

Metropolitan Railroad power house.—This well, at Four-and-a-half and O streets SW., is across the Anacostia River from the asylum wells, and draws from the same basal beds, as shown in section 3, Pl. XIV. The upper water-bearing beds were reported at 88 to 95 feet, but the deeper waters were desired. The following record is given:

Feet.	
0–20	clay and surface.
20–75	sand and some water.
75–88	clay.
88–95	sand, water bearing.
95–198	clay.
198–208	sand with large supply of clear, pure water.

Hygienic Ice Works.—At this establishment, Fifteenth and E streets NE., there are six wells, ranging in depth from 100 to 300 feet. They yield a very large supply of fine water, which is principally from a depth of 150 feet. At 90 feet a supply of 30 gallons a minute is obtained. An attempt to obtain water in the basal Potomac beds was not entirely successful, as only about 15 gallons were found. The boring was made to and into the crystalline rocks, which began at 350 feet

and were penetrated to 365 feet. The following record was furnished by Mr. George Patton, the well driller:

Feet.	
0–20	fine sand.
20–50	clay and sand with gravel streaks.
50–53	fine white sand with wood.
53–75	white and red clay, mottled; tough.
75–95	white clay, very sandy; some water.
95–128	red clay; tough.
128–135	pure white clay.
135–159	fine sand; full of water.
159–180	white and red mottled clay.
180–184	tough, white clay.
184–212	sand and clay interbedded; some water.
212–216	tough dark-blue clay.
216–240	sand and clay; some gravel streaks; some water.
240–256	sticky clay with sandy streaks.
256–260	very hard dark clay.
260–272	clay and sand.
272–274	hard dark clay.
274–298	clay and sand mixed; light lead color.
298–320	pebbles and sand with conglomerate streaks.

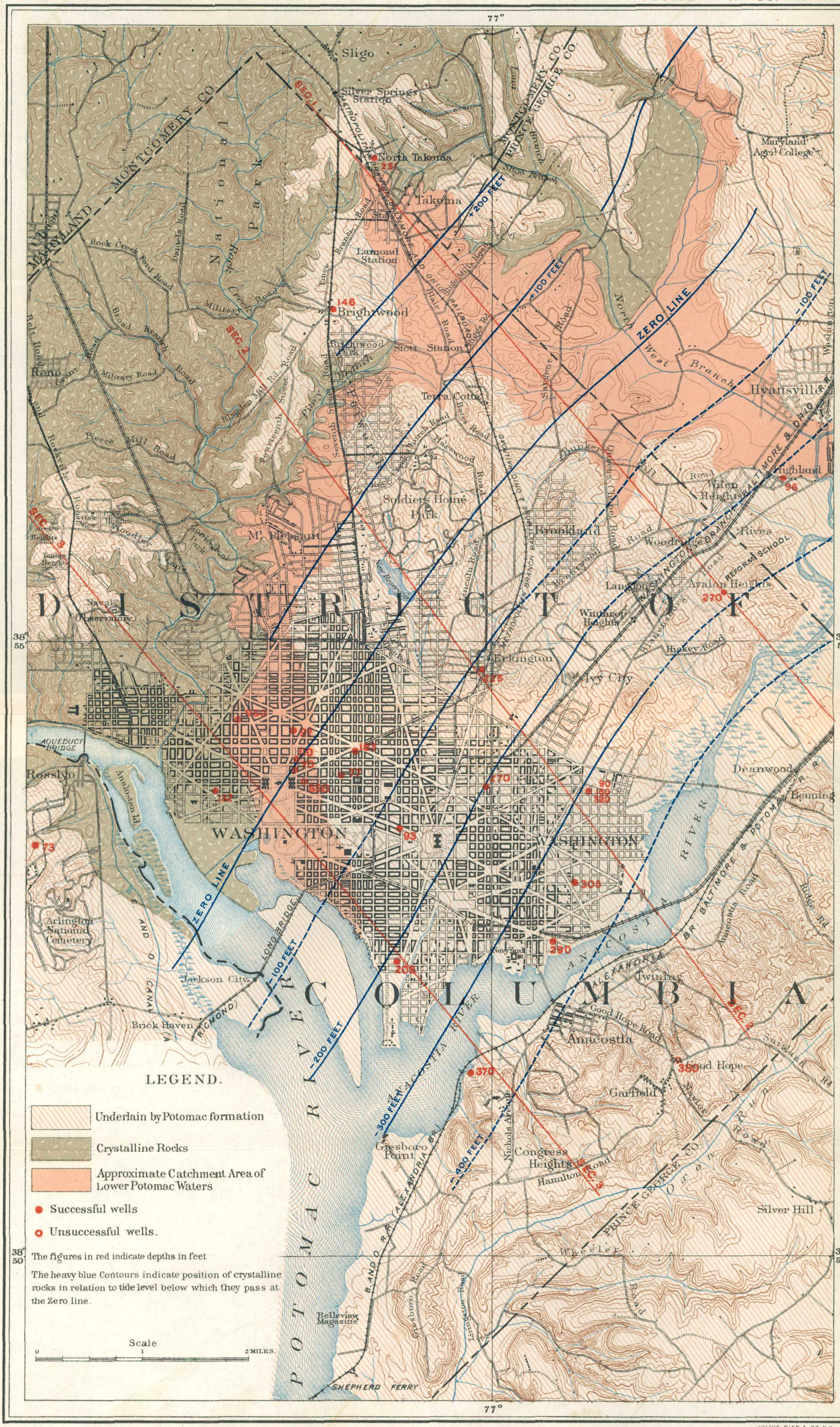
National Capital Brewing Company.—The well at this brewery has a depth of 310 feet, a 10-inch bore, and yields from 100 to 130 gallons of water per minute. No record could be obtained, but it is stated that alternating layers of sand and clay were penetrated to 230 feet, below which the materials were mostly sands with a small amount of gray clay.

The following analysis of the water has been furnished:

Analysis of water from well at Fourteenth and D streets SE., Washington, D. C.

	Parts per 100,000.
Lime	1.7
Magnesia	1.24
Sulphuric acid	0.6
Chlorine	0.71
Ammonia	Traces.
Albuminoid ammonia	Traces.
Iron	Traces.
Nitrous acid	None.
Nitric acid	None.
Oxygen required for organic matter	0.071
Total residue	9.0
Loss of residue by calcination	2.0
Total hardness	4.2°

Eckington.—The well is at the power house of the Eckington and Soldiers' Home Railroad. It was sunk to a depth of 225 feet, of which the last 66 feet were in crystalline rocks. The water is supplied both from crystalline rocks and the basal gravels of the Potomac formation.



MAP OF A PORTION OF THE DISTRICT OF COLUMBIA ILLUSTRATING FEATURES OF UNDERGROUND WATERS.

The supply is stated to be 100,000 gallons a day. The following record was given:

Feet.	
0–15	gravel.
15–20	coarse gravel and bowlders.
20–150	alternating layers of sand and clay with some water.
150–159	coarse gravel, containing water.
159–225	crystalline rocks.

Reform School.—This well is on the high hill just south of Rives Station. It was bored on a prediction which I made that waters could be found at about 260 and 400 feet, respectively, below the engine house, which is at an altitude of about 170 feet. The upper water was found at 270 feet in large supply and of excellent character, although slightly chalybeate. Samples of the borings were kindly sent to me by the board of trustees. They afford the basis for the following record:

Feet.	
0–4	light reddish-brown clay.
4–21	buff and white variegated clay.
21–30	reddish-buff clay.
30–42	buff sand, moderately coarse, in clay matrix.
42–59	reddish-brown clay.
59–72	brown-red sandy clay.
72–77	fine buff sand.
77–80	red, white, and buff variegated clay.
80–101	arkosic sand with clay and quartz pebbles; light color.
101–105	reddish-gray clay.
105–113	coarse light-brown sand, gray clay pebbles.
113–125	gray clay with sand and pebbles.
125–130	brownish-buff clay.
130–149	red clay with "paint" streak.
149–165	gray, very sandy, micaceous clay.
165–173	dark-gray heavy clay.
173–180	coarse gray sand, some clay as matrix.
180–191	gray clay with lignite and some sand.
191	lignite in sandy clay.
192–198	lignite, iron pyrites, and siderite.
198–213	no sample.
213–214	quartz pebbles, one-half to three-fourths inch.
214–217	coarse, gray sand, somewhat arkosic.
217–240	sands (no samples).
240–250	moderately coarse, gray sand with pyrites.
250–259	gray sand with quartz pebbles.

Palais Royal.—The following record is given for the Palais Royal well, at Eleventh and G streets NW.

Feet.	
0–5	surface material.
5–10	sand and gravel.
10–20	clay with thin beds of water-bearing sand.
20–40	sand and gravel.
40–80	?
80–97	gravel with water in large supply.

This gravel is at or very near the base of the Potomac formation.

Lafayette Square Opera House.—The following record is given of the well at this locality, Madison place, near H street NW.:

Feet.	
0–50	loam.
50–55	sand.
55–61	clay; blue, sticky.
61–70	coarse sand with water.
70–71	clay ?

Mount Vernon Apartment House.—This well, at Ninth street and New York avenue NW., found no coarse beds at the base of the Potomac formation, and passed down into the crystalline rocks, where a supply of 60,000 gallons a day of "very pure water" was found. The following record is given:

Feet.	
0–10	surface materials.
10–50	yellow loam and clay.
50–65	sand.
65–133	clay and sand; stiff clay at base.
133–183	crystalline rocks.

North Takoma Hotel.—The well at this hotel has a depth of 251 feet, of which about 40 feet at the top are in the Potomac beds, the remainder being in crystalline rock, quite deeply decomposed.

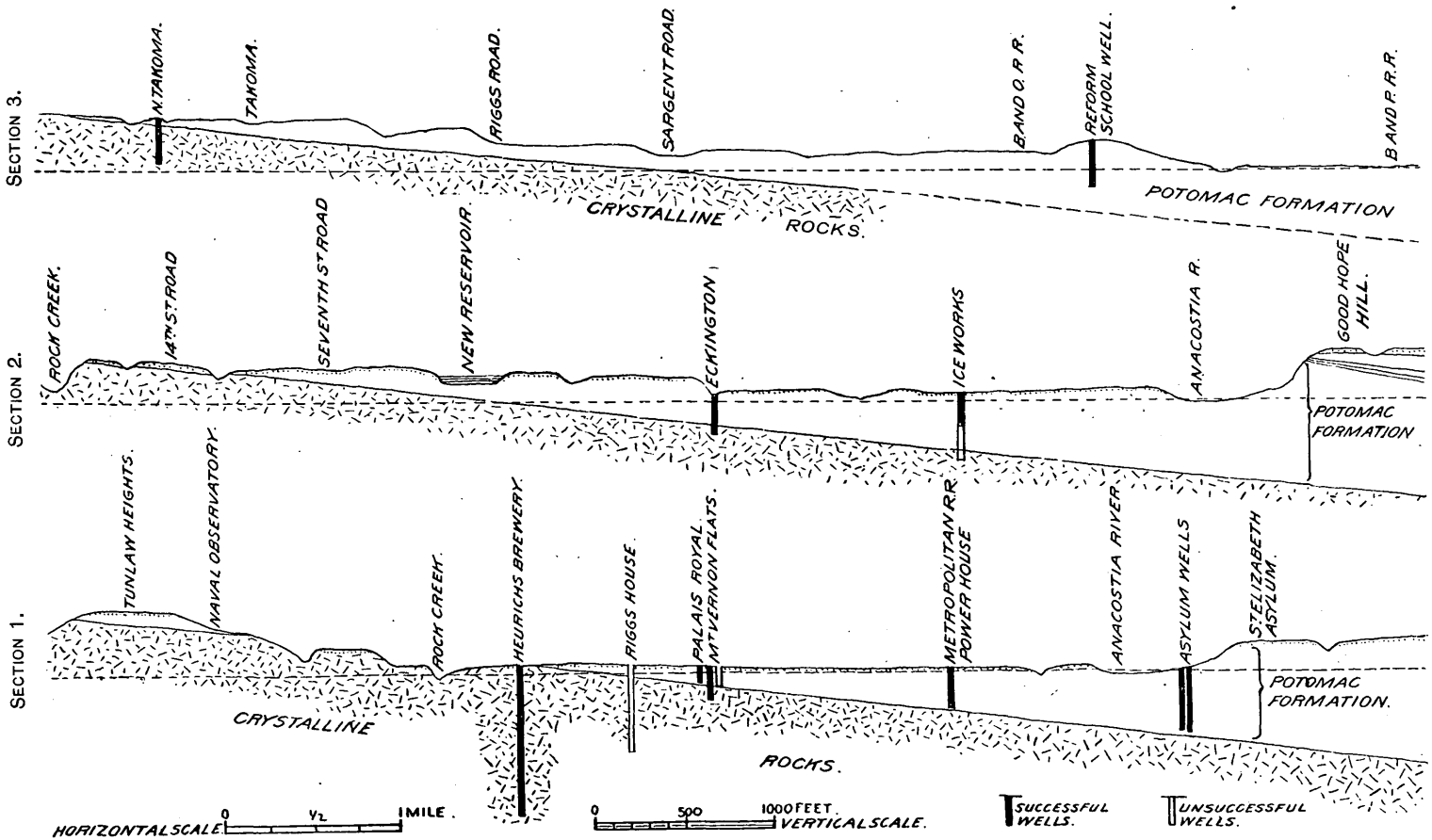
The Cairo.—The well at this place (Q street between Sixteenth and Seventeenth streets NW.) is 312 feet deep. It first penetrated the Columbia loams and gravels and then disintegrated crystalline rocks, from which a fair supply of water is obtained at a depth of about 70 feet. From 70 feet to the bottom the boring was in hard, crystalline rocks which furnished no water.

Good Hope.—The well now in progress on the summit of Good Hope Hill, about 280 feet above tide level, is down to a depth of 380 feet, but has not found water. It has not yet reached the Potomac horizons which yield water at 240 and 350 feet below tide level at the Asylum wells, 2 miles west.

Highlands.—The well at the hotel has a depth of 96 feet. The water is soft, slightly chalybeate, and very cold. The boring is said to have passed through clay to 60 feet, then some quicksand, then clay, and finally a coarse, nearly white sand containing a large water supply, probably from the same bed as that at the Reform School.

WATER HORIZONS AND PROSPECTS IN THE DISTRICT OF COLUMBIA.

The deeper-seated underground waters have been tapped by a sufficiently large number of wells in the District to demonstrate the almost general extension of water-bearing beds in the basal and lower bed of the Potomac formation, and there is often a fair prospect for finding waters in the crystalline rocks. The wells that did not find a satisfactory water supply in the basal Potomac beds are at the Ice Works, at a



SECTIONS, DISTRICT OF COLUMBIA.

depth of 360 feet, and at the Mount Vernon Apartment House, at 133 feet. On the other hand, the St. Elizabeth, Metropolitan Railroad power house, Palais Royal, Eckington, Washington Brewery, and National Capitol Brewery wells obtain large supplies from that horizon. In surface outcrops the basal Potomac beds are usually coarse sands and gravels, which are filled with water, but in some few instances there are local areas in which there is a clay matrix, or even quite pure clay extending down to the crystalline floor. This latter was found to be the case at the Mount Vernon Apartment House, while at the Palais Royal, three squares southwest, the basal beds were coarse sands and gravels containing much water. In the 380-foot well at the ice works, coarse basal beds were found, but they contain no large supply of water; which leads to the conclusion that the waters are in part choked off by a local area of clay admixture to the northward, but which does not influence the wells at the breweries near by.

These considerations must everywhere qualify a judgment as to the prospects for basal Potomac waters at any given point in the eastern portion of the District, but the general prospects are so good that I should never hesitate to sink wells to these basal beds, particularly as there is always a good chance also of finding water in overlying beds, as at the ice works. The area to which this prognostication applies lies east of the zero line on the map, Pl. XIII. Along this line the basal beds of the Potomac formation pass beneath tide level, but to the west and north they rise, and the waters are in greater or less measure free to flow out in surface springs. The heavy blue contour lines east of the zero line indicate the depths below tide level of the basal Potomac beds, for each 100 feet. To calculate the depth for a well, it is necessary to add the elevation of the ground above tide level, which is indicated for each 20 feet by the brown contour lines on the map. The slope and depths of the basal beds are also indicated in the sections on Pl. XIV.

To the east of the 100-foot contour line (in blue on map, Pl. XIII), the higher Potomac waters may be expected, as indicated by the experience of the Reform School, Highlands Hotel, Ice Works, Asylum, and power house wells, at from 120 to 160 feet above the basal Potomac beds or crystalline rock floor. This horizon appears to be continuous, and to be due to the wide extension of a bed of sand among the clays.

As to waters in the crystalline rocks, I can make no prediction from present knowledge. They occur in steeply inclined fissures and in decomposed belts in the rocks, of which the extent and course are difficult to determine and impossible to predict without many additional data. The wells given in the list on page 156 which draw their waters from the crystalline rocks, obtain only moderate supplies, with the exception of the well at the Mount Vernon Apartment House, where the supply is claimed to amount to 40 gallons a minute.

VIRGINIA.

GEOLOGIC RELATIONS.

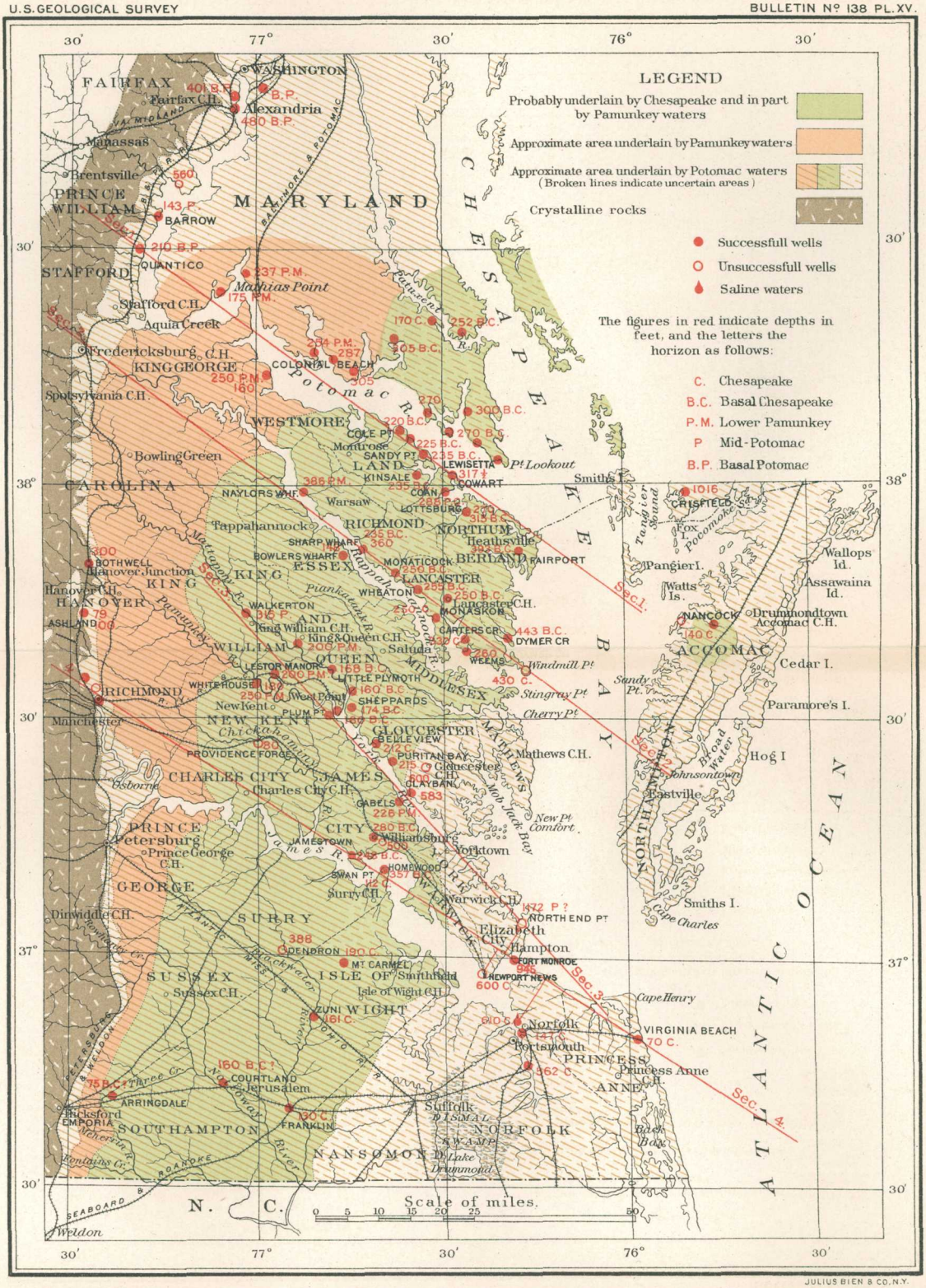
The Coastal Plain region of Virginia lies east of a line which passes through Alexandria, Fredericksburg, Bothwell, Richmond, Petersburg, and Emporia, comprising an area of about 9,500 square miles. This district is traversed from northwest to southeast by a series of great rivers, which divide it into a succession of long ridges. These are remnants of a plateau surface which slopes from an altitude of from 300 to 200 feet on the west to about 100 feet on the east. The larger rivers are tidal estuaries occupying low valleys and meandering through wide terrace plains. Chesapeake Bay is widely bordered by these terraces, and the eastern shore of Virginia, which lies east of the bay, is a low plain, as is also the wide area which lies between Dismal Swamp and the Atlantic Ocean.

The geologic structure is in general similar to that of eastern Maryland, but there are certain differences in the stratigraphy. The Potomac formation becomes predominantly sandy, and the Severn and Magothy sands are absent in the outcrop zone, so that the Pamunkey marls lie directly on the surface of the Potomac beds. Far to the eastward, under the bay and Eastern Shore, there is probably presented the same sequence that is found in Maryland. The Chesapeake formation extends farther to the west in southern Virginia and often overlaps on the crystalline rocks. In the sections, Pl. XVI, there are shown the general structural relations in Virginia so far as they are known. The Coastal Plain formations which outcrop in the State are as follows:

Formation.	Characteristics.	Age.
Columbia	Loams, sands, and gravels in terraces	Pleistocene.
Lafayette	Orange sands, loams, and gravels	Pliocene?
Chesapeake	Clays, sands, infusorial earth, and marl	Miocene.
Pamunkey	Glauconitic marls and sands	Eocene.
Potomac	Sands, sandstone, and clays	Early Cretaceous.

POTOMAC FORMATION.

This formation underlies the other Coastal Plain formations throughout, and is exposed in certain areas where those formations have been eroded. These areas are short narrow belts in the Nottaway, Appomattox, James, Pamunkey, and Rappahannock depressions near the western border of the Coastal Plain region, and a district of considerable width extending from Fredericksburg to the Potomac River and thence on both sides of the river to Washington. The formation consists of sand, coarse below and in part finer above, with many beds of



JULIUS BIEN & CO. N.Y.

MAP OF EASTERN VIRGINIA SHOWING DISTRIBUTION OF UNDERGROUND WATERS

BY N. H. DARTON.

clay of various sizes and degrees of purity. The sandstones are a local feature. The basal beds are mainly coarse, cross-bedded sands, with scattered pebbles and bowlders and local pebble and bowlder beds, which are filled with water. How far east these coarse materials extend is not known, for the deepest wells do not appear to have reached them. The thickness of the formation in the outcrops in the Fredericksburg region and northward is not over 350 feet. The basal Potomac beds lie mainly on an irregular floor of crystalline rocks consisting of granites, gneiss, and slate. In the vicinity of Bothwell they lie on red and gray sandstones and shales of the Newark formation, which there occur in a local area among the crystalline rocks.

PAMUNKEY FORMATION.

This member underlies nearly all of the Coastal Plain region south of Stafford County, but it is exposed only in the valleys where the Lafayette and Chesapeake formations are eroded. Its upper surface passes beneath tide-level along a line extending nearly due south from the eastern boundary of King George County to a point on James River about 7 miles below City Point. South of the James it does not appear to be exposed unless possibly in the Nottoway Valley. The Chesapeake-Pamunkey contact dips almost due east 5° south at the rate of from 10 to 12 feet per mile.

The materials of the formation are marls or dark sand and sandy clays containing a large amount of "greensand" or glauconite, and fossil shells. Some thin beds of purer clays and sands occur, and also local thin beds of very hard rock. The thickness of the formation rapidly increases from a thin edge westward to about 200 feet eastward. The formation lies in an irregular, steeply east-dipping floor of Potomac formation, and for a long distance eastward the basal beds are mainly coarse sands with gravel and bowlders, containing a large amount of water.

CHESAPEAKE FORMATION.

This formation underlies all the Coastal Plain area south of Fredericksburg except when it has been cut through for a greater or less distance by the Rappahannock, Mattapony, Pamunkey, James, and (possibly) Nottoway rivers. It consists mainly of clay, fullers' earth, shell marl, and very fine sand. It lies on the east-sloping floor of the Pamunkey formation and thickens rapidly to the eastward under its thin mantle of Lafayette orange sands.

The deeper wells along the bay shore near the mouth of the Rappahannock penetrate a thickness of 400 feet of the formation, and in the well at Fort Monroe considerably more was found. Along the western margin of the region the formation thins, as is shown in sections 1, 2, and 4 on Pl. XVI. There are many thin local beds of coarser sands among the clays and fine sands, and at the base of the formation

to the eastward there appears to be a series of thin layers of rock in coarser sands which are of wide extent and are great water bearers. In certain wells in the Rappahannock River region some local beds of rock also occur above the basal beds. The clays are usually blue and very hard. They are often 200 to 300 feet thick, including occasional sand partings. The marl varies from a fine-grained sticky material full of chalky shells to a mixture of sand and broken shells, but the former variety predominates.

LAFAYETTE FORMATION.

This caps the plateau levels which constitute the surface of the ridges lying between the valleys. It is in greater part an orange sandy loam with scattered pebbles and streaks of pebbly materials which increase in proportion and size to the westward. Its thickness averages from 15 to 30 feet, and it is similar to the Columbia formation in being a superficial capping with coarser, water-bearing beds at its base. It lies on the Chesapeake sands and clays in greater part, but overlaps on the crystalline rocks to the west. About Fredericksburg and northward it overlaps across the Pamunkey and Potomac formations to the crystalline rocks in most cases, and west of Alexandria it overlies a wide area of Potomac formation.

COLUMBIA FORMATION.

This caps the terraces along the Potomac, Rappahannock, Mattapony, Pamunkey, York, Chickahominy, James, Blackwater, Nottoway, and Merherrin rivers, the lowlands bordering Chesapeake Bay, the Eastern shore counties, and all of Norfolk and Princess Anne counties. Its thickness varies from 10 to 30 feet, and it is merely a superficial capping. At its base there are usually coarse materials, consisting of gravelly sands or gravel, which contain the water that supplies shallow wells in the low-lying regions.

WELLS IN EASTERN VIRGINIA.

It may be seen on reference to the map, Pl. XV, that there is a fairly large number of wells in the Coastal Plain region of Virginia, and most of them have been successful in obtaining abundant water supplies from very moderate depths. Eastward the higher waters appear to cease to be available, or yield only saline water, but the lower water horizons promise to furnish satisfactory supplies, as is indicated by the success of the well just completed at Chamberlain's Hotel, Fort Monroe. A boring now in progress at Norfolk will throw further light on the question, and, it is hoped, secure a water supply.

I have not been able to obtain as much data regarding Virginia wells as I desired, particularly in regard to the nature of the beds penetrated. Mr. L. Rude, of Sharps Wharf, Mr. Moore, of Courtland, and Mr. F. E. Pearce, of West Point, all practical well borers, have furnished many

data of a most satisfactory kind, which are in no small part the basis of the following table and notes:

List of deep wells in eastern Virginia.

Location.	Depth.	Size.	Capacity per minute.	Height to which water rises. *a*	Horizon.	Remarks.
	Feet.	*In.*	*Gallons.*	*Feet.*		
Alexandria Brewery	430	8	90	.....	Basal Potomac.....	Soft water.
Alexandria Ice Works.	401	8	20	—12	.....	Poor water at 300 feet.
Arringdale, 2 wells ..	75	.....	Flows 10	+10	.....	Slightly alkaline water.
Ashland.....	79	1½	Many.	—4½	Granite?.....	
Do.....	100	4	Many.	.....	Granite.....	
Barrow	195	.....	Many.	.....	In Potomac.....	No water below 143 feet.
Bellevue, 2 wells	212	1½	Flows 15 to 20	+4 to +6	Basal Chesapeake..	
Bothwell	300	6	20	—7	Newark	
Bowlers Wharf	143	4	7	Flows.	Chesapeake.....	Soft water.
Carters Creek.....	330	.....	.....	+12	.....do	
Clay Bank	538	1½	Flows 2	+4	Basal Pamunkey? .	
Clifton, 2 wells.....	175	1½	Flows 10 to 12.	+4 to +6	.....do	
Coan, 8 wells.....	270	1½	Flows 2½	+12	Basal Chesapeake..	Water also at 240 feet.
Coan, 1 well.....	315	4	15	+12	.....do	
Coles Point	220	1½	3	+12	.....do	
Colonial Beach, 5 wells.	250	1½	5	+8 to +15	Basal Pamunkey ..	Water also at 160 feet.
Courtland, 30 wells...	160	.....	30	.....	Chesapeake?.....	
Cowart	288	2	Flows 2	+6	Basal Chesapeake..	
Ditchley.....	620	1½	Flows 2	+4 to +6	.....	
Dendron.....	386	6	None.	.....	.....	
Dudleys Ferry, 4 wells.	175	1½	Flows 10	4 to 6	Basal Chesapeake..	
Dymer Creek.....	443	3	Flows 7	.....	Basal Pamunkey...	No water 464–507½ feet; water also at 240 and 464 feet
Fairport.....	393½	1½	Flows 2	.....	Basal Chesapeake..	Soft, good water.
Fort Monroe.....	907	.....	None.	.....	Potomac?.....	
Fort Monroe, Chamberlain's Hotel.	945	.....	Flows 50	+10	.....do	Slightly saline water.
Franklin, 16 wells....	130	.....	Many.	Flow.	Chesapeake.....	
Gabels Mill.....	226	1½	Flows 20	+10	Basal Chesapeake..	
Gloucester Court House.	600	.....	None.	.....	Pamunkey?.....	Stopped at rock stratum.
Homewood, 5 wells..	317	1½	Flows 30	.....	Basal Chesapeake..	Fine water 54°. Sulphurous water at 270 feet.
	112	1	Fair supply.	+2	Chesapeake.....	Ferruginous water.
Jamestown	248	3	Flows 2½	+35	Basal Chesapeake..	Fine water 68°.
King and Queen	200	2	Flows 1	.....	Basal Pamunkey?..	
Kinsale.....	235	1½	5	+15	Basal Chesapeake..	

a +, feet above the surface; —, feet below the surface.

List of deep wells in eastern Virginia—Continued.

Location.	Depth.	Size.	Capacity per minute.	Height to which water rises. *a*	Horizon.	Remarks.
	Feet.	*In.*	*Gallons.*	*Feet.*		
Lancaster	250	.....	Flows 12	.....	Basal Chesapeake	
Do	285?	.....	.....	.....	.....	
Lester Manor, 3 wells.	200	1½	Flows 12	+8 to +12	Basal Pamunkey?	
Lewisetta	317½	.....	.....	.....	Basal Chesapeake	
Little Plymouth	168	2	Flows 2	.....	do	
Monaskon	255	.....	.....	.....	Basal Chesapeake	
Monatico Creek	250	1½	Flows 2	+	do	
Mount Carmel Church.	190	.....	Flows 1½	+6	Chesapeake	
Naylors	386	1½	Flows 3	+45	Basal Pamunkey	Much water at 326 feet.
Newcastle	187	1½	Flows 10	+2	.....	
Newport News	±600	.....	None.	.....	Chesapeake	
Norfolk	147	6?	Much.	—6	do	Very hard water.
Norfolk, Lambert Point.	610	.....	65	.....	do	Saline water.
Norfolk, Money Point.	562	.....	Much.	+5	do	Ferruginous water.
North End Point	1,172	.....	None.	.....	Potomac	
Oak Springs	400	1½	Flows 10–12	+6	.....	
Onancock	140	4½	5	.....	Chesapeake	140–486 feet; no water.
Plum Point, 3 wells	168	1½	Flows 10–12	+8–12	Basal Chesapeake	
Possums Nose	200	.....	.....	.....	Potomac	
Providence Forge	80	1½	None.	.....	Chesapeake	Unfinished.
Puritan Bay, 2 wells	215	1½	Flows 10–12	+4–6	Basal Chesapeake	
Puritan Bay, 1 well	180	1½	Flows 10–12	+4–6	.....	
Quantico	350	.....	4–5	Flows.	Basal Potomac	
Ragged Point	225	1½	1	12	Basal Chesapeake	
Richmond:						
Paper Mill	400	.....	Fair.	.....	Granite	Surface contamination.
Sherwood Park	900	.....	None.	.....	do	
Sherwood Park, 1 mile northeast.	250	.....	None.	.....	do	
Ginter's farm	400	.....	Satisfactory.	.....	do	Fine water.
Sandy Point:						
Westmoreland County.	235	1½	3	+12	Basal Chesapeake	
Fairfax County	560	.....	Satisfactory.	—24	Basal Potomac	No water below 270 feet; rock, 270–560 feet.
Sharps Wharf	235	1½	Flows 12–35	+24	Basal Chesapeake	
Do	360	.....	.....	.....	Pamunkey	Water also at 240 feet.
Sheppard's warehouse, 2 wells.	160	1½	Flows 10–15	+6–8	Basal Chesapeake	
Swan Point	+100	.....	.....	.....	Chesapeake	
Virginia Beach	70	.....	Fair supply.	.....	Upper Chesapeake	Ferruginous water
Walkerton, 2 wells	315	1½	Flows 5–8	+4–6	Potomac	
Weems	260	.....	.....	.....	Chesapeake	

a +, feet above the surface; —, feet below the surface.

List of deep wells in eastern Virginia—Continued.

Location.	Depth.	Size.	Capacity per minute.	Height to which water rises. *a*	Horizon.	Remarks.
	Feet.	*In.*	*Gallons.*	*Feet.*		
West Point, 200 wells.	160	1½	Average 12	Average +2.	Basal Chesapeake.	
Whealtons	250	.....	20	.....	Basal Chesapeake?	
White House, 3 wells.	180–230	1½	1–6	+5–20	Basal Chesapeake.	
Williamsburg	876	.....	None.	.....	Potomac	
Do	280	.....	Many.	.....	Basal Chesapeake.	Under hard rock stratum.
Windmill Point	430	.....	None.	.....	Near to basal Chesapeake.	To top of rock stratum.
Zuni	161	.....	Flows 2	.....	Chesapeake	

a +, feet above the surface; —, feet below the surface.

DESCRIPTIVE NOTES ON WELLS IN EASTERN VIRGINIA.

For many of the wells I have been unable to obtain any further data than are given in the preceding table, but for others a greater or less amount of information has been furnished.

Fort Monroe.—A well was started at this locality in 1845, but was abandoned at 168 feet. In 1864 another boring was started and a depth of 906 feet was attained. No water supply was obtained in these wells, but they both appear to have been badly managed, and the failure of the deeper one may be due to this cause. I believe, however, that it was not sufficiently deep and that the stratum in which water should be expected is at a somewhat greater depth. This is a very important consideration, and, as it rests mainly on the identification of the geologic horizon of the well borings, I shall discuss at some length the basis of my opinion. During the boring of the well samples of the borings were sent to Prof. W. B. Rogers, formerly State geologist of Virginia, who prepared the following descriptive list of the strata penetrated:[1]

Ft.	In.	
151	0	fine yellowish-gray sand with fragments of shells.
158	0	buff argillaceous marl.
160	0	fragments of Turritella and Pecten in gray marl mostly; comminuted shells.
164	6	fragments of Turritella and Pecten in gray marl mostly; comminuted shells.
166	10	more sandy than last; fragments of Arca.
168	10	more sandy than last, with Balanus, etc.
170	10	gray sand, with Arca, etc.
192	0	greenish gray; sandy; Turritella.
194	0	lighter gray; sandy; Turritella.
197	0	more clayey than 194 feet.

[1] This record is published in The Virginias, Vol. III, pp. 151, 152, and in Geology of the Virginias, New York, 1884, pp. 731–736.

Ft.	In.	
202	0	more clayey than 194 feet; fragments of Venus, etc.
204	0	more clayey than 194 feet; fragments of Venus, etc.
208	0	more clayey than 194 feet; fragments of Venus, etc., with Perna, Venus, etc.
390	0	tenacious gray clay with shelly matter.
400	0	gray sandy clay; Artemæ, Venus, etc.
430	0	yellowish sandy clay.
555	0	light clay, gray brown in color; Foraminiferæ.
558	0	infusorial earth containing many species.
576	0	Miocene down to about this depth.
574	0	cetacean bone.
577	0	concretions of sand, marl, and shells, composed of loam sand, little pieces of milky and smoky and sometimes rose quartz, often subangular; between 577 and 583 feet is probably the base of the Miocene; between 580 and 590 feet shark's teeth and *Galeocerda lateralis*.
583	0	sandy clay, brownish.
590	0	very sandy clay; about 5 per cent sand; shark's teeth.
604	0	brownish-gray, sandy clay.
628	0	brownish-gray, sandy clay; less sand.
640	0	greenish gray, sandy.
670	0	lightest gray clay.
699	0	brownish-gray, sandy clay; less sand than 604 feet; same in bed as 628 feet.
784	0	brownish-gray, sandy clay; same as 604 feet.
815	0	gray sandy clay.
835	0	very coarse sand.
853	0	conglomerate of clay, sand, and pebbles.
863	0	rather fine clay with a little sand.
865	0	rather fine clay with a little sand.
870	0	coarse sandy clay, brownish or reddish blotches.
877	0	clay, embedding fragments of granite.
885	0	gray clay with occasional fragments of coarse sand.
890	0	gray clay with occasional fragments of coarse sand.
900	0	clay and sand in layers, with some coarse pebbles and reddish blotches.
901	0	reddish mottled clay with quartz pebbles.
902	0	reddish mottled clay with coarse sand.
903	0	reddish mottled clay with coarse sand.
907	0	total depth of boring below parade ground.

This table does not give the thickness of the beds, which is greatly to be regretted. The suggestion of Professor Rogers that the base of the Miocene (Chesapeake) is between 577 and 583 feet was based on the idea that the infusorial beds here characterized the very base of the formation and that the occurrence of shark's teeth indicated the underlying Eocene (Pamunkey) deposits. It was also suggested that the lower beds, from perhaps 835 feet to the bottom, may possibly be Jurasso-Cretaceous, or the Potomac formation of later writers. This was based on the presence of reddish mottlings and coarse sand streaks in the lowest clays.

In 1880 Professor Fontaine, of the University of Virginia, examined the old records of the borings, and an account of these, which he has

published, adds materially to our knowledge of the strata penetrated.[1] The record, as compiled from Fontaine's notes and descriptions of the old records, is as follows:

Character of borings from each stratum.	Number of feet bored.	Thickness of stratum.
White beach sand	0-30	30
Yellow beach sand	30-40	10
Small bowlders	40-43	3
Mud or marl with shells	43-63	20
Greensand with shells	63-155	92
Impervious mud; no shells	155-162	7
Greensand and shells	162-167	5
Concrete sand, stones, shells, sharp grit	167-185	18
Greensand, with shells	185-228	43
Concrete, hard shells, and sandstones	228-229	1
Marl; shells abundant	229-239	10
Concrete (shell rock), hard	239-240	1
Marl and shells	240-248	8
Concrete sand	248-249	1
Marl and shells	249-254	5
Concrete sand	254-256	2
Marl and shells	256-265	9
Marl free from shells	265-280	15
Stiff clay, very tenacious, of greenish-yellow color, which changes to a light gray after exposure to the atmosphere	280-475	195
Very fine sand	475-480	5
Stiff clay of light greenish-yellow color, which changes to light gray on exposure	480-572	92
Concrete sand with shark's teeth and cetacean vertebræ	572	.....
Clays more sandy	572-599	27
Sands with 10 to 20 per cent of clay; they were water-bearing, and the water rose above level of parade ground for several days; it was very saline	599	.....
Stiff clay, becoming sandy below	599-669	72
Stiff pure clays, becoming sandy at base	669-830	61
Clays contain 80 per cent of sand	830	.....
Very sandy clays	830-851	21
Few pebbles	851	.....
?	851-853	2
Conglomerate of clay, sand, and small gravel	853	.....
?	853-855	2
Hard crust	855-858	3
Stiff clay	858-874	16
Stiff clay, variegated in color	874-885	11
Very dark stratum (clay?)	885-890	5
Change in color	890	.....
Sandy clay	890-906	16

Unfortunately, as Professor Fontaine observes, this record is so meager that it yields only hints as to horizons. He expresses the opinion that the Miocene and Eocene have a thickness of at least 800 feet and "that there is little doubt that at a depth of 851 feet the borings were

[1] The Artesian well at Fort Monroe, Va., The Virginias, Vol. III, pp. 18, 19, 1882.

in the Mesozoic (Potomac) strata. This is indicated by the presence of the pebbles, * * * and the variegated strata give us another proof that the beds at 874 feet are Mesozoic, for many of the Mesozoic strata along the eastern border are strikingly variegated."

In 1891 I secured an order from the Chief Engineer of the Army at Washington and visited Fort Monroe for the purpose of examining the borings. Having spent several years in studying the outcrops of the beds, I believed I could recognize the strata penetrated by the well. It was found, however, that the greater part of the borings were lost, but fortunately a series from 600 feet to 877 feet were remaining. Portions of these were secured, and have been studied with considerable care. They are in greater part light greenish and brownish clays, which are not distinctive, and I could not form a judgment as to their age. The 877-foot sample is a mixture of fine sand and clay of dirty gray color, containing moderately small angular quartz grains; the 865-foot and 811-foot samples were more argillaceous.

At Richmond and along the western border of the Coastal Plain belt the infusorial series of the Chesapeake formation is of moderate thickness and lies in greater part near the base of the formation, but eastward it is now known to thicken, and to comprise a considerable series of dark, heavy clays of various kinds. Whether this relation is due to the overlap of older Miocene deposits or to an ascent of the diatom fauna through the formation is not yet definitely determined, but the overlap is probable. The thickness of diatomaceous beds is at least 300 feet eastward, but from the records as above given and the samples, I could not determine their limits in the Fort Monroe borings. It is probable that the lowest beds recorded are of Potomac age, but the evidence is not conclusive. I believe we should expect the Severn formation and, probably also the Magothy formation, in the Fort Monroe region, as in the Crisfield well.

In a boring just completed at the Chamberlain Hotel at Fort Monroe a good supply of water has been obtained at a depth of 945 feet, 38 feet deeper than the old boring at the fort. It is reported that the flow is 78,000 gallons per day and the water rises about 10 feet above the surface; a larger supply can be obtained by pumping. The water is "slightly saline." The water horizon is thought to be Potomac, but its relative position in the formation is not yet ascertained; possibly it is Magothy which furnishes the saline water in the deep Crisfield boring. The well affords important encouragement for deep-seated water supplies in the southeastern portion of Virginia.

As neither the thickness of the Potomac in this region nor the precise depth to its surface is known, I can give only approximate figures, but it is believed that its basal beds on the granite bedrock should be expected at a depth less than 1,350 feet at Fort Monroe; whether they will be found to yield large supplies of good water remains to be determined.

About three years ago an allotment was made for a new well at Fort Monroe, and I was consulted by Lieutenant-Colonel Hains, of the United States Engineer Corps, in regard to its prospects. I predicted that basal Potomac water would probably be found between 1,300 and 1,350 feet, and that its amount and quality would be satisfactory. Owing to some official causes, the boring has not as yet been commenced, and I do not know the plans of the War Department regarding it. A well to the granite bedrock at Fort Monroe would throw much-needed light on the underground geology of southeastern Virginia and would probably afford a complete basis for water predictions over a wide area of that region.

North End Point, Back River.—This well is about 6 miles north-northeast of Fort Monroe, and was bored in 1886–87 to a depth of 1,172 feet. It did not yield a supply of water, owing, I believe, to insufficient depth, if not also to improper management. It is asserted to have reached granite, but no sample was obtained, and the nature of the rock was only surmised from its hardness. The record of this well, kindly furnished to me by Mr. C. C. Knox, of Norfolk, is as follows:

Feet.	
0–75	white sand and gravel.
75–80	blue clay.
80–100	white sand.
100–130	thin layers of sand and blue clay.
130–155	blue or gray sand.
155–165	quicksand.
165–170	hard white sand.
170–185	loose white sand.
185–187	black marl.
187–249	white sand and marl.
249–250	rock.
250–267	blue clay.
267–268	stone.
268–275	hard sand.
275–530	blue clay with thin marl layers.
530–600	hard blue clay.
600–618	quicksand.
618–620	stone or bowlder.
620–625	white sand.
625–626	yellow sand.
626–695	clay and sand mixed.
695–696	gravel and clay.
696–740	hard and soft layers of blue clay.
740–748	very hard clay.
748–913	soft blue clay.
913–920	hard blue clay.
920–926	coarse sand.
926–939	sandstone.
939–955	hard sandstone.
955–973	hard sand with few gravels.
973–1,000	hard sandstone.
1.000–1,007	sandstone with two veins of gravel and some water.

Feet.	
1,007–1,015	alternate layers of sand and sandstone, 3 to 4 feet thick.
1,015–1,080	alternate layers of sand and sandstone, 5 to 15 feet thick.
1,080–1,100	very hard white sand.
1,100–1,155	sandstone.
1,155–1,160	red sandstone.
1,160–1,170	hard sandstone.
1,170–1,172	hardest kind of stone or granite; here drill rods broke and work was abandoned.

Unfortunately, I was unable to examine any of the borings from the well, and from the above notes can not identify the lower strata with certainty. The Chesapeake and Pamunkey formations extend to 700 feet, if not beyond, and the sand and sandstones from 920 to 1,170 feet are almost certainly the representatives of the Potomac formation, but the position of the upper limit of this formation is not recognized in this well. It is possible that this well penetrated the Potomac formation to the underlying granite, and if this is the case the probability of artesian water supply in the region is not great, for no water will be found in the granite. If, on the other hand, the boring stopped in a hard sandstone within the Potomac formation, it is probable that water would be found in gravels and sands which I should expect to find lying on the granites at no great depth below.

Lamberts Point, near Norfolk.—A well was bored at Lamberts Point to supply water for the Norfolk and Western Railroad terminal. It attained a depth of 610 feet, and at 606 feet penetrated a water-bearing stratum which yielded 65 gallons per minute. The water was quite saline, and the well is regarded as a failure. The officers of the railroad company kindly permitted me to examine some of the borings, which are as follows:

Feet.	
0–17	beach sands; shell fragments.
17–44	bluish clay; shell fragments.
44–183	gray micaceous sand, fine; shell fragments.
183–191	greenish-gray sandy clay.
191–233	gray micaceous sands.
233–264	fine sand and clay, greenish gray; tough when dry; shell fragments; Pecten, Venus.
264–286	gray clay.
286–355	fine gray sand; shell fragments.
355–377	gray clay.
377–397	fine gray sand; shell fragments.
397–407	dark-gray clay.
407–526	gray sand, moderately coarse; some glauconite.
526–534	small gravel; shell fragments.
534–540	rock (no sample).
540–563	gray clay.
563–564	rock stratum; shell fragments.
564–568	gray clay.
568–603	rocky strata with thin layers of clay and shell fragments.
603–606	small gravel in gray sand; shell fragments. Water.
606–610	rocky stratum.
610–616	gray sand, moderately coarse; micaceous; oyster shells (?).

From 44 feet down the well is in the Chesapeake formation. The saline water horizon at 603 to 606 feet appears to be the same as that at 599 feet at Fort Monroe.

Norfolk.—A well was bored at Norfolk many years ago to a depth of 147 feet, which yielded a fair supply of hard water. After the introduction of the public waterworks it fell into disuse and was finally abandoned.

The present water supply for the city is obtained from ponds lying to the eastward, and, although a surface water, its quality is fair. As the supply is limited in amount and the city population is increasing steadily, an interest has been taken during recent years in obtaining an underground water supply. A series of test borings to depths of from 38 to 117 feet were made in the region east of the city and a fair prospect for water was found at from 30 to 50 feet, but with growing faith in the prospects for deeper-seated waters the commissioners have decided to try a deep artesian boring. This boring is now in progress, and the expectation is to obtain a supply of 5,000,000 gallons a day. Plans are perfected to sink to a depth of 1,800 feet if necessary, in order to get to the basal beds of the Coastal Plain formations—those which lie upon the granite floor, or bed rock, as shown in section 3 of Pl. XVI.

At Money Point, 5 miles south of Norfolk, up the Southern Branch, a well was sunk some years ago to a depth of 502 feet, from which flowed a good supply of slightly ferruginous water. Its supply came from sands low in the Chesapeake formation.

Newport News.—I learn that a well was bored at Newport News to the depth of about 600 feet, but without reaching water. I was unable to secure the well record, but undoubtedly the boring did not penetrate to the base of the Chesapeake formation.

Onancock, Accomac County.—This place is on the eastern shore of Virginia. The well was bored to a depth of 486 feet, but found no water below 140 feet. The water is utilized, and the well yields about 5 gallons a minute. The following partial record was furnished:

Feet.	
150–175	shells and gravel in sand.
180–308	fine sand; no water.
308–310	hard rock, 9 inches; clay, 2 inches; rock, 5 inches; clay, 5 inches.
310–333	clay and sand.
333–480	clay.

Williamsburg, James City County.—The boring made at the insane asylum at Williamsburg reached a depth of 876 feet without finding water, but in a recent boring to a depth of 280 feet a satisfactory supply has been obtained from the horizon at the base of the Chesapeake formation. In this shallower boring a very hard stratum of siliceous rock was pierced at 276 feet, and water was found in sands beneath.

Homewood, Surry County.—This place is on Hog Island, in James River, about 6 miles east of Williamsburg. There are five wells at various points on the island, with depths from 112 to 317 feet. They yield large supplies of water, of which that in the deep wells is of very fine quality, with a temperature of 54°. The following record has been furnished:

Feet.	
0–15	clay and loam.
15–25	gravel with surface water.
25–85	clay, blue below.
85–112	shell marl, with hard crust of shell marl at base.
112	ferruginous water which flows.
112–220	marl.
220–221½	rock.
222	water, better quality than that at 112 feet, and greater flow.
220–287½	blue clay.
287½–290	hard rock.
290	black water-bearing sand; 30-gallon flow; fine water.

In the wells on the southeastern part of the island the depth to the lower water is 315 feet. The horizon of this lower water is probably basal Chesapeake, or the same as in the many wells on York and Rappahannock rivers.

Jamestown, James City County.—This well is on Jamestown Island, in James River, a couple of miles above Homewood and about 5 miles from Williamsburg. It is 248 feet deep, and yields a large supply of fine water from the same horizon as that in the deeper wells on Hog Island.

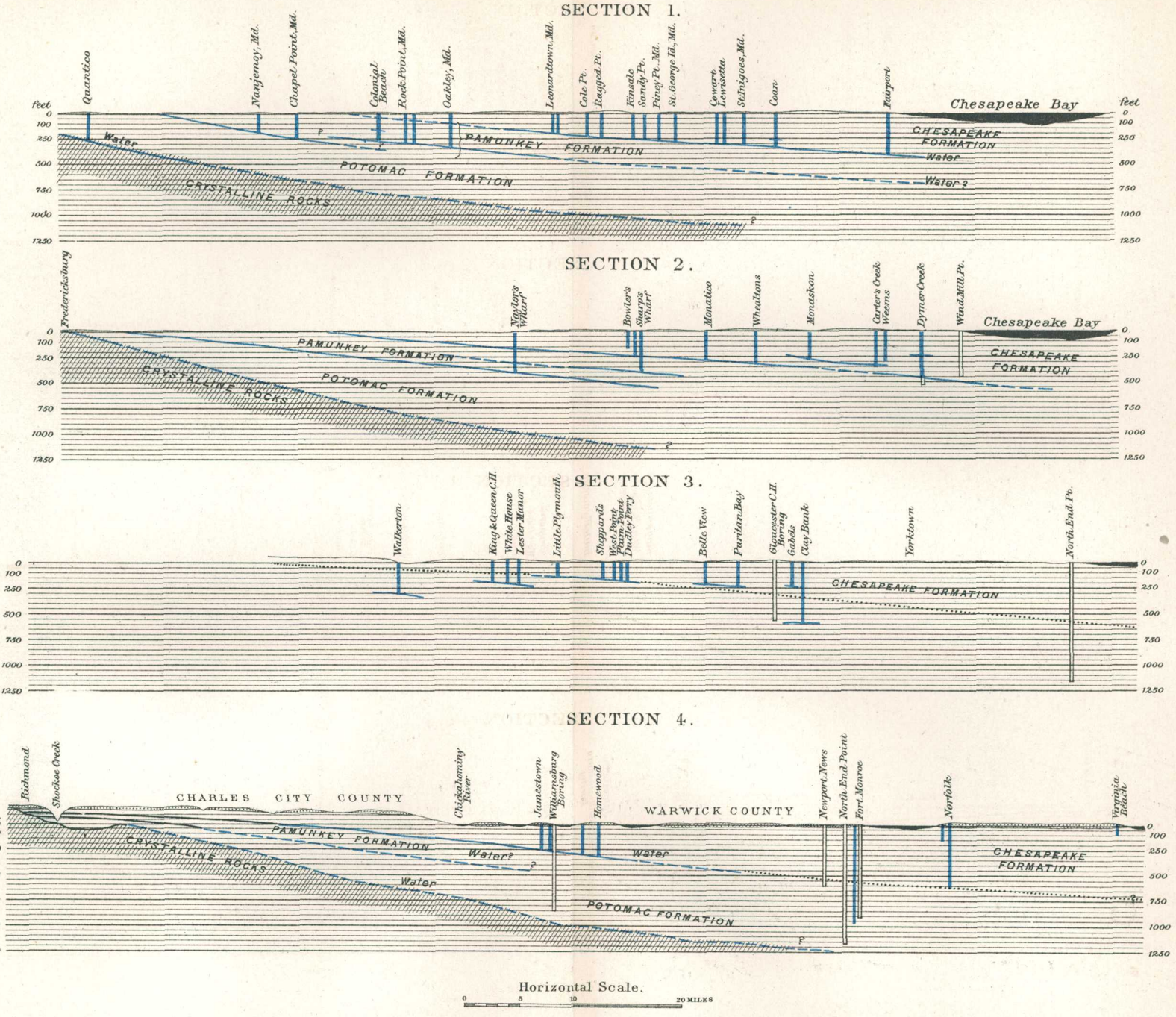
White House, New Kent County.—The three wells in the vicinity of White House vary in depth from 180 to 230 feet. The following record was supplied by Mr. P. H. Sweet, of White House:

Feet.	
0–15	soil.
15–25	yellow clay.
25–65	blue fullers' earth.
65–70?	several thin rock strata, one 18 inches thick.
70–95	soft sand rock.
95–115	red clay.
115–165	greensand marl?.
165–210	black sand.
210	water.

The pressure in the wells differs, but in one of them the water will rise to 20 feet above the surface of the ground. The water is probably in the basal beds of the Pamunkey formation.

Lester Manor, King William County.—The same horizon is tapped at Lester Manor in three flowing wells 200 feet deep.

Wells along the Mattapony and York rivers.—The wells in this valley begin at Walkerton, on the Mattapony, and occur at frequent intervals to Clay Bank Landing on the York River. They are all flowing wells, and yield large supplies of good water. Some of their features are given in the table on pages 165–167. The Walkerton well, with a depth



SECTIONS, EASTERN VIRGINIA.

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of 315 feet, no doubt draws from the Potomac formation, but I have not been able to determine the precise horizon. The well at King and Queen probably draws from the basal Pamunkey bed. The others, at West Point, Plum Point, Dudleys Ferry, Bellevue, Puritan Bay, Sheppard's warehouse, etc., draw from the lower and basal Chesapeake beds, which are found at a depth of 160 feet at West Point and 226 feet at Gabels Mill. The deep boring at Gloucester is only a few miles from the wells on York River, but it found no water down to a depth said to be over 600 feet. The relations of these wells and borings are shown in section 3 of Pl. XVI, and their distribution is indicated on the map, Pl. XV. The section shows the manner in which the beds dip gently to the eastward, but as the section line is on a northwest-southeast course it does not indicatethe maximum inclination, which is almost due east.

I have not been able to obtain many data for the York River wells, but the following general record, furnished by Mr. F. E. Pearce, of West Point, will afford an idea of the stratigraphy in the West Point region:

Feet.	
0–20	clay and sand.
20–110	blue clay.
110–160	sand, with water above and sandstone 1 to 16 feet thick below.
160	water.

Wells along the Rappahannock River.—At frequent intervals along this valley from Naylors Wharf to Windmill Point there are flowing wells which furnish large supplies of good water. They are at Naylors, Bowlers Wharf, Sharps Wharf, Monatico Creek, Whealton, Monaskon, Carters Creek, and Weems. They draw their water mainly from two horizons in and near the base of the Chesapeake formation, but at Naylors and Sharps Wharf a water-bearing bed in the Pamunkey sands has been reached. The structural relations of these waters are so clearly represented on section 2 of Pl. XVI that they do not require discussion. The depths gradually increase to the east at a rate of about 6 feet per mile along the Rappahannock, but this river flows at an angle of nearly 45 degrees to the maximum inclination, which is 10 feet per mile nearly due east.

The beds which are penetrated in the wells are nearly all represented in the boring to a depth of 386 feet at Naylors Wharf, of which Mr. L. Rude has kindly furnished the following record:

Feet.	
0–20	surface deposits.
20–120	blue fullers' earth.
120–135	marl.
135–155	strata of rock from 1 to 5 feet apart and containing water.
155–170	black sand.
170–260	blue fullers' earth.
260–275	dark orange-colored loam.
275–325	black sand full of water, which rises to 35 feet above tide.
325–385	blue fullers' earth, underlain by a soft rock layer, with water that rises to 45 feet above tide.

At Sharps Wharf the first rock stratum was reached at a depth of 200 feet and was bored through to 235 feet. The black sand, with water, was found at 360 feet in another boring at the same place. At Windmill Point the rock strata were found at a depth of 430 feet, but owing to an accident to the boring tool they were not penetrated and the well was not a success.

Dymer Creek.—The boring at Dymer Creek is on the wharf. It had a depth of 507½ feet when first bored, but was finished at 443 feet. The following record has been furnished by Mr. L. S. Bell, at Salisbury, Md.:

Feet.	
0–237	tough blue clay, with a 3-inch sand bed at 170 feet.
237–239	marl, with shells and gravel.
239–241	gravel, with a good supply of water, which rises to within 10 feet of the surface.
241–248	blue clay.
248–250½	rock stratum underlain by coarse sand mixed with yellow and green clay.
253?–385	clay.
385–388	rather coarse, dark sand.
388–435	blue clay.
435–443	sand, fairly coarse, dark above and white below; 7-gallon flow of water.
443–464	hard rock, very rough, porous texture.
464–474½	coarse sand, much mixed with clay and mica; 5-gallon flow of water.
476–479	rock stratum, quite hard.
479–507½	blue clay and sand.

This record shows a fair degree of correspondence with the record of the Naylors Wharf borings, making due allowance for difference in location and verbiage of the recorders. The rocky strata from 443 to 479 feet, with associated water-bearing sands, are apparently the same as those found at 135 to 155 feet at Naylors Wharf, 35 miles distant, and at 430 feet in the Windmill Point boring. The thin rock stratum at 250 feet and the water at 240 feet in the Dymer Creek well are probably local features.

Lancaster.—This well is on the peninsula between the Potomac and Rappahannock rivers, about 8 miles from the bay shore. The well was sunk 300 feet, but the water was taken at 250 feet. Its mouth was 60 feet above tide water. The record is as follows:

	Feet.	
	0–30	bright orange sand, moderately coarse (Lafayette).
Chesapeake.	30–75	gray sands, moderately coarse, with shell fragments.
	75–115	white and yellow sand intermixed, moderately fine.
	115–160	gray sand, moderately coarse, some glauconite grains, few shells, and thin ferruginous crusts.
	160–180	greenish-gray fine sands, mud, with some mica and many shell fragments; some glauconite.
	180–250	clay, light brownish-gray in color, few sandy streaks, shell fragments.
	250–300	clay, light greenish-gray in color.

Wells along the Potomac River.—(See also section 1 of Pl. XVI). The wells in the line extending with frequent intervals from Coles Point to Fairport all appear to draw their waters from the basal Chesapeake beds, or the same horizon as in the wells on the Rappahannock side of the peninsula and in the group of wells across the Potomac River in Maryland. At Coles Point the water is at a depth of 220 feet, and the depths gradually increase to Fairport, where the well is 393½ feet deep. The water is in good supply, and rises to about 12 feet above tide level.

Only scanty data have been secured as to the records of this group of wells. At Cowart the following are reported:

Feet.	
0–50	sand and gravel.
50–250	fullers' earth.
250–288	porous rock, with sand beds bearing water.

At Fairport there are reported:

Feet.	
0–70	sand and mud.
70–370	blue clay or fuller's earth.
370–393	quicksand.

At Colonial Beach the Chesapeake water horizon is only a few feet below the surface, and the wells penetrate to basal and mid Pamunkey horizons, which are found at depths of 250 and 160 feet respectively.

At Quantico there is a flowing well which has a depth said to be 210 feet in which the water supply is probably from the basal beds of the Potomac formation. A record of the beds furnished by the engineer of the Pennsylvania Railroad Company is as follows:

Feet.	
0–22	white clay.
22–28	fine gravel.
28–53	red clay.
53–58	fine red sand.
58–86	very hard blue clay.
86–89	fine sand.
89–124	dark clay.
124–127	coarse dark sand.
127–205	light-colored clay.
205–210	very coarse sand and water.

About 5 miles north of Quantico, near Possums Nose, a well was bored at the projected town of Barrow. Its depth was 195 feet, and a large supply of water was reported at 143 feet.

Its record, kindly furnished by Mr. R. P. Hughes, of Washington, is as follows:

Feet.	
0–10	clay and marl.
10–20	gravel.
20–30	clay.

Feet.	
30–44	sandstone.
44–45	coarse sandstone; water.
45–57	sandstone.
57–58	bluish sandy clay.
58–73	brown clay.
73–113	bluish sandy clay and fine sand.
113–143	sandstone; large supply of water.
143–147	yellow clay.
147–160	sand, with pebbles.
160–165	yellow clay.
165–195	brown clay.

A well was sunk on Sandy Point, in Fairfax County, just north of Occoquan Bay, which furnishes some interesting data. Its depth was 560 feet, of which the lower 275 feet were in rock. The following record was furnished by Mr. L. W. Shepard, the well borer:

Feet.	
0–20	clay, white and yellow.
20–100	swamp muck, blue, very soft.
100–115	gravel and sand (water).
115–130	clay.
130–140	gravel and sand (water).
140–150	clay.
150–210	fine sand and clay (water).
210–230	clay.
230–255	fine sand and clay.
255–264	clay.
264–270	pebbles, small, and lignite.
270–285	clay.
285–290	soft rock.
290–560	rock.

No water was found in the rock, but after dynamiting the well a good supply was obtained at 264 feet (?) which rises to tide level and rises and falls with the tide. The horizon is basal Potomac.

Richmond.—Several attempts have been made to obtain underground waters in or near the city of Richmond, but with only partial success. The Coastal Plain formations lie above tide-water level west of Shockoe Creek, so that they do not hold water. The wells in the lower part of the city are in granite and furnish a water supply for manufacturing purposes, but they appear to contain surface water in part. The well 400 feet deep at Major Ginter's farm, north of the city, obtains from the granite a supply of water which is said to be of excellent quality. In a 900-foot boring in granite at Sherwood Park no water supply was found, but a boring 250 feet deep in granite, a mile northeast, obtained an excellent supply.

Many years ago a well was bored at the Exchange Hotel, but it was not successful. It penetrated the Chesapeake, Pamunkey, and Potomac beds, but I have not learned whether it was bored into the underlying granite.

Ashland, Hanover County.—There are two wells at this place which obtain a satisfactory water supply at 79 and 100 feet, in the upper portion of the crystalline rocks or in the beds just above. The following record was furnished by Mr. Richard Irby, of Ashland:

Feet.	
0–20	clay and soil.
20–42	gravel and sand.
42–79	blue clay, with beds of fine sand.
79–85	stratum of sandstone.
85–120	disintegrated stone, with water in its upper portion.
120–140	granite.

Bothwell, Hanover County.—The well at this place was sunk for the railroad company. It is in the red and gray sandstone and sandy shales of the Newark formation to a depth of 300 feet.

Arringdale, Southampton County.—Nothing further was learned regarding the well at this place than is given in the table on page 165. The horizon of the water is not known, but it is supposed to be in the basal Chesapeake beds.

Courtland, Southampton County.—The wells of the group at this place have an average depth of 160 feet and furnish a fine water supply. It is reported by Mr. Moore that marl was penetrated from 50 to 100 feet. This marl is of Chesapeake age, and probably the water horizon is in the basal beds of this formation, or the same as at Arringdale.

Franklin, Southampton County.—The wells of the group which supply Franklin with water have a depth of only 130 feet, so that they draw from a much higher horizon than those of Courtland, which is several miles northwest, and up the dip. The only data obtainable were that there are marl beds at a depth of from 40 to 80 feet in the wells, but as the greater part of the Chesapeake formation in this region consists of marl, this does not definitely indicate the horizon.

Zuni, Isle of Wight County.—The flowing well here has a depth of 161 feet, and a marl bed is reported to extend from 60 to 140 feet. As the well is on higher ground and slightly east of the Franklin wells, it is probable that both draw from the same water horizon.

Mount Carmel Church, Isle of Wight County.—This well is 10 miles from Zuni and on higher land. Its depth is 190 feet and it is supposed to draw from the Zuni and Franklin horizon.

Dendron, Surry County.—A boring was made at this place to a depth of 386 feet without success in finding a water supply. The well probably did not quite reach the base of the Chesapeake formation, where the water found at 317 feet at Homewood might have reasonably been expected. The Zuni-Mount Carmel-Franklin water horizon was either passed or does not extend so far northwest as Dendron.

Swan Point, Surry County.—A dug well at this place has a depth over 100 feet and obtains a water supply of very satisfactory character from a sand bed in the Chesapeake formation. The horizon can not be defined at present.

WATER HORIZONS IN EASTERN VIRGINIA.

The greater part, if not all, of the Coastal Plain region of Virginia is underlain by water-bearing strata, of which to the eastward there are several horizons. The failures to obtain the higher water in some of the wells near the bay indicate that in this area at least there are no good water supplies in the higher horizons, but the waters of the lower horizons have not yet been fully developed. The success of the new well at Fort Monroe definitely proves the existence of one of these. The failure of a single well, as at North End Point, does not always disprove the existence of a water horizon, for we know of many instances in which water has been passed unnoticed, or willfully, by well borers.

The principal water horizons in eastern Virginia are the Chesapeake, the Pamunkey, and the Potomac.

POTOMAC.

There is more or less water in all of the coarser sand beds of the Potomac formation, but the principal supplies may be expected from the sands and gravels of the basal members lying on the basement floor of crystalline rocks. This horizon has been well explored about Washington and Alexandria, in most cases with great success, and was probably reached by the 210-foot well at Quantico. South of Quantico for some distance it does not appear to have been reached by any of the wells except one (at 315 feet) at Walkerton, on the Mattapony River; but from the general character of the formation as exhibited in its outcrops, and its productiveness of water northward, I have reason to believe that it is a great water bearer throughout a wide extent. Its general relations are shown in the sections in Pl. XVI. How far eastward the coarse materials extend in the basal beds of the Potomac formation is not known, for they lie deeper than any of the wells appear to have penetrated. The North Point well is reported to have reached "granite" and found no water supply in the basal beds, but, as I have elsewhere explained, the record and conduct of this well do not afford conclusive evidence either of the actual absence of water or of the presence of granite at the bottom of the boring. The well no doubt reached the Potomac formation, and it may have penetrated far into it. The water at the Chamberlain Hotel at Fort Monroe is thought to be from upper Potomac or possibly Magothy beds, but the evidence is not conclusive as to the precise horizon.

Water occurs at various horizons in the Potomac formation above the basal beds, in sands intercalated among the clays. This water is an important source of supply in the District of Columbia, and it also affords a large yield at the well at Barrow, near Quantico. Only one of the wells south of Fredericksburg has penetrated to these waters—the one at Walkerton at a depth of 315 feet—so that their southeastern extension has not been well explored, but there is a fair possibility of finding one or more of them in that region. The 600-foot boring at

Gloucester may have reached the Potomac beds, and even penetrated them for some distance, without finding water, but as this boring missed the higher waters that probably underlie Gloucester, it can not be regarded as a decisive test for any of the waters.

PAMUNKEY.

The coarse gravel and sand at the base of this formation appears to extend far to the east, and it is a water bearer throughout its extent. It was reached by the deep well at Naylors Wharf at a depth of 386 feet, where sands with rock layers yielded a large flow of water which rose to 45 feet above tide level. At Chapel Point, Md., at 237 feet, in the several deeper wells at Colonial Beach, at Lester Manor at a depth of 200 feet, and at White House at depths from 180 to 230 feet, it furnishes a large supply of fine water under considerable pressure. These wells indicate a wide extent of the waters in a region which probably comprises the western half of the area indicated by a distinctive pattern for Chesapeake and Pamunkey waters on the map, Pl. XV. This horizon is about 250 feet below the Chesapeake water. The meager supply of water in the Clay Bank well and the failure of the deeper borings at Williamsburg and Gloucester probably indicate the limits of the horizon as a water bearer to the eastward. It may extend under all of the region south of the James River, but none of the wells appear to have been bored sufficiently deep to reach it, and higher waters are utilized. The experience of the unsuccessful boring to a depth of 386 feet at Dendron is not conclusive, for it probably did not reach the horizon, and if it did, may not have properly tested it; still, it is in line with the experience at Williamsburg and Gloucester. The latter criticism applies also to the North End Point well. It is to be expected that to the eastward the materials of this horizon finally become too fine grained to carry water, and the eastern limits of conditions favorable for water bearing appears to be at Clay Bank, on York River. Probably the well now being bored at Norfolk will throw light on the question, although I do not really expect Pamunkey beds to be sufficiently coarse at that locality to yield water in large amount, and have advised that the boring be planned to go to deeper horizons.

Water also occurs in sands in the Pamunkey formation about 90 feet above its base, as indicated by the water at 160 feet at Colonial Beach, and at 275 to 325 feet at Naylors Wharf; but as it has not been further explored by other wells, its extent can not be discussed.

CHESAPEAKE.

Lying between the clays, marls, and fine sands of the Chesapeake formation and the top of the Pamunkey formation, there is a series of sands and gravels which may be regarded as the basal bed of the Chesapeake formation. To the eastward this series contains thin interstratified rock strata which do not appear in the surface outcrops. In this series, and in another similar one not far above, there is a large volume of water, at a horizon or horizons which appear to be of wide

extent in eastern Virginia. These waters have been explored by many wells and been found to underlie a belt of country about 20 miles in width lying east of a nearly straight line extending from Mathias Point, on the Potomac River, to Emporia, on the Atlantic Coast Line Railroad. This belt has been indicated on the map, Pl. XV, by a distinctive pattern, and the relations of the waters are shown in sections on Pl. XVI. The wells which reach these horizons are given in the following list:

Locality.	Depth.	Remarks.
Richmond County.	*Feet.*	
Naylors Wharf	135	
Sharps Wharf	235	
Lancaster County.		
Monatico Creek	250	
Whealton	230	
Monaskon	.....	
Lancaster	250	
Carters Creek	330	
Weems	260	
Windmill Point	450	Well blocked by breaking of tools.
Westmoreland County.		
Coles Point	220	
Ragged Point	225	
Sandy Point	235	
Maryland.		
Piney Point	270	
St. George Island	270	
Leonardtown	200	Water begins at 170 feet.
St. Inigoes	300	
Northumberland County.		
Kinsale	235	
Lewisetta	317½	
Cowart	238	
Coan	315	Water also at 270 feet.
Fairport	393	
Dymer Creek	443	
Mattapony River.		
Little Plymouth	168	
Sheppards Warehouse	160	
York River.		
Dudleys Ferry	175	
West Point	160	
Plum Point	168	
Gabels Mill	226	
Belleview	212	
Puritan Bay	215	
James River.		
Williamsburg	280	
Homewood	290–317	
Jamestown	248	
Courtland	160	Horizon doubtful.
Arringdale	78	Do.

The horizon of the waters at 130 feet at Franklin, 161 feet at Zuni, and 190 feet at Mount Carmel is not certainly known, but it is thought to be in the Chesapeake formation considerably above its base. The Arringdale well at 75 feet and the Courtland wells at 160 feet are doubtfully referred to the basal Chesapeake beds, but the former may be down to a lower horizon.

Basal Chesapeake waters were apparently absent in the North End Point, Fort Monroe, Dendron, Claybank, and Gloucester wells. The wells at Crisfield, Md., found no appreciable supply of water in the basal Chesapeake beds.

There are several higher horizons of water in the Chesapeake formation, and it is believed that the wells at Franklin, Zuni, and Mount Carmel draw from Chesapeake beds about 100 feet above the base of the formation. The water of the Bowlers Wharf well at 143 feet is from about the same horizon, but water reported at 240 feet in the Dymers Creek well is somewhat higher than the others. The water beginning at 170 feet at Leonardtown and the waters at 240 and 270 feet at Coan are from the top of a considerable thickness of sandy basal members.

The salty water at 606 feet at Lambert Point and at 599 feet at Fort Monroe, and the ferruginous water at 562 feet at Money Point, all near Norfolk, are from somewhat higher horizons. The waters at 140 feet at Onancock on the eastern shore and at 70 feet at Virginia Beach are at still higher horizons. I am not inclined to regard any one of these upper Chesapeake horizons as widespread, and with our present meager knowledge they can not be predicted with safety.

As I regard the waters in the Lafayette and Columbia formations to be superficial, I secured no data regarding them.

WELL PROSPECTS BY COUNTIES.

ALEXANDRIA COUNTY.

The portion of this county occupied by the Potomac formation is underlain by waters which are available in wells of moderate depth, as indicated by the success of the wells at Alexandria.

FAIRFAX COUNTY.

The portion of this county immediately adjoining the Potomac River and extending west of the Baltimore and Potomac Railroad is underlain by water-bearing beds of the Potomac formation. They have only been tested by the boring at Sandy Point, near Occoquan Bay, which reached the basal waters and passed into bed-rock at 270 feet. At Mount Vernon the basal Potomac gravels and sands may be expected at a depth of about 350 feet. Possibly water will also be found in higher beds. As the dip is quite steep to the east, the depth diminishes toward the Baltimore and Potomac Railroad, where the basal beds

emerge at the surface and are exposed in railroad cuts, etc. The floor of crystalline rocks rises to the surface west of the railroad.

PRINCE WILLIAM COUNTY.

The conditions in this county are precisely similar to those in Fairfax County. The Potomac formation occupies a belt extending about 3 miles west from the river, but the distance is less in the larger depressions. The well at Barrow on the Potomac developed a large water supply at a depth of 143 feet in Potomac beds, and it is probable that another water horizon would have been found in the basal beds lying on the crystalline rocks from 150 to 200 feet below.

STAFFORD COUNTY.

The conditions in Stafford County are similar to those above described, but the area underlain by the Potomac formation widens rapidly south of the Potomac Creek. The well at Quantico found water in the basal Potomac beds at 210 feet, and there is every reason to believe that this water extends over the entire area occupied by the formation. Along the eastern border of the county, south of Aquia Creek, there is a belt of country about 3 miles wide in which the basal Pamunkey gravels will be found to contain water at depths which increase to about 75 feet below tide-water level along the King George line. The basal Potomac waters are at least 400 feet deeper, but there is everywhere a fair prospect for water at higher horizons within the Potomac formation.

KING GEORGE COUNTY.

Although I know of no deep wells in this county, the geologic conditions and the indications of the Colonial Beach and Chapel Point (Md.) wells are such that water may be quite safely predicted throughout the county in the basal Pamunkey beds. The depths will be found to increase gradually from about 75 feet below tide-water level along the Stafford line to 200 feet on the Westmoreland line. Waters may also be expected at greater depths in the Potomac sands. Some of the relations of the beds in the county are shown in sections 1 and 2 of Pl. XVI.

WESTMORELAND COUNTY.

This county is underlain throughout by the Pamunkey horizon at depths which increase from 250 feet at Colonial Beach to 386 feet at Naylors Wharf. At greater depths the Potomac waters may also be looked for, but there is less certainty of these lower waters eastward. The eastern part of the county is also underlain by the basal Chesapeake waters, which lie about 250 feet higher than the basal Pamunkey horizon. They have been extensively developed in the flowing wells from Coles Point, where their depth is 220 feet, to Kinsale and Sandy Point, where they are 235 feet below tide-level.

RICHMOND COUNTY.

The experience of the Sharps Wharf and Naylors Wharf borings indicates the extension of the basal Chesapeake waters through the county and the existence of a mid-Pamunkey water in large volume. (See sec. 2 of Pl. XII). The Naylors Wharf well reached the basal Pamunkey water at 386 feet, and this water will no doubt be found to underlie all of the county if there is occasion to go below the mid-Pamunkey and basal Chesapeake horizons for water supplies.

NORTHUMBERLAND AND LANCASTER COUNTIES.

The conditions and prospects in these counties are similar to those in Richmond and Westmoreland, but the dip to the eastward carries the water horizons deeper, as is shown in sections 1 and 2 of Pl. XVI. The wells in Northumberland and Lancaster counties draw their supply from the lower and basal Chesapeake horizon, as shown on Pl. XII, and there has been no occasion to go to the deeper waters which no doubt underlie the counties.

SPOTTSYLVANIA COUNTY.

The eastern corner of this county is underlain by the Potomac formation, and there is every prospect that this area will prove to be underlain by basal Potomac waters, if not also by waters higher in that formation.

CAROLINE COUNTY.

All but the western corner of this county is underlain by the Potomac, Pamunkey, and Chesapeake formations, in which the prospects for water are everywhere excellent. I have learned of no deep wells, but have no doubt as to the extension of the water-bearing beds. The structure is similar to that shown on the western third of section 2 of Pl. XVI. At Bowling Green I believe that water may be expected in the basal Pamunkey beds, if not also in the basal Chesapeake horizon, and there are further chances for water in the Potomac formation below. It is estimated that the basal Pamunkey gravels lie about 300 feet below the court-house at Bowling Green.

ESSEX COUNTY.

The conditions in this county are similar to those in Westmoreland and Richmond counties, as described above and shown in section 2 of Pl. XVI. The well at Bowlers Wharf found plenty of water at 143 feet in the horizon about 100 feet above the base of the Chesapeake formation.

MIDDLESEX COUNTY.

No wells are reported from this county, but the conditions and prospects are similar to those described under Lancaster County.

KING AND QUEEN COUNTY.

The basal and lower Chesapeake horizons have been tapped by wells at Little Plymouth (probably), at Sheppard's warehouse, and at Dudleys Ferry; and they probably underlie all of the southeastern end of the county, as indicated in section 3 of Pl. XVI. The basal Pamunkey water appears to yield the small supply in the court-house well. I am not certain that it extends to the south and east, but probably it underlies the region to the north and west.

KING WILLIAM COUNTY.

No wells were reported from the northwestern end of this county, but the many flowing wells at West Point and near by in adjoining counties indicate a wide extension of basal and lower Chesapeake waters over the southern part of the region, while the wells at White House and Lester Manor indicate an extension of the basal Pamunkey waters. In the northwestern end of the county the Potomac formation lies at no great distance below the surface, and judging from the coarse beds which outcrop between Bothwell and Hanover, and the success of the well at Walkerton, it may be expected to contain a large supply of water.

GLOUCESTER COUNTY.

The successful flowing wells at Bellevue and Puritan Bay indicate an extension of water in lower Chesapeake beds into the county, but the failure to find water in them at Clay Bank and Gloucester probably indicates that they do not extend far to the east. The Clay Bank well to 538 feet is thought to draw from the basal Pamunkey bed, and its small water supply may indicate that no water is to be expected to the eastward at this horizon. Possibly, as appears to be the case in the Gloucester well, the boring stopped at the rock stratum, and water might have been found below. The chances for still deeper waters have not been tested in this region, and we can not predict how great they may be.

MATHEWS COUNTY.

I have heard of no boring in this county, but should expect the water-bearing beds of the Lancaster wells to extend into the county, or at least into the northern portion. The failure of the 600-foot boring at Gloucester may indicate that this is not the case; but, as explained above, the evidence of that well is not conclusive. A well to a depth of 1,000 feet would probably reach the Potomac beds, in which there is some prospect of finding water, if water were not found in the basal or higher Pamunkey beds above.

EASTERN HANOVER COUNTY.

The portion of this county lying east of the Richmond, Fredericksburg and Potomac Railroad is underlain by Potomac and Pamunkey

beds, which in all probability carry their usual water supply. No wells have been bored to them, but the outcrops exhibit gravel deposits at the base of the Pamunkey marls and coarse gravel and sand in the Potomac formation, which are the requisite conditions for water-bearing beds. The well at Bothwell is in the sandstone of the Newark formation, a water bearer which is not under discussion in this report. The wells at Ashland are in basal Potomac beds and the underlying disintegrated granite.

NEW KENT COUNTY.

This county presents similar conditions to those in central and eastern King William. The wells at White House indicate the extension of the basal Pamunkey waters, and the wells to a depth of 168 feet at Plum Point and 160 feet at West Point indicate the presence of basal Chesapeake waters. The boring which was abandoned at 80 feet at Providence Forge would no doubt have reached the basal Chesapeake waters at no great depth below.

CHARLES CITY COUNTY.

I have learned of no wells in this county, but there exists in it the same favorable conditions for water as in New Kent County. The Potomac formation is not far below tide-water level in the eastern portion of the county, where it presents the relations shown in section 4 of Pl. XVI. The coarse, gravelly basal beds of the basal Pamunkey beds pass beneath tide-water level near the western border of the county, and no doubt will yield water to the eastward as far as the Chickahominy River.

Of the basal Chesapeake beds, which underlie all of the eastern portion of the county, I can speak with less confidence, for they have not yet been explored on this section of James River. In the outcrops about the City Point region they are gravelly sands only a few inches thick, but water runs out of them in springs and seeps in every exposure. At Jamestown, Williamsburg, and Homewood they yield large supplies of fine water.

JAMES CITY COUNTY.

The success of the many wells about West Point and of the wells at Jamestown, Williamsburg, and Homewood would appear to indicate a general extension of the basal Chesapeake water horizon under this county. The failure of the deeper well at Williamsburg to find water at this horizon can, I believe, be explained only by the suggestion that the water was overlooked in boring, as it was found in the shallower well, but the deep well no doubt indicates the absence of waters in the basal Pamunkey beds.

YORK AND WARWICK COUNTIES.

No wells have been reported in these counties, but possibly the waters found at Gabels Mill, Williamsburg, Jamestown, and Homewood

continue at least part way across them. There is great need for water at Yorktown, and there is sufficient possibility of finding water in basal Chesapeake beds at a depth of about 450 feet to warrant the sinking of a well to test for it. This suggestion would also apply to Warwick and vicinity. There is a possibility of water also at the 538-foot horizon of Claybank.

ELIZABETH CITY COUNTY.

The success of the new 945-foot well at the Chamberlain Hotel, Fort Monroe, gives encouragement for deep-seated water supplies in this county. The failure of the boring at North End Point is thought to be due to inadequate testing of the beds, but it may possibly indicate that the waters at Fort Monroe do not extend northeastward. The slight salinity of the Fort Monroe water is unfortunate, but this may decrease as the well flows, and on the other hand the source of the salinity may not be widespread. The earlier Fort Monroe boring was within 38 feet of this water, but the 600-foot boring at Newport News was discontinued over 300 feet above it.

I am of the opinion that it will be well worth the expense to sink a boring at Fort Monroe which shall go to bed rock—at about 1,350 feet—to ascertain whether there are lower and basal Potomac waters under the peninsula.

NORFOLK COUNTY.

The only attempts to obtain water in this county have been borings to moderate depths in the vicinity of Norfolk. The well at Money Point obtained fair water at 562 feet in Chesapeake beds, but at Lambert Point, Norfolk, these beds yielded only saline water. On the basis of my belief that there is a fair possibility of water in the basal beds of the Potomac formation near the bed-rock surface, I have encouraged the plan of sinking a boring at Norfolk to this horizon, which will probably be found between 1,500 and 1,700 feet at the very greatest (see section 4 of Pl. XVI). Possibly good supplies will be found in higher beds, as at Fort Monroe. The boring is now in progress, but the result will be learned too late to go into this report.

PRINCESS ANNE COUNTY.

There are no deep borings in this county, and as the general conditions are similar to those in Norfolk County, there is nothing to add to the statement made above.

ACCOMAC AND NORTHAMPTON COUNTIES.

The well at Onancock, which was bored to a depth of 486 feet, but found no water below 140 feet, is the only one of which I have learned

on the Eastern Shore of Virginia. The wells at Crisfield, Md., were bored to a depth of 1,016 feet before a water supply was found, and this demonstrated that for the Crisfield region, at least, there are no basal Chesapeake or Pamunkey waters. The water found at Crisfield may be expected with some degree of confidence in Accomac and Northampton counties at about 1,100 feet below the surface. There is also a possibility of even lower water in basal Potomac beds a few hundred feet deeper.

EASTERN HENRICO COUNTY.

The city of Richmond and the region eastward are underlain by the Potomac, the Pamunkey, and the Chesapeake formations, of which the western limit is in the western part of Richmond. The Potomac formation lies on the floor of granite which passes beneath tide-water level in Richmond, and contains water to the eastward, but the basal Pamunkey and the Chesapeake formations lie above tide level to the east line of the county, and the water that they contain farther east is, in some measure at least, free to flow out into the James River. The relations in the region are shown in section 4 of Pl. XVI. The only wells I know of in the county are in or near Richmond, and these are mainly in the granite. A list of them is given on page 166, and some further statements regarding them may be found on page 178.

EASTERN CHESTERFIELD COUNTY.

In the portion of this county that lies east of the Richmond and Petersburg Railroad water may be expected in the basal Potomac sands at depths from 100 to 250 feet. I know of no deep wells in that section.

PRINCE GEORGE AND SUSSEX COUNTIES.

These counties are underlain by the Potomac, Pamunkey, and Chesapeake formations, and probably these members will be found to carry the usual water-bearing beds as in the adjoining region. No wells have been reported, but the geologic relations have been studied and the regular succession of beds and conditions for water found to prevail. The approximate distribution of the water-bearing beds is shown in the map, Pl. XV.

SURRY COUNTY.

The very successful group of wells at Homewood, on Hog Island, are in this county, and they and the Jamestown well give a good basis for the belief that the basal Chesapeake waters will be found in a wide area to the south and west. The Dendron boring, however, may indicate a restriction of this area. The underlying Pamunkey horizon has not been tested, and the chances for water in it are sufficient to warrant a boring. Its relations are shown in section 4 of Pl. XVI.

ISLE OF WIGHT COUNTY.

The wells to depths of 160 to 190 feet at Zuni on the Blackwater and at Mount Carmel Church, respectively, indicate an area of water in mid-Chesapeake beds which may be widespread, but of which the full extent can be determined only by further boring. The water is probably at the same horizon as that at Franklin, at a depth of 130 feet. Notwithstanding the failure of the boring at Dendron, in Surry County, I believe there are some chances for basal Chesapeake waters throughout, and an almost certain prospect for them in the north, toward the Hog Island region, where they yield such large supplies. The Pamunkey and Potomac horizons remain to be tested, for no wells have yet been sunk to them.

SOUTHAMPTON COUNTY.

The Courtland and Franklin wells indicate the existence of two water horizons at moderate depths in this county. The Franklin water was not reported in the Courtland wells, where it should not be more than 40 or 50 feet below the surface. The Courtland water has not been sunk to at Franklin, where it probably lies about 250 feet below the surface. The extent of these waters in the county is not known. The Arringdale water may be from the same horizon as that at Courtland, and if this is the case, it would be reasonable to expect it to be found throughout the intervening distance. The Potomac formation is probably a water bearer in this county, but nothing can be promised for the Pamunkey formation, as it has not been studied. It is thought that a well to about 350 feet at Courtland would reach the basal Pamunkey beds.

NANSEMOND COUNTY.

No wells were reported from this county, and there are no data on which to base predictions, except for a few miles from Franklin in an area under which the Franklin water may reasonably be expected to extend.

NORTH CAROLINA.

GEOLOGIC FEATURES.

All of the data for this State were supplied by Prof. J. A. Holmes, State geologist, and they are presented by him under the very convenient headings of counties. A general review of the horizons is not attempted at present, but for each county in the Coastal Plain region the well prospects are pointed out, so far as there is any evidence on which to base predictions.

The general geologic structure of the Coastal Plain in North Carolina is indicated in the accompanying section by Professor Holmes, fig. 8.

The principal difference in the geology of this region from that of Virginia is the reappearance of the marine Cretaceous beds, which

thicken rapidly and rise to tide-water level and above nearly as far east as Wilmington. The Eocene formation thins somewhat, and in the southern counties lies almost entirely above tide level, on an irregular floor of marine Cretaceous sands and marls.

The Chesapeake beds thin rapidly southward, and lie mostly above tide level in shallow basins on the Eocene or marine Cretaceous.

The Potomac, the most important of the water-bearing formations of the Coastal Plain region, is best developed along the western border of this region in the counties southwest of the Neuse River—Harnett, Moore, and Richmond. In these counties it is exposed at intervals over considerable area; and, dipping gently southeastward on the eroded surface of the crystalline rocks, these Potomac strata doubtless carry considerable quantities of water. The Potomac formation also reaches the surface over limited areas, both to the north and south of the Roanoke River, above Weldon; and there are also limited outcrops of the formation at intervals between the Roanoke and Neuse rivers, but in this latter region the exposed areas of the formation are far less extensive than between the Neuse and the Pedee, and consequently the underground water supplies below the Tertiary marls of the counties between the Neuse and Roanoke will probably prove to be less abundant than in the more southerly counties.

The following list of these wells is arranged geographically from north to south:

List of deep wells in the Coastal Plain region of North Carolina.

Locality.	County.	Depth.	Remarks.
		Feet.	
Elizabeth City, 10 wells	Pasquotank	64	Flow 15 gallons each; water hard and sulphurous.
Edenton	Chowan	340	No water.
Avoca	Bertie	180	Do.
Washington	Beaufort	140	Water not very satisfactory in quality.
Do	do	100	Do.
Do	do	360	No water.
Yatesville	do	215	Flows 50 to 60 gallons.
D. C. Way Lumber Co	do	300	Flows 15 gallons of sulphurous water; water also at 120 feet.
Roper	Washington	50–75	Yields 10 gallons of unsatisfactory water.
Lake Landing	Hyde	205	Pumps 15 gallons of fine water; water also at 85 feet.
Lake Comfort	do	115	Flows; water sulphurous.
Swanquarter	do	86	Flows a good supply of fine water; no water 86–340 feet.
Rose Bay	do	130	Flows good water.
Scranton, 3 wells	do	100, 160, and 195	Satisfactory water.
Middleton	do	212	Flows good water.
Fairfield	do	230	Flows.
Newbern	Craven	350	Pumps good water.
Do	do	50	Do.
Do	do	90	Do.

List of deep wells in the Coastal Plain region of North Carolina—Continued.

Locality.	County.	Depth.	Remarks.
		Feet.	
Springer Lumber Co	Pamlico	90	Pumps very hard water.
Beaufort	Carteret	200	Flows sulphurous water.
Jacksonville, 3 wells	Onslow	160	Do.
Tarboro	Edgecombe	75	Flows 2 gallons.
Do	do	82	Pumps.
Do	do	160	Do.
Do	do	218	Flows.
Greenville	Pitt	200+	Water obtained, but pipe filled with sand.
Wilson Cotton Mills	Wilson	125	Hard water.
Goldsboro	Wayne	266	Quantity and quality satisfactory.
Kinston	Lenoir	115	Pipe filled with quicksand.
Lagrange (5 miles south)	do	57	Flowing well.
Warsaw	Duplin		In progress.
Burgaw	Pender	100	Water to near surface; quantity and quality satisfactory.
Long Creek	do	175	Stopped in quicksand.
Vineland	Columbus	63	Flows 4 gallons.
Do	do	225	Water nearly to surface.
Wilmington	New Hanover	495	Flows 75 gallons; very saline water.
Wilmington, 3 wells	do	84–100	Pump 400 gallons each of good water.
Hammocks	do	400	8-gallon flow of good water from 100 feet(?).

NOTES ON WELLS AND PROSPECTS, BY COUNTIES.

Quite a number of wells have been sunk in the Coastal Plain region of North Carolina, but they have not been very successful. Many of the waters are unsatisfactory, owing to sulphur or other minerals, and only a few have furnished large supplies. Their depths are mainly less than 300 feet, and it seems probable that more satisfactory water would be found lower down, below the marls and their associated clays.

PASQUOTANK COUNTY.

At Elizabeth City, in 1891, Mr. Henry E. Knox, jr., bored ten wells in different portions of the town, the average depth of which was 64 feet. At several of these wells, which are located at slightly lower portions of the surface, the water overflows the top of the pipe. There are two water-bearing strata, having an average depth of 58 and 78 feet, respectively, below the surface. The water from both strata is strongly sulphurous and hard, but free from surface contamination. Each well, lined with a 2-inch pipe, as estimated by Mr. Knox, will easily yield 10,000 gallons of water per day. In the following statement as to thickness and depth of the strata penetrated in boring these wells, two wells are selected—Nos. 2 and 8—as representing the varying character and thickness of the materials in different portions of the town.

Well No. 2 is located on the north bank of the north branch of Poindexter Creek where crossed by Pool street. This well is 78 feet

6 inches deep, and penetrates the following strata, beginning at the surface:

Feet.	
0–12⅜	muck.
12⅜–14⅜	yellow sand.
14⅜–41½	marl.
41½–43	fine sand.
43–55	blue clay.
55–60	coarse water-bearing sand.
60–65½	fine sand.
65½–78½	coarse water-bearing sand, and under this a blue clay of unknown thickness.

Well No. 8 is located near the crossing of McMourine and Main streets, has a depth of 60 feet, and penetrates the following strata:

Feet.	
0–19	yellow sand.
19–54	marl.
54–56½	fine sand.
56½–60	coarse water-bearing sand.

The occurrence of these water-bearing strata at comparatively shallow depths at Elizabeth City would seem to indicate that similar water-bearing strata might be found in other portions of this and adjoining counties.

NORTHAMPTON AND HALIFAX COUNTIES.

No deep wells are reported as having been bored in either of these counties. In the southern and eastern portions, however, it is probable that supplies of good water could be obtained at depths not greater than from 100 to 200 feet. In the northern and western portions of these counties, and in adjacent regions in Virginia, the Potomac arkose and gravels are exposed over limited areas, and these water-bearing strata, when not removed by erosion, should be reached in the eastern and southern portions of these counties at depths not greater than those given above.

GATES AND HERTFORD COUNTIES.

No overflowing or deep wells have been reported from these counties. In view of the fact, however, that at both Franklin and Courtland, 10 to 15 miles to the north of these counties, excellent supplies of water are obtained at depths varying from 100 to 165 feet, it is reasonable to suppose that these water-bearing strata would be penetrated along the upper portions of both these counties at depths not greater than from 200 to 300 feet; and in all portions of these counties it is probable that supplies of good water can be obtained at depths not much greater than those just given, and may possibly be reached at depths not so great.

CHOWAN COUNTY.

At Edenton, in this county, a well has been bored to the depth of 340 feet by Mr. J. W. Branning. In boring this well the surface sands

and loams were found to extend down to a depth of 21 feet, and below this the marl extended to 340 feet; at which point, no water-bearing strata having been reached, the well was abandoned. At other places in the county driven wells and bored wells have been sunk to a depth of from 20 to 100 feet. Of these, none are reported as overflowing, but in many of them water of good quality comes so near that it can be raised to the surface with an ordinary cheap pump.

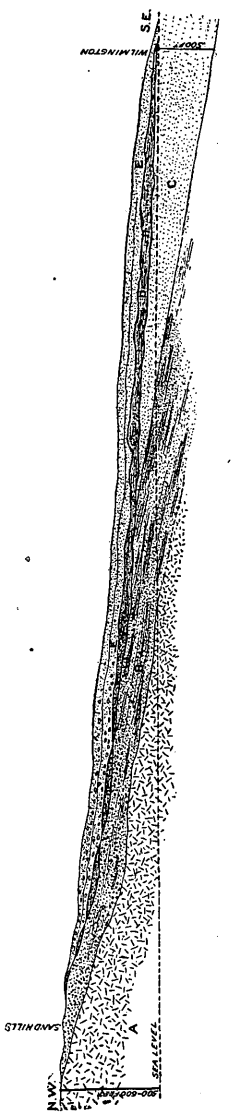


FIG. 8.—Cross section of the Coastal Plain region of North Carolina, from the crystalline schists near Sanford to the coast near Wilmington, looking north. A, crystalline schists; B, Potomac sand, arkose, and clays; C, marine Cretaceous sands, marls, etc.; D, Tertiary marls and shell rock (Eocene and Chesapeake); E, Lafayette and overlying Columbia formations. Vertical scale greatly exaggerated.

As to the probabilities for deep wells in this county, it may be said that the flowing wells at Franklin and Courtland, Va., some 50 miles to the northwest of this point, where water-bearing strata are reached at a depth of from 100 to 150 feet below the surface, indicate that similar water-bearing strata ought to be reached at a greater depth below the surface in Chowan County. At just what depth these water-bearing strata would be reached the information in hand is insufficient to warrant one to predict. The failure of the Branning well at Edenton seems to indicate the absence of water-bearing strata nearer the surface than 340 feet. It is probable that water-bearing strata will be reached at a depth not much greater than this.

In the adjacent counties of Perquimans, Pasquotank, Camden, and Currituck no deep or flowing wells have been reported. In the first named of these counties a number of driven wells have been sunk to a depth of from 50 to 175 feet in the vicinity of Hertford, on the Norfolk and Southern Railroad. In these, water of good quality rises so near the top that it can be easily brought to the surface by cheap pumps. In Pasquotank County good water is reported as having been reached in a similar way at Elizabeth City, and no reason is known why the same should not be done in Camden and Currituck counties.

BERTIE COUNTY.

At Avoca, the head of the Albemarle Sound, a pipe has been driven to a depth of 180 feet without securing a flow of water. At this depth quicksand interfered so seriously with the progress of the work that

the undertaking was abandoned. The fact that at Edenton (Chowan County), only a few miles east, a well was sunk to a depth of 340 feet without success indicates that in the eastern part of Bertie County wells will probably have to be sunk to a depth of 300 feet or more before a water-bearing stratum will be reached. In view of the facts, however, that the Potomac gravels and arkose are found at the surface well developed toward the northwest and north, at distances of 30 to 50 miles from Bertie County, and that at Franklin and Courtland, Va., 35 to 45 miles north of Bertie County, supplies of artesian waters of excellent quality are obtained below the marl, and at depths of 150 to 170 feet below the surface, it may be reasonably supposed that in portions of Bertie County water-bearing Potomac strata should be reached within 300 or 400 feet of the surface.

MARTIN COUNTY.

No borings of deep wells have been reported from this county. It may be said, however, that in the northwestern portion of the county, adjoining Edgecombe, the success of the wells in the latter county at Tarboro would seem to indicate that water-bearing strata would be reached here at a depth of between 150 and 300 feet below the surface. In the lower part of the county these same water-bearing strata could be reached at a slightly greater depth.

BEAUFORT COUNTY.

Several deep wells have been bored in this county, but the records of the strata penetrated at different depths are generally incomplete, and the supplies of water obtained have not been altogether satisfactory.

In the town of Washington several wells were bored: (1) At the residence of W. B. Rodman, 140 feet deep. A considerable supply of water was obtained, but it was hard and not very palatable. It does not overflow, but rises sufficiently near to the surface to be lifted by the use of an ordinary pump. (2) The ice factory well, about 100 feet deep; general character of water about the same as in the Rodman water just described. (3) The city well, which was bored by the city a few years ago to a reported depth of about 360 feet. In the boring the pipe was broken off. The water did not overflow; its supply proved to be insufficient and the well was abandoned.

At Covington's mill, Yatesville, a well was bored in 1891 to a depth of 215 feet with successful results. The water overflows through a 3-inch pipe at the rate of 50 or 60 gallons per minute, at an elevation of 2½ feet above the surface. The strata passed through in boring this well consist of sand with intervening beds of marl and shell rock. Near the bottom it passed through 10 feet of soft rock, below which it reached an abundant supply of water.

The D. C. Way Lumber Company has a flowing well on the west of Pungo River, 3 miles north of Leachville. It is located about 50 yards

from the river. The top of the 3-inch iron pipe is about 8 feet above the mean tide of the river surface, and water from the well overflows the pipe at the rate of 15 gallons per minute.

In boring this well the first important water-bearing stratum was reached at a depth of 120 feet. The water obtained here was "cool and nice," but the quantity was insufficient. Pumping brought to the surface large quantities of sand, and the boring was continued down through sand, a part of which was bluish colored, to a depth of 300 feet. At this point the drill cut through 2 or 3 feet of rock, from below which the water rose and overflowed the top of the pipe. This water, however, has sulphurous odor and taste, and can not be used either for drinking or boiler purposes. It has a temperature of 62° to 64° F., and is shown by analysis to contain, per United States gallon, 59.97 grains of mineral matter, consisting mainly of sulphate of lime and carbonate of magnesia.

WASHINGTON AND TYRRELL COUNTIES.

In Washington County several wells have been bored to a depth of from 50 to 75 feet, under the supervision of the Norfolk and Southern Railroad Company. From four to six of these wells were bored at Roper, in the northern part of Washington County, where strata were penetrated as follows:

Clay from surface to about 15 feet;
Below this a few feet of fine sand;
Below this about 20 feet of clay;
Below this a blue mud, containing small shells in considerable quantity, which has a thickness of about 20 feet, underlain by a few feet of rather coarse sand which is water bearing.

A 2-inch pipe penetrating these strata is found to yield, with the aid of a pump, from 500 to 800 gallons per hour. Unfortunately, the waters from these wells are highly impregnated with salts of magnesia and calcium, so that they are not well adapted for either domestic or boiler purposes.

In the southern part of the county, at Belhaven, several wells were bored to a less depth than those at Roper, but they reached water of the same general character. It is probable that if the wells at this and other places were sunk to still greater depth they would yield a larger and better supply of water.

In Tyrrell County (adjoining Washington on the east) no deep wells have been reported, consequently there is very little upon which to base an opinion. No doubt considerable supplies of good water are secured from the juniper swamps in many portions of the county. Judging from the success which has attended the boring of deep wells in Hyde County it may be considered probable that in Tyrrell wells bored to a depth of from 75 to 300 feet below the surface would penetrate water-bearing strata, and that the water from them would either rise to the surface and overflow or come sufficiently near to the surface to be reached with ordinary pumps.

DARE COUNTY.

No deep wells have been reported from this county, but the success attending the boring of deep wells in the adjoining county of Hyde is sufficient to encourage the belief that wells bored to depths of from 100 to 1,000 feet in Dare might yield flowing supplies of water. The existing wells in this county have generally a depth of from 3 to 10 feet.

HYDE COUNTY.

Two or three years ago a number of deep wells were bored in Hyde County, mainly in the more thickly settled region around Mattamuskeet Lake. They range in depth from 50 to 340 feet, and at some of them the water overflows, while at others it rises within reach of ordinary pumps. The following are the more important of these wells concerning which reports have been received:

Lake Landing well, about 1 mile southwest of Lake Landing post-office and 1 mile from the shore of Mattamuskeet Lake, was bored for Mr. W. B. Lavender, of Lake Landing. The strata penetrated in boring the well were as follows:

Feet.	
0–8	black clayey soil.
8–38	gray sand, alternating with blue clay, mixed with shells.
38–85	pure sand, in the lower part of which is a water-bearing stratum.
85–190	shell marl and black sand alternating; occasionally layers of yellow clay and shell rock.
190–191	shell rock 8 inches thick.
191–204	sand and shell marl.
204–205	shell rock 15 inches thick, where an excellent supply of drinking water of the best quality was struck, but it was interfered with by quicksand.

Just below the shell rock, at 205 feet, an abundant supply of water was reached. It is the water from this stratum which now yields, with an ordinary pump, 15 gallons per minute. The two main water-bearing strata penetrated in this well are those at about 85 and 205 feet below the surface. The water obtained at the first of these levels was soft and without disagreeable taste or odor; but this supply, at this particular well, was stopped on account of the quicksand coming into the pipe. The water from the 205-foot stratum is light, soft, cool, and quite clear. It has, however, when first drawn a slightly unpleasant taste and odor, due to the sulphur which it contains.

Lake Comfort well, at Lake Comfort, on the south shore of Mattamuskeet Lake, was bored to a depth of 115 feet. This well overflows in a 1½-inch stream under about 6 inches head. When the pump is applied the supply of water is equal to the capacity of the pipe, and immediately upon the stopping of the pump the water continues to flow rapidly. The water obtained at this point is also clear, but has a strong sulphurous taste and smell. The strata penetrated in boring this well were, on the whole, quite similar to those penetrated in boring the Lake Landing well described above.

Swanquarter well.—This well, located at Swanquarter (county seat), is only 86 feet deep, but was originally bored to a depth of 340 feet. On account of the failure of abundant water supply at that depth the pipe was withdrawn to a point 86 feet below the surface, where the supply of excellent water appears to be ample for all purposes. From the surface down to a depth of 205 feet the strata were much the same as in the Lake Landing well just described. From 205 to 340 feet (the bottom of the well) the strata penetrated are mainly fine sand.

Rose Bay well.—This well is located on Rose Bay, about 3 miles southwest of Swanquarter, and has a depth of 130 feet, and a 3-inch pipe, which overflows about 1½ feet above high tide-water surface. The strata passed through resemble in a general way those described above. The water is described as clear and soft and is considered a remarkably fine drinking water. It has at first a slight sulphur smell and taste, but this disappears on exposure.

Scranton wells.—About 10 or 12 miles west of Swanquarter there were bored for the Scranton Land and Lumber Company three wells, having depths of 100, 160, and 195 feet, which penetrated strata somewhat similar to those above and with similar supplies of water.

Middletown well, located near the eastern shore of Hyde County, has a depth of 212 feet. The strata penetrated in boring this well are about the same as those penetrated in boring the Lake Landing well, about 5 miles west of this point, and, as in the case of this latter well, a 2-inch pipe in the well rests on a stratum of shell rock 204 feet below the surface. The water comes from a water-bearing stratum just below this rock. The water from the Middletown well is said to have a sulphurous smell, which, however, disappears on standing, and it is considered to have medicinal properties like the water from the other wells near by. The pipe extends 12 inches above ground and the water overflows at the top.

Fairfield well.—In the town of Fairfield, on the north shore of Mattamuskeet Lake, a well was dug for Mr. William S. Carter to a depth of 230 feet. The strata penetrated in boring this well were about the same as those penetrated in the boring of the Lake Landing well, on the opposite side of the lake. Below the depth of the latter well this Fairfield well is continued to the depth of 230 feet, where another rock mass is struck. The water from this well is said to be slightly brackish. It overflows the surface continuously.

Several other wells are reported to have been bored in different parts of the county with results similar to those described above. These are sufficient to show that probably in all portions of this county good supplies of water can be obtained at a depth of either about 80 feet or about 215 feet below the surface, and that in cases where water does not overflow the surface it can be counted upon to come sufficiently near to permit of being drawn to the surface by an ordinary pump.

CRAVEN COUNTY.

A number of wells have been bored in the vicinity of Newbern reaching depths of from 50 to 100 feet, and one well has been bored by the Newbern Water Company to a depth of 350 feet. None of these wells overflow, though all yield abundant supplies of water which rises sufficiently near to the surface to be drawn out easily with cheap pumps. Water-bearing strata yielding most abundant supplies occur at depths of about 50, 90, and 350 feet below the surface. The character of the water is generally good, that from the 90-foot stratum yielding on analysis only 16 parts of mineral matter in 100,000 parts of water. The strata passed through in one of the more shallow wells, that of Mr. M. W. Carman, are as follows:

Feet.	
0–2	surface soil.
2–12	clay loam.
12–22	quicksand.
22–30	red clay.
30–40	gravel and sand.
40–52	shell rock.

From this point down to the lowest depth reached the strata are said to be mainly of sand, with occasional layers of shell rock and sand rock.

The fact that at none of these wells at Newbern has the water overflowed may indicate the improbability of discovering flowing wells at this or less depth in other portions of Craven County. It is not impossible, however, that by boring to greater depths flowing wells might be obtained at Newbern and other portions of Craven County. The results obtained at Newbern indicate that satisfactory results may be expected in other portions of the county in at least bringing deep supplies of water to within reach of surface pumps.

PAMLICO COUNTY.

The only deep well reported from this county is one which was bored by the Springer Lumber Company to a depth of 90 feet on a bluff near South Creek, in the northern border of the county. In boring this well the following strata were penetrated:

Feet.	
0–6	surface soil and clay.
6–37	quicksand and sand.
37–40	shell rock.
40–82	sand and clay.

This well did not overflow, but the water rose to near the surface and yielded a large supply, which was easily obtained by pumping. Unfortunately the water contained so large a percentage of lime that its use was abandoned and the pipe removed from the well.

In the western portion of this county the conditions for obtaining deep-well supplies of water may be considered quite similar to those

at Newbern, in Craven County, adjoining it. It is probable that, in all portions of the county, in wells bored to a depth of from 100 to 300 feet a sufficient quantity of water will rise near the surface, so that large supplies can be easily pumped from the deep wells.

CARTERET COUNTY.

The only deep well reported as being located in this county is one at Beaufort, which was bored to a depth of 200 feet by the Gibb's Preserving Company, of Baltimore, Md. The water overflows the top of the well at a point 6 or 8 feet above mean tide water in the harbor. The water has the taste and odor of sulphur, and consequently is not generally used.

JONES COUNTY.

No deep wells have been reported from this county, but, judging from the success which has attended the boring of the wells in Craven County, and to a lesser extent in Lenoir County, it may be said that water-bearing strata will probably be reached in different parts of Jones County by deep wells bored to depths varying from 100 to 300 feet. The water from such wells may or may not reach the surface and overflow, but it will probably at least come sufficiently near the surface to be within reach of pumps.

SAMPSON COUNTY.

No deep wells are reported from this county. In the region northward from Clinton the Potomac sand and other water-bearing strata should lie sufficiently near the surface to be tapped by wells bored to depths of from 150 feet to 300 feet, but it is possible that water-bearing strata may be reached at a less distance below the surface. In the southern portion of the county these water-bearing strata lie at a greater depth below the surface than they do to the northward, and even here they should be within the reach of deep wells.

ONSLOW COUNTY.

Only one deep well has been reported from this county, that bored by the Parmelee & Eccleston Lumber Company on the east side of New River, 3 miles above Jacksonville, the county seat. At a depth of 160 feet the water overflowed the surface in considerable quantity, but it was impregnated with sulphur and various salts, which made it valueless for boiler or domestic purposes. The strata penetrated by boring are reported to have consisted of alternating layers of blue mud, sand, clay, and rock, but no reliable record has as yet been secured. Had this boring been continued to a greater depth it is probable that water of better quality would have been reached. Wells bored to the same depth in other portions of the county may be freer from objectionable salts.

EDGECOMBE COUNTY.

Several deep wells have been bored during the past few years at Tarboro, the county seat, the following of which have been reported on: (1) A well with pipe 2 inches in diameter located near the waterworks on Hendricks Creek, with the top of pipe in a place several feet below the level of the general surface of the region. This well was bored to a depth of 75 feet, and it overflows at the rate of 2 to 3 gallons per minute. (2) Well with 1¼-inch pipe near the town hall, 82 feet deep. Water rises to within 5 feet of the surface and can be easily obtained by cheap pumps. (3) A well near the court-house, 160 feet deep, 2-inch pipe, in which the water rises within 15 feet of the surface. (4) Another well has been reported as having been bored to a depth of 284 feet, from which the water is said to rise 18 feet above the surface of the ground.

The strata penetrated in boring these wells average about as follows, in descending order: 15 to 20 feet of sandy loam, with water-bearing quicksand and fine gravel (in places) at the base; 10 to 30 feet of blue marl; 30 to 40 feet of hard white sand and yellowish clay in alternate layers, in the lower part of which occurs a layer of hardpan about 2 feet thick. The first water-bearing stratum is at 72 to 75 feet, just underneath the hardpan mentioned above, and other water-bearing strata are reached at 110 feet and 284 feet, from both of which the water overflows the top of the pipe. At 160 feet there is a water-bearing stratum of fine kaolin or arkose material, which gives a milky color to the water and renders it undesirable for domestic purposes. The water from the strata at 75, 110, and 284 feet below the surface is said to be soft and palatable for drinking purposes.

GREENE COUNTY.

No deep wells are reported from Greene County. The occurrence of granite rocks at the surface 10 to 12 miles west and southwest of this county makes it probable that these rocks would be reached in Greene County at a depth of not more than 300 feet below the surface. It is probable that the water-bearing Potomac strata would be found here below the blue marl and between the latter and the crystalline rocks. Hence it seems probable that in portions of the county supplies of water could be obtained at a reasonable depth; and should the water not rise to the surface and overflow, it would nevertheless rise sufficiently near the surface to be reached by ordinary pumps.

PITT COUNTY.

In Greenville, the county seat, one well was bored by Maj. L. C. Latham to a depth of a little over 200 feet, at which point the water-bearing stratum was penetrated, but it did not overflow the surface and the pipe filled with sand before the supply of water was finally tested. The strata passed through were: 20–25 feet of sandy clay; about 20

feet of blue mud (Miocene), with some gravel at its base. Below this the material is mainly micaceous sand, with occasional fragments of rock. No other deep wells are reported as having been bored in his county. It is probable that in the upper portion of the county, at a depth of from 200 to 300 feet, water-bearing strata should be found corresponding to those to be met with at Tarboro, in Edgecombe County; and in the eastern and southern portions of the county it is probable that these water-bearing strata could be tapped at a depth not much greater than this.

WILSON COUNTY.

Two or three deep wells have been bored, but without success so far as water supply is concerned. One at Wilson Cotton Mills was bored to a depth of 125 feet, the first 28 feet being through laminated sand and clays (Lafayette), and the remainder of the distance to 125 feet being in the blue clay (Miocene). At the base of the sands and clays 28 feet below the surface a limited amount of water was obtained, and it is to about this depth that the open wells of the town are usually driven. Again, at the depth of 67 to 70 feet below the surface a layer of small gravel and shell was found in the blue clay and proved to be water-bearing to a limited extent; but the water obtained from this depth was so highly impregnated with lime and other mineral matter as to be unfit for use as domestic or boiler water.

No other deep wells have been bored in the county. It is probable that in other portions of the county supplies of deep-well water may be obtained below the marl and on top of the crystalline rocks, which would probably be reached in the eastern half of the county at depths varying from 100 to 200 feet below the surface. Should such a water-bearing stratum be reached below the marl and between it and the crystalline rocks, it is probable that the water would be of good quality and that it would come near the surface, so as to be available by pumping, even if it did not overflow.

WAYNE COUNTY.

Two deep wells are reported from Wayne County, one bored to a depth of 266 feet by the Goldsboro Ice Company, in the town of Goldsboro, and the other bored at the Eastern State Hospital, 1 to 2 miles west of Goldsboro, which is still unfinished. Neither is a flowing well, but the one bored by the ice company yields a considerable supply of good water by pumping.

The strata penetrated in the ice company's well are as follows:

Feet.	
0–7	reddish sandy clay.
7–15	coarse white sands, water bearing.
15–40	blackish sandy clay, with fragments of vegetable remains, pyrite, and shell-marl.
40–45	bluish-gray sand.

Feet.
45–50.....blue and white coarse sand, water bearing.
50–125.....fine white sand and quicksand.
125–150.....reddish, stiff, fine mud or clay.
150–220.....strata of fine sand, with occasional layers of hardpan near the bottom.
220–226.....coarse whitish sand, water bearing.
226–266.....crystalline schists.

The layer of coarse sand mentioned above as resting directly on top of the crystalline rock will probably be the most reliable water-bearing stratum of the series penetrated at Goldsboro, though valuable supplies of good water may also be obtained in places at a less depth, as from the water-bearing stratum of coarse sand which occurs at Goldsboro at 45–50 feet below the surface.

At the western boundary of the county the crystalline rocks appear at the surface in local outcrops, but to the west, as well as to the eastward of this point, the Coastal Plain formations reach a considerable thickness. In the eastern and southern portions of the county these water-bearing strata will no doubt be reached within less than 300 feet of the surface, and will probably yield considerable supplies of good water. Wells bored in this region may not overflow except possibly in low places, but the water may be expected to come near enough to the surface to be within reach of pumps.

LENOIR COUNTY.

No very deep wells are reported as having been bored in Lenoir County. In Kinston, the county seat, one well was bored to a depth of 115 feet, but abandoned on account of quicksand. The strata penetrated in this boring were, after passing through a few feet of surface, about 20 feet of sandy clay, and then several feet of coarse sand, which yields a considerable supply of fairly good water. It is this water-bearing stratum which is now being tapped by a number of driven wells in the town of Kinston. A layer of sandy clay above it is probably sufficient to prevent any considerable amount of contaminating surface material from reaching this water-bearing stratum. Below this water-bearing sandy layer is a considerable bed of quicksand, the thickness of which is unknown, as it has not yet been penetrated. It is probable that when this quicksand is penetrated, a water-bearing stratum of coarser sand will be found underneath it which will yield considerable supplies of good water. It may rise to within easy reach of the surface.

In the western portion of this county, about 5 miles south of La Grange and on the south side of Neuse River, a well has been bored to the depth of 57 feet, on the lands of Mr. Thomas Dawson, which is said to overflow at the rate of 6 gallons per minute. This well penetrated the following strata: Thirteen feet of sandy loam and sand; 44 feet of blue marl. Immediately below this blue marl the pipe penetrated a layer of sand from which the water rose and overflowed the pipe.

The well is located in a rather low, flat region. In portions of the county it is probable that this marl would be penetrated and good supplies of water reached at a depth not greater than 100 to 200 feet.

DUPLIN COUNTY.

No deep wells have been reported from this county, but one is now being bored at Warsaw, on the Wilmington and Weldon Railroad. It is probable that in the upper portion of the county, adjoining the county of Wayne, water-bearing strata will be reached at a depth of from 100 to 300 feet, and that in the southern portion similar strata may be reached at slightly greater depth. It is not certain that in portions of this county flowing wells could be reached, though it is likely that water from these deeper strata would rise sufficiently near the surface to be within reach of ordinary pumps, and in some of the lower areas the water may overflow the surface.

PENDER COUNTY.

Several wells have been bored at Burgaw, the county seat, to a depth of nearly 100 feet. One of these, bored by Mr. Bruce Williams, penetrated the following strata:

Feet.	
0–15	surface soil sandy, bluish clay.
16–40	stiff bluish clay with occasional admixtures of coarse sand.
41–70	blue mud and clay, alternating strata of each.
71–75	gravel with round pebbles as large as buckshot.
76–96	fine sand with an occasional small lump of marshy mud about the size of buckshot.

At this point the boring was stopped. The water does not overflow, but comes sufficiently near the surface to be reached with a pump. It has a slightly saline taste, but is considered of good quality, both for domestic and for boiler purposes.

At Long Creek, in the western part of the county, a few miles southwest of Burgaw, on the land of Mr. W. W. Larkins, a well was bored to the depth of 175 feet, but because of quicksand and rock it was abandoned without securing a supply of water. The strata penetrated in boring this well were as follows:

Feet.	
0–20	sand and clay.
20 –120	blue mud.
120 –126½	hard, dark-colored rock.
126½–146	quicksand.

At the base of this quicksand another layer of hard rock was struck, and the well has been temporarily abandoned on account of quicksand rising in the pipes. The result of these borings at Long Creek and Burgaw seems to indicate that no well-marked water-bearing stratum in this county occurs within a hundred feet of the surface. The evidence, however, should not be considered as conclusive for all portions

of the county. It is possible that water-bearing strata may be reached a short distance below the rocks which appear at the bottom of the Long Creek well, 175 feet below the surface.

CUMBERLAND COUNTY.

No deep wells are reported as existing in Cumberland County, but the Potomac arkose sands and gravel, which appear at the surface over considerable areas to the north and west of Cumberland, are also exposed in the bluffs of the Cape Fear River, which passes through this county, and wells bored to a depth of from 100 to 300 feet in different portions of the area would probably yield ample supplies of water.

BLADEN COUNTY.

No deep wells have been reported as bored in this county, but there are two or more shallow "flowing wells" at Bladenboro, on the Carolina Central Railroad, in the southwest portion of the county, on the lands of Messrs. S. N. Ferguson and J. W. Callahan. One of these has a depth of 35 feet and the other a depth of 40 feet; 1½-inch pipe was used in both cases. In one case the upper end of the pipe rises 2 feet above the surface and the flow of water amounts to 2 gallons per minute, while in the other case the pipe rises no higher than the surface soil and the flow amounts to 3 gallons per minute. The materials penetrated in boring these wells are a compact clay underlain by coarse bluish sand, which is water bearing, and in which the pipes stop.

It is probable that in many portions of the county wells bored to similar depths would meet with similarly successful results, and at greater depths, 200 to 400 feet, it is probable that much larger supplies of water would be obtained.

ROBESON AND RICHMOND COUNTIES.

No deep wells are reported from these counties; but the conditions may be considered fairly favorable for securing underground supplies of water in the southeastern portion of Richmond, and in all of Robeson, except, possibly, in the northwestern portion. Among the sand hills about Hamlet, and northward along the Seaboard Air Line Railroad, the Potomac or other sandy and arkose strata that directly overlie the eroded surface of the crystalline rocks are exposed over a considerable area. The rainfall absorbed by these sands may be expected to move southeastward in part, and should be reached by penetrating the overlying formation southeast of this region to depths varying, in Robeson and southeastern Richmond, from probably 100 to 300 feet, the depth increasing farther southeastward. No assurance can be given that, when tapped, these water supplies will overflow the pipes at the surface, though in low areas they might do so in some cases; but in many more cases probably the best that can be expected is that the water will rise near enough to the surface to come within reach of ordinary pumps.

COLUMBUS COUNTY.

Only one flowing well is reported—that at Vineland (formerly Whiteville), on the Wilmington, Columbia and Augusta Railroad, 43 miles west of Wilmington. This well has a depth of 63 feet and yields a little over 4 gallons per minute. Several other deep wells have been bored at Vineland, the deepest being about 225 feet, but none of them overflow. The overflowing of the one first mentioned is probably in a measure due to the fact that it is located in a place several feet lower than the general surface of the surrounding country. In each of these deep wells at Vineland the water rises to within a few feet of the surface and can be easily secured by pumping. In boring these wells but a thin deposit of marl was struck. The deep wells which do not furnish a flowing stream nevertheless yield as large a supply of water, or a larger one, which rises sufficiently near the surface to enable it to be pumped with a cheap pump. In boring these wells little marl was found, but at intervals layers of shell rock and sand occurred.

In view of the extensive surface exposures of the water-bearing Potomac arkose sands and gravels 50 to 75 miles northwest of this county, it seems probable that wells bored here to a depth of 300 to 500 feet would penetrate the eastward extension of these water-bearing strata and furnish ample supplies of good water.

BRUNSWICK COUNTY.

No deep wells have yet been bored in this county. The strata would probably be the same as those penetrated in sinking the well at Wilmington; and the results of a deep boring would no doubt be much the same as in that case. In many cases flowing shallow wells might be obtained, similar to those in Bladen County.

NEW HANOVER COUNTY.

The well bored by the Clarendon Water Works Company at Hinton Park, Wilmington, is the deepest yet bored in the Coastal Plain regions of the State, having reached the depth of 496 feet. From this depth the water overflows at the rate of about 75 gallons per minute, and will rise in the pipe about 30 feet above tide water. The water is highly saline and no use is made of it.

This well is located on the east bank of the Northeast River, only a few feet above the water surface, and on the upper surface of the Cretaceous formation, the overlying Tertiary marl and later sands having been removed by river erosion. The entire boring is in what has been classed by Mr. T. W. Stanton as the Ripley Cretaceous. As the Potomac water-bearing strata are believed to underlie these Cretaceous beds, it is probable that if this boring were continued downward until these Potomac strata are penetrated abundant supplies of good water would be reached and would rise to the surface.

In the city of Wilmington, at an elevation of about 60 feet above tide, three wells were bored by Mr. W. E. Worth at the ice factory. In neither of these does the water overflow, but it rises to a point 2 feet above mean tide level. These three wells, 60 to 80 feet apart, were sunk to the depth of 84, 96, and 100 feet, respectively, one being 6 inches and the other two 8 inches in diameter. Each well has for some time been yielding 400 gallons of good water per minute, containing not more than 14.80 grains of mineral matter per United States gallon.

The strata penetrated by these wells are as follows:

Feet.	
0–20	sand.
20–85	marl (Tertiary).
85–101	alternating layers of sand and shell rock 6–10 feet thick.

The only other deep well reported from this county is that bored to a depth of 400 feet at the Hummocks, in Wrightsville Sound. Here an 8-inch pipe was sunk to a depth of 100 feet without favorable results. A 6-inch pipe was then lowered inside the 8-inch pipe and sunk to a depth of 400 feet without securing any considerable supply of water. After the sinking of this inner pipe, however, the water came up between the outer (100-foot) pipe and the inner (400-foot) pipe and overflowed the surface at the rate of about 8 gallons per minute. The water is of good quality, though it has a slight sulphur taste and odor.

No record of the strata penetrated in boring the well has been found. It appears, however, from the testimony of several persons, that at 90–100 feet there is a considerable layer of rock, and that the water supply probably comes from beneath this stratum.

SOUTH CAROLINA.

GEOLOGIC RELATIONS.

The geology of the greater part of the Coastal Plain region of South Carolina was studied with care by Tuomey a half century ago, and very little has since been added to our knowledge. Many of the relations were clearly determined by Tuomey, but some were not fully investigated, and they have remained in doubt. The principal undetermined relations were those of the lower members of the Coastal Plain series, which lie on the east-dipping floor of crystalline rocks, and as these members are important water-bearers, I made a special visit to the State to study their character and relations. According to Tuomey, the Eocene formation embraces a series which lies directly on the granite in the southern portion of the State, while to the northward marine Cretaceous beds emerge from beneath the edge of Middle Eocene members. The formations underlying the marine Cretaceous beds were not described fully, and apparently they and the Cretaceous beds were supposed to pass under and be overlapped by the lowest Eocene members, which were stated to lie directly on the granite south of the

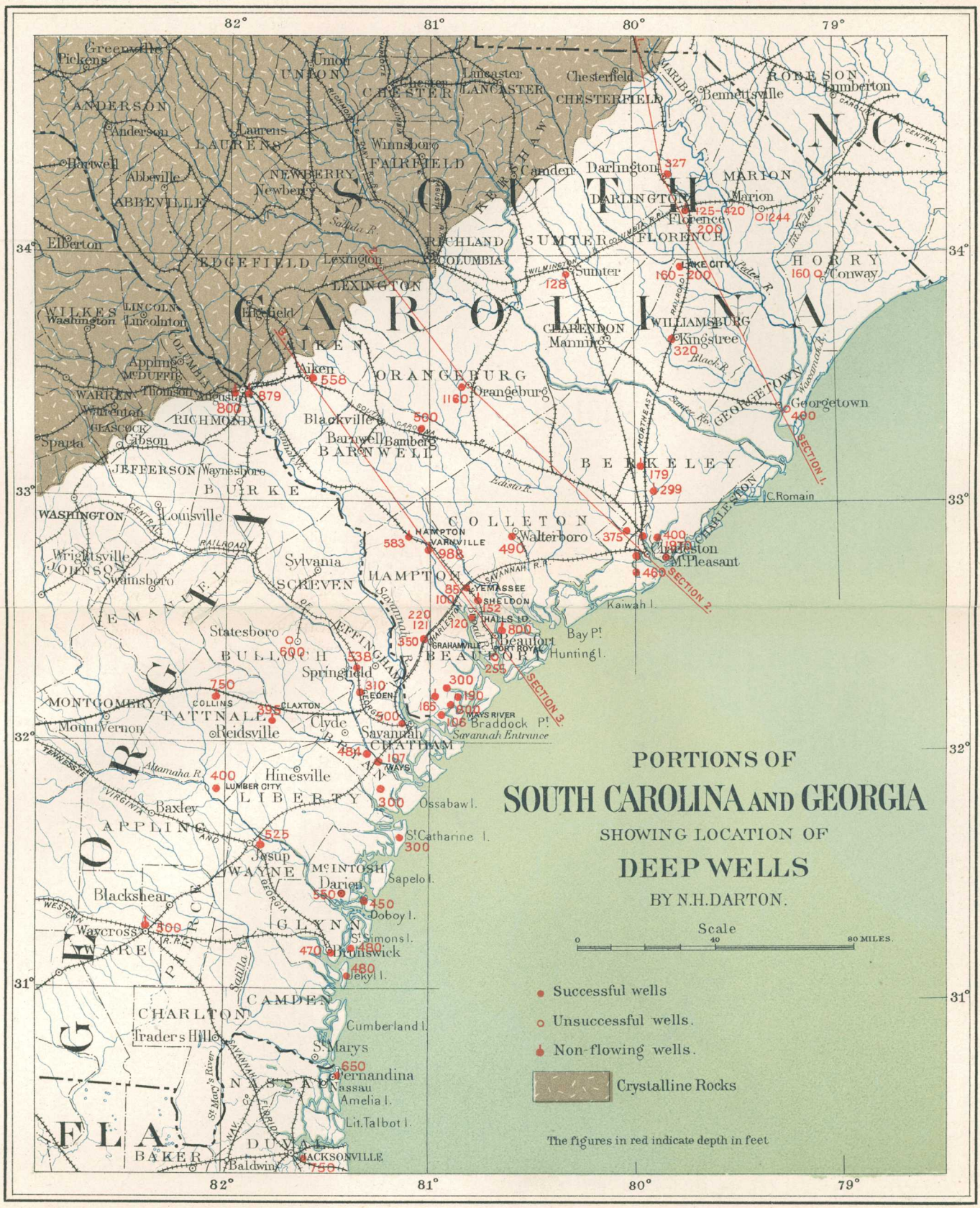
Wateree River. From a study of this problem in the field, I find that the so-called basal members of the Eocene are not Eocene at all, but are representatives of the Potomac formation, and they extend northward beneath the marine Cretaceous formations (marls), the edge of which emerges from beneath the Eocene north of the Wateree. Thus it was found that, as suggested by Mr. McGee, there is a continuous sheet of Potomac formation lying on the crystalline rocks throughout South Carolina, which is overlain by Eocene to the south and marine Cretaceous to the north. The Potomac formation extends out under the Coastal Plain to the eastward with gradual increase in depth, and is probably the source of the water in the Charleston, Orangeburg, Darlington, and some other deep wells. The following are the principal Coastal Plain formations in South Carolina:

Formations.	Characteristics.
Columbia	Gray sand, etc.
Lafayette	Orange loams.
Miocene	Sands and marls.
Eocene	Buhrstone below, marls above.
Marine Cretaceous	Marls and sands.
Potomac	Sands, sandstone, and clay.

The general structural relations of these formations are shown in the sections on Pl. XVIII.

POTOMAC FORMATION.

This formation consists of a series of sands, sandstones, and clays, which lies on the crystalline or bed rock to a thickness of several hundred feet. It outcrops in a belt 4 or 5 miles in width, which extends from Augusta, Ga., through Aiken, south of Lexington, and through Columbia to Camden and Cheraw. The basal beds are mainly coarse sands with pebbles, which to the southward are sometimes consolidated to a soft sandrock. Finer sands clays and occur higher up in the formation, and these are overlain by the Eocene buhrstone to the southward and by the marine Cretaceous marls to the north of the Wateree. The formation is, however, very irregular in character, and clays occur at low horizons at some points, while near Congaree Creek, south of Lexington, I observed the Eocene beds lying on cross-bedded sandstones which merged into a kaolinic arkose on the one hand and into white clays on the other. On the Pedee River I found coarse sands with intercalated beds of gray sandy clays which are overlain unconformably by the Cretaceous marls. The sands and sandstones in the bottom of the Charleston wells are thought to be the upper portion of the Potomac beds, but the identification is not established. The upper beds of the Potomac formation may finally merge into marine deposits as far to the eastward as Charleston.


82°
81°
80°
79°
34°
33°
32°
31°
SOUTH CAROLINA
GEORGIA
FLA.
N.C.
Greenville
Pickens
ANDERSON
Anderson
Union
UNION
Chester
CHESTER
Lancaster
LANCASTER
Chesterfield
CHESTERFIELD
Bennettsville
ROBESON
Lumberton
MARLBORO
Laurens
LAURENS
Winnsboro
FAIRFIELD
Harwell
Abbeville
ABBEVILLE
NEWBERRY
Newberry
Camden
Darlington
DARLINGTON
MARION
Marion
Florence
FLORENCE
Elberton
EDGEFIELD
Lexington
RICHLAND
COLUMBIA
SUMTER
Sumter
HORRY
Conway
LAKE CITY
WILKES
Washington
LINCOLN
Lincolnton
Edgefield
AIKEN
Aiken
CLARENDON
Manning
WILLIAMSBURG
Kingstree
ORANGEBURG
Orangeburg
Appling
McDUFFIE
Thomson
Augusta
WARREN
Warrenton
RICHMOND
GLASCOCK
Gibson
Sparta
Blackville
Barnwell
Bamberg
BARNWELL
Georgetown
GEORGETOWN
BERKELEY
JEFFERSON
Waynesboro
BURKE
WASHINGTON
Louisville
C.Romain
COLLETON
Walterboro
HAMPTON
VARNVILLE
Wrightsville
JOHNSON
Swainsboro
Sylvania
SCREEN
HAMPTON
Charleston
Mt.Pleasant
Kaiwah I.
EMANUEL
YEMASSEE
SHELDON
Statesboro
BULLOCH
Springfield
EFFINGHAM
HALLS ID.
Beaufort
Bay Pt.
GRAHAMVILLE
PORT ROYAL
Hunting I.
MONTGOMERY
COLLINS
CLAXTON
TATTNALL
Reidsville
Mount Vernon
Clyde
EDEN
MAYS RIVER
Braddock Pt.
Savannah
Savannah Entrance
CHATHAM
TENNESSEE
Altamaha R.
Hinesville
LUMBER CITY
LIBERTY
Baxley
APPLING
Ossabaw I.
St.Catharine I.
Jesup
WAYNE
McINTOSH
Darien
Sapelo I.
Blackshear
Doboy I.
Waycross
GLYNN
St.Simons I.
WARE
Brunswick
Jekyl I.
CAMDEN
CHARLTON
Traders Hill
Cumberland I.
St.Marys
Fernandina
Nassau
Amelia I.
Lit.Talbot I.
BAKER
DUVAL
JACKSONVILLE
Baldwin
St.Mary's River
SECTION 1.
SECTION 2.
SECTION 3.
PORTIONS OF
SOUTH CAROLINA AND GEORGIA
SHOWING LOCATION OF
DEEP WELLS
BY N.H.DARTON.
Scale
0 40 80 MILES.
Successful wells
Unsuccessful wells.
Non-flowing wells.
Crystalline Rocks
The figures in red indicate depth in feet
JULIUS BIEN & CO. N.Y.

MARINE CRETACEOUS.

This is mainly a shell marl, which is at or near the surface in Horry, Marion, Florence, Williamsburg, and Georgetown counties, but sinks beneath later formations to the southward. With the marl there are associated marlstone, soft gray shales, and sands, which are all frequently exposed along the Pedee and Waccamaw rivers. In its extension to the south under the Eocene and other formations this series increases greatly in thickness and probably comprises the beds from about 450 to at least 1,950 feet in the Charleston wells. As suggested above, it is possible, however, that these lower beds in this well include some marine representatives of the Potomac formation.

EOCENE.

These formations include the buhrstone and a series of overlying marls, which cover a wide area in the southern section of the State. To the northward, in Williamsburg and Marion counties, they thin out and are represented by only thin, scattered outliers. The western edge of the buhrstone, which is usually the basal member of the formation westward, passes from Aiken to within 10 miles of Columbia, and thence to the eastward to below the junction of the Congaree and Wateree rivers. In the well at Charleston the Eocene members have a thickness of about 400 feet, and are supposed to lie about 60 feet below the surface. They there consist of marls of various kinds, which are mainly argillaceous above and calcareous below. The buhrstone is a hard, siliceous rock, often filled with shells, which constitutes the basal Eocene member in the outcrops along the western margin of the formation as above outlined. The overlying marls and marlstones are known as the Santee beds and the Ashley and Cooper beds. Their western margins lie in succession to the east of the buhrstone outcrop, and they thicken gradually to the eastward, as seen in the Charleston well (see Pl. XVIII). The Santee beds are mainly light-colored marls, with some beds of marlstone of considerable extent, and the Ashley and Cooper marls, which outcrop quite widely in the basin of the Ashley and Cooper rivers, are of darker color.

MIOCENE.

These deposits consist of sands and marls, which occur in scattered areas, mainly in the northeastern and eastern counties. Their thickness is usually not over 30 feet, and they lie on an irregular surface of the Eocene, or marine Cretaceous formations.

LAFAYETTE FORMATION.

This is a superficial mantle of orange loams and sands which covers the higher plateau regions at elevations of about 650 feet along the western border of the Coastal Plain province. There it has a thick-

ness of from 30 to 80 feet, and its more loamy portions are the "Red Hills." Its eastern extension has not been traced, but it is thought to be the same as some of the younger Pliocene marls.

COLUMBIA FORMATION.

This is a thin capping, mainly of sands and loams, which covers the lower lands and appears to extend as high as 400 feet or more in the higher region, giving rise to some portions of the "Sand Hills" districts.

WELLS IN SOUTH CAROLINA.

List of deep wells in eastern and southern South Carolina.

Locality.	Depth.	Diameter.	Capacity per minute.	Height to which water rises. *a*	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Aiken	558	8–6	50	—170	In granite; water also at 543 feet.
Bamberg:					
30 wells	65–100				In buhrstone.
5 wells	470	2	40	+ 15	In Potomac sands.
	495	2	35	+ 20	
	520	2	35	+ 12	
	555	1¼	40	+ 30	
Barnwell					
Beaufort:					
Coosaw Company	800				
Iron works	63	6		— 15	
Blacksville	120				
Bluffton. (See Mays River.)					
Charleston	1,970	2¾	250	+ 4	
	1,945	3½	170		
	1,950	5	800		
	2,000?	6–4	(?)		
	109		Many.	Flowed.	
	1,260	Small.	Many.	+ 25	Saline water.
Commercial Cotton Press.	380				
Chisholm's Mill	425				
Ashepo Company	465				
Edisto Company	375				
Stono Company	475				
Bulow Phosphate Mines.	450				
Sineath Station	323				
Johns Island Ferry	460		60	To surface.	
Fort Sumter	347				Abandoned in boring.
Conway, 2 wells	160		Not any.		Stopped at rock.
Darlington	327		30	To surface.	In Potomac formation.
Florence, city works	1,215	10—8	100	— 20	608 to 1,335 feet in Newark sandstone; waters also at 600 and 800 feet.
Do	182			— 24	
Florence, Ice Works	200		Many.		Fine water.
Florence, Machine Shop	420	Small.	Many.		Do.
Grahamville, 2 wells	121	6	170	Flows.	Well is 164 feet deep.
Do	220	2	Few now.		Water at 170 feet.

a +, feet above surface; —, feet below surface.

List of deep wells in eastern and southern South Carolina—Continued.

Locality.	Depth.	Diameter.	Capacity per minute.	Height to which water rises. *a*	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Grahamville, 2 wells	220	4	Few now.	Flow.	Hard water; water at 170 feet.
Do	350	4	Few now.	Flow.	Hard water; water at 250 feet.
Georgetown	400?	.....	Not any.	.....	
Georgetown, 10 wells	65–74	2	Many.	— 4	8 feet of water.
Halls Island, Donner Bros	120	6	150	+20 above high water.	Sulphurous water.
Hampton	583	6	Many.	— 9	Soft, irony water.
Do	186	.....	.....	— 3	
Do	46	.....	1 in. stream	+ 4	Irony water.
Kingstree, 3 wells	320	2	Many.	Flows.	Fine water.
Lake City, 10 wells	160–200	3 and 2	7–15	+15	
Marion	1,244	8–6	½	Flows.	Small flow at 700 feet on top of bed rock.
Moncks Corner	179	2	35	—14	16–148 feet in lime with flint rock below.
Moncks Corner, 8 miles distant.	175	2	15	Flows.	
Mays River, Bluffton	165	.....	Many.	.....	
Mays River, Capt. T. R. Hayward's place.	800	.....	Fair.	— 1	Very sulphurous water.
Mays River, Col. J. H. Estill's place.	190	.....	Many.	.....	Sulphurous water.
Mays River, Col. J. H. Estill's plantation, 4 wells.	360	.....	Many.	Flows.	Fine water.
Mays River, Snyder & Mittle's sawmill.	106	.....	Many.	Flows.	Do.
Oakley Depot	299	2	Many.	Does not flow.	Do.
Orangeburg, 4 wells	1,160	.....	Many.	—48	Much water at 250 feet.
Port Royal Naval Station	255	6	Very few.	Does not flow.	Water very impure.
Port Royal Naval Station, 3 wells.	60	5 and 2	Many.	—12–16	Water hard and saline.
Sumter	128	2	2	Flows.	Soft water.
Shelden	152	3	Many.	Does not flow.	On high land.
Swansea	100?	.....	.....	.....	
Varnsville	988?	6	Many.	—17	
Walterboro	490	6	Many.	—30	Soft water.
Yemassee, G. G. Martin	90	4½	Many.	Flows to +13.	Sulphurous water.
Yemassee, J. B. Gregorie, 3 wells.	100	6	Many.	Flows.	Sulphurous water; flow decreasing.

a +, feet above surface; —, feet below surface.

NOTES ON SOUTH CAROLINA WELLS.

I have not been able to obtain any great number of data regarding some of the wells, but several important records and much special information were secured in a visit to the State and in correspondence

with various persons. For the Charleston wells I have used the data which were published some years ago by the committee appointed by the city to prepare a report on the first deep well.

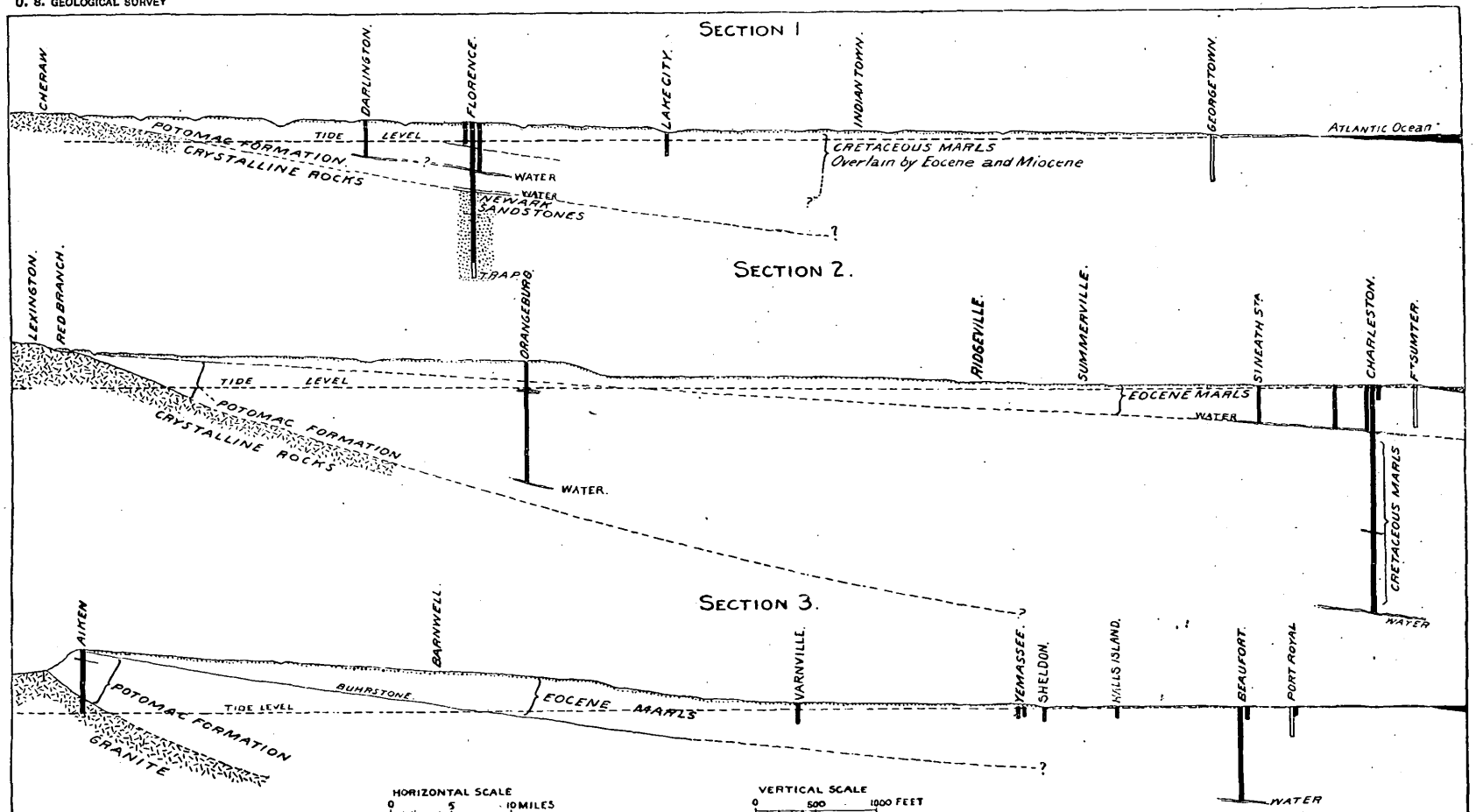
Charleston.—Many attempts were made to obtain water by deep wells in and about Charleston, but they were practically unsuccessful until 1879, when a large supply was found at a depth of from 1,940 to 1,970 feet. The management of this well was placed in charge of a committee of scientific citizens, who prepared a report on its results, which is a model as a thorough and comprehensive document.[1] The borings were carefully preserved and sent for examination to one of the foremost geologists of the world, and exhaustive chemical analyses and investigations were made of the waters of the well and of other wells, and of various materials from the borings, so that we have very complete scientific data for the Charleston well. The water obtained has a temperature of 99.5°, but it is of excellent quality. The flow at about 4 feet above the surface, or 16 feet above mean low-tide level, was found to be 250 gallons a minute.

In the earlier wells at Charleston water was found in considerable amount and fair degree of purity at 60 feet, in the sand, under the stiff blue-clay stratum. In a well on Washington street, between Calhoun and Inspection streets, which was bored over half a century ago, water was found in limestone marl at 109 feet. It flowed to the surface, and still continues to afford an undiminished stream of water. The well bored in 1846 reached a depth of 1,260 feet, where water was found which rose to a level nearly 25 feet above the surface, but owing partly to the small bore of the casing it furnished a supply of only about 30 gallons a minute. The water was perceptibly saline, but it was extensively employed as a beverage. It contained 134.7 grains per gallon of solid matter, of which 63.3 grains were chloride of sodium. The water from the deeper well was analyzed by Dr. Robinson in 1879 with the following result:

Analysis of water from 1260-foot well at Charleston, S. C.

	Grains per gallon.
Organic matter and water of crystallization	1.73
Carbonate of iron	.34
Sulphate of lime	.44
Sulphate of magnesia	.17
Chloride of magnesium	.23
Chloride of sodium	11.40
Carbonate of soda	47.26
Nitrate of soda	.55
Silicate of soda	2.52
Silica	.36
Total	65.00

[1] Municipal report of the city of Charleston, S. C., 1881; Artesian Wells, Report of Scientific Committee [etc.], 61 pp., 1 plate. Charleston, 1882.



SECTIONS, EASTERN SOUTH CAROLINA.

The record of the Charleston well, as prepared for Dr. James Hall and published in the report of the well committee, is reproduced in Pl. XIX on a somewhat smaller scale. Dr. Hall also furnished the committee with some notes on the borings, from which the following statements are compiled:

Too few fossils were found in the higher beds to indicate precise ages and subdivisions, but they were clearly Tertiary down to 430 feet. Then there was a gap of 170 feet from which no distinctive fossils were obtained. The borings from 600 to 1,955 feet contained characteristic Cretaceous shells, mainly Exogyra and Gryphæa of several species.

The specimens indicated that from 1,940 to 1,980 feet are of greenish clay, without fossils. This last statement in regard to the nature of the beds is at variance with the columar section, in which are shown alternations of sand and sandstone from 1,825 to 1,970 feet. It seems probable that the water horizon is at the base of the marine Cretaceous formations, and it is possible that the sands with sandstones are at the top of the Potomac formation. Three other wells have since been bored to 1,945, 1,950, and 2,000 feet. One, 3¼ inches in diameter, is said to furnish a quarter million gallons a day, and another, 5 inches in diameter, is reported to furnish considerably over a million gallons a day. The third is, I believe, just finished to a depth of 2,000 feet.

An attempt was made in 1844 to bore a well at Fort Sumter, but at 347 feet the rods broke and the boring was abandoned.

Commercial cotton press, Charleston: This well is half a mile from the city hall and its depth is 380 feet. No further data are given regarding it except the following analysis by C. U. Shepard:[1]

Analysis of water from well at cotton press, Charleston, S. C.

	Grains per gallon.
Carbonate of lime	26.25
Chlorides of sodium, etc	204.41
Sulphate of lime	10.61
Sulphate of magnesia	13.88
Silica	1.98
Undetermined	7.35
Total	264.48

[1] Municipal report of the city of Charleston, S. C., 1881, p. 51.

Chisolm's mill, Charleston: The depth of this well is 425 feet. The following analysis by Dr. Robertson is reported by C. U. Shepard:[1]

Analysis of water from well at Chisholm's mill, Charleston, S. C.

	Grains per gallon.
Potassium sulphate	19.21
Calcium sulphate	4.12
Magnesium sulphate	2.82
Magnesium chloride	4.85
Sodium chloride	136.89
Sodium carbonate	30.88
Sodium silicate	0.66
Silica	2.34
Loss on ignition	13.17
Total	214.94

Ashepoo Phosphate Company.[2]—This well is on Charleston Neck, 3½ miles from the city hall in Charleston. It is 465 feet deep. The water was analyzed by C. U. Shepard, who reports that it contains 167 grains of solid matter per gallon, in which were found about 50 per cent of chloride of sodium and 25 per cent of carbonate of soda, the remainder consisting chiefly of sulphate of lime and magnesia, with silica.

Edisto Phosphate Company.—This well is 4 miles from the city hall in Charleston. Its depth is 375 feet. It is reported[2] to contain 149 grains of solid matter to the gallon, consisting of carbonate of soda, 28.63 grains; sulphate of soda, 17.09 grains; chloride of sodium, 81.64 grains.

Stono Phosphate Company.—The works of this company are situated about 4½ miles from the city hall in Charleston. The depth of the well is 475 feet. Dr. C. U. Shepard reports[3] that the water contains the following mineral ingredients:

Analysis of water from well of Stone Phosphate Company.

	Grains per gallon.
Chloride of potassium	2.99
Chloride of sodium	74.46
Carbonate of soda	27.70
Sulphate of soda	4.90
Sulphate of magnesia	5.34
Sulphate of lime	4.99
Silica	2.39
Loss on ignition	3.63
Total	126.40

[1] Municipal report of the city of Charleston, S. C., 1881, p. 51.
[2] Loc. cit., p. 52.
[3] Loc. cit., p. 53.

Sineaths Station.—This place is 13 miles from Charleston, on the South Carolina Railroad. The record is as follows:[1]

Feet.	
17–20	clay.
26–30	phosphatic nodules and marl.
34	marl.
46	argillaceous marl.
70	phosphatic nodules.
85	argillaceous marl.
90	argillaceous marl.
104	phosphatic nodules.
110–112	phosphatic nodules in argillaceous marl.
125–128	phosphatic nodules and hard marl.
145	argillaceous marl.
170	argillaceous marl.
228	argillaceous marl.
255	argillaceous marl.
280	phosphatic nodules.
286	argillaceous marl.
287–290	marl and phosphate grains.
300–305	argillaceous marl.
305–306	sandy marl.
307	sandy marl.
309–311	hard marl.
312–313	phosphatic pebbles and hard pebbly marl.
315–316	sandy limestone.
321–322	firm limestone.
323	sandy limestone.

Analyses of all of these materials were made by Dr. Wamer and reported by Dr. C. U. Shepard. The water from a depth of 323 feet was examined by Dr. Shepard, who gives the following analysis:[2]

The residue on evaporation was 67 parts per 100,000, which contained the following ingredients:

Analysis of water from well at Sineaths Station, South Carolina.

	Per cent.
Chloride of sodium	16.71
Sulphate of soda	7.86
Carbonate of soda	52.08
Silicate of soda	10.51
Carbonate of potash	5.19
Carbonate of lime	2.23
Undetermined	5.42
Total	100.00

Johns Island Ferry.—Distance, 10 miles from Charleston. The depth of the well is 460 feet. It yields 60 gallons a minute and the water

[1] Municipal report of the city of Charleston, S. C., 1881, p. 45.

[2] Loc. cit., pp. 33–34.

rises to the surface. It is reported to contain 56.8 grains per gallon of mineral matter.

Bulow Phosphate Mines, St. Andrews Parish.—This well is 15 miles from Charleston. Depth, 450 feet. The following analysis, by Mr. F. F. Chisolm, is reported by Dr. C. U. Shepard:[1]

Analysis of water from well at Bulow Phosphate Mines, South Carolina.

	Grains per gallon.
Carbonate of soda	25.65
Chloride of sodium	15.19
Sulphate of lime	2.28
Silica	2.01
Loss on ignition	3.18
Total	48.31

Grahamville, Beaufort County.—The wells are on the plantation of J. S. Claghorn, 3 miles from the village. Their depth is 164 feet, and it is stated that clays, marls, and shells, with some rock strata, were penetrated to a calcareous conglomerate, with minute shells and sharks teeth, which is the water-bearing bed. The water flows and furnishes about 200,000 gallons a day, but the amount is decreasing. It is soft and sulphurous.

Mays River.—There are a number of wells on Mays River Neck which yield water supplies, some of which are very pure, while others are too sulphurous to be palatable.

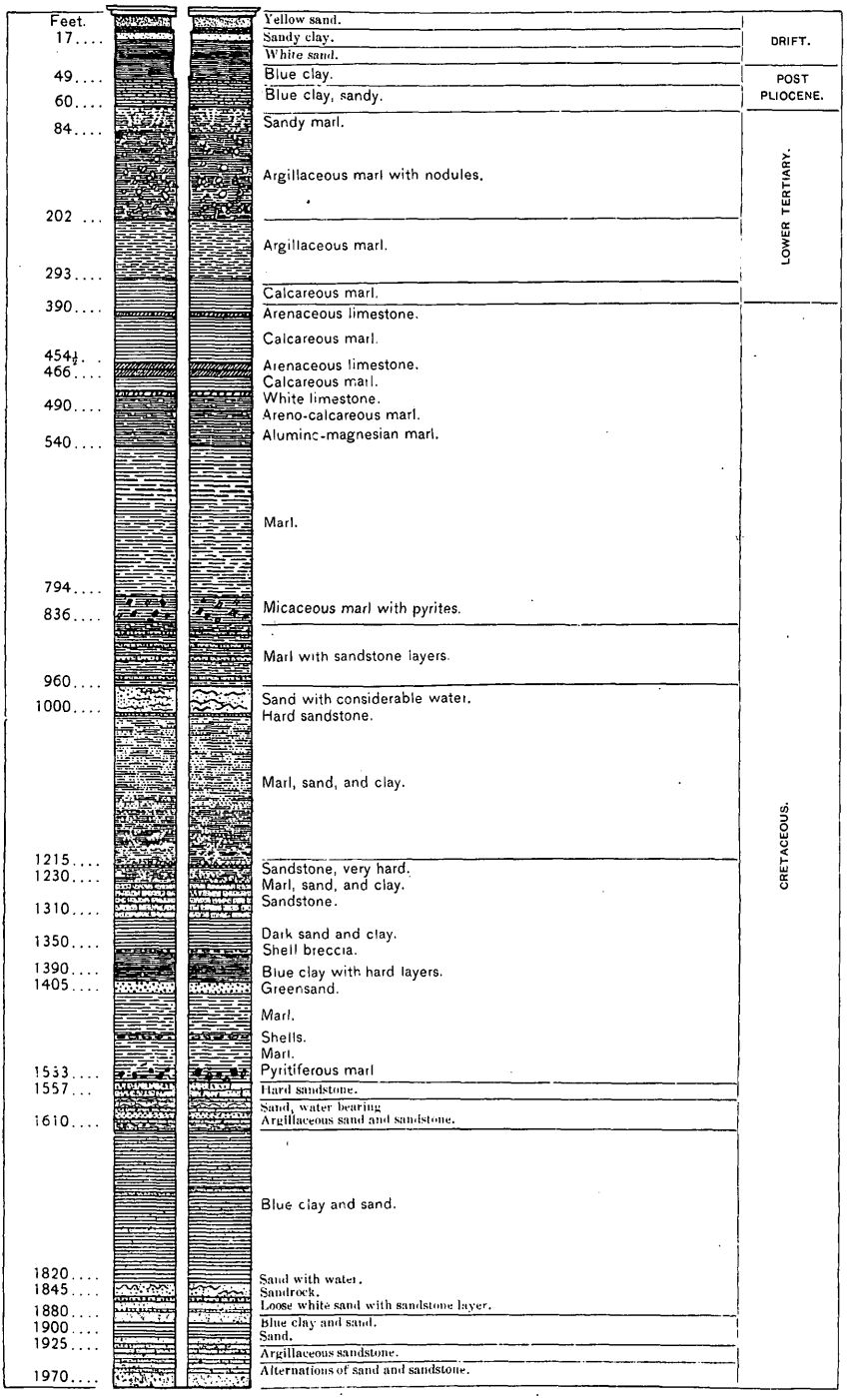
At Snyder & Nuttle's sawmill a well 106 feet deep furnishes a continuous overflow of pure water, the flow of which is affected somewhat by the tides.

Four wells on the rice plantation of Col. J. H. Estill, on South Mays River Neck, furnish a large overflow of pure water from an average depth of 360 feet. The well at the residence of Col. J. H. Estill, on Mays River, has a depth of 190 feet, but the water is highly sulphurous. Capt. T. R. Heyward's well, on Mays River, has a depth of about 800 feet, and the water rises to within a foot of the surface, but is too highly sulphurous for use.

There are wells in Bluffton which average 165 feet in depth and have an overflow to about 13 feet above tide level. It has been found in this district that the exclusive use of artesian waters moderates, if it does not entirely overcome, the baneful effects of the malaria which is so prevalent there.

Port Royal.—At the United States naval station a 6-inch boring was made to a depth of 255 feet, but the water found is too impure for domestic use and is very small in amount. Three wells, having a depth of 60 feet, now afford an abundant supply, but the water is hard and

[1] Municipal report of the city of Charleston, S. C., 1881, p. 54.



COLUMNAR SECTION OF WELL AT CHARLESTON, SOUTH CAROLINA.

saline. The water rises to within 12 to 16 feet of the surface, and varies with the tide. The following record of the deep boring was furnished by Engineer George Mackay:

Feet.
0–7.....yellow sandy loam.
7–12.....fine brownish-yellow sand.
12–17.....fine gray sand.
17–20.....gray sand.
20–24.....coarse gray sand.
24–27.....quartz sand.
27–35.....fine dark sand.
35–38.....coarse gray sand.
38–43.....fine gray sand.
43–56.....very compact, hard, fine sand and clay.
56–59.....phosphate pebbles, water bearing.
59–61.....gray sand, water bearing.
61–124.....marl, with bed of water-bearing sand 92–95 feet.
124–132.....fine gray pipeclay.
132–133.....gravel and quartz grains with water.
133–135.....marl.
135–138.....fine white sand with water.
138–180.....marl.
180–190.....white sand with water.
190–196.....marl.
196–200.....marl with sand and water.
200–210.....fine white sand.
210–250.....fine white sand with water.
250–255.....tenacious pipeclay.

Beaufort.—The well at the Coosaw Company's works is reported to be 800 feet deep, but beyond this fact and the following analysis, which indicates that the water is potable and suitable for use in boilers, I have learned nothing regarding it. The analysis is by F. F. Chisolm, reported by Dr. C. U. Shepard.[1]

Analysis of water from well at Beaufort, S. C.

	Grains per gallon.
Organic matter and water	1.47
Sulphate of lime	.63
Sulphate of magnesia	1.05
Chloride of potassium	1.94
Nitrate of potash	.80
Chloride of sodium	6.29
Carbonate of soda	30.75
Sulphate of soda	2.24
Silicate of soda	1.82
Silica	1.20
Total	48.19

[1] Municipal report of the city of Charleston, S. C., 1881, p. 55.

The iron works at Beaufort obtain water from a depth of 63 feet in large amount and excellent quality, suitable for all uses.

Florence.—Several wells have been bored at Florence, one of which reached a depth of 1,335 feet. They are successful, but the waters have not been fully utilized as yet. For the deep well, Capt. E. W. Lloyd has given me data, and Dr. McCorkle kindly permitted me to examine some of the borings. The borings were as follows:

Feet.
10.....reddish buff clay.
20.....light buff loam.
30.....gray sandy clay.
40.....gray sandy clay (more sandy).
50, 60.....gray sandy clay (less sandy).
60–100.....gray sandy clay (varying amount of sands).
105.....gray sandy clay with lignite.
110.....coarse gray sand.
120.....moderately coarse gray sand with lignite and iron sulphate.
150.....moderately coarse gray sand; micaceous.
210.....very fine gray sands.
220.....coarse gray sands.
350.....coarse gray sands; reddish tinge; few quartzite pebbles.
700.....coarse gray sand from sandstone.

From 400 feet to 608 feet, clays of white, red, and brown colors are reported. The brown and gray sandstones began at 608 feet and were bored through to 1,335 feet, where a hard black rock stopped further progress. This sandstone is of the Newark formation, and the black rock was no doubt a sheet of trap, such as frequently occurs in that formation. The lowest water was at 1,215 to 1,220 feet. It rose to within 18 to 20 feet of the surface and was pumped 100 gallons a minute when tested. An analysis made by M. B. Hardin, of Clemson Agricultural College, at Fort Hill, is as follows:

Analysis of water from deep well at Florence, S. C.

	Grains per gallon.
Carbonate of soda	6.198
Carbonate of lime	.676
Carbonate of magnesia	.513
Sulphate of potash	1.166
Sulphate of soda	.519
Chloride of sodium	4.070
Sesquioxides	.210
Silica	2.420
Total	15.772
Ammonia.....parts per million..	.003
Ammonia albuminoid.....do.....	.008

Water was found also at 608 feet, just above the sandstone, and at about 800 feet, in the sandstone, but as deep waters were desired these were not tested. The 600-foot water is probably in the basal beds of the Potomac formation. At the ice works in Florence there is a well which draws a supply of excellent water from beds at a depth of from 199 to 224 feet, and at the machine shops there was formerly a small tube which found a good supply at 420 feet below the surface. This latter water is probably in the Potomac formation.

Marion.—The boring made at this place several years ago may be regarded as unsuccessful, for it supplies less than a gallon a minute. The depth is 1,244 feet, of which the portion below 700 feet is in crystalline rocks. A small flow of water was found at 700 feet, at the base of the Coastal Plain formations. It rose 12 to 15 feet above the surface, but was not fully tested as to pressure and yield, as larger supplies were expected at greater depths. Very little information is available regarding the record of this boring, and the only definite feature of geologic significance of which I could learn, in addition to the facts above presented, is the occurrence of alternating strata of sand and tough clay with occasional rocky layers from 400 to 500 feet. This series probably represents a portion of the Potomac formation, which here lies between the superficial marine Cretaceous marls and the crystalline rocks, probably with a thickness of about 500 feet.

Darlington.—The Darlington well has a depth of 327 feet and furnishes a large supply of excellent water, which rises just above the surface. The water contains iron and magnesia and has a strong odor of sulphur, which soon passes away in the open air.

The following statement regarding the beds penetrated is given from memory by Prof. J. J. Ward, of Darlington, who furnished all the information regarding this well:

Feet.	
0–16	clay.
16–50	alternating sand and clay.
50–250	fuller's earth, with thin layers of sand and soft black shale.
250–327	quicksand.

The upper beds comprise the Lafayette (?), Miocene, and Cretaceous marine beds, of which the black shales are characteristic. Probably the quicksand and water are in the upper part of the Potomac formation. It is stated that the health of Darlington has improved greatly since the artesian water was introduced.

Lake City, Williamsburg County.—The group of ten wells in this town have depths of from 160 to 200 feet, and each yields from 7 to 15 gallons of water a minute, which rises to 15 feet or more above the surface. The water is said to be of the very finest character. There are about twenty-five wells in the surrounding country. An analysis of the Lake City water, made at Clemson College, is as follows:

Analysis of water from wells at Lake City, S. C.

	Grains per gallon.
Carbonate of soda	5.073
Carbonate of potash	.362
Carbonate of lime	.892
Carbonate of magnesia	.659
Sulphate of potash	.162
Chloride of sodium	.945
Iron and alumina	.023
Silica	1.096
Total	9.212

Conway, Horry County.—Several attempts were made to obtain water at Conway and elsewhere in Horry County, but without success, as the borings were not deep enough. The depth attained at Conway was only 160 feet.

Aiken.—The Aiken well has a depth of 558 feet and furnishes an abundant supply of excellent water. Water was also found at 543 feet, and the "chalk" formation under Aiken yields water in fair supply at a depth of about 100 feet. A partial record of the Aiken well is as follows:

Feet.		
0–45	red clay.	Lafayette formation.
45–100	sand.	Potomac formation.
100–130	"chalk" or "kaolin."	Potomac formation.
130–465	sand.	Potomac formation.
465–558	granite.	

A well on a high hill in Hammond Township,[1] Aiken County, found a large supply of water at a depth of 120 feet. It passes through sand. The well presents the curious phenomenon of a current of air which in stormy or threatening weather issues from the orifice with considerable force.

Orangeburg.—There are four wells in this place which yield a satisfactory supply of excellent water. The deepest borings were to a depth of 1,160 feet, but no greater pressure of water was found there than at 250 feet. The water rises to within 48 feet of the surface, but pumps down to 54 or 56 feet. The following record was furnished through the kindness of Mr. George H. Cornelson, of Orangeburg:

Feet.	
0–42	red clay.
42–62	water-bearing sand.
62–122	clay.
122–132	sand with some water.
132–232	marls of different colors.
232–252	sand with fair supply of water.
252–962	fine sand with shells, sharks' teeth, bones, etc.
962	6-inch layer of wood.
962–1,160	fine sand with water.

[1] Resources of South Carolina, 1883, p. 119.

This lower sand is probably in the Potomac formation, and I should expect that at 1,160 feet the boring was not far above the basal beds and their floor of crystalline rocks.

Bamberg, Barnwell County.—A large water supply is obtained at Bamberg from thirty wells of moderate depth and five flowing deep wells. The shallow wells range in depth from 65 to 100 feet and draw mainly from cavities in the Eocene limestone. The deep wells range from 470 to 555 feet in depth, and probably reach a horizon in the Potomac formation. The following notes regarding the beds penetrated were supplied by Mr. Bamberg:

Feet.
0–67.....sand and clay.
67–272.....rocks with cavities; typical buhrstone.
272–322.....quicksand.
?.....dark-gray argillaceous rock with shell fragments.
?–447.....micaceous sand yielding a 6-gallon flow of water.
470.....40-gallon flow to 15 feet above surface.
495.....35-gallon flow to 20 feet above surface.
520.....35-gallon flow to 12 feet above surface.
555.....40-gallon flow to 30 feet above surface; smaller pipe.

The water has a peculiar taste, to which persons soon become accustomed, and it is in general use. It is stated that the introduction of these waters has made a very marked improvement in the health of the community.

WATER HORIZONS AND PROSPECTS IN SOUTH CAROLINA.

We are not as yet sufficiently well informed as to the underground geology of the Coastal Plain region in South Carolina to discuss at any length the water horizons and well prospects. Considering the wide area of the region, only a relatively few wells have been sunk, and except in the case of the Charleston well and of one or two other wells we have no definite record of the formation penetrated. The Potomac formation is probably a water bearer under very wide areas, as indicated by wells at Charleston (probably), Orangeburg, Darlington, Bamburg, Florence (400–600 feet), and other points. At Marion it yielded water in small supply that rose 15 feet above the surface, but it probably was not properly tested. The deeper waters at Aiken and at Florence are from the crystalline rocks, so that they present no positive evidence regarding waters in the Coastal Plain deposits. I am convinced that there is a fair chance for finding the Potomac waters throughout the region, although they can not be predicted with certainty. They lie at depths which are moderate in the central part of the State, but which gradually increase to about 2,000 feet below the surface along the ocean shore, as shown in the sections on Pl. XIV.

The higher water horizons are quite numerous, but they have not been sufficiently explored or definitely determined geologically for discussion or prediction. The buhrstone appears to contain water-bearing cavities in Barnwell County, and possibly the area of this water horizon is extensive in the southern portion of the State. The Bamberg wells draw on these waters at a depth of less than 100 feet below the surface,

but it is not known that they are reached by other wells to the south and east.

There appears to be a wide area for several miles about Charleston in which waters are found in wells averaging about 400 feet deep, in calcareous beds at the base of the Eocene, possibly the eastward representative of the buhrstone horizon, but nothing is known of the extent of this water beyond this group of wells. The failure of the Conway and Georgetown wells was probably due to insufficient depth.

EASTERN GEORGIA.

This region was not so thoroughly canvassed for well data as the States to the north, and I can now present little more than a list of some of the wells. The location of wells is shown on Pl. XVII.

The geology of eastern Georgia is very similar to that of the adjoining portion of South Carolina, with a succession of widely extended east-sloping sheets of clays, sands, and marls, which thicken gradually to the eastward. The region has not been studied with sufficient care by any geologist to afford data for even a general outline of the stratigraphic succession, so that any attempt at present to discuss the geologic horizons of the waters or to prognosticate on a geologic basis is out of the question.

The success of most of the wells, especially those along the coast, gives great encouragement that the water-bearing beds underlie a wide area of the Coastal Plain region of the State at moderate depths. The large supply of water from the twelve wells at Savannah, and the height to which the waters rise in the flowing wells along the coast from St. Catherine Island to Fernandina, Fla., are features which give great prominence to the underground water resources of eastern Georgia.

List of deep wells in eastern Georgia.

Locality.	Depth.	Diameter.	Capacity per minute.	Height to which water rises.	Remarks.
Augusta:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Arsenal	800	8	16	—200	In granite; soft pure water.
Chemical Co	879	5⅝	Many.	.....	In granite; medium hard water.
Brunswick, 4 wells	475	3, 4, and 6	200 each.	+45	
Claxton	395	.....	.....	—80	Sulphurous water.
Collins	750	6	Fair supply	—50	
Darien	530	6–4	50	+35	
Doboy Island	450	6	250	+58	
Eden, 2 wells	280 and 310	.....	Many.	.....	Fine water.
Jekyl Island	480	6	250	+45	
Jesup	525	.....	.....	Pumped.	Fine water; sand rock beds from 350 to 500 feet.
Keller, 8 wells	300	.....	Many.	.....	

List of deep wells in eastern Georgia—Continued.

Locality.	Depth.	Diameter.	Capacity per minute.	Height to which water rises.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Lumber City, 6 wells	400	2⅜	50 each.	+16	Supply increasing; rock from 326 to 400 feet.
Meldrim	538	6 or 8	Many.	Flows.	Sulphurous water.
St. Catherine Island, 5 wells	300	3	.....	+33	Water in coarse marl under 5 feet of rock.
St. Simons Island, 3 wells	480	3 and 6	100–150	+40	
Savannah, 12 wells	500 and 600	12	500 each.	To surface.	
Statesboro	600	4	None.	.....	
Union Island	475	4	150	+58	
Ways Station	107½	4	Many.	Pumped.	Soft water.
Ways Station near Ways, 3 wells.	484	2 and 6	Many.	Flows.	Said to yield 13,000,000 gallons a day.
Waycross	500	6	150	Pumped.	

NOTES ON WELLS IN EASTERN GEORGIA.

Savannah.—This city is supplied with water from twelve 12-inch wells, which yield 4,000,000 gallons a day. They are in the western extremity of the city, on low ground, and the water rises to the surface level but does not overflow. Their depths are 500 and 600 feet. No record could be obtained of the beds penetrated in boring, except a statement that they were "clay, porous rock, and a thin layer of flint rock," The water is clear and tasteless, although it has an odor of sulphur when it first reaches the atmosphere. The following analysis of the water was kindly furnished by the superintendent of the waterworks:

Analysis[1] *of artesian well water, Savannah, Ga.*

	Grains per gallon.
Chlorine of chlorides	0.6192
Equivalent to sodium chloride	1.0218
Phosphates	Trace.
Nitrates	None.
Nitrogen in nitrates	6.0283
Free ammonia	None.
Albuminoid ammonia	0.0017
Hardness equivalent to carbonate of lime	[2]4.0463
Hardness equivalent to carbonate of lime	[3]1.7804
Soda	0.7987
Potash	0.1252
Lime	2.0344
Magnesia	0.7093
Oxides of iron and alumina	0.0233
Silica	2.1929
Sulphuric acid	0.5160
Equivalent to sulphate of iron	0.8772
Organic and volatile matter	0.5832
Mineral matter	12.8299
Total solids at 110° C	13.4131

[1] Made by W. A. Chandler, New York. [2] Before boiling. [3] After boiling.

The geologic horizon of the Savannah water is not known.

Lumber City, Telfair County.—Through the kindness of J. B. Spencer, of Lumber City, I am able to publish the following:

Analysis[1] *of artesian water from well at Lumber City, Ga.*

Total solids, grains per United States gallon	10.96
Chlorine, grain per gallon	.58
Free ammonia, parts per million	.013
Albuminoid, parts per million	.030
Hardness, degrees	8.20

The solids comprise chlorine, iron, lime, magnesia, sulphuric acid, silica, carbonic acid, and soda, making a hard water, but otherwise of excellent quality.

The following record of the Lumber City well was also furnished by Mr. Spencer:

Feet.	
0–4	top soil.
4–20	red clay.
20–30	coarse sand.
30–250	hard blue clay with few streaks of sandstone.
250–350	quicksand.
350–430	limestone, with water seams 380 to 430 feet. This limestone contains shell fragments of Eocene age.

It is stated that since the introduction of these waters malarial diseases, which formerly prevailed, have entirely disappeared.

[1] Made by G. F. Payne, State chemist of Georgia.

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