DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

WATER-SUPPLY PAPER 397

GROUND WATER IN THE WATERBURY AREA CONNECTICUT

BY

ARTHUR J. ELLIS

Under the direction of HERBERT E. GREGORY

Prepared in cooperation with the
Connecticut State Geological and Natural History Survey

WASHINGTON
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GROUND WATER IN THE WATERBURY AREA, CONNECTICUT.

By Arthur J. Ellis.

INTRODUCTION.

The Waterbury area comprises a section of west-central Connecticut approximately 25 miles long, 7 miles wide, and 171 square miles in extent, reaching from Housatonic River northward to Thomaston and including the lower part of the Naugatuck Valley, its east and west borders coinciding approximately with the divides between the Naugatuck and other rivers. Within it are the towns of Ansonia, Seymour, Oxford, Beacon Falls, Naugatuck, Middlebury, Waterbury, Watertown, and Thomaston. (See fig. 1.)

Topographically the area consists of a troughlike valley with narrow floor, intersected by narrow valleys of streams tributary to the Naugatuck. At some places bare rock cliffs rise from the edges of the river to heights of more than a hundred feet; at other places, where tributaries enter, the lowlands are a mile or more in width. The lowest land, on Naugatuck River, where it crosses the south line of Ansonia, is only 18 feet above sea level; the highest, on Lattin Hill near the north boundary of Thomaston, is 1,022 feet above sea level.

Naugatuck River flows southward through the entire length of the Waterbury area, having a total fall within the area of about 400 feet. It receives a number of small but important streams between Thomaston and Ansonia, notably the West Branch of the Naugatuck, Mad River, Steel Brook, Long Meadow Pond Brook, Little River, and Bladens River. A small part of the drainage passes directly into Housatonic River above the mouth of the Naugatuck, and Eightmile Brook, which collects the drainage in the southwestern part of the area, is also tributary to the Housatonic.

The excellent water-power sites along the Naugatuck invited settlers into that valley very early in the history of the State, and the growth of industrial enterprises, although somewhat slow at first, has been very rapid during the last few decades. The manufacture of brass articles and general foundry work rank first among the industries, and in these as well as nearly all others water power has played an important part. But water is needed not only for power but for other industrial purposes as well as for municipal supplies,

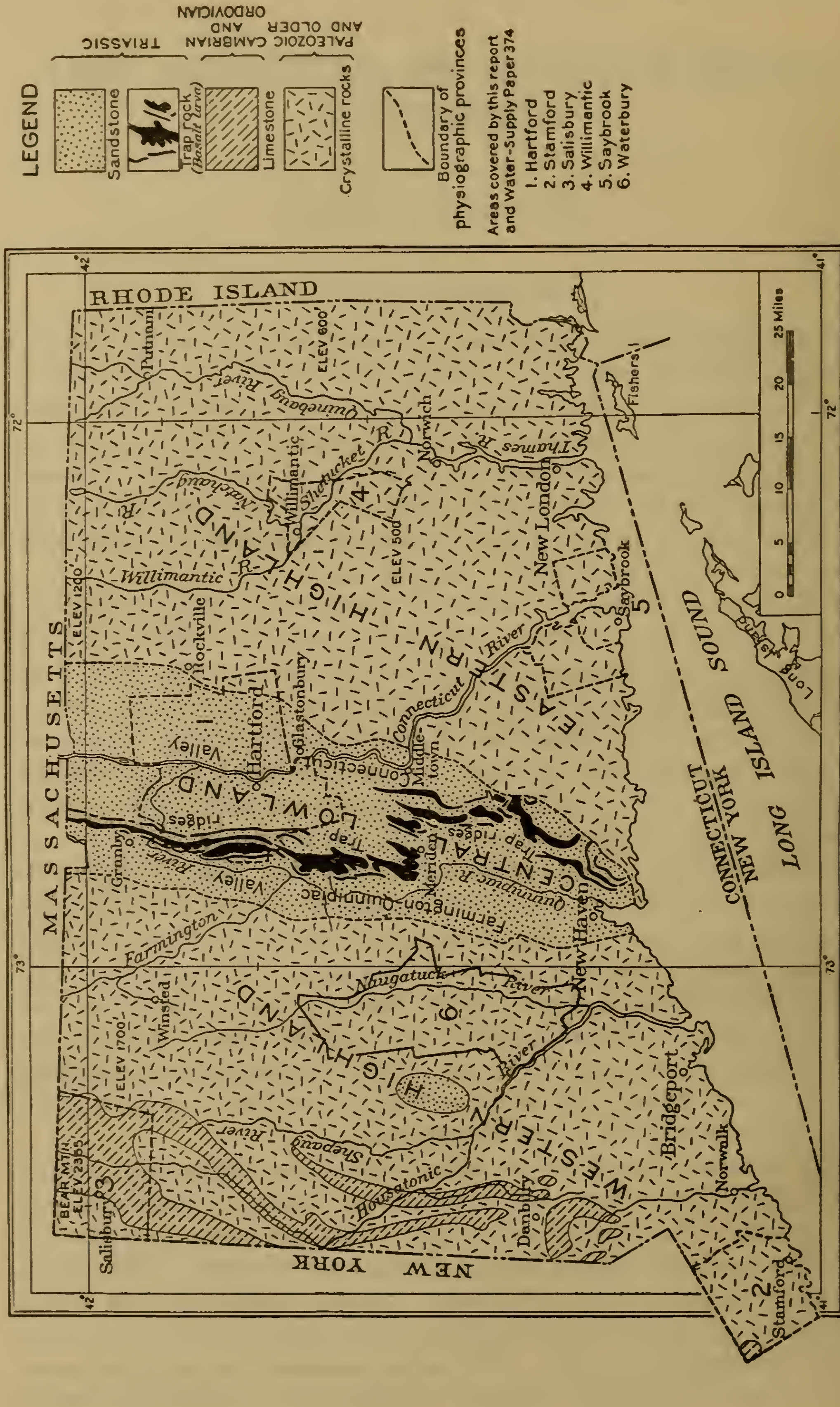


FIGURE 1.—Map of Connecticut showing physiographic provinces, geologic formations, and areas covered by this and previous reports.

and with the increase and diversification of population and industries conflicts of interest have arisen—conflicts between water-power users and domestic consumers, between towns for the right to make use of a given stream or area; and between cities interested in sewage disposal and adjacent communities affected thereby. Industrial development inevitably taxes the natural water resources of a community, and although investigations of the local water problems may aid in formulating methods for conserving the use of water, it is necessary that State-wide regulations, following intelligent legislation, should be adopted to provide for the future.

GEOLOGY.

CRYSTALLINE ROCKS.

The area is underlain by crystalline rocks of undetermined age, which have been classified according to lithologic characteristics into the formations [1] described in the following paragraphs:

1. *Orange phyllite.*—This rock is a slate or phyllite, highly fissile, sericitic, and usually dotted with minute garnets. It is characterized by many quartz veins and lenses of quartz. It is believed to have been originally a more or less calcareous shale.

2. *Thomaston granite gneiss.*—This rock varies in structure from an almost massive granite to a rock with distinctly schistose phases. It is of igneous origin, as shown by the fact that it often occurs as dikes and includes fragments of other rocks.

3. *Hoosac ("Hartland") schist.*—This formation is everywhere a mica schist of well-marked character, but exhibits great variation in texture, composition, and appearance, due to large intrusions of igneous rock. It is of sedimentary origin. The "Hartland" schist of Connecticut has been traced into the Hoosac schist of Massachusetts, and the name "Hartland" has been abandoned by the United States Geological Survey in favor of the older name Hoosac. The Hoosac schist is regarded as of Ordovician age.

4. *Waterbury gneiss.*—This gneiss was doubtless originally Hoosac ("Hartland") schist, whose texture has been changed by granitic intrusions and quartzose veins.

5. *Prospect granite gneiss.*—This is a light-gray granitic rock whose gneissoid appearance is produced by bands of granular quartz and feldspar interbedded with layers composed chiefly of biotite. The porphyritic mineral is usually white or pink orthoclase in crystals ranging in length from one-sixteenth inch to 3 inches. The rock was probably a granite porphyry intruded into the Hoosac schist.

[1] Rice, W. N., and Gregory, H. E., Manual of the geology of Connecticut: Connecticut State Geol. and Nat. Hist. Survey Bull. 6, pp. 96–110, 1906. Gregory, H. E., and Robinson, H. H., Preliminary geologic map of Connecticut: Connecticut State Geol. and Nat. Hist. Survey Bull. 7, pp. 33, 34, and map, 1907.
The retention in this economic report of the geologic names used in the reports published by the State does not imply their adoption by the United States Geological Survey, and all are subject to revision, except Hoosac schist, which has been adopted.

6. *Amphibolite.*—This rock is distinctly gneissoid in structure, and is composed in large part of porphyritic feldspar and green hornblende, with a subordinate amount of quartz.

7. *Diabase.*—This rock is a colored trap occurring as dikes intruded into the older crystalline rocks. It is probably of Triassic age.

GLACIAL DRIFT.

The crystalline rocks are covered by deposits of glacial drift derived from the great ice sheets which in the Pleistocene epoch extended over the State. They are of two general types: The unstratified drift, also called "till," which consists of heterogeneous mixtures of all the rock débris deposited directly by the ice; and the stratified drift, which consists of glacial materials that were rehandled by water and are therefore assorted into layers of different degrees of coarseness. Till constitutes the surface deposits over most of the highland areas, and stratified drift is found chiefly in the stream valleys.

SOURCE AND OCCURRENCE OF GROUND WATER.

ORIGIN.

The ground water of the Waterbury area is derived from the precipitation within the area and near its borders. Owing to the ruggedness of the bedrock surface and the thinness of the overlying drift, which together prevent an extensive underground circulation, the ground water of any particular locality is derived from very local sources.

Owing to the small size of the area, the precipitation is evenly distributed, and, as shown in the following table, is nearly uniform throughout the year.

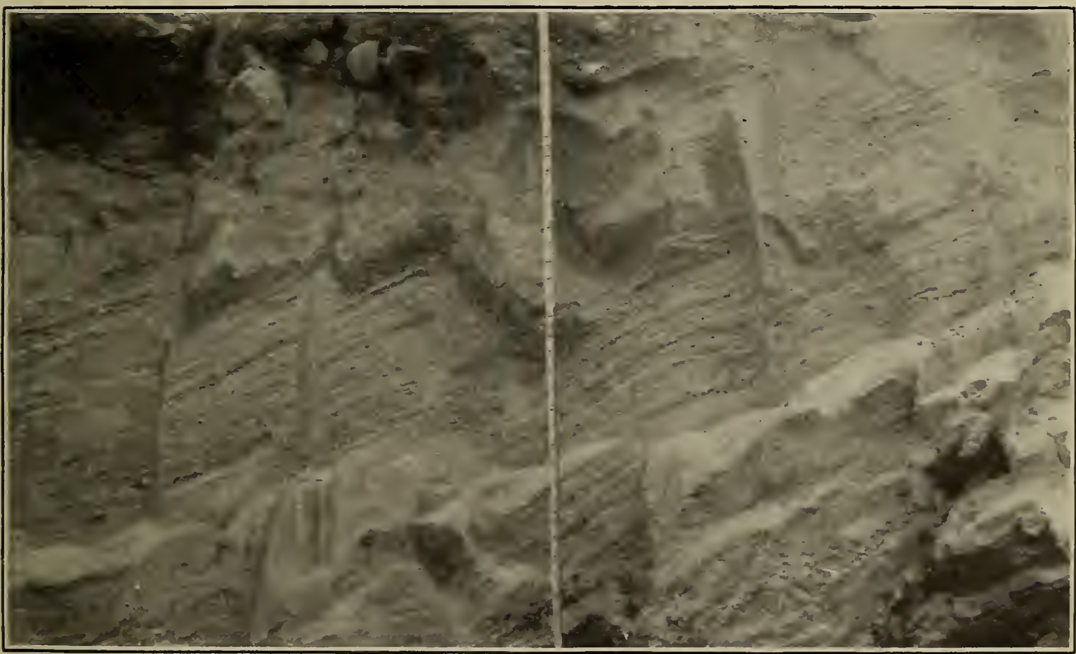
Rainfall in Waterbury from 1887 to 1912, inclusive.[a]

[Recorded by N. J. Walton.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1887	4.75	6.07	4.24	3.94	0.13	6.60	3.79	5.64	1.68	2.97	2.25	5.20	47.26
1888	4.73	5.11	6.46	1.78	4.13	1.55	2.73	4.53	7.57	4.72	4.42	5.84	53.57
1889	5.85	1.61	2.02	4.29	4.64	4.09	10.83	2.76	4.26	4.03	8.74	2.74	55.86
1890	2.54	3.77	6.08	2.43	5.97	3.26	4.96	4.50	4.98	6.89	0.93	5.21	51.52
1891	10.06	5.65	5.08	3.86	1.84	1.14	4.17	3.04	1.68	3.04	3.33	5.71	48.60
1892	6.01	1.30	3.45	.95	5.55	2.27	4.37	5.30	2.62	.92	5.96	1.74	40.44
1893	2.96	7.37	4.83	3.49	6.44	1.82	3.31	7.22	1.75	5.21	2.49	4.08	50.97
1894	2.68	4.13	1.43	3.16	7.58	.54	2.43	2.41	5.35	4.91	4.30	4.21	43.13
1895	4.86	1.92	2.58	3.85	1.96	2.82	3.73	7.29	2.16	5.19	5.22	3.83	45.41
1896	2.37	9.25	5.99	1.83	2.34	5.71	3.16	2.67	5.01	2.77	3.09	2.39	46.58
1897	4.58	3.48	2.67	1.97	5.34	3.77	18.10	3.51	2.18	1.08	6.00	5.99	58.67
1898	5.09	3.49	2.47	3.67	6.86	.94	3.37	9.48	2.52	5.82	7.57	3.86	55.14
1899	3.82	4.58	6.75	1.80	2.07	2.32	6.02	1.03	5.30	2.42	1.69	2.81	40.61
1900	3.77	8.46	5.51	2.23	4.39	3.02	3.10	2.09	2.15	3.59	5.96	2.56	46.83
1901	1.78	.55	7.44	11.51	8.08	.65	4.44	9.37	6.25	4.32	2.37	9.82	66.58
1902	3.43	6.67	5.56	4.11	2.01	5.16	4.58	2.82	6.42	6.19	1.34	6.92	55.21
1903	3.78	4.32	6.45	3.38	.73	11.25	3.71	6.36	3.02	4.77	2.30	4.37	54.44
1904	4.45	2.54	3.74	4.50	3.31	4.20	4.62	4.93	8.02	3.05	1.59	3.28	48.23
1905	6.51	1.50	3.59	2.85	1.27	4.22	4.20	5.65	4.27	2.50	1.72	3.72	42.00
1906	2.79	2.29	5.97	4.30	3.74	4.83	5.49	2.71	1.92	6.26	2.18	4.13	46.61
1907	3.45	2.52	1.53	2.77	3.87	4.37	2.29	1.35	9.82	5.89	5.69	5.81	49.36
1908	4.72	6.86	3.07	2.65	5.85	1.10	6.53	6.53	1.39	2.43	1.14	3.75	46.02
1909	3.83	6.15	4.36	7.97	2.83	3.11	1.56	3.47	4.51	1.17	1.89	4.83	45.68
1910	8.05	4.27	1.16	4.08	2.95	3.30	3.04	3.16	2.56	.98	5.40	2.21	41.16
1911	2.99	2.81	3.69	3.75	.87	3.33	4.54	8.11	2.24	8.27	4.48	3.44	48.52
1912	2.36	3.20	7.87	4.38	5.51	.91	3.63	3.12	2.34	3.52	3.97	4.64	45.45
Average	4.31	4.23	4.38	3.67	3.86	3.32	4.72	4.58	3.92	3.96	3.69	4.35	48.99

[a] From Waterbury City Engineer's Ann. Rept., 1912.

A. BOWLDER-STREWN LANDSCAPE IN TILL-COVERED AREA, ANSONIA, CONN.



B. STRATIFIED BEDS OF COARSE SAND, ANSONIA, CONN.

WATER IN THE GLACIAL DRIFT.

CIRCULATION.

The chief water-bearing formations of the Waterbury area are the unconsolidated materials that cover the bedrock. These materials absorb rain water at a rate and to an extent depending chiefly on their porosity. The most porous beds are composed of gravel and sand, the least porous of compact clays. The unstratified drift, which covers most of the area, is a mixture of bowlders, gravel, sand, and clay, and its porosity depends on the relative amounts of these materials. (See Pl. I.) Much of the unstratified drift is of the "stony" or "bowldery" type, which contains practically no clay and which possesses a porosity equal to that attained by coarse varieties of stratified drift. The less porous types of unstratified drift may be represented by the following averages of the analyses of 16 samples collected from 12 drumlins in the Boston basin.[1] These analyses were made after removing all stones 2 inches or more in diameter, which constituted about 10 per cent of the original material.

Average composition of unstratified drift in Boston basin.

	Per cent.
Gravel	24.90
Sand	19.51
Rock flour	43.86
Clay (three-fourths rock flour)	11.67
	99.94

Other factors influencing the amount of water absorbed are the growth of vegetation, the topography, the occurrence and duration of frost in the ground, and the atmospheric conditions that govern evaporation and rates of precipitation.

The water absorbed by the soil descends and saturates the lower part of the glacial drift, which serves as a reservoir for the storage of this water. The efficiency of the drift in this respect depends largely on the rate of underground drainage, the three principal factors of which are porosity, the arrangement of layers having different porosities, and the topography of the bedrock on which the water-bearing bed rests. The most porous beds, such as the gravels of the Naugatuck River valley (Pl. III, in pocket), absorb water most rapidly, but they also allow the water to circulate most freely and therefore are most rapidly drained. Impervious materials, such as clays, occurring among porous deposits are related to underground drainage as dams or other obstructions are related to surface drainage. They divert or impound the percolating waters and in many places produce springs and swamps. Except where the drift is thick, the topography of the bedrock below the water-bearing beds

[1] Crosby, W. O., Composition of till or bowlder clay: Boston Soc. Nat. Hist. Proc., vol. 25, p. 124, 1890.

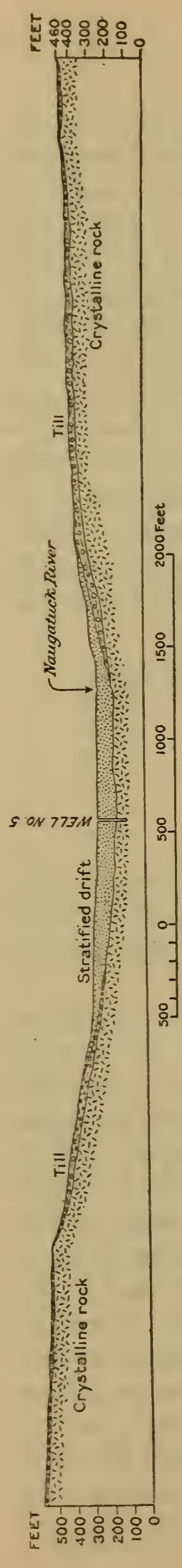


Figure 2.—Section across Naugatuck River valley below Waterbury, showing relation of bedrock surface to land surface.

is related to underground drainage as the topography of the land is related to surface drainage. Over most of the Waterbury area the drift is thin and the topography of the bedrock surface closely conforms to the present topography of the land surface, except that it is more rugged and has greater relief. The bedrock usually outcrops on the hilltops and steep slopes (Pl. III) but lies at considerable depths in some of the valleys, for example, in the Naugatuck Valley near Waterbury, where bedrock is reached at a depth of more than 100 feet below the river (fig. 2). Because of the similarity between the forms of the rock surface and the surface of the ground the direction of underground drainage corresponds very closely to the direction of surface drainage. The ground water, like the surface water, flows most rapidly on steep slopes, but because of the resistance offered by the soil particles it moves much more slowly than the surface water and is generally replenished by rainfall before the supply contributed by previous precipitation has been drained away. Most of the ground water finds its way to the surface through the flow of springs and seepage areas, by capillary rise and evaporation, and by transpiration of trees and other plants; a comparatively small amount is drawn from wells.

THE WATER TABLE.

The water table is the plane below which the ground is saturated with water. Its topography is similar to that of the land surface but less rugged. Consequently it is generally nearest the land surface in the valleys and farthest from the surface on the hilltops, where it may lie at a depth of 30 or 40 feet. The surfaces of streams, ponds, and lakes are generally continuous with the water table and may be regarded as forming parts of it. In bogs, marshes, and other places where the ground is saturated to the surface, the water table and the surface of the ground coincide. Where the water table is not exposed its position is shown by the surface of the water in wells. The position of the water table depends also on the character of the drift. Except in very low places it is, in general, nearer the surface in areas where the drift consists of clay or compact till, and farther below the surface in areas where the drift is gravel and sand, because clay and till are less porous than gravel and sand and do not drain as rapidly.

The accompanying map (Pl. III, in pocket) shows the average depth to the water table at the wells that were examined. Where dense rocks appear at or near the surface there is no water table; the rock masses rise above the ground water like islands in a lake, and the position of the water table immediately surrounding them is indeterminate. Figure 3 illustrates the relative position of the water table in various kinds of drift and under different topographic conditions.

The water table is constantly changing its position with respect to the surface of the ground, rising rapidly after a heavy rain, then gradually descending as the water is drained away. These changes may be observed by making successive measurements of the depths to water in wells. The zone through which the water table fluctuates is called in this report the zone of fluctuation.

In elevated positions where the drift is thin the water table may descend during a period of drought until it touches the rock surface and is all drained away; but in the vicinity of perennial streams or permanent bodies of water the change may not exceed a few inches during a year. The zone of fluctuation, therefore, has the least thickness in the valleys and the greatest on the hills, where it may include the entire distance from the highest water level to the bedrock surface.

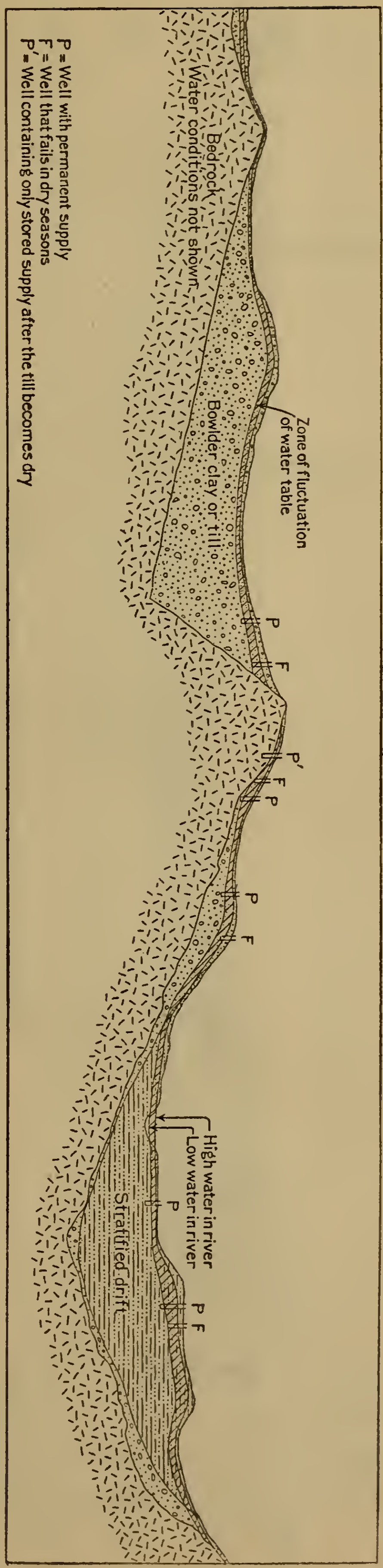


FIGURE 3.—Diagrammatic section showing position and fluctuation of water table under various conditions.

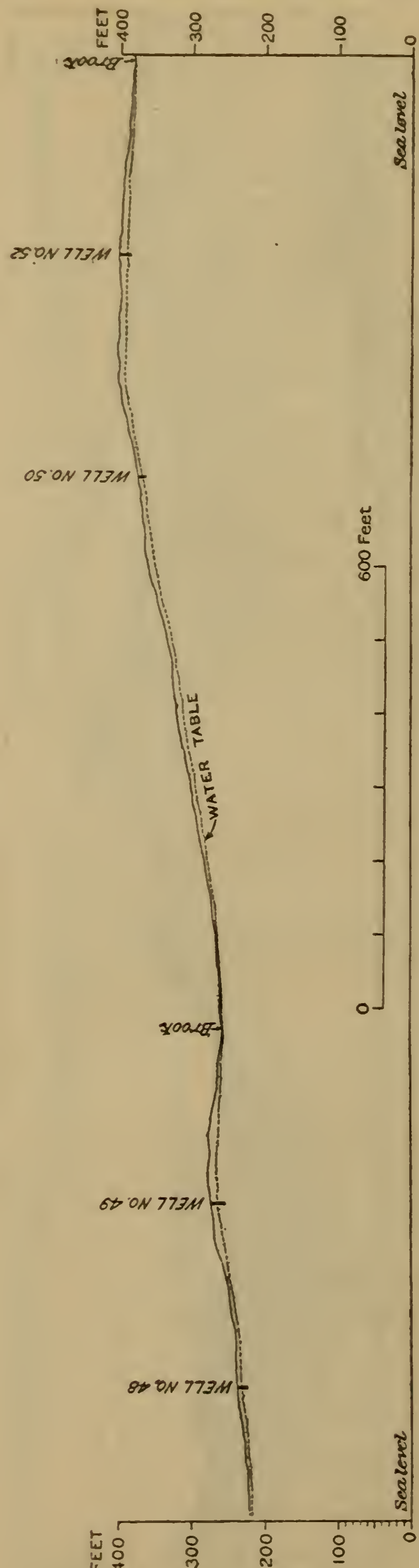


FIGURE 4.—Section showing relation of water table to surface of ground.

AMOUNT OF WATER.

A rough conception of the annual supply of ground water may be gained by analyzing the relations between precipitation and stream flow. Measurements of precipitation show the total amount of water which falls on a drainage basin, but only a part of this is added to the underground supply, a part of the rest being returned to the atmosphere, and another part discharged by streams. The total run-off from a drainage basin, as determined by stream measurements, includes both the surface drainage (that is, the water which has never formed part of the underground supply) and the underground drainage—the water which has passed into the surface streams from the water-bearing beds.

The water that is returned to the atmosphere by evaporation and transpiration is in part surface water and in part ground water. A rough index of its amount is obtained by subtracting the total annual run-off from the total annual precipitation. In the Housatonic River basin above Gaylordsville, Conn. (area, 1,020 square miles), the annual rainfall is 47.86 inches and the mean annual run-off is 29.43 inches. The difference of 18.43 inches is attributed to loss by evaporation and plant growth. Similarly, in Connecticut River basin above Orford, N. H. (area, 3,300 square miles), the annual precipitation is 36.76 inches and the annual run-off is 21.66 inches, the loss being 15.10 inches.

These and other data compiled by Mr. Hoyt [1] indicate that in northeastern United States between 30 and 40 per cent of the rainfall is returned to the atmosphere. It is not possible to determine, from

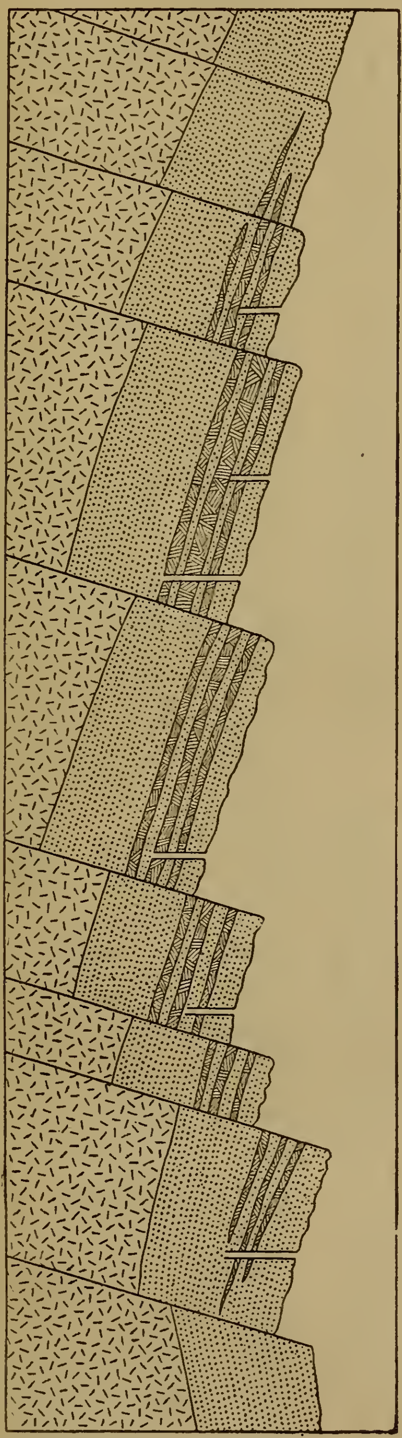


FIGURE 6.—Diagram showing possible artesian conditions in Connecticut.

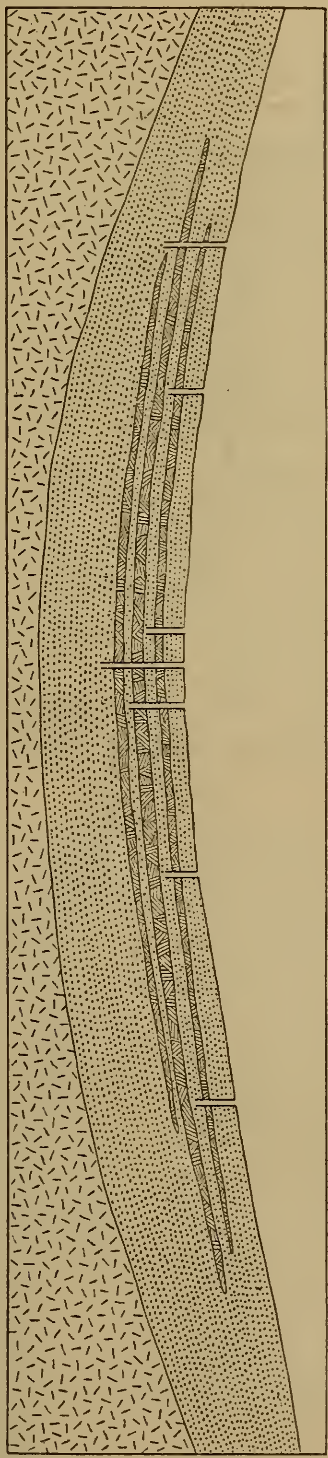


FIGURE 5.—Diagram showing possible artesian conditions in Connecticut.

the data at hand, what part of this is derived from the underground supply. All perennial streams lie below the water table and are maintained during dry seasons by infiltration from the saturated part

[1] Hoyt, J. C., Comparison between rainfall and run-off in northeastern United States; Am. Soc. Civil Eng. Trans., vol. 59, p. 470, 1907.

of the drift. During a rainy season and for some time thereafter the streams carry more or less water which has never formed a part of the ground-water supply. During the succeeding dry season this surface water is discharged and the streams finally reach a stage at which nearly the entire run-off is water from underground sources. In Connecticut the discharge of underground water is never less than the amount carried by the streams at their lowest stages, but it is probably greater immediately after rains, owing to the contribution from intermittent springs and seepage areas and to a general acceleration of underground circulation by hydrostatic pressure. In addition to the amount of ground water discharged by streams there are large quantities stored in drift-filled rock basins below the valley floors, as for example in the valley of Naugatuck River near Waterbury, where saturated deposits consisting largely of gravel and sand extend nearly 100 feet below the river bed (fig. 2). The amount of water in such basins depends on the size of the basins and the porosity of the valley fill. But the water contained in such basins, if withdrawn, must be replenished by that usually carried in the streams, therefore, strictly speaking, these supplies are not available

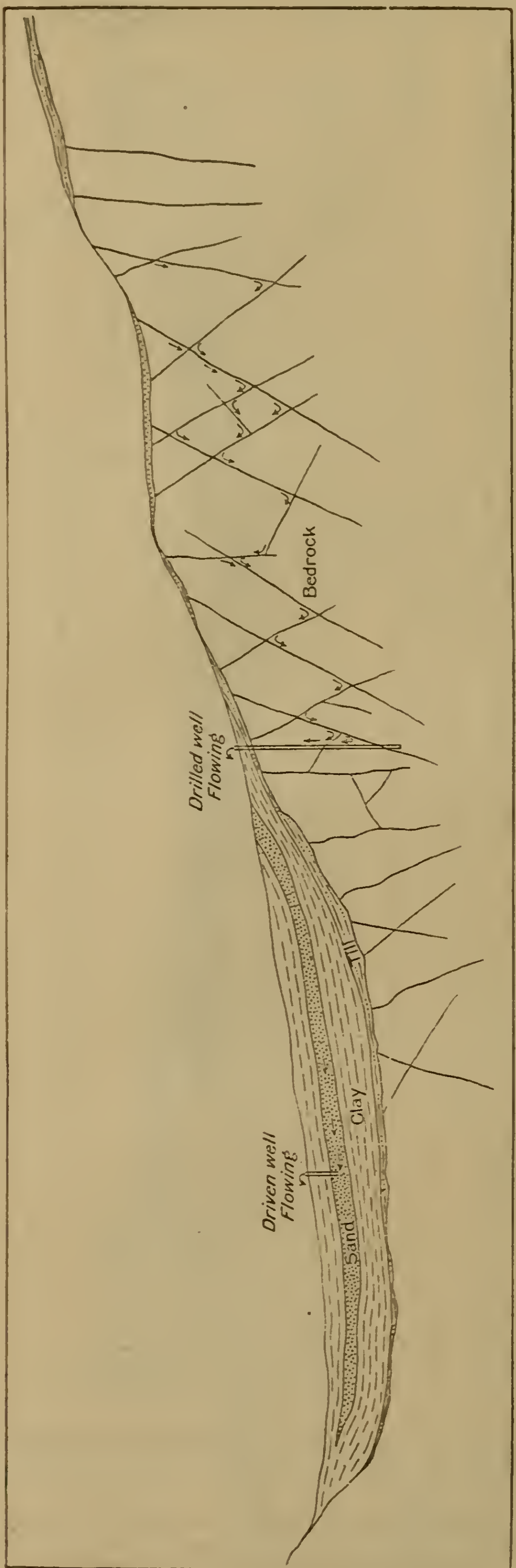


FIGURE 7.—Diagram showing possible artesian conditions in Connecticut.

in addition to the amounts discharged by streams, except as their withdrawal would decrease the amount of evaporation and transpiration.

WATER IN CRYSTALLINE ROCKS.

The area described in this report is underlain by crystalline rocks whose age has not been definitely determined (p. 9). As a result of the work of dynamic agencies these rocks are intensely fractured, cracks being visible wherever the rocks are exposed (Pl. II, *B*). All the crystalline rocks have a very low porosity—less than 1 per cent—and for this reason the circulation of water in them is practically restricted to the cracks. Water enters the openings from the overlying drift and passes in the direction of least resistance, down some sloping planes and up others, through vertical cracks and horizontally through level ones until it becomes imprisoned in cracks with no outlets or until it reappears at the surface as springs or seepage.

In general, the thickness of the zone of active circulation is nearly equal to the relief of the land surface. That is, openings below the level of the valleys are generally filled with water that is not in motion until wells reach these depths and start circulation by drawing water to the surface. In some places, however, these more deeply seated waters are forced by hydrostatic pressure along fault planes or major joints and reach the surface as artesian springs or artesian wells. (See figs. 5, 6, and 7.)

The amount of water in crystalline rocks depends chiefly on the number and size of the cracks. Most of the openings are too narrow, even at the surface, to allow any considerable quantity of water to pass, but they are generally connected, either directly or indirectly, with larger fissures into which they drain, and it is the ramifying systems of minor cracks which to a large degree regulate the supplies derived from rock borings. The openings in these rocks do not extend to great depths and their size rapidly diminishes from the surface downward. Nearly all the cracks pinch out entirely within a few hundred feet from the surface, and water-bearing fissures at greater depths are rare. As compared with the more porous drift, crystalline rocks contain little water, the average yield of wells in the crystallines of Connecticut being about 15 gallons a minute. Many deep rock wells in the State are practically dry, but a number of others obtain water from joints and cracks within 100 feet of the surface.

GROUND WATER FOR MUNICIPAL USE.

PROBLEMS INVOLVED.

The problems to be considered in planning the use of ground water for a new or enlarged public water supply relate to the quantity of water to be obtained, the quality of the water, the methods of procuring it, and the cost of establishing and maintaining the works. These problems are largely interdependent and their relative importance depends on the proposed uses of the water and the conditions under which it is to be used.

QUANTITY REQUIRED.

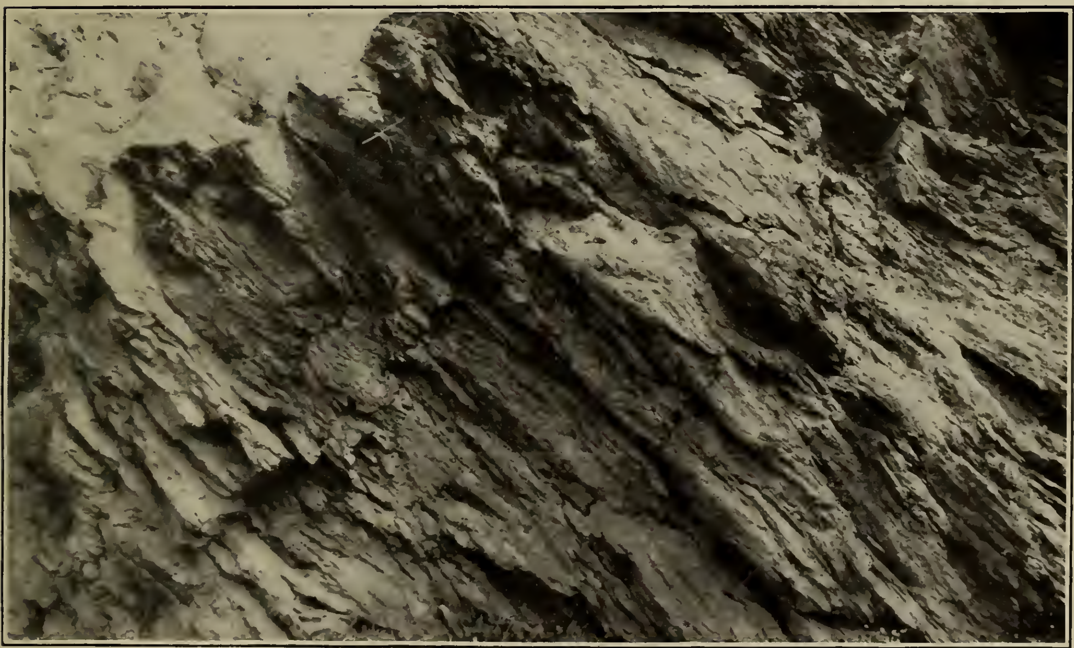
In towns with an established water system the per capita consumption is known and the quantity of water required for extending the system can be estimated with a fair degree of accuracy. In small towns or communities in which a public supply is designed to replace private wells an estimate of the quantity of water required should be based on a comparative study of the consumption in towns of similar characteristics. Plans for cities or for smaller communities involve a consideration of future needs based on the probable rate of increase in population and the circumstances affecting it and also on the estimated rate and amount of development of industrial enterprises. In a community where the significance of past conditions and present trends of population and industries are fairly well understood, plans for a 20-year service for an average town of less than 10,000 may be based on the present population. For larger cities estimates of future needs are much less likely to be reliable, and so far as practicable future requirements should be provided for by maintaining a system capable of extension at reasonable cost as the need arises. The data available for the larger cities of Connecticut are sufficient to serve as a guide in planning ten years in advance of present needs, on the basis of an estimated consumption of 100 gallons per capita per day.

The factors which determine the amount of water required are as follows:

1. The number of inhabitants.
2. The nature of the local industries.
3. The wealth and habits of the people.
4. The extent to which water is used in fountains and in lawn and street sprinkling.
5. The climate as affecting the use and waste of water to prevent freezing.
6. The prevention of leakage.
7. The basis of revenue (meter or flat rate).
8. Quality, quantity, and pressure, as tending to encourage or discourage liberal use and great wastefulness.
9. The popularity of a new or improved supply.

The consumption of water is usually stated in number of gallons per capita per day, but it is not sufficient to take into account only this average daily rate of consumption, for the demand varies during the year and during the day, and the supply must be adequate for temporary heavy draughts. The following table shows the average daily consumption in Hartford, Conn., for each month during 1912 and during the period from 1903 to 1912, inclusive:

A. STRATIFIED SAND AND GRAVEL, NAUGATUCK VALLEY, SEYMOUR, CONN.



B. CRYSTALLINE ROCK (HARTLAND SCHIST) SHOWING FISSURES WHICH AT GREATER DEPTHS AFFORD WATER SUPPLIES, NAUGATUCK, CONN.

Average daily consumption of water during each month in Hartford, Conn.[a]

Month.	1912.	Average for 10 years (1903–1912).	Month.	1912.	Average for 10 years (1903–1912).
	Gallons.	*Gallons.*		*Gallons.*	*Gallons.*
January	8,317,000	6,717,000	July	9,245,000	7,642,000
February	8,730,000	6,959,000	August	8,694,000	7,315,000
March	8,625,000	6,896,000	September	8,675,000	7,411,000
April	8,445,000	7,044,000	October	8,674,000	7,191,000
May	8,800,000	7,380,000	November	8,283,000	6,978,000
June	9,128,000	7,648,000	December	8,142,000	6,775,000

[a] Board of Water Commissioners, City of Hartford, Conn., Fifty-ninth Ann. Rept., for year ending Mar. 1, 1913, p. 190.

The following table illustrates the variation in the rate of consumption during the day:[1]

Consumption from the Mystic supply of Boston, Mass., August, 1893.

Hours.	Rate of consumption per capita (gallons per 24 hours).	Per cent of total consumption.
1 to 4 a. m.	[a] 40.8	6.9
4 to 7 a. m.	58.6	9.9
7 to 10 a. m.	103.8	17.6
10 a. m. to 1 p. m.	93.0	15.8
1 to 4 p. m.	98.2	16.8
4 to 7 p. m.	79.5	13.6
7 to 10 p. m.	61.9	10.5
10 p. m. to 1 a. m.	52.9	8.9
Average	73.6	100.0

[a] "The large consumption from 1 to 4 a. m. must have been mostly waste."

To meet these daily peak loads and to insure against such emergencies as might arise from fire or disability of pumps a ground-water supply system should be equipped with a surface reservoir or elevated tank unless the capacity of the pumps and wells is much greater than the normal consumption.

QUALITY OF WATER.

A municipal water supply should be suitable in quality for both domestic and industrial uses. To meet these requirements the installation of purifying equipment may be necessary, whether the supply comes from surface or underground sources. Surface waters are always liable to pollution, and contamination of some is practically inevitable. The mineral content and hardness of most surface waters are not such as to render them unfit for general use, but ground waters, especially ground waters drawn from the bedrocks, may require softening or at least the removal of iron before the waters are usable. Ground waters are less liable to pollution than surface waters, but they are more strongly mineralized and may be mineralized to an objectionable degree.

[1] Turneaure, F. E., and Russell, H. L., Public water supplies, p. 29, 1908.

METHODS OF OBTAINING WATER.

The method of collecting water for a municipal supply depends on the natural conditions existing in the locality where water is needed. The possible sources to be considered are streams, springs, deep wells, filtration galleries, and shallow wells.

The extent to which each of these methods is employed in New England is shown in the following table:

Sources of water in public water supplies in New England.[a]

State.	Number of public supplies derived from—										
	Surface water.[b]	Surface water and springs.	Surface water and shallow wells.	Springs	Shallow wells.		Shallow wells and springs.	Galleries.	Shallow wells and galleries.	Deep and artesian wells.	Total.
					Dug.	Driven.					
Maine	53	2	0	12	1	0	0	0	0	2	70
New Hampshire	37	2	0	17	1	2	0	0	0	2	61
Vermont	21	3	0	13	0	0	0	0	0	0	37
Massachusetts	67	2	3	23	20	14	3	6	4	1	143
Rhode Island	12	0	0	0	1	0	0	0	0	0	13
Connecticut	48	9	0	8	0	0	0	0	0	2	67
	238	18	3	73	23	16	3	6	4	7	391

[a] Compiled from Baker, M. N., Manual of American waterworks, 1897.
[b] Surface water includes supplies from streams, lakes, and impounding reservoirs.

STREAMS.

Streams generally afford the simplest means of obtaining water. If the minimum daily discharge of the available stream exceeds the maximum daily consumption by an amount sufficient to provide for fire protection, the water may be diverted directly into the street mains; if, however, the daily discharge as determined by measurements extending through a number of years is not sufficient to meet the daily consumption and afford fire protection, storage must be provided. Since large streams are generally utilized in the disposal of sewage, it is the custom to go to the smaller ones for water supplies, hence the most common type of development involves the construction of reservoirs. A useful rule for estimating the required storage is that the amount stored shall be about the same percentage of the total yearly consumption as the total yearly consumption is of the total yield of the drainage basin.[1]

Practically all the available ground water of the drift, except that stored in the deposits below Naugatuck River, and a considerable amount from crevices in the bedrocks returns to the surface along the stream courses. For this reason the most effective method of

[1] International Library of Technology, vol. 36, Water supply, pp. 1, 322.

recovering this ground water is by constructing dams in the streams that carry it. Ground water is thus brought to the surface without pumping and if a reservoir is available from which water can be delivered by gravity the cost of pumping may be eliminated entirely.

SPRINGS.

Springs may be grouped into two classes, the first including those which serve as outlets for ground waters that have reached horizons far below the earth's surface, and the second comprising those which derive their supply from ground waters that have passed to shallow depths only.

So far as known all the springs in this area belong to the second class. They are numerous along nearly all the streams, which owe their persistence through dry seasons to water from this source. Most springs of this kind are small. They vary in yield with the amount and character of local precipitation, and their permanence depends on the seasonal distribution of rainfall, the areas of their individual collecting basins, and the nature of the soil and vegetation. Most of the small, so-called surface-water supplies in the State are supported to a large extent by springs of this type, but, because of their liability to fail in dry seasons and their average low yield these springs are not adapted for use as public supplies, unless they occur close together and in localities where the surplus yield during wet seasons may be stored for use in droughts. A sufficient number of springs in a favorable locality would result in either a lake or a stream. The accumulated waters from such groups of springs would possess the qualities of surface-water supplies and would properly be classed with them.

Most deep-seated springs are independent of seasonal changes and are free from surface pollution. They may, however, contain sufficient mineral matter to render them undesirable for a municipal supply or desirable for medicinal use. Springs of this type in other parts of Connecticut furnish waters of high purity and are widely exploited. Their commercial value as bottled waters, as well as their moderate yields, will doubtless continue to prevent their use as parts of public water systems.

DRILLED WELLS.

The often-expressed idea that a well of water, or even a flowing well, may be obtained anywhere by drilling deep enough is based on an erroneous conception of the occurrence of ground water. Some artesian areas, as, for example, those of Texas and South Dakota, are underlain by extensive beds of porous water-bearing rocks capable of furnishing large and continuous supplies. In such districts it is usually possible, after a few wells have been drilled, to predict with considerable accuracy the depth at which water will be found and the quantity that will be obtained. In areas underlain by such materials as those forming the rock floor of this area, however, large supplies are seldom obtained by drilling into the bedrock. Moreover, the yields of new wells can not be predicted from the records of existing rock wells because the supplies are obtained from discontinuous and irregular fissures which vary in size, distribution, and water content.

Wells that overflow at the surface are not common in Connecticut, but in some places flowing water has been obtained both by drilling into bedrock and by driving "points" to shallow depths in the drift. Where flows have been struck the head is generally low and the flow often ceases within a few days or even within a few hours. In drilled wells the flow is due to conditions illustrated in figures 5, 6, and 7. If a sloping rock surface is covered by an impervious stratum of clay or till such a stratum may confine the water in the rock crevices and generate hydrostatic pressure that forces the water to the surface when a well penetrates the impervious stratum. In some shallow wells the conditions are similar. A sloping stratum of sand or gravel confined between beds of clay may contain water under sufficient pressure to afford a flowing well when the upper impervious layer is penetrated by a driven point.

Conditions favorable for producing flowing wells are seldom encountered, and ground waters must therefore generally be recovered by pumping. Moreover, in most drilled wells the water does not rise to a level within the suction limit, and a gang of drilled wells can therefore generally not be pumped by means of a suction main, and a lift pump is required in each well except where air lifts can be used to advantage. On account of the small yields, high costs, and great uncertainty in regard to every phase of the development, drilled wells are hardly to be considered for supplying large municipalities. For villages in which the consumption does not exceed 50,000 gallons a day and where surface-water supplies are not easily available satisfactory supplies may be obtained by drilling one or more wells into rock.

DUG WELLS.

Dug wells draw their supplies from the glacial drift. They are best adapted to areas in which the drift is not very porous and yields water slowly, whereas driven wells are best adapted for areas in valleys in which deposits of porous stratified drift supply water more freely. The yield from a dug well depends on the porosity of the drift, the dimensions of the well, and the depth of the well below the water table. To obtain permanent supplies these wells must pass below the lowest position of the water table. Dug wells are not adapted for furnishing public supplies unless the amount of water required is small, and even then such a supply would hardly justify the installation of the necessary pumps and pipe lines because the cost would be great for each unit of water developed.

INFILTRATION GALLERIES.

Underground galleries or tunnels are usually constructed for the purpose of filtering stream waters. Under favorable conditions they may be used to recover ground water, but in general wherever the deposits are porous enough to yield much water to infiltration galleries, water can be obtained more economically and satisfactorily by means of driven wells. Infiltration galleries are expensive to construct and are subject to decreases in efficiency which are not easily remedied. It is probable that in this area driven wells will be found to possess a number of advantages over infiltration galleries. (See p. 35.)

DRIVEN WELLS.

The Naugatuck River valley contains deposits of coarse sediments which are capable of yielding large quantities of water, provided the recharge is adequate. The valley is narrow, however, and most of the coarse deposits rest on the valley walls (Pl. III), where they are rapidly drained and are consequently of no importance as a source of water even for domestic use. Furthermore, the valley is constricted in places and at such points the underflow is interrupted. In some parts of the valley, however, the coarse deposits below the river are sufficiently broad and deep to afford storage of large quantities of water. Driven wells with perforated iron casings 6 or 8 inches in diameter, as described on page 33, probably afford the most economical method of obtaining water from this source. A project involving the use of driven wells differs from one in which drilled rock wells are to be used in that reliable information regarding the quantity and quality of water available can be obtained at moderate cost. The thickness and extent of the water-bearing formation can be determined by rough surveys, and pumping tests by means of drive points will establish the feasibility of proceeding with the project. It seems improbable, considering the availability of surface water, that ground water could be economically used as a source of supply by a city as large as Waterbury, but it is certain that many communities, such as the villages of Beacon Falls, Thomaston, and possibly Seymour, requiring moderate amounts of water, could obtain supplies of this kind, and the cities of Waterbury, Ansonia, and Naugatuck could obtain supplementary supplies in this manner if demand should arise.

The use of driven wells is illustrated by the following plants at Brookline, Mass., Brooklyn, N. Y., and Plainfield, N. J.:

Plant at Brookline, Mass.—The following description of the municipal pumping plant at Brookline, Mass., was given by Mr. F. F. Forbes, the superintendent:[1]

The material for this paper was gathered from work which was done under my direction in Brookline, two and four years ago, to increase the water supply of this town.

The work consisted in laying a suction main made up as follows: 2,054 feet of 24-inch pipe, 2,093 feet of 20-inch pipe, 531 feet of 16-inch pipe, 1,427 feet of 10-inch pipe, and 155 feet of 8-inch pipe, a total of 6,260 feet; and driving 201 2½-inch wells, and connecting 160 wells; the other 41 wells were failures.

The plant was designed to deliver water at the rate of 5,000,000 gallons per day for as many hours each day as might be necessary to supply the town. A slight study of such a plant will convince one that it is very important that the pipes and connections should be air-tight, and so put together that they will remain in this state even if some small settling should take place in the suction main;' for not only does it cost money to pump air from which no benefit is received, but its presence in the conducting pipes lessens the amount of water they will carry, also decreases the quantity which can be taken from the ground by partially destroying the vacuum and also causes the pumps to perform badly unless the air is removed before it reaches them.

It is not an easy matter to lay a long line of pipe, drive and connect numerous wells, and leave no place through which the air can flow. Not only must the material used be without defects, but the work must be most faithfully done—the latter being by far the most difficult part. It is with much satisfaction that I can speak of the results obtained in Brookline. The plant has now been in use nearly two years without giving the least trouble from air leaks, or, in fact, from any other causes.

A description of the principal details of construction is as follows: The 24-inch suction main is connected directly to the pumps without an air separator or sand receiver. The top of this main is laid from 6 to 8 feet below the surface of the ground, and about 5 feet below the usual level of Charles River during the summer months. The main was laid at this depth for two reasons: First, that more water might be drawn from the ground, and, second, that the main might be in the most favorable position, not to be affected by expansion or contraction due to changes of temperature. The main has a slight pitch from the pump, the farther end being about 6 inches lower. This construction is necessary to allow any air which may be in the pipes to flow toward the station and not pocket at any point on the line.

This suction main is composed of ordinary cast-iron bell and spigot pipes, laid in the usual way with lead joints. Extra pains were taken, however, in calking these joints. During the laying of the main and the connecting of the wells, it was necessary to keep a 6-inch rotary pump running day and night to free the trench from water. The bottom of the trench was a rather fine sand, and the pipe was supported on a blocking reaching to a timber platform placed about 8 inches below the bottom of the pipes to allow room to calk the joints. Short cast-iron Y branches of special design were placed in the main for each well. The 2½-inch outlets of these Y branches were drilled and tapped to a templet at the foundry before being tarred, under the watch of an inspector.

The wells were connected to the Y branches by two lead connections, 2½ inches in diameter and of a weight of 11 pounds per foot. A gate with companion flanges was placed between these lead connections, the flanges forming the union joint between the wells and suction main. The soldering nipples used with the lead connections were made to order of the best steam metal. They were delivered untinned in order that any defect in them could be easily found. Special care was

[1] New England Waterworks Association Jour., vol. 11, No. 3, p. 195, 1897.

taken to solder these nipples to the lead connections. A wiped joint was not considered to be always air-tight and of this size rather difficult to make, and we finally decided to sweat the nipples in, as this process is sometimes called. The necessary heat was obtained from cast-iron plugs heated in a portable forge which fitted loosely into the nipples. The well pipes were screwed together with special wrought-iron couplings until the ends butted, and special cement was used on the threads. The wells were from 35 to 95 feet deep. Two and one-half inch tees of a special pattern were placed on the wells at a proper grade to allow them to be connected by means of the lead connections to the suction main. The piping of the wells was carried to the height of about 1 foot above the surface of the ground and capped with a special cap. The wells have open ends, no strainers of any kind being used. In the bottom pieces there are five rows of holes with nine holes in a row, spaced 2½ inches apart from centers, and bushed with ⅜-inch brass pipe.

As before stated, we have had no air leaks so far, and as the suction pipe is laid with lead joints, and the connection between this pipe and the wells made with lead pipe, thus making the whole construction flexible, we can see no reason why air leaks should ever occur.

The cost of construction of the work done two years ago, which included laying all of the 20, 16, 10, and 8 inch pipe, and driving 159 wells, is as follows:

Cost of driving and connecting 118 good wells and driving and pulling up 41 poor wells.

Cost of labor, driving wells	$1,561.00
Cost of labor, connecting wells	210.00
Cost of labor, pumping out wells	369.00
Cost of the well pipes, not including bottom pieces	572.06
Cost of the bottom pieces	196.23
Cost of preparing bottom pieces	118.00
Cost of the gate tops for wells	360.37
Cost of the gates	660.80
Cost of 2½-inch tees	94.40
Cost of soldering nipples	250.16
Cost of solder	23.00
Cost of ⅜-inch rope	5.31
Cost of oil	6.25
Cost of red and white lead	23.59
Cost of lead pipe	333.40
Cost of making lead connection in the shop	52.50
Cost of 2½-inch plugs	2.29
Cost of 2½-inch coupling	155.40
Cost of pulling up poor wells	80.00
Cost of Akron pipe for gate boxes	306.92
Cutting threads on pipe	206.72
Teaming	14.00
Miscellaneous	51.26
Total cost of wells	5,652.66
Number of feet of good wells driven	5,977
Number of feet of poor wells driven	1,741
Total	7,718
The average depth of the wells	50 feet.
Average number of feet driven per day with gang of four men	50 feet.
Cost of labor driving wells, per foot	$0.21
Average cost of each good well, including driving and connecting and expense of driving and pulling the poor wells	$47.90

Cost of laying the suction main.

Cost of labor	$10,428.32
Cost of lumber	1,118.55
Cost of pipes	6,248.07
Cost of gates	341.16
Cost of lead	515.09
Cost of pumping, the engineer	458.56
Cost of pumping, coal	174.71
Cost of unloading pipes	39.00
Cost of inspecting pipes	183.00
Cost of rubber boots	210.00
Cost of shovels	52.00
Cost of carting men to and from work	947.30
Cost of hauling the pipe from cars	300.00
Cost of expressage	79.30
Cost of oil for engine	4.80
Cost of jute packing	12.74
Miscellaneous	155.43
Total cost of laying pipe	21,268.03
The amounts laid are as follows:	
20-inch pipe	2,023 feet.
16-inch pipe	551 feet.
10-inch pipe	1,420 feet.
8-inch pipe	155 feet.
	4,149 feet.
The total cost of laying pipe	$21,268.03
The total cost of driving and connecting wells	5,652.66
Total cost of system	26,920.69
The total cost of laying the pipe, driving and connecting wells, per foot of suction main	6.45

Plant at Brooklyn, N. Y.—The borough of Brooklyn, N. Y., obtains a large part of its water supply from driven wells arranged in gangs at several places on Long Island. The first wells constructed were of the closed-end type, but later ones are of the open-end type. The wells are arranged in two rows, one on each side of the suction main, the wells in some gangs being in files and in others staggered. A description of one of the new plants is as follows:

The main suctions are about 2,340 feet long with a fall of 12 inches from center to each end. The 62 wells are staggered along the main suction pipe, 12 feet from it and 75 feet apart on each side. Their average depth is 45 feet, a stratum of fine sharp sand being met with at that depth. The outside casing is 4½ inches, with a 6-foot strainer, 2-foot sand pocket,[1] and 6-inch point. Suctions are 3 inches in diameter and 28 feet long. Lateral branches are 3½ inches, and each is provided with a gate. It is expected to get 6,000,000 gallons from this station. The contract price for the last 25,000,000 was $167,250 for sinking and connecting wells, the yield to be determined by a test lasting one year and taken as the lowest average for five consecutive days.[2]

[1] A sand pocket is a large drum or box inserted in the suction pipe to catch sand that is drawn up with the water. It is provided with handholes to facilitate cleaning.

[2] Turneaure, F. E., and Russell, H. L., Public water supplies, p. 308, 1909.

Plant at Plainfield, N. J.—The following is a description[1] of the driven-well system at Plainfield, N. J.:

The region itself is a comparatively level valley, some 7 miles long and from three-fourths to 2 miles wide, is fairly well wooded, and slopes gently to the westward. It is divided by a small stream running to the southwest, having several short tributaries; together they furnish excellent surface drainage for the city.

The soil consists mostly of sand, clay, and gravel strata, rock not being encountered, except at considerable depths.

It has always been an easy matter to procure water in abundance for domestic use by driving pipe wells from 20 to 80 feet deep at each residence, and attaching pumps directly thereto; and for fire supplies, sinking large brick curbs some 15 or 20 feet into the gravel gave an abundant flow. But obviously, with the increasing population and no sewerage system, individual wells became a source of danger to health, yet for nearly 20 years no definite result was accomplished, more than the mere organization of a private water company.

In 1890 active measures were taken and tests and examinations made, which finally resulted in the sinking of pipe wells on a plot of ground 1½ miles east of the center of the city in a soil where the upper clay stratum was some 30 feet or more in thickness, underlain by a very coarse water-bearing gravel. This spot was selected for its freedom from probable contamination on ground slightly higher than the city, which at the same time was convenient.

Several test wells were sunk at various points previous to the observations of the writer, and pumping tests made with a low-lift pump of a number of the main wells then driven, under the care of Mr. Rudolph Hering, M. Am. Soc. C. E. The quantity of water obtained from 10 wells for periods of eight hours' daily consecutive pumping, during two weeks of observation, was at the rate of from 2,000,000 to 2,125,000 gallons in 24 hours.

An inspection of Plate III [IV in the present report] will show the final arrangement of the wells, test wells, pumping plant in general, and details of the well tubes. The construction of the cast heads is such as to transform each water tube into practically an open well, giving atmospheric pressure free play rather than forcing its action through the earth, as in systems where but a single tube is used. The most distant well is 500 feet from the pumps and shows in an interesting manner by the vacuum at the well head and increased vacuum at the pump the effect of long suction and friction in the main.

The 2-inch pipe test wells * * * were observed daily by the writer, while resident engineer, during several months. They each had a simple balanced float gage and scale, which indicated the rise and fall of water level. They were all very sensitive to draft on the main wells when pumping was going on, though the nearest was 200 feet from the line of wells.

Comparison of these observations under the different conditions and seasons showed, among other things, that in about 1,900 feet the underground water level fell to the westward about 3 feet, or at about the same rate as the average surface of the ground. This evidenced conclusively that the flow of water was toward the city with a head sufficient to prevent any back flow of contaminated waters from the city.

In summary, the plant consists of 20 wells 6 inches in diameter from 35 to 50 feet in depth each, ranged in a double row on a strip of land 25 feet wide and 1,000 feet long, having in each a 4½-inch open-end suction tube, connected with a wrought-iron main varying from 8 to 12 inches in diameter. This main is in two sections, each 500 feet, connecting 10 wells.

Two compound surface-condensing duplex plunger pumps, Worthington make, one of 3,000,000 and one of 2,000,000 gallons daily capacity, and a boiler plant of

[1] Tribus, L. L., Am. Soc. Civil Eng. Trans., vol. 31, No. 700, pp. 371 et seq., 1894.

sufficient power, with various essential small machines, are housed in a rough-stone building, slate roofed.

The water, drawn as before stated, direct from the wells, is pumped into a wrought-iron standpipe (situated near at hand) 25 feet in diameter and 140 feet high, through a 20-inch interior tube rising 5 feet above the top. Two lower openings on this rising main, with valves operated from the outside spiral staircase, afford opportunity for filling the standpipe at lesser head if required.

The object of this interior tube, which was almost unique when erected, is threefold:

First, by its fountain action, enforcing complete aeration.

Second, complete circulation.

Third, to afford instant fire pressure, no matter what the elevation of water in the main tower. This is accomplished by opening a by-pass, not otherwise used, connecting the rising main and the distribution line, the city's supply being drawn regularly from the bottom of the standpipe with pressure due to level of water in main tower.

From the standpipe the Plainfield pipe system extends to the west, comprising some 30 miles of mains from 6 to 16 inches in diameter, having fire hydrants spaced about 11 and valves 6 per mile. * * *

After the tests made by Mr. Hering and the partial completion of the works, various other tests were made with the permanent pumping plant. It was found that the wells on the westerly line yielded more abundantly than the easterly ones, under equally good conditions, and gave a lower vacuum for the same quantity pumped. * * *

The tests were made with the large pumps, under both free discharge and full working head, singly and together, and drawing from the wells in groups of 5, 10, 15, and 20, using each combination of 5; also, by cutting off one by one until the smallest number that could be used was reached, then adding one by one in reverse order. until the full series were again in use. Five wells were found to be the smallest number possible to use and run the pumps smoothly. Wells Nos. 6 to 10 gave the best results, while Nos. 16 to 20 furnished but little water. The best results were obtained for a full flow by using Nos. 1 to 15 inclusive. * * *

During the long-continued dry weather of 1891 the water level became so low that difficulty arose with the extreme suction lift obtained, from 20 to 28 feet, according to rate of pumping, a fall of some 6 or 7 feet since the earlier observations, so that in the summer of 1892 it was deemed best to lower the pumps, which was done to the depth of 8 feet 1 inch below the former positions.

For the sake of a constant observation and record, a 3-inch open tube was driven from the engine room into the water-bearing gravel, and a permanent float gage suspended in it, indicating by a balanced point on a scale of feet placed conveniently in the room. Although some 80 feet from the nearest main well, therefore not showing the lowest level of the water at the wells when pumping, it does show the relative water level under the same conditions and the daily and monthly range. When pumping, the average lowering of the gage is about 8 inches, with an almost immediate return after stopping the pump.

Rainfalls need to be exceptionally heavy to make any marked showing in the water level, and not much then inside of 24 hours. This seems to indicate that the water supply comes from a distance, but there is an insufficiency of data for determining this interesting point.

In these two years or more of operation, the wells have furnished daily, without difficulty or signs of falling away, the full demand of from 200,000 gallons at the start to 1,700,000 gallons at the present time, apparently derived, as the early tests indicated, from the western 15 of the 20 wells driven. The water itself has been of uniformly excellent quality, both for domestic and manufacturing purposes; so far, therefore, a decided success as an underground water supply.

GROUND WATERS FOR PRIVATE USE.

Most of the private wells in Connecticut are used for domestic supplies, although a few are used by manufacturing plants. The problems involved in obtaining a supply of good water from private wells have seldom been seriously considered. Many of the wells were dug before present-day ideas of sanitation became prevalent; they were constructed in the best manner possible under the circumstances, and for a long time they have been regarded as admirable relics of earlier days; and there is a disposition to copy them even at the expense of both sanitary and economic considerations.

Sanitary precautions are necessary not only in the case of dug wells but also in the case of springs and drilled wells. Springs are especially susceptible to pollution because the water is obtained at the surface and almost always on a slope where surface drainage can readily enter the pool. Springs should be equipped with a concrete reservoir and kept covered, and the water should be drawn from a delivery pipe. Such an equipment is not necessarily elaborate or expensive. It is important only to provide for the exclusion of surface drainage and the prevention of contamination either by persons or animals by preventing access to the stored water. Drilled wells properly constructed by reliable drillers exclude surface waters. If the well casings are properly set and the pump fittings are tight, such wells are in little danger from pollution.

The average per capita consumption of water from private wells is much less than the consumption from public supplies, largely owing to the general lack of convenience in well equipment; consequently the amount of water required will depend on the equipment to be installed. For example, about ten times as much water will be required if a pneumatic or a tower system is to be installed for the purpose of furnishing running water in the house and barns as if the equipment were to consist merely of a hoisting bucket or a small hand pump. The type of well is also a factor. An ordinary dug well yielding continuously 2 gallons a minute might, because of its storage capacity, meet a temporary draught of 50 or 100 gallons a minute; whereas a driven well, having no stored supply, could not meet a draught in excess of its maximum yield. Therefore, the estimate of the quantity required should be based not only on the total amount of water used in a day but also on the greatest rate at which it is to be pumped from the well.

The water delivered by springs is, in general, of the same quality as the water to be obtained from shallow wells in their vicinity. Therefore the choice between opening up a spring and sinking a well depends on the relative cost and the resulting convenience. Springs so situated that water may be delivered to buildings by gravity afford very desirable supplies, but springs situated at low elevations and therefore requiring pumping afford no more economical supplies than dug wells.[1]

The water obtained from dug wells is slightly harder than surface water, but in Connecticut the difference is ordinarily not appreciable, well waters, so far as their mineral quality is concerned, being suitable for ordinary domestic use.

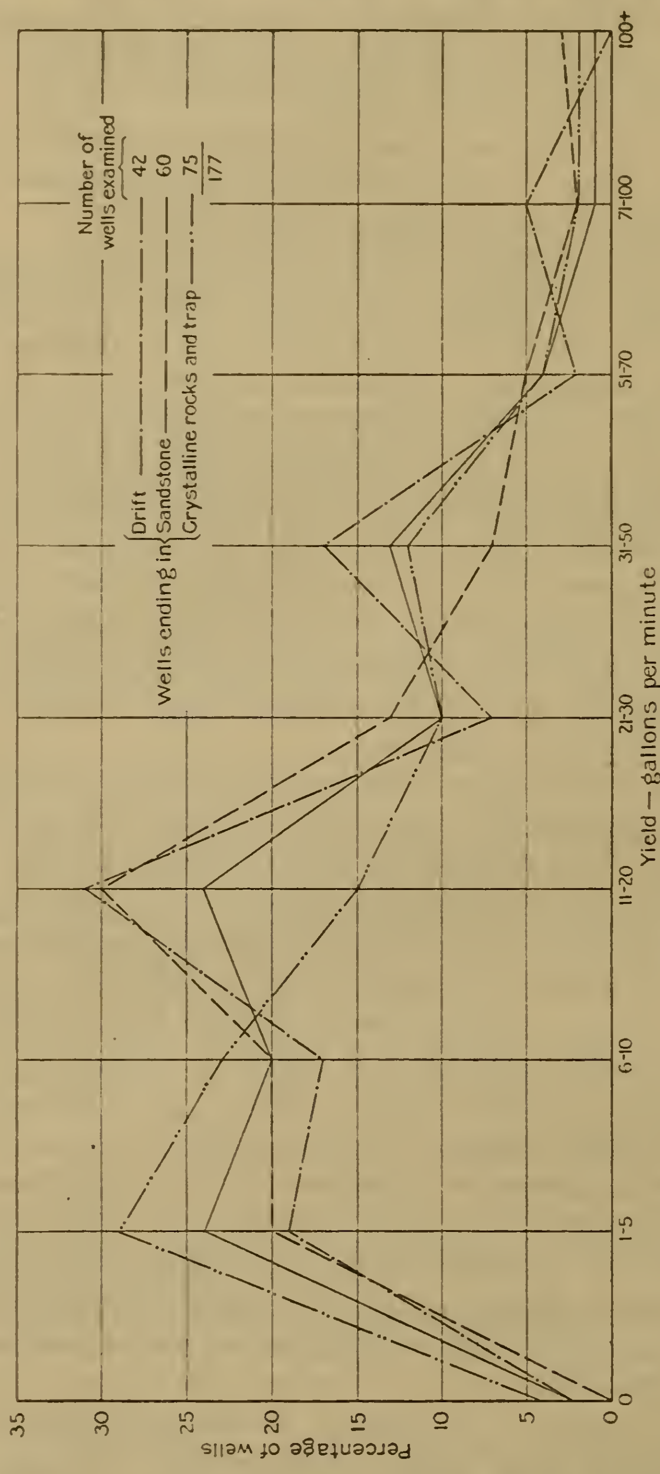


FIGURE 8.—Curves showing yield of drilled wells.

Dug wells generally afford satisfactory domestic supplies, but they should not be expected to do so without some attention. Wells, especially open wells, that have not been cleaned for 25 years and yet remain serviceable are not always things to be proud of, a fact that is generally discovered when the wells are cleaned.

Where the unconsolidated material consists of sand or gravel, driven wells are likely to be more convenient than wells of other types. Driven wells are especially adapted to use in gardens, pastures, and barn yards, where water is required for stock and plants and where dug wells would be objectionable.

The water from driven wells is of the same mineral quality as that from dug wells in the same vicinity since it comes from the same source, and it is to some extent susceptible to pollution.

[1] Fuller, M. L., Underground waters for farm use: U. S. Geol. Survey Water-Supply Paper 255, 1910.

Therefore the surroundings of driven wells should be kept scrupulously clean.

Drilled wells generally yield at least 2 or 3 gallons a minute, a quantity adequate for most households. (See fig. 8.) The water is generally suitable for domestic uses, although in Connecticut it may be harder than the water of shallow wells.

METHODS OF DEVELOPING GROUND-WATER SUPPLIES.

DRILLED WELLS.

CONSTRUCTION.[1]

Two general methods of well drilling are employed in obtaining water supplies, namely, the percussion method and the abrasion method. In Connecticut the percussion method is most commonly used. It consists of lifting and dropping, by means of suitable apparatus, a heavy string of drill tools which punches or cuts a hole through the unconsolidated materials and breaks the solid rock into fragments small enough to be removed from the hole. When drilling is done in unconsolidated material iron pipe or well casing as large in diameter as the hole will admit—usually either 6 or 8 inches—is generally driven down as rapidly as the drill descends, each added length of casing being securely screwed to the preceding one to make a tight joint. If the well penetrates bedrock, the casing is driven a few feet into the rock to prevent infiltration of surface water. If the well ends in loose materials the casing extends to the bottom of the hole and may be perforated or slit at the lower end to admit water more rapidly. The casing is allowed to extend several inches above the surface of the ground to prevent inflow of surface water, and a flange is fitted to the top, to which a pump is attached.

In drilling by the abrasion method hollow drill tools armed with some harder materials, such as diamonds or chilled shot, are rotated on the rock in such a way that a cylindrical core is cut out and brought to the surface in short pieces. The wells sunk by this method are finished in the same way as those made by percussion drilling.

Drillers differ in opinion as to the relative efficiency of these two methods, the points of contention being that the abrasion method is more expensive and that the rotation of the drill tools tends to seal up the smaller veins, thereby affording a comparatively lower yield than is obtained by percussion drilling. Data bearing conclusively on these questions are lacking, but the fact remains that both methods are used, the percussion method to a much larger extent, and that good results are obtained by each.

[1] Bowman, Isaiah, Well-drilling methods: U. S. Geol. Survey Water-Supply Paper 257, 1911.

COST.

Owing to the competition among well drillers there is no uniform scale of prices for drilling wells. The minimum prices charged range from about $1 to $4 per foot, including the casing. Usually the minimum price is charged for the first 100 feet and an additional charge of about $1 per foot is made for each succeeding 100 feet or fraction thereof. Other factors which affect the prices are the character of the bedrocks and depth of the unconsolidated materials; the accessibility of fuel and water for the engines and the distance from the well to suitable lodging places for the drillers.

No reliable driller will agree to obtain a water supply within a given depth in the bedrocks of the Waterbury area. A driller may offer to obtain a certain amount of water for a stated sum of money, but as he can not predict the depth or the location of a successful rock well such an arrangement amounts to little more than a game of chance, in which the advantage is necessarily largely on the side of the driller.

QUALITY OF WATER.

Drilled wells are usually protected against contamination by their manner of construction and this is one of their chief advantages. The principal disadvantages of drilled rock wells lies in the fact that neither the quantity nor the mineral quality of the water can be definitely ascertained before drilling and consequently an expensive well may be drilled without obtaining a suitable supply.

The water from drilled wells that end in the drift at depths of 75 or 100 feet is just as likely to be free from pollution as that from wells that end in rock, and it is less likely to contain undesirable amounts of mineral matter. Moreover, drilled wells that end in the rock are not invariably free from pollution, especially where the rock outcrops or lies a short distance below the surface, owing to the possibility of the passage of infected matter through open rock fissures to the well. Many rock wells situated near the coast are contaminated by salt because some of the fissures intersected by the well come to the surface below tidewater. The contamination in such wells is easily detected, but it is not so easily detected if fissures contributing to the water supply come to the surface in barnyards or in the beds of polluted rivers. It is not necessarily a fortunate thing if a well strikes a vein that yields water giving an "odor of sulphur" because odors not easily distinguishable from "sulphur" may be due to pollution. The origin of any odors, colors, or tastes should be determined before a water is used. Even deep drilled wells may be contaminated in a thickly populated community unless the protective cover of clay is thick and the casing is water-tight and fits tightly into the drill hole.

IMPROVEMENTS.

Drilled wells which end in the drift do not differ essentially from driven wells, and they should be finished in the same manner. The casing should be perforated or slit at the principal water-bearing horizons and for some distance above the lower end. This will generally increase the yield materially.

Some wells that produce water of an undesirable mineral character may be improved by casing off the mineral water and drawing from a different horizon. This method is not likely to be generally successful in Connecticut, however, because the quality of the groundwater does not differ very much from one local horizon to another.

If the yield of a well is reduced by pumping from other wells in the vicinity the pump cylinder should be lowered, and if this does not recover the yield, deepening the well may do so; but there is likely to be more or less permanent interference when a number of wells are drilled close together. A method of increasing yields of drilled wells which has not been used sufficiently to warrant its recommendation for general use consists of exploding a charge of nitroglycerine or dynamite at the bottom of the well, the object being to develop radiating fissures that may tap otherwise unavailable water veins. This method is used extensively in improving oil wells, and there appears to be no reason why, under favorable conditions, it should not be equally beneficial in water wells. In many cases it would be advisable to try this remedy before abandoning dry holes ending in rock. It is not recommended for wells ending in drift.

DRIVEN WELLS.

Two general types of wells are classed as driven wells, namely, the closed-end well and the open-end well. A closed-end well is constructed by driving into the ground with a sledge or drop hammer a "drive point" and strainer screwed to a piece of pipe. Other lengths of pipe are added and the driving is continued until the strainer penetrates the groundwater horizon (fig. 9). The diameter of the pipe and strainer may be 1 inch to 4 inches and the length of the strainer is usually between 1½ and 4 feet.

The open-end well is constructed by driving a casting into the ground and at the same time removing the material from the interior by means of a sand bucket or sand pump or a jet of water. If the formation is rather hard, it may be necessary to remove the material in advance of the casing by means of a heavy sand pump or combination jet and drill, or ordinary drilling may have to be done. A strainer may be attached previous to driving, or it may be adjusted after the casing is down by lowering it on the inside. Where the water-bearing deposits include coarse material and large quantities of

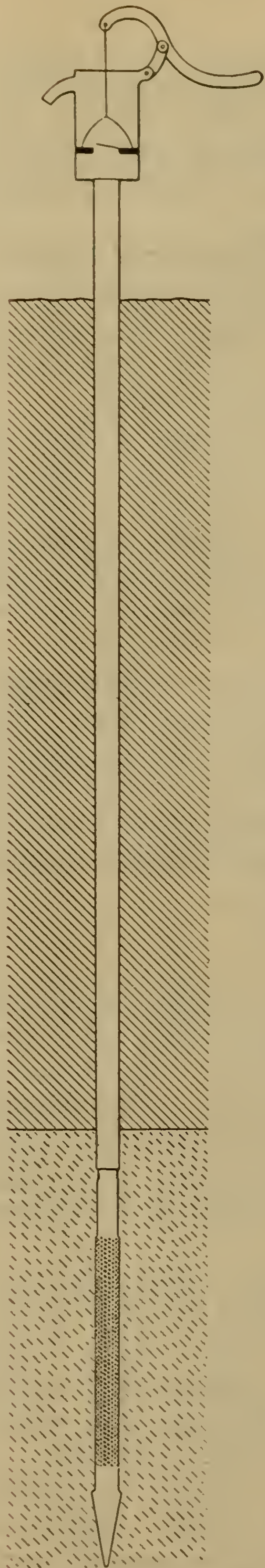


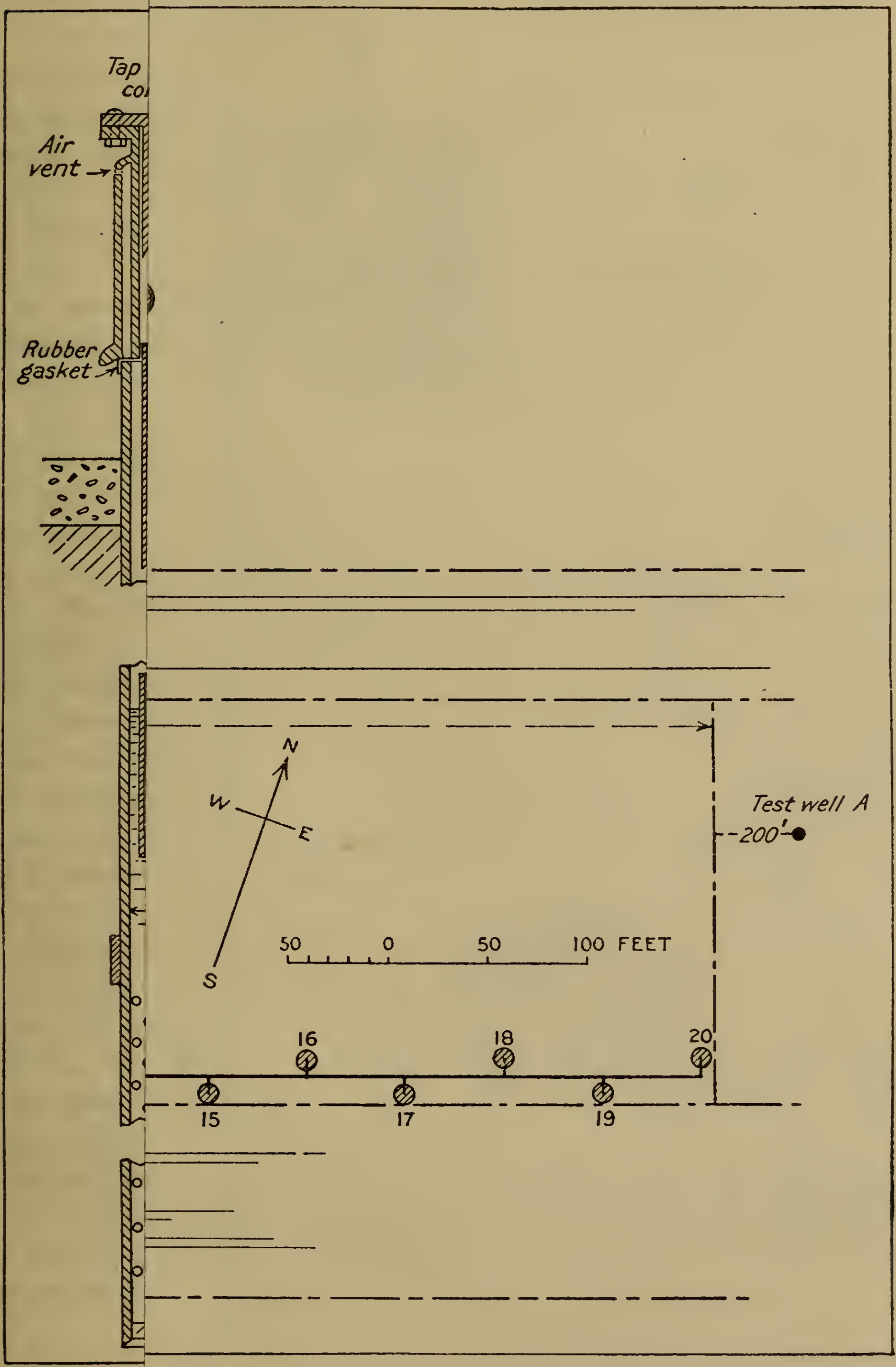
FIGURE 9.—Diagram of driven well.

water are desired, as for municipal or industrial supplies, the most satisfactory results will be obtained by not using any of the ordinary strainers, but by perforating the casings where water is to be admitted with numerous circular holes at least one-fourth inch in diameter or slits at least one-fourth inch wide. These perforations can be cut or drilled before the casing is inserted, or they can be made by perforating tools after the casing is in place.[1]

After the casing is in place and the perforations have been made the well should be thoroughly cleaned out, in order to remove the fine sediments and give the water free access to the well. This can best be done by first using a sand bucket or sand pump and then applying an air lift. If an air lift is not available, rapid pumping with a centrifugal or other pump can be substituted. Strong wells can often be developed by removing large quantities of sand and silt and thus leaving a thick layer of clean gravel around the intake of the well. Wells of this type are better adapted for harder ground and larger diameters than the closed-end well. The use of drive points is restricted to areas in which water can be obtained in rather fine gravel or sand at moderate depths, but open-end wells may be used in almost any unconsolidated deposits and they may be sunk to depths of several hundred feet. It is probable that in Connecticut either drive points or the usual drilled wells ending in the drift and having the casings perforated will be found satisfactory.

Driven wells are used both in domestic and in municipal supplies. For domestic purposes it is seldom that more than one well is required to furnish the desired amount of water, but for public supplies for large towns these wells are commonly driven in gangs, arranged in one or two rows along a suction main to which each well is con-

[1] Bowman, Isaiah, Well-drilling methods: U. S. Geol. Survey Water-Supply Paper 257, pp. 67–69, 1911.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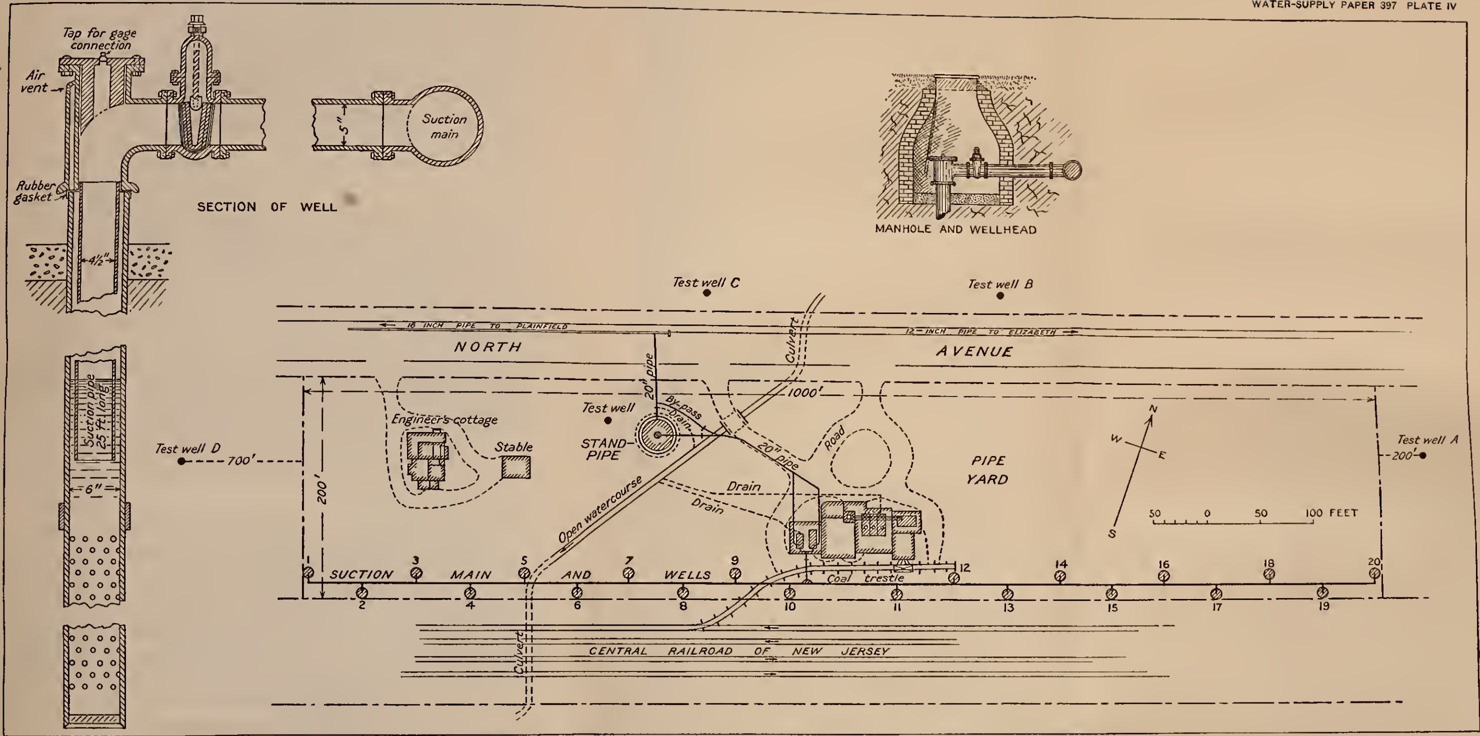

PLAN OF PROPERTY AND DETAIL OF WELLS, WATER SUPPLY OF PLAINFIELD, N. J., 1891.

nected by a lateral branch (Pl. IV). The most economical system is one in which the suction main can be laid on the surface of the ground, but in some systems, either for the purpose of obtaining the maximum yield or because the water stands below the suction limit from the surface, it is necessary or desirable to lay the suction main in a trench.

It is not possible to give figures in regard to the requisite number of wells and their size and spacing that would be everywhere applicable, owing to the diverse conditions under which such plants are used; but in general it is advisable to place the line of wells at right angles to the direction of underflow, and the distance between the wells should be between 15 and 100 feet, depending on the size of the wells. The number and size of wells to be used will be determined by the amount of water required, the size and character of the water-bearing formation, and by the results of pumping tests to determine the permeability of the formation.

One of the principal difficulties encountered in the operation of driven wells is clogging. Infiltration of fine sand or incrusting of the strainer may reduce the yield of a well materially, and it is necessary, therefore, to keep the tube clean. It is usually advisable to subject a newly driven well to heavy pumping for the purpose of drawing out the fine material adjacent to the strainer. Coarse material will be left in its place, forming a natural screen, which will minimize the tendency to clogging, and the yield of the well will be increased by the consequent increase in the porosity of the material surrounding the screen.[1] When clogging is due to sand only it is usually possible to remove the obstruction by forcing water into the wells under high pressure or by means of a steam jet, but when the sand is cemented it is necessary to withdraw the strainers to be cleaned or replaced by new ones.

The liability to pollution of supplies from driven wells depends on the depth from which the wells draw, the effectiveness of overlying clay beds in shutting out pollution, the amount of water that is drawn, and other conditions. Though the danger of pollution is less than in open dug wells care should nevertheless be exercised in the selection of sites and in protecting the surroundings against contamination. Where large supplies are developed, such as are required for large municipalities, there is danger of drawing polluted water from near-by streams though smaller supplies drawn from the same wells might not be in danger of pollution.

INFILTRATION GALLERIES.

Infiltration galleries are trenches or tunnels, with sides and roofs constructed usually of masonry or concrete and the floors made to admit water. Galleries may be built in the banks or beds of streams

[1] Meinzer, O. E., Geology and underground waters of southern Minnesota: U. S. Geol. Survey Water-Supply Paper 256, p. 86, 1911.

for the purpose of intercepting the underground drainage as it approaches the streams. The deposits in filled valleys are saturated below the level of permanent streams, and galleries located in such deposits offer practicable means of obtaining water supplies. The bottom of a gallery may profitably be made lower than the bed of the stream to insure the maximum infiltration. Water from the stream itself does not enter the gallery unless the draught on the gallery exceeds the infiltration from the landward side. A gallery is a modified form of dug well, from which it differs essentially only in capacity and the same sanitary rules apply to both.

DUG WELLS.

The most common type of well is a dug hole, 2½ to 4 feet in diameter and deep enough to procure a suitable supply of water. The hole is then walled up from the bottom to the surface of the ground with loose irregular stones and bowlders picked up in the vicinity of the well. Brick laid in mortar and glazed tile have been used to a small extent for walls, but these materials, although much more desirable for the purpose, are more expensive than the stone commonly used. The top of the well is commonly finished by fitting a square curbing of boards over the hole and adding a wheel or windlass for hoisting a bucket. Better equipments, ranging from screened well sheds to concrete seals with good pumps, are found in many wells. Wells of this type generally end in the drift, but in areas where the drift is thin they may end at the rock surface or penetrate the rock a few feet, in which case the rock is removed by blasting. The principal advantages of the wells of this type are the ease with which they may be cleaned and refitted with pumps, and the large storage capacity; the chief disadvantages are their liability to pollution and their response to changes in the weather.

The following extract [1] regarding the essentials of a good well is an excellent summary of the proper sanitary construction of dug wells:

> The location of the well is of the greatest importance. It should be as far as possible from the house, barn, and privy. If possible, the surface of the ground about the well should be a little higher than the surrounding soil so that any surface washings may be carried away from the top of the well. The ground about the top should be well sodded in grass. This not only adds to the attractiveness of the well but it takes care of a great deal of water that would otherwise have to stand in pools about the well. If the stock have to be watered from the well, there should be a pipe leading to a stock trough not less than 20 feet away, so that the stock need not come up to the well itself.
>
> A well, to be safe, should be not less than 20 feet deep. That is to say, 20 feet from the surface of the ground to the top of the water. It should go well through the surface soil, preferably through a layer of clay. The lining should be of brick or stone laid in cement. Any lining that allows water to seep through it above the

[1] Virginia Health Bulletin, vol. 1, p. 113, September, 1908.

surface of the water may lead to pollution. The space between the casing and the surrounding soil should be filled with sand or earth.

The top of the well should be raised from the ground about a foot and set in cement or masonry coping that goes at least 3 feet below the surface of the ground. Over the top should be laid a solid, double tongue-and-groove flooring that is absolutely waterproof. This is essential. Most wells are polluted by material that falls in or is washed in from the top, and not by seepage through the soil.

On the well top there should be a good pump, carefully set so as to exclude leakage from around its base. If the pump can not be used there should be an automatic tipping bucket. The well bucket should not be handled with the hands. Many wells have been infected by handling the bucket with soiled hands and then letting it back into the well, the filth being then washed off into the water.

Below the spout there should be a trough with a pipe leading some distance away so that the waste water may be carried away from the well.

A well constructed in the manner described above will almost always furnish water that is perfectly safe, and the saving of sickness and trouble will many times overpay for the expense and care involved.

For convenience in discussion, dug wells may be divided, according to their relation to bedrock, into groups to include, first, wells that penetrate bedrock; second, wells that just reach rock; and third, those that end in drift.

Wells that penetrate bedrock are sunk in localities in which the drift is thin. The thickness of the water bed in the vicinity of such wells may be less than the normal fluctuation of the water table, and consequently in times of drought there may be no available water in the drift. But the rock basins generally act as reservoirs for the storage of water which has seeped in from the drift, and these wells therefore usually carry small supplies through dry seasons. In cleaning rock wells, and sometimes in digging them actual veins of water are encountered, and this has led to the belief that the well supply is derived from some deep sources in the bedrocks. While such a condition is possible, most of these "veins" are shallow, water-filled cracks, developed naturally in the rock or produced by blasting. These cracks, radiating from the well, tap all along their courses the saturated zone of the overlying drift, and thus make it possible for the well to drain a much larger area than it otherwise could.

Wells that extend to the surface of the bedrock are usually found in areas of thicker drift than are those which penetrate the rock. Like the rock wells they pass entirely through the saturated part of the drift but they do not contain a stored supply and therefore fail if the water table sinks to the rock surface. Consequently in localities where both types are found the supplies of the rock wells last longer in times of drought, although the others, drawing from a greater average thickness of saturated deposits, have a greater average yield.

Most of the wells that do not reach rock are found in areas of deep drift. These wells are sunk below the water level to a depth which at the time of digging is considered sufficient to supply the required

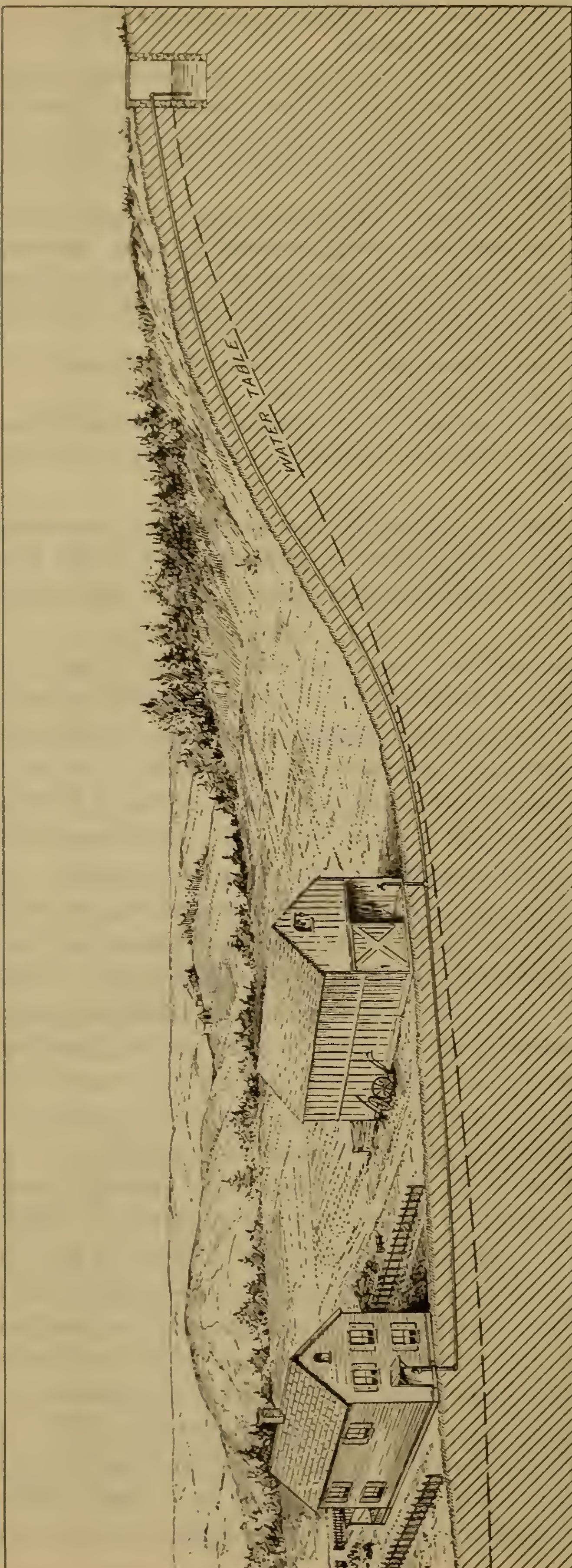

FIGURE 10. Sketch showing siphon well and domestic waterworks.

amount of water. Most of the wells which fail are of this kind, the failure being usually due to some one of of the following causes:

(*a*) The well may be too shallow. To be reliable it should be sunk at least several feet below the lowest water level. This can be most easily accomplished during dry seasons.

(*b*) The well, originally deep enough, may become "filled in" with sand and mud carried by inflowing water. In this manner the bottom of the well may be raised in wet seasons, when the water table stands high, to a level below which the water table sinks in dry seasons.

(*c*) There may be a permanent lowering of the water table so that the bottom of the well lies within the zone of fluctuation. This may result from tiling, from a heavy draught on wells, or from lowering surface drainage either by removing dams or by deepening the channels of neighboring streams.

Wells that end in the sand or loose till should be cleaned about once a year. Wells that end in the rock may require attention less often. In any case cleaning should be the first remedy employed to restore the yield of a well. If this is not effective then the well should be deepened, and if this is done when the water is lowest it will be easy to judge the necessary depth.

Wells may be deepened without disturbing the old wall by sinking 18-inch or 24-inch tiling from the original bottom to the required depth. A method sometimes employed where the well ends in sand consists in driving a "point" (p. 34) into the bottom of the well to the necessary depth. If the strainer is more than 25 feet below the surface of the ground—that is, below the suction limit—the pump cylinder may be attached at some point between the surface of the ground and the bottom of the dug well. In some cases, especially those in which the well ends in rock, the most feasible way to obtain a suitable supply is by drilling from the bottom of the old well. This amounts practically to constructing a new well except that the cost of drilling to the depth of the old well is saved.

An adaptation of the dug well which is popular in some parts of Connecticut is illustrated in figure 10. This consists in placing a well on a hillside above the house and barns so that water may be delivered to the buildings by gravity and under pressure. This is an excellent device wherever it can be used.

DESCRIPTIONS OF TOWNS.

ANSONIA.

POPULATION AND INDUSTRIES.

Ansonia is in the western part of New Haven County near the mouth of Naugatuck River. It is reached by the Berkshire and Naugatuck divisions of the New York, New Haven & Hartford Railroad and by the Derby division of the Connecticut Co.'s Electric Railway. Ansonia was separated from Derby and incorporated in April, 1889. Its area is 6 square miles. The town and city are consolidated.

The population in 1910 was 15,152. The census reports for 1900 and 1890 give 12,681 and 10,342, respectively. The principal industries are the manufacture of brass and copper articles, iron casting, and general foundry work.

TOPOGRAPHY.

The east boundary lies along the divide between Wepawaug River and Naugatuck River, and the town extends westward to the top of the west valley wall. The highest elevation—450 feet above sea level—is about the middle of the east boundary, and the lowest—about 18 feet above sea level—is at the place where Naugatuck River crosses the south boundary of the town. The valley floor in Ansonia has an average width of about 1 mile.

Naugatuck River receives all the drainage except that from a very small area in the southern part of the town, which enters the Derby reservoirs. About one-fourth of the town is wooded, the timbered areas including most of the northeast quarter and some of the slopes in the southeast and northwest quarters.

WATER-BEARING FORMATIONS.

Bedrocks.—The Prospect granite gneiss and the Orange phyllite (p. 9) compose the rock floor of Ansonia. These rocks are dense, and it is only through their ramifying system of joint cracks that they are capable of furnishing moderate supplies of water (p. 17). The bedrocks are exposed in the hills and on some of the slopes, as indicated in Plate III, but exposures are not so numerous here as in Seymour.

Till.—Unstratified mixtures of clay, sand, gravel, and bowlders deposited by the last retreating glacier constitute the rock cover on the hills. It ranges in thickness from a few inches to 30 or 40 feet and yields moderate domestic water supplies where the thickness exceeds 10 or 15 feet (p. 11).

Stratified drift.—Stratified deposits, consisting of poorly sorted sand and gravel, occur along the river, and a few small deposits are found in the valleys in the eastern part of the town. The stratified deposits along Naugatuck River are capable of yielding supplies to shallow wells, but the deposits in the eastern part of the town, on account of their topographic position and their small extent, are not important as water-bearing formations (p. 13).

SURFACE-WATER SUPPLIES.

Surface waters are used to a moderate extent both for power and for domestic consumption. The brook that rises in the southeast corner of Seymour and joins Naugatuck River at Ansonia is the principal source of the Ansonia supply. The Ansonia Water Co. maintains an ice pond on this brook near Ansonia, and not far below it is a dam that furnishes power for the Cook machine shops. A dam in Naugatuck River just north of the Seymour line diverts water into a power canal which, together with a dam at Ansonia, furnishes power for factories in the city. A site for a small storage reservoir near the headwaters of Twomile Brook is said to be regarded by the Ansonia Water Co. as a possible additional source of supply for the city.

According to tests of monthly samples from Naugatuck River at Ansonia made by the Connecticut State Board of Health from 1894 to 1897 the water of that stream contains an average of 54 parts per million of total solids, 16 parts of which is volatile matter and 3.8 parts is chlorine, and has a total hardness of 14 parts and a color of 39 parts.[1]

[1] Compiled from data in annual reports of the State Board of Health of Connecticut for 1894–1897.

GROUND-WATER SUPPLIES.

The 11 dug wells which were examined range in depth from 11 to 35 feet and average 19 feet. The depth to water ranges from 9 to 29 feet and averages 16 feet. Most of the wells are of the ordinary open type, walled with cobblestones, and equipped with a rope and bucket lift. The supplies obtained from these wells are generally adequate for ordinary domestic needs. Only one of the walls is said to fail, but it is probable that failures would be more common if the city water were not so generally available.

Six drilled wells were examined, three of which were said to be 70 feet deep. The meager data in regard to these wells are given in the table on page 43.

Owing to the small area of Ansonia and the possible extension of the public water systems, it is not likely that private ground-water supplies for domestic use will be in great demand. It is probable that if new developments are undertaken because of its low cost the dug well will continue to predominate. In all parts of the town outside that represented by the dotted area in Plate III till or rock, or both, will be encountered in sinking a well. Water will be obtained at a depth of about 5 to 20 feet, except on some of the steepest drift-covered slopes, where the depth may in some places exceed 20 feet. The rock surface is very uneven and may be encountered at any depth below the ground, but where the depth is less than 10 feet it would usually be more economical to drill a well than to dig one. The amount of water available by means of dug wells will generally be adequate for ordinary domestic needs. In the area of stratified drift (Pl. III) shallow dug wells are very likely to be contaminated, and if private supplies are desired they should be obtained by means of drilled or deep-driven wells.

On account of the thinness of the drift most drilled wells draw their supplies from the bedrocks. Supplies from this source vary largely in quantity, and the success of any particular well can not be predicted. However, most of the drilled wells furnish ample supplies for domestic needs, so that it is reasonably safe to invest in drilling if that kind of a supply is desired.

Driven or drilled wells ending below the river level in stratified deposits would doubtless yield large supplies, but if the draft were heavy and continuous it is probable that sooner or later contaminated water from Naugatuck River would be drawn from the wells.

PUBLIC WATER SUPPLIES.

Ansonia is supplied with water by two private companies. The Fountain Water Co. supplies that part of the city lying west of Naugatuck River and the Ansonia Water Co. supplies all of the city east of the river. The works of the Fountain Water Co. include a reservoir in Derby, from which water is delivered by gravity.

The Ansonia Water Co., of which Theodore L. Bristol is president and F. J. Davis superintending engineer, has one high-pressure reservoir, one low-pressure reservoir, and one distributing reservoir. The high-pressure reservoir covers 43 acres, is controlled by a masonry dam 20 feet high at an elevation of 326 feet above sea level, has a capacity of 200,000,000 gallons, and affords a pressure of 90 pounds in the city. The low-pressure reservoir is controlled by a masonry dam 15 feet high at an elevation of 138 feet above sea level and furnishes 20 pounds' pressure in the city. Its capacity is 33,000,000 gallons. The distributing reservoir is 266 feet above sea level, is controlled by an earth dam, with masonry spillway 35 feet high, giving a pressure of about 60 pounds. Its capacity is 12,000,000 gallons. There are 19 miles of mains, 102 hydrants, and about 900 service connections.

The maximum daily consumption is 5,000,000 gallons and the average daily consumption 1,250,000 gallons. About 10,500 people are supplied, and when, at the end of the season, no shortage is anticipated, water is supplied for industrial uses. The cost of construction was about $290,000, the cost of operation about $450 ($456.04 in 1912), and of maintenance $2,600 ($2,600.87 in 1912). The income is about $36,500. Charges are based on both meter and flat rates. The supply is adequate for the present, and plans are in hand for an extension of the system when that becomes necessary.

RECORDS OF WELLS.

Information concerning dug and drilled wells in Ansonia is presented in the following tables:

Dug wells in Ansonia, Conn.

Map No.[a]	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea level.	Cover.	Remarks.
		Feet.	*Feet.*	*Feet.*	*Feet.*		
1	Hill	260	35	20	240	Open	12 feet to rock.
2	Hill	225	12.5	9.2	216	Mesh	
3	Slope	155	20.6	18.6	134	Lattice	
4	Flat	145	12.9		132	Lattice	Use city water largely.
5	Slope	345	[b] 18.0		327	Closed	
6	Slope	315	12.0	9.2	303	Open	
7	Slope	125	14.0	11.2	111	Open	Not used.
9	Slope	390	16.0	15.5	374	Open	
12	Slope	340	11.2	10.0	330	Open	Use not over 10 gallons a day.
15	Hill	410	30	28.0	382		
17	Slope	340	30	29.4	311	Mesh	Well fails; brook water used.

[a] See Pl. III, in pocket.

[b] Depth reported.

Drilled wells in Ansonia, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Diameter.	Yield per minute.	Cost.
			Feet.	*Feet.*	*Inches.*		
8	Bergin	Hill	375	70	6	Good	
10	J. G. Tingley	Hill	400		6		$1.50 per foot.[a]
11	James Winn	Flat	320		6		
13	C. C. Ford	Hill	410		6		
14	McCrety	Hill	420	[b] 70	6		
16	William Ellis	Hill	390	[b] 70	6	Low	

[a] Does not include cost of casing.
[b] Drilled from bottom of dug well 30 feet deep; 30 feet to rock; drilled about 1893.

BEACON FALLS.

POPULATION AND INDUSTRIES.

Beacon Falls is in the west-central part of New Haven County, on Naugatuck River. It is reached by the Naugatuck division of the New York, New Haven & Hartford Railroad and by the Derby division of the Connecticut Co.'s Electric Railway. It was separated from Bethany, Oxford, Seymour, and Naugatuck and incorporated in May, 1871. Its area is 10 square miles.

The population of Beacon Falls in 1910 was 1,160. In 1880, 1890, and 1900 it was 379, 505, and 623, respectively. The principal industries are agriculture and the manufacture of rubber boots and shoes, small hardware, and bronze panels.

TOPOGRAPHY.

Beacon Falls extends across the valley of Naugatuck River. The highest elevation is in the northwest corner of the town, where Toby's Rock Mountain reaches an elevation of 730 feet above sea level. The lowest elevation, about 110 feet, is at the point where the river crosses the south boundary. The valley floor is narrow and is less than 2 square miles in area. The slopes and the hills in the eastern half of the town are all wooded.

The Naugatuck passes through the middle of the town and receives all the drainage. It is joined at Beacon Falls village by Hocanum Brook which rises in the western part of Bethany.

WATER-BEARING FORMATIONS.

Bedrocks.—The Hoosac ("Hartland") schist and the Prospect and Thomaston granite gneisses (p. 9) underlie Beacon Falls and are exposed in bare cliffs on both sides of Naugatuck River as well as on the steep slopes in other parts of the town. The bedrocks are too dense to afford large water supplies, but moderate supplies can be obtained from wells which intercept water-bearing fissures in the rock. (See p. 17.)

Till.—The unconsolidated surface deposits in all the upland parts of the town consist of mixtures of gravel, sand, and bowlders with some clay or rock powder, which were laid down as the last glacial ice melted. The material as it occurs in these deposits is called till. It ranges in thickness from a few inches to 25 or 30 feet, and moderate supplies of water for domestic purposes are obtained from the shallow wells which penetrate it. (See p. 11.)

Stratified drift.—Sand and gravel are found in the valley at the village of Beacon Falls. (See Pl. III.) The thickness of the deposit is not shown by data collected in this locality, but in Waterbury and in Seymour similar deposits have thicknesses of more than 100 feet. (See p. 14.)

SURFACE-WATER SUPPLIES.

The factory of the Beacon Falls Rubber Shoe Co., at Beacon Falls, is operated almost entirely by water power. Steam engines have been installed for use in emergencies, but the river is seldom so low as to necessitate their use. A storage reservoir belonging to the Seymour waterworks is situated on the west border of the town northwest of Pines Bridge.

GROUND-WATER SUPPLIES.

Eight dug wells examined in Beacon Falls range in depth from 9 to 27 feet and average 17 feet. Depth to water ranges from 7 to 18 feet and averages 13 feet. Most of the wells in this town draw their supplies from the till. The yields are low but adequate for ordinary domestic needs. Few wells are situated in the stratified deposits because the Seymour water system extends up the valley and supplies that part of the town which is underlain by the stratified drift.

Data obtained in regard to four drilled wells are given in the table on page 45.

In all parts of the town except the area represented by the dotted pattern on Plate III, till or rock will be encountered at the surface, and owing to the general thinness of the drift, dug wells will generally reach or even penetrate the bedrock. Drilled wells must be expected to draw their supplies from the rock, and they are likely to be more economical than dug wells where the drift is less than about 10 feet. Dug wells 20 to 30 feet deep are likely to obtain supplies adequate for ordinary domestic needs (see p. 36), and where it is possible good results may be expected from the siphon equipment described on page 39.

In the area underlain by stratified deposits (See Pl. III) drilled or deep-driven wells should furnish large supplies, but it is possible that impure water will be obtained if the wells are pumped hard, because the principal source of recharge is Naugatuck River.

PUBLIC WATER SUPPLIES.

There is no generally distributed public water supply, but a main which extends from the works of the Seymour Water Co. to Beacon Falls supplies part of the water used by the Beacon Falls Rubber Shoe Co. and a few houses in the immediate vicinity of the rubber mill.

RECORDS OF WELLS AND SPRINGS.

Information concerning wells and springs at Beacon Falls is given below. The map cited is Plate III, in pocket.

Drilled wells in Beacon Falls, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Diameter.	Yield per minute.
			Feet.	*Feet.*	*Inches.*	*Gallons.*
1	R. A. Rice	Flat	395	55	6	25
2	Arthur Faetch	Slope	360	50	6	4
7	Beacon Falls Rubber Shoe Co	Flat	270	90	6	....
8	.....do	Slope	300	*a* 130	6	1.6

a 20 feet to rock.

Dug wells in Beacon Falls, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea level.	Cover.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
3	Daniel Edwards	Hill	400	17.2	16.0	384	....	Fluctuation, 12 feet.
5	....	Slope	350	18.3	17.4	333	....	Well fails.
6	....	Slope	340	14.7	12.5	317	Closed	
9	....	Flat	210	19.4	15.5	194	Open	
10	....	Flat	240	16.3	11.2	229	Closed	
11	....	Slope	220	9.0	6.0	214	Open	
13	....	Slope	350	....	....	....	Closed	
14	....	Hill	350	27.3	18.2	332	Open	Well fails.
15	....	Slope	240	16.9	7.8	232	Open	

Springs in Beacon Falls, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Temperature.
			Feet.	° *F.*
4	Cornelius Munson	Flat	300	54
12	....	Slope	215	....

MIDDLEBURY.

POPULATION AND INDUSTRIES.

Middlebury, in the northwestern part of New Haven County, is bordered by Woodbury, Watertown, Waterbury, Naugatuck, Oxford, and Southbury. It is reached by electric railway from Waterbury and Woodbury, which operates on a 15-minute schedule during the summer season and on an hourly schedule during the winter. The town was organized from parts of Woodbury, Southbury, and Waterbury and was incorporated in 1807. Its area is 19 square miles.

The population in 1910 was 836, or practically the same as a hundred years ago. The slight fluctuations in population from 1810 to 1910 are shown in the accompanying table. The principal industry is agriculture.

Population of Middlebury, Conn., 1810–1910.

Year.	Population.	Increase.	Decrease.	Year.	Population.	Increase.	Decrease.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
1810	847			1870	696	5	
1820	838		1	1880	687		1
1830	816		3	1890	566		18
1840	761		7	1900	736	30	
1850	763	0.3		1910	836	14	
1860	664		13				

TOPOGRAPHY.

Middlebury is hilly but much less rugged than adjacent river towns. The relief is nearly as great but the slopes are more gentle and comparatively few of them present bare rock surfaces. The lowest elevation is on the east border of the town, where Welton Brook crosses the line at an elevation of about 350 feet above sea level. The highest elevation—900 feet—is between Middlebury Center and Quassapaug Lake. As indicated on Plate III, the slopes and narrow valleys are generally wooded, but the broad hilltops are for the most part cultivated.

The principal streams are Hop Brook, Long Swamp Brook, Meschapock Brook, Long Meadow Brook, and Eightmile Brook. These are all small streams, having their heads in Middlebury, and all discharge into Naugatuck River except Eightmile Brook, which empties into Housatonic River. The town is not thoroughly drained, as is indicated by the appearance on the map (Pl. III) of several swampy areas, and Long Meadow Pond and Quassapaug Lake. Quassapaug Lake is endowed with considerable natural beauty and it is utilized as a summer resort.

WATER-BEARING FORMATIONS.

Bedrocks.—Middlebury is underlain by crystalline rocks which, on the basis of lithologic differences, have been separated by the Connecticut Geological Survey into two formations and named the Waterbury gneiss and the Thomaston granite gneiss (p. 9). Crystalline rocks are not porous enough to allow free circulation of ground water, and consequently wells drilled into them must depend for their supplies on water-bearing fissures which they may intercept. This accounts for the wide range in the yields of different wells and for occasional dry holes in close proximity to good wells. (See p. 17.)

Glacial drift.—The bedrocks are overlain by a mantle of glacial drift consisting of till (p. 10), with a very few local deposits of coarsely stratified sand and gravel. The thickness of the drift ranges from a few inches to 30 or 40 feet, and averages about 20 feet. The occurrence of water in unconsolidated deposits is discussed on page 11.

GROUND-WATER SUPPLIES.

The depth to water, as determined by measurements of 28 dug wells, ranges from 3 to 25 feet and averages 9 feet. The wells range in depth from 9 to 31 feet and average 17 feet. All of the dug wells examined are in till and five of them go dry during dry seasons, but in general their supplies are adequate for domestic needs.

Eight drilled wells were examined in this town, which range in depth from 47 to 558 feet and average 166 feet. The yields range from 1.5 to 20 gallons per minute.

RECORDS OF WELLS AND SPRINGS.

Data in regard to wells and springs are given in the accompanying tables.

Dug wells furnish good supplies for domestic purposes in all parts of the town where the thickness of the drift is more than about 10 feet. The amount of waer available depends to some extent on the thickness of the drift, and where this is less than about 10 feet it is likely to be more economical to drill into the rock. In many places it will be possible to use the siphon well described on page 39.

Good domestic supplies may be obtained from drilled wells ending in the rock, but large yields should not be expected from single wells. (See p. 17.)

The wells and springs are numbered on Plate III (map in pocket) as indicated in the first column of the table.

Dug wells in Middlebury, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea level.	Cover.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
1	....	Hill.....	580	27.2	20.2	560	Closed....	
3	....	Flat.....	540	13.4	8.0	532	Open.....	
4	....	Hill.....	745	30.3	12.9	732	Open.....	Not used.
8	....	Slope...	760	....	7.0	753	Open.....	
10	....	Hill.....	560	14.5	10.7	549	Open.....	Fails.
13	....	Slope...	580	17.8	10.0	570	Open.....	
14	....	Flat.....	560	11.5	3.5	556	Open.....	
15	....	Flat	530	18.8	10.5	519	Closed....	
17	....	Flat.....	500	10.0	5.0	495	Open.....	
18	....	Flat.....	480	....	3.0	477	Closed....	
19	....	Flat.....	420	13.8	6.0	414	Open.....	
20	....	Flat.....	400	14.7	9.4	391	Open.....	
21	....	Slope...	680	9.9	4.6	675	Open.....	
22	....	Hill.....	675	13.5	7.2	668	Open.....	Not used.
24	A. J. Abbott.........	Hill.....	740	31.0	15.0	725	Closed....	
25	....	Hill.....	660	11.0	5.2	655	....	
27	Nichol Ferrante.....	Hill.....	710	20.1	8.4	702	Closed....	
28	Nichol Ferrante.....	Hill.....	710	11.0	5.6	704	Closed....	
32	....	Hill.....	840	29.9	25.3	815	Open.....	Fails.
33	....	Hill.....	820	9.0	2.9	817	....	
34	....	Slope...	560	19.6	6.6	553	....	
35	....	Hill.....	520	31.4	19.6	500	Closed....	Fails.
36	....	Flat.....	460	13.4	6.8	653	Open.....	Fails
37	....	Slope....	500	12.0	10.5	489	Closed....	Not used.
38	....	Flat.....	555	10.6	4.1	551	....	
39	....	Hill.....	660	15.8	8.7	651	Closed....	
40	....	Slope....	710	16.2	11.9	698	Open.....	Fails.
41	....	Slope....	710	9.0	3.7	706	Open.....	

Drilled wells in Middlebury, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Diameter.	Yield per minute.	Remarks.
			Feet.	*Feet.*	*Inches.*	*Gallons.*	
2	T. L. Atwood.........	Slope....	755	47	....	....	Use 500 gallons a day.
5	W. H. White.........	Slope....	760	186	6	20	6 gallons a minute was capacity of pump. Water stood at 27 feet below surface after 8 hours pumping.
6	W. H. White.........	Hill.....	800	158	6	1.5	Well abandoned after shooting.
11	Ford..................	Hill.....	840	....	....	....	
12	Carter................	Hill.....	825	....	....	....	
16	Westover School.....	Flat.....	700	558	(a)	[b] 1,000	Yield inadequate: well abandoned; drilled in 1907; cost $4,080.
23	D. M. Atwood........	Slope....	700	82	6	4	
26	Wm. Davis...........	Hill.....	700	....	6	....	
29	Alida Allerton........	Flat.....	800	115	6	2	
30	Alida Allerton........	Flat.....	800	81	6	4	
31	H. C. Bronson........	Flat.....	835	100	6	3	

[a] 10 inches to rock and 8 inches in rock. [b] Per day.

Springs in Middlebury, Conn.

Map No.	Topographic position.	Elevation above sea level.	Temperature.	Yield per minute.	Remarks.
		Feet.		*Gallons.*	
7	Top of slope..........................	820	....	Low.	Covered.
9	Slope..................................	700	54	2	Piped across road to house but not used.

NAUGATUCK.

POPULATION AND INDUSTRIES.

Naugatuck is in the northwestern part of New Haven County on Naugatuck River. It is reached by the Naugatuck division of the New York, New Haven & Hartford Railroad, which has stations at Naugatuck and Union City; by the Highland division of the same railroad, which has a flag station at Allerton Farms; and by the Derby division of the Connecticut Co.'s Electric Railway. The town was organized from parts of Waterbury, Bethany, and Oxford, and incorporated in May, 1844. It has an area of 17 square miles.

In 1910 the population was 12,722. The table presented below, which gives the population in each decade from 1850 to 1910, shows a rapid growth in recent years accompanying the growth of the city of Waterbury. The chief industries are agriculture and the manufacture of india-rubber goods, knit underwear, malleable iron, buttons, copper and brass plating, chemicals, gas and electric fixtures, and cut-glass ware.

Population of Naugatuck, Conn., 1850–1910.

Year.	Population.	Increase.	Year.	Population.	Increase.
		Per cent.			*Per cent.*
1850	1,720		1890	6,218	45
1860	2,590	51	1900	10,541	70
1870	2,830	9	1910	12,720	21
1880	4,272	51			

TOPOGRAPHY.

Naugatuck River passes through the middle of the town, receiving all the drainage, and this stream together with its tributaries, Long Meadow Pond Brook, Beacon Hill Brook, and Spring Brook, has deeply dissected the surface, producing an average relief of about 400 feet. The highest elevation—850 feet—is on Huntington Hill, in the southwest corner of the town. The lowest elevation is 170 feet, where Naugatuck River crosses the south boundary. The upper parts of the slopes and the lower hills are wooded, but the tops of the higher hills and the lower parts of the slopes are clear and to some extent cultivated.

WATER-BEARING FORMATIONS.

Bedrocks.—The rock formations which underlie Naugatuck are the Waterbury gneiss, the Hoosac ("Hartland") schist, and the Thomaston granite gneiss (p. 9). These are metamorphosed rocks of igneous and sedimentary origin, and are too dense to allow ground water to circulate freely, but they are cut by numerous fissures some of which contain water (p. 17).

Till.—In all the upland parts of the town till (p. 10) is the rock cover. It ranges in thickness from a few inches to 30 or 40 feet and has an average thickness of about 15 feet. The occurrence of water in till is discussed on page 11.

Stratified drift.—Naugatuck Valley and the valley of Beacon Hill Brook contain deposits of sand and gravel. These deposits are narrow but they may be as much as 100 feet thick in some places. The occurrence of water in stratified deposits is discussed on page 11.

SURFACE-WATER SUPPLIES.

Water power is used to a large extent by the mills and factories of Naugatuck and Union City. Power dams are situated on Long Meadow Pond Brook, Beacon Hill Brook, on the brook which flows through Union City, and on Naugatuck River. A small storage reservoir of the Naugatuck waterworks is situated just west of Union City.

GROUND-WATER SUPPLIES.

Seventeen dug wells, which range in depth from 8 to 27 feet and and average 17 feet, show depths to water ranging from 2 to 26 feet and averaging 11 feet. One of these wells, near the top of Andrews Hill at an elevation of about 650 feet above sea level (No. 9, Pl. III), is subject to a fluctuation in the water level of about 17 feet, but it has never been dry. All of these wells are in till, and only one of them is likely to fail in dry seasons. (See table, p. 51.)

In those parts of the town which are underlain by till good domestic supplies may be obtained from dug wells, provided the till is more than about 10 feet thick. Where the rock lies within about 10 feet of the surface satisfactory dug wells are likely to be more expensive than drilled wells, and the chances of obtaining good supplies are probably better in drilling. Siphon wells (see p. 39) are successfully used along Beacon Hill Brook and they could be used to advantage in other parts of the town where dwellings are situated near drift-covered slopes. The stratified deposits in the valleys would yield large quantities of water, but if they were subjected to heavy drafts their supply would probably be replenished to some extent from Naugatuck River.

PUBLIC WATER SUPPLIES.

The Naugatuck Water Co., of which D. P. Mills is president and E. C. Barnum general manager, furnishes water to the city of Naugatuck. The works include seven reservoirs, as follows:

Naugatuck city reservoirs.	Capacity, in gallons.
Prospect reservoir	110, 000, 000
Long Hill Brook reservoir	1, 500, 000
New reservoir	500, 000, 000
Candy Brook reservoirs (2)	5, 500, 000
Distributing reservoir	7, 000, 000
High-service (Mulberry) reservoir	11, 000, 000
	635, 000, 000

Water is delivered by gravity under a pressure of about 110 pounds, through 40 miles of mains, supplying a population of about 10,000. The average daily consumption is between one and two million gallons, three-fourths of which is used for manufacturing purposes. In cases of emergency, water is pumped from Beacon Hill Brook by means of a Dean pump (steam) into the distributing reservoir. No germicidal treatment is used. Charges are based on both meter and flat rates.

RECORDS OF WELLS.

Information concerning wells in Naugatuck is presented in the following table. The map referred to is Plate III, in pocket.

Dug wells in Naugatuck, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea level.	Cover.
			Feet.	*Feet.*	*Feet.*	*Feet.*	
2		Hill	520	21.2	13.9	506	
3		Flat	360	17.4	8.2	352	Open.
4		Slope	290	22.0	17.8	272	Closed.
5		Slope	225	23.0	21.0	204	
6		Flat	330	9.0	4.4	326	
7		Slope	660	[a] 14.0	2.5	657	Open.
8	W. E. Hunter	Flat	700	21.6	6.5	693	Closed.
9	W. E. Hunter	Slope	650	20.0	2.0	[b] 648	Closed.
10		Hill	330	16.7	9.0	321	Open.
11		Flat	360	17.5	13.1	347	Open.
12		Slope	455	21.5	20.5	434	Mesh.
13		Slope	500	12.0	10.0	490	Closed.
15		Slope	630	27.0	26.4	604	Open.
17		Slope	660	19.0	17.0	643	
18		Slope	375	8.5	5.0	370	Closed.
19		Slope	365	10.0	5.0	360	Closed.
20		Flat	330	[c] 12.8	11.8	318	Open.

[a] Well goes dry. [b] Fluctuation, 17 feet. [c] Well not used.

OXFORD.

POPULATION AND INDUSTRIES.

Oxford, in the northwestern part of New Haven County, is reached by the Highland division of the New York, New Haven & Hartford Railroad, which has a station at Towantic, and by highway from Seymour, which is on the Naugatuck division of the same railroad, and on the Derby division of the Connecticut Co.'s Electric Railway. Stevenson, on the Berkshire division of the New York, New Haven & Hartford Railroad, is one-third of a mile west of the western border and is the station and post office for that portion of the town. Oxford was taken from Derby and Southbury and incorporated in October, 1798. The area of the town is 33 square miles.

The population of Oxford in 1910 was 1,020. The following table gives the changes in population from 1800 to 1910, and shows that there was a gradual decline from 1830 to 1890, but a slight increase more recently. The principal industry is agriculture.

Population of Oxford, Conn., 1800–1910.

Year.	Population.	Increase.	Decrease.	Year.	Population.	Increase.	Decrease.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
1800	1,410			1860	1,269		8
1810	1,453	3		1870	1,338	5	
1820	1,683	15		1880	1,120		16
1830	1,763	5		1890	902		19
1840	1,626		8	1900	952	5	
1850	1,564		4	1910	1,020	7	

TOPOGRAPHY.

Elevations in Oxford range from about 40 feet above sea level on Housatonic River at the south corner of the town to 890 feet on Woodruff Hill on the north boundary. The town is characterized by high, steep, wooded slopes, narrow valleys, and by the absence of level land.

Housatonic River and Eightmile Brook form parts of the west boundary. Little River passes through the middle of the town, parallel to Housatonic River, and the headwaters of Long Meadow Pond Brook reach into the northeast corner of the town. These streams with their tributaries drain almost the entire area. A small area along the east border is drained by a small brook which joins Naugatuck River at Pines Bridge in Beacon Falls.

WATER-BEARING FORMATIONS.

Bedrocks.—Oxford is underlain by crystalline rocks which, according to their lithologic characters, are recognized as three different formations. The most extensive of these is the Waterbury gneiss which underlies the west half of the town. The Hoosac ("Hartland") schist underlies all of the east half of the town except a small area in the southeast corner where the Thomaston granite gneiss appears (p. 9). These rocks are exposed at the surface on steep slopes throughout the town, and in the beds of most of the brooks. The occurrence of water in rocks of this character is discussed on page 17.

Glacial drift.—The prevailing rock cover in Oxford is till, which consists of unassorted bowlders, gravel, sand, and rock powder, deposited by the last retreating ice sheet. This formation is generally very thin and is irregularly distributed; but it is, nevertheless, the most important source of ground water in the town, although only shallow well and spring supplies are obtained from it. Stratified drift occurs only in small patches along Little River and in the valley of Eightmile Brook north of Quaker Farms, where several small eskers extend into the valley. These stratified deposits, on account of their limited extent, furnish only shallow, domestic supplies. (See p. 11.)

SURFACE-WATER SUPPLIES.

Water power is developed on Eightmile Brook at Southford and near Quaker Farms and on Little River at Oxford. There are several unused power sites, some of which seem to have been permanently abandoned, on small brooks tributary to these streams. One of the reservoirs of the Seymour Water Co. is situated in this town.

GROUND-WATER SUPPLIES.

Sixty-one dug wells examined in Oxford range in depth from 7 to 37 feet and average 17 feet. Depth to water ranges from 2 to 22 feet and averages 9 feet—in 41 of these wells the depth to water is less than 10 feet. Practically all are in till, 10 are not used, and 4 are said to fail in dry seasons. Samples of water were examined by the methods described in Water-Supply Paper 151 with the following results:

Six springs were observed, all of which were small gravity springs. (See p. 55.)

Eight drilled wells have depths ranging from 52 to 600 feet and yields ranging from 1 to 40 gallons a minute. The average depth is 160 feet and the average yield is 12 gallons a minute.

Stratified deposits in Oxford are so limited in extent that they are of little importance in determining the location of wells. Good water for domestic supplies is available in all parts of the town. Where the drift is more than about 10 feet deep dug wells generally furnish desirable supplies, but where it is thinner better wells are likely to be obtained by drilling. Supplies larger than those ordinarily required for domestic purposes should not be expected from wells, because they are usually not available. But comparatively large supplies can be obtained from surface-water reservoirs, sites for which are numerous.

RECORDS OF WELLS AND SPRINGS.

Information concerning wells and springs in Oxford is given in the following tables. The wells and springs are numbered on Plate III.

Dug wells in Oxford, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea level.	Cover.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
1	....	Slope...	605	20.6	13.0	592	Closed...	Not used.
2	....	Slope...	630	14.4	6.6	623	Open...	Not used.
3	F. B. Wheeler....	Slope...	700	20.2	9.3	691	Open...	Fails.
6	....	Slope...	455	10.6	4.5	450	Open...	
7	....	Slope...	525	10.0	4.5	520	Open...	
8	....	Hill.....	670	18.1	7.4	663	Open...	
9	Franklin Nichols..	Hill.....	620	21.1	16.0	604	Open...	
10	....	Slope...	550	16.4	12.4	538	Open...	
11	....	Hill.....	560	32.3	12.2	548	Open...	Not used.
12	....	Flat.....	565	12.1	5.1	560	Open....	
13	....	Slope...	660	....	5.7	654	Open...	
14	Town well in Towantic.	Flat.....	640	7.9	2.0	638	Open...	Two houses supplied.
15	....	Flat.....	500	9.2	4.8	495	Closed...	
17	....	Slope...	570	22.6	8.3	562	Open...	
18	....	Slope...	500	15.1	9.2	491	Open....	
21	....	Flat.....	600	11.4	5.7	594	Open....	Fails.
22	B. T. Nash........	Slope....	560	27.3	22.3	538	Open...	Fluctuation, 12 feet.
23	....	Slope...	600	25.1	21.7	578	Open...	Fails.
24	....	Hill.....	605	20.4	3.2	602	Open...	
25	....	Hill.....	605	26.4	8.8	596	Open...	
26	....	Slope...	550	8.2	2.9	547	Open...	
27	....	Hill.....	610	13.6	5.1	605	Open...	
28	....	Hill.....	600	32.6	13.8	586	Open...	
29	....	Slope...	500	12.1	5.0	495	Open...	
30	J. B. Berry.......	Slope...	540	18.7	9.1	531	Open...	Not used.
31	....	Hill.....	625	27.7	16.1	609	Closed...	Not used.
33	....	Hill.....	610	15.1	7.2	603	Open...	
35	....	Flat.....	360	8.5	5.0	355	Closed...	Not used.
37	....	Flat.....	440	15.3	11.2	439	Closed...	
38	....	Slope....	360	11.3	8.8	351	Lot......	
39	....	Flat.....	380	33.0	18.3	362	Open...	
40	....	Slope...	350	16.6	14.2	336	Open...	Not used.
41	....	Slope...	345	19.9	15.6	329	Open...	Fails.
42	....	Slope...	380	27.2	21.1	359	Open....	
43	....	Slope....	420	13.2	4.9	415	Open....	Not used.
44	....	Slope...	460	10.6	6.3	454	Open...	
45	....	Hill.....	500	12.4	5.3	495	....	
46	....	Slope...	495	7.7	3.2	492	Open...	
47	....	Slope....	360	12.5	6.9	350	Open....	
48	....	Flat.....	355	10.8	4.7	350	Open....	
50	....	Flat.....	420	14.5	8.4	412	Open....	
51	....	Slope....	660	29.2	15.2	645	Closed...	
52	....	Slope....	510	11.3	6.7	503	Open....	
53	....	Flat.....	295	9.6	4.6	290	Open....	
54	....	Hill.....	550	37.0	18.8	531	Closed...	
55	....	Slope....	98	22.1	19.4	79	Open....	
58	....	Flat.....	60	32.0	....	....	Closed...	Depth given as reported.
59	....	Hill.....	385	17.1	7.5	377	Closed...	Not used.
60	....	Hill.....	560	11.9	4.9	555	Open....	
61	....	Hill.....	570	20.2	7.4	562	Open....	
62	....	Hill.....	600	17.9	8.2	592	Open....	
63	....	Slope....	630	19.2	7.3	623	Open....	
64	....	Flat.....	570	13.0	8.0	562	Open....	
65	....	Slope....	400	13.7	5.2	395	Open....	
66	....	Slope....	605	13.2	5.0	600	Open....	
68	....	Slope....	530	17.8	11.8	518	Open....	
71	....	Flat.....	360	11.8	9.0	351	Open....	Not used.
72	....	Slope....	430	15.3	13.3	417	Open....	
73	....	Slope....	380	12.4	6.1	374	Closed...	
74	....	Slope....	270	12.6	7.0	263	Open....	
75	....	Flat.....	200	19.6	16.6	183	Open....	
76	....	Flat.....	200	22.6	13.5	186	Open....	

Drilled wells in Oxford, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Diameter.	Yield per minute.	Remarks.
			Feet.	*Feet.*	*Inches.*	*Gallons.*	
16	M. J. Cassidy	Hill	520	55	6	1.5	
20	Catherine Frazer	Slope	495	52	6	1	2 feet to rock.
32	G. W. Cable	Hill	630	70	6	20	
34	R. L. Androus	Slope	470	58	6	40	20 feet to rock.
36	Mrs. Julia Sanford	Flat	370	140	8	17	10 feet to rock; 10-hour test for yield; well completed May, 1910; cost of well, $640.
49	Chas. Davis	Flat	385	175	....	4	100 feet to rock.
67	J. H. Hale	Hill	670	128	8	4	10 feet to rock; well completed Sept. 1, 1905; cost of well, $540.
69	C. M. Eckstrom	Mill	580	600		12	40 feet to rock; cost of well, $3,600.

Springs in Oxford, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Temperature.	Yield per minute.	Remarks.
			Feet.	°*F.*	*Gallons.*	
4	F. B. Wheeler	Top of slope	720	57	[a] 0.5	
5	David B. Wheeler	Top of slope	690	56	[b] 3.0	
19	....	Slope	470	....	Low.	
56	....	Slope	80	....	Low.	
57	....	Slope	100	....	....	Delivered by siphon.
70	....	Flat	60	....	....	Do.

[a] Well goes dry. [b] Flow is constant.

SEYMOUR.

POPULATION AND INDUSTRIES.

Seymour is in the western part of New Haven County on Housatonic and Naugatuck rivers. It is reached by the Naugatuck division of the New York, New Haven & Hartford Railroad, and the Derby division of the Connecticut Co.'s Electric Railway. It was separated from Derby and incorporated in May, 1850. The area of the town is 15 square miles.

The population of Seymour in 1910 was 4,786, a substantial increase over 1900. The population from 1850 to 1910 is shown in the following table:

Population of Seymour, Conn., 1850–1910.

Year.	Population.	Increase.	Year.	Population.	Increase.
		Per cent.			*Per cent.*
1850	1,677	....	1890	3,300	42
1870	2,172	28	1900	3,541	7
1880	2,318	7	1910	4,786	35

The principal industries are the manufacture of brass and copper goods, plush, hard-rubber goods, boring implements, edge tools, horseshoe nails, paper, telegraph cables, bicycle parts, and eyelets, an iron foundry, and agriculture.

TOPOGRAPHY.

Elevations in Seymour range from about 30 feet to 640 feet above sea level, the lowest elevation being at Housatonic River, in the southwest corner of the town, and the highest about a mile and a half north of that place, on Great Hill. Eastward from Great Hill the land slopes rapidly downward to Naugatuck River, where the elevation is about 40 feet above sea level, and then rises rapidly to 500 feet above sea level on the east border of the town. Most of the slopes are wooded but the hilltops are cultivated.

Housatonic River forms a part of the western border and receives the drainage from that part of the town. Naugatuck River, which flows through the town parallel to and about 2 miles from the east border, drains about two-thirds of the area.

WATER-BEARING FORMATIONS.

Bedrocks.—Hoosac ("Hartland") schist and the Prospect granite gneiss (p. 9) comprise the bedrocks of Seymour and they are exposed at the surface on many of the steep slopes throughout the town. The Prospect granite gneiss is cut by a nearly vertical diabase dike which is about 40 feet wide. This diabase appears at the surface in a line parallel to and just east of Naugatuck River and is locally called trap rock because of its similarity to the "trap rocks" of the Connecticut River valley. None of these rocks is capable of furnishing a large supply of water, but the water-bearing fissures, which are numerous in all of them, afford moderate supplies to wells (p. 17).

Till.—In all parts of Seymour except the narrow valleys of Housatonic River, Naugatuck River, and Bladens River, the rock is covered with unassorted sand, gravel, and bowlders of glacial origin. The maximum thickness of this material was not determined, but it probably does not exceed 30 or 40 feet and the average thickness is about 15 feet. Most of the domestic water supplies are obtained from shallow wells in the till (p. 10).

Stratified drift.—The stratified deposits found along Housatonic, Naugatuck, and Bladens rivers are narrow and discontinuous. Their occurrence throughout the Waterbury area suggests that they were deposited by the smaller tributary streams while the principal valleys were still filled with ice. The thickness of the fill in the middle of the valley is shown by the logs of wells Nos. 58 and 59 (p. 59), to be about 125 feet. The occurrence of water is discussed on pages 11 and 14.

SURFACE-WATER SUPPLIES.

Bladens, Little, and Naugatuck rivers furnish power for mills and factories in Seymour. A mill at Squantuck obtains power from Fourmile Brook, and a dam in Naugatuck River about 2 miles south of Seymour diverts water into a power canal which leads to Ansonia. Some of the storage reservoirs of the Ansonia waterworks are situated in the southeast corner of the town.

GROUND-WATER SUPPLIES.

The depths of 49 dug wells in Seymour range from 6 to 45 feet and average 18 feet. The depth of the water table below the surface of the ground, as determined by measurements of 48 wells, ranges from 6 inches to 38 feet and averages 14 feet—in 20 wells it is less than 10 feet to water. Eight of the wells examined are subject to failure and six wells are not used.

Six small gravity springs were observed, two of which are regularly used.

The depths of four drilled wells range from 60 to 447 feet and average 210 feet. They yield from 1.5 to 90 gallons a minute and average 28 gallons. Two are used for domestic purposes, one for manufacturing, and one situated in a public park furnishes drinking water. (See table, p. 59.)

Ground water for domestic use can be obtained from dug wells in all parts of Seymour where the drift is more than about 10 feet thick, but where bedrock is less than that distance below the surface it is generally advisable to drill into the rock. Very shallow wells are not likely to be permanent and they are not desirable from a sanitary viewpoint.

Shallow wells in the stratified deposits are especially liable to contamination on account of the topographic positions of these deposits and on account also of the greater density of population in the valleys underlain with stratified beds than on the till-covered uplands. Drilled or driven wells ending in gravel below the level of the river would probably furnish large supplies, but a large part of the water from this source would come from Naugatuck River because a heavy draught would soon exhaust the supply furnished from the narrow and steep slopes adjacent to the river. Larger supplies than those ordinarily required for domestic purposes should not be expected from wells in this area, although some drilled wells have furnished comparatively large amounts.

PUBLIC WATER SUPPLIES.

Seymour is supplied with water by a private company, of which Mr. D. A. Blakeslee, of New Haven, is secretary and treasurer. Very little information was obtained in regard to the system. It was said merely that the system comprises two reservoirs, and 55 public and 8 private hydrants. The water is delivered by gravity under a pressure of 100 to 120 pounds, and is sold at a flat rate, except to manufacturers, who pay on a meter basis.

RECORDS OF WELLS AND SPRINGS.

Information concerning wells and springs in Seymour is presented in the following tables. The map cited is Plate III, in pocket.

Dug wells in Seymour, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea level.	Cover.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
2	....	Slope...	90	45.3	32.6	57	Open...	
3	....	Flat.....	60	16.8	9.5	50	....	
4	....	Slope....	560	7.9	.5	559	Open....	
5	....	Hill.....	650	185	5.7	644	Open....	
6	....	Slope....	560	7.3	.9	559	Open....	Surface drainage entering when well was measured.
7	....	Hill.....	495	15.3	7.5	487	Mesh....	
8	....	Slope....	430	11.7	3.2	427	Open....	Fails.
9	....	Slope....	460	17.6	9.2	451	Open....	
10	....	Slope....	210	16.3	8.0	202	Mesh....	Not used.
11	....	Flat.....	365	11.0	6.0	359	Open....	Not used.
12	....	Slope....	520	9.8	3.3	517	Open...	Seldom used.
13	....	Flat.....	495	14.1	12.5	482	Open...	Not used.
14	Wilson Duckley.	Hill.....	505	29.1	26.6	478	....	Fails.
15	....	Hill.....	525	20.0	12.2	513	Open ...	Unclean.
17	....	Slope....	375	22.5	16.4	359	Open....	
18	....	Hill.....	390	15.8	25.3	365	Open....	
19	....	Hill.....	300	7.2	3.4	297	Open...	
20	....	Slope....	260	16.1	13.6	246	Mesh....	
21	....	Slope...	120	21.1	18.1	102	Lattice..	Fails.
22	....	Flat.....	75	26.4	22.6	52	Open...	
23	....	Flat.....	75	23.7	14.0	61	Open....	
24	....	Hill.....	550	18.0	9.7	540	Closed..	
25	....	Hill.....	520	18.4	15.2	505	Open....	
26	....	Slope....	410	15.8	5.8	404	Open....	Fails.
29	....	Slope....	280	10.6	3.2	277	Open...	Fails.
30	....	Slope...	185	6.2	3.1	182	Mesh....	
31	....	Flat.....	80	18.1	14.0	66	Mesh....	
32	....	Slope....	500	20.8	20.2	480	Open....	
35	....	Slope....	300	17.5	16.3	284	Open....	
36	....	Slope....	265	24.0	22.0	243	Open...	
37	....	Flat.....	220	18.1	17.2	203	Open...	
38	....	Slope....	250	10.2	8.4	246	Open....	
39	....	Flat.....	165	9.0	5.4	160	....	
41	....	Slope....	210	31.1	Dry.	....	Closed ..	Dry June to December each year.
42	....	Flat.....	185	20.1	13.5	171	Closed..	
43	....	Flat.....	170	30.2	27.9	142	Mesh....	
44	....	Flat.....	155	37 9.	30.6	124	Mesh....	Never less than 5 feet of water.
45	....	Flat.....	120	42.6	38.5	81	Open....	
47	....	Slope...	230	15.2	14.5	215	Open....	
48	....	Slope....	235	10.3	6.8	226	Open....	
49	....	Hill.....	270	19.9	12.1	258	Mesh....	
50	....	Hill.....	380	9.0	5.2	375	Open...	
51	....	Slope....	380	24.9	22.5	357	Open....	
52	....	Hill.....	380	14.6	11.0	369	....	
53	....	Hill.....	400	20.9	19.9	380	Lattice..	Not used; pump city water from reservoir.
54	....	Hill.....	390	15.9	14.2	376	....	
55	....	Slope...	340	7.0	2.0	338	....	
56	....	Slope....	360	21.0	21.0	339	....	Dry 2 months every year.
57	....	Slope....	320	26.6	26.0	294	....	Dry 2 months every year; not used.

Drilled wells in Seymour, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Diameter.	Yield per minute.	Remarks.
			Feet.	*Feet.*	*Inches.*	*Gallons.*	
33	Smith Holbrook	Hill	395	98	....	5	26 feet to rock.
34	Joel Chatfield	Slope	370	60	6	18	
58	Waterman Pen Co., H. P. and E. Day.	Flat	85	447	8	(a)	128 feet to rock; cost of well, $2,159.
59	Seymour	Hill	155	234	6	1.5	230 feet to rock; cost of well, $841.

a Yields 30 gallons at suction and 90 gallons at 70 feet.

Springs in Seymour, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Temperature.	Yield per minute.	Remarks.
			Feet.		*Gallons.*	
1	Sidney Downs	Slope	80	....	....	Converted to well.
16	....	Foot of slope	400	....	....	Pumped by windmill.
27	....	Slope	305	57	1	Constant.
28	....	Slope	300	....	....	
40	Edmund Day	Slope	255	55	....	
46	Arethusa Spring Water Co.	Slope	187	50	2	

THOMASTON.

POPULATION AND INDUSTRIES.

Thomaston is in the southeastern part of Litchfield County, in the Naugatuck Valley. It is reached by the Naugatuck division of the New York, New Haven & Hartford Railroad, which has stations at Thomaston and Reynolds Bridge; by trolley from Terryville station on the Highland division of the same railroad, 1 mile to the village of Terryville, thence 3 miles by stage; by trolley from Waterbury hourly. The town was separated from Plymouth and incorporated in May, 1875. It has an area of 12 square miles.

The census reports show a very slow growth in population since the first enumeration in 1880, as indicated in the following table. In 1910 the population was 3,533. The principal industries are agriculture and the manufacture of clocks and watches, brass goods, cutlery, clock bells, etc.

Population of Thomaston, Conn., 1880–1910.

Year.	Population.	Increase.	Year.	Population.	Increase.
		Per cent.			*Per cent.*
1880	3,225	....	1900	3,300	1
1890	3,278	2	1910	3,533	7

TOPOGRAPHY.

The highest elevation, 1,022 feet, is on Lattin Hill, near the north boundary of the town; the lowest—about 330 feet above sea level—is at the confluence of West Branch of Naugatuck River with Naugatuck River. These rivers occupy narrow valleys whose walls rise abruptly 400 to 500 feet and embrace practically the entire area of the town.

WATER-BEARING FORMATIONS.

Bedrocks.—The rock floor is comprised of Waterbury gneiss, Thomaston granite gneiss, and a small body of amphibolite. These are crystalline rocks (p. 9), very dense in texture, and consequently poorly suited to furnish large quantities of water. Owing, however, to the intense fracturing which they have undergone water-bearing fissures are sufficiently numerous to afford moderate supplies to drilled wells. The occurrence of water in rocks of this character is discussed on page 17.

Glacial drift.—Unstratified drift or till (p. 10) consisting of bowlders, gravel, sand, and rock powder constitutes the rock cover in all the upland parts of the town. (See Pl. III.) Its thickness ranges from a few inches at the edge of rock outcrops to 25 or 30 feet and in all the deeper parts water may be obtained from dug wells. Stratified drift occupies the lowland adjacent to the rivers, as shown on Plate III, and ranges in thickness from a few feet to about 50 feet. The occurrence of water in unconsolidated deposits is discussed on page 11.

SURFACE-WATER SUPPLIES.

Power is developed on Naugatuck River at Thomaston; and the Wigwam reservoir of the Waterbury waterworks is situated on West Branch of the Naugatuck in the northwest corner of the town.

GROUND-WATER SUPPLIES.

Eighteen dug wells were examined in Thomaston ranging in depth from 10 to 30 feet and averaging 19 feet. Depth to water in these wells ranges from 2 to 16 feet and averages 8 feet. Most of the dug wells are in till and some of them doubtless penetrate rock, but no reliable information on this point is available. The annual fluctuation of the water level in one well was reported to be 14 feet and in another 8 feet. None of the wells examined have recently been dry, and the water supplied by all has been adequate for domestic needs.

Nine drilled wells were visited, and these range in depth from 40 to 338 feet and average 132 feet. Their yields, as determined by the drillers as the wells were finished, range from one-fourth gallon to 15 gallons a minute, and average 5 gallons. The depths to bedrock range from 3 to 48 feet and average 14 feet. The cost of drilling was in most cases $3.50 a foot, but for three of the wells the total cost was reported, as indicated in the table on page 62. A considerable amount of well drilling is being done in Thomaston, notwithstanding the fact that the public water supply is available.

PUBLIC WATER SUPPLY.

The Thomaston waterworks were built by the Thomaston Water Co., a corporation, in 1880. The supply is obtained from springs and delivered by gravity from an impounding reservoir. The area of the reservoir is 40 acres and its capacity is between 80,000,000 and 100,000,000 gallons. The pressure is 90 to 125 pounds. There are 269 service connections and 50 fire hydrants. The use of meters is optional with the consumers but compulsory for the railroad company and town buildings. Twenty-nine are now in use. The consumption is not known. The flat rates range from $2 to $10, and the income for 1912 was $6,906.28. Mr. F. R. Roberts is secretary-treasurer.

According to tests by the State Board of Health of six samples collected in 1904 the water supply of Thomaston has an average color of 30 parts per million and an alkalinity of 7 parts.[1]

RECORDS OF WELLS.

Information concerning the wells in Thomaston is presented in the following tables. The map cited is Plate III, in pocket.

Dug wells in Thomaston, Conn.

Map No.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea level.	Cover.	Remarks.
			Feet.	*Feet.*	*Feet.*		
1	Hill	925	22.3	7.3	918	Open	Lowest on Nov. 5, 1913; at that time contained 3 feet of water.
2	Slope	740	....	10.0	730	Closed	
3	Hill	810	10.7	5.0	805	Open	
4	Hill	920	20.3	7.1	913	Closed	2.5 feet of water at lowest stage in 1913.
5	Slope	440	23.3	16.9	423	Closed	
6	Slope	400	13.9	7.0	393	Open	
7	Hill	800	15.4	5.8	794	Closed	Use 35 gallons a day.
8	Hill	965	24.6	2.1	963	Closed	Not used.
9	Hill	900	41.0	10.0	890	Closed	
10	Slope	795	14.0	5.8	789	Closed	Not used.
11	Slope	675	23.6	14.3	661	Open	
12	Flat	480	14.1	7.9	472	Closed	
22	Flat	480	16.0	6.9	473	Open	
23	Flat	410	14.0	8.5	401	Closed	
25	Flat	370	19.3	17.0	353	Closed	
26	Flat	390	17.5	13.8	376	Open	Not used.
27	Slope	460	10.0	2.0	458	Closed	Supplies nine families; fluctuation, 8 feet.
28	Slope	360	30.0	7.2	353	Open	Fluctuation, 14 feet.

[1] Connecticut State Board of Health Ann. Rept. 1904, p. 225.

Drilled wells in Thomaston, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Diameter.	Yield per minute.	Cost.	Remarks.
			Feet.	*Feet.*	*Inches.*	*Gallons.*		
13	Seth Thomas Clock Co.	Flat..	460	338	8	8	$1,766.......	3 feet to rock.
14	W. T. Woodruff.....	Slope.	580	330	8	6	$1,596.......	6 feet to rock; completed Dec. 1, 1913.
15	Louis Schiappicasse..	Flat..	400	87	6	15	$3.50.per foot	3 feet to rock.
16	Alfred Holm.........	Slope.	420	65	6	¼	$3.50 per foot	8 feet to rock.
17	Robert Innes........	Flat..	400	50	6	2	$3.50 per foot	4 feet to rock.
18	"Thomaston".......	Flat..	375	110	8	....	....	Presented by W. C. T. U.
19	Geo. Hosford.........	Flat..	400	40	6	1	$3.50 per foot	5 feet to rock.
20	.....do.................	Flat..	410	55.5	6	10	$3.50 per foot	14 feet to rock.
21	S. H. Goodman......	Flat..	380	....	8	....	....	48 feet to rock; incomplete.
24	R. S. Newton........	Flat..	400	110	6	¼	$395.........	33 feet to rock.

WATERBURY.

POPULATION AND INDUSTRIES.

Waterbury is in the northern part of New Haven County, in the Naugatuck Valley. It is reached by the Naugatuck and Highland divisions of the New York, New Haven & Hartford Railroad, which has stations at Waterbury and Waterville, and by the Meriden division of the same road, which has a station at Waterbury; by trolley from New Haven via Cheshire, and from New Haven and Bridgeport via Derby; by trolley from Woodbury, Middlebury, and Thomaston; by stage from Woodbury and Middlebury daily. The town was named in 1686. The town and city are consolidated and have an area of 29 square miles.

The population in 1910 was 73,141. The following table shows the changes in population from 1756 to 1913.

The principal industries are the manufacture of rolled and cast brass and copper, german-silver goods, lamp trimmers, boilers, buttons, clocks, watches, plated wire, pins, eyelets, and buckles, electric-light and telephone wire, machinery, chemicals, etc., and agriculture. The city is the center of the brass industry in this country.

Population of Waterbury, Conn., 1756–1913.

Year.	Population.	Increase.	Decrease.	Year.	Population.	Increase.	Decrease.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
1756..........	1,829	....	....	1850..........	5,137	40	....
1774..........	3,536	93	....	1860..........	10,004	95	....
1782..........	2,240	....	36	1870..........	13,106	31	....
1790..........	2,937	31	....	1880..........	20,270	55	....
1800..........	3,256	11	....	1890..........	33,202	64	....
1810..........	2,874	....	12	1900..........	51,139	54	....
1820..........	2,882	....	....	1910..........	73,141	43	....
1830..........	3,070	6	....	1913..........	[a] 81,000	11	....
1840..........	3,668	19	....				

[a] Estimated.

TOPOGRAPHY.

The town extends across Naugatuck Valley and its topography is characteristically troughlike. The highest elevation—920 feet above sea level—is in the extreme northeast corner, and the lowest, about 220 feet, is on the river where it crosses the south boundary. The valley floor ranges in width from a few hundred feet at the south line to about a mile in the middle of the town, and from its edges the walls rise abruptly to elevations of 600 and 700 feet above sea level.

Hancock Brook, Steel Brook, and Mad River join Naugatuck River within the town.

WATER-BEARING FORMATIONS.

Bedrocks.—Crystalline rocks of three varieties—Hoosac ("Hartland") schist, Waterbury gneiss, and Thomaston granite gneiss, (p. 9)—comprise the bedrocks underlying the town. These rocks appear at the surface on the steep slopes in the south and east parts of the town and, except in the bottom of the valley, they are nowhere thickly covered by drift. The occurrence of water in crystalline rocks is discussed on page 17.

Glacial drift.—In the upland parts of Waterbury the rock cover consists of till or bowlder clay (p. 10) ranging in thickness up to 75 feet or more. On the flat lands along Naugatuck River the deposits are stratified and reach a thickness of over 100 feet in some places, as indicated by the log of a well drilled in the middle of the valley just south of the city, which reached bedrock at a depth of 111 feet below the surface. (See No. 5, p. 67.) The distribution of stratified and unstratified drift is shown on Plate III. The occurrence of water in unconsolidated deposits is discussed on page 11.

SURFACE-WATER SUPPLIES.

Water power is used in manufacturing plants on Naugatuck and Mad rivers. Several reservoirs belonging to the city waterworks are in the town east of the river, as indicated on the map (Pl. III).

GROUND-WATER SUPPLIES.

The average depth of the water table below the surface of the ground, as determined by measurement of 22 representative dug wells, is 13 feet. (See table, p. 66.) These wells range in depth from 7.1 to 39.9 and average 20 feet, the depth to water ranging from 3.5 to 32.2 feet. The annual fluctuation of the water table in one of the wells was reported to be about 13 feet. The average fluctuation, however, probably does not exceed 8 feet, taking into consideration the lowland areas in which changes in ground-water levels are relatively small.

Eight drilled wells that were examined range in depth from 55 to 550 feet and average 175 feet. The yields reported for six of these range from 4 to 60 gallons a minute and average 16 gallons. Detailed information in regard to these wells is tabulated on page 67.

The city water system extends to nearly all parts of the town and consequently there is little need for private dug wells. Drilled wells, however, are used by manufacturing companies to furnish water for drinking and for some special purposes in manufacturing, and they are used also in some parts of the city at higher elevations than those at which city water is effectively delivered. All wells are drilled into bedrock, even those located in the river valley, where the stratified stream deposits are more than 100 feet thick.

No attempt is made to obtain supplies from the drift itself because the till deposits are too thin and compact to furnish adequate supplies, and it is the popular belief that the water in the gravels near the river is contaminated. The problem of utilizing the underflow of the Naugatuck Valley is discussed on page 23.

Analyses of the water of three drilled wells in Thomaston are given in the subjoined table; the numbers refer to the descriptions of the wells in the record on pages 66 and 67. Comparison of the analyses illustrates the difference in composition likely to be encountered in ground waters from fractured crystalline rocks.

Analyses of water from drilled wells in Thomaston.

[Parts per million. Samples collected June 24, 1915; R. B. Dole, analyst.]

No. on map.[a]	Iron (Fe).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total hardness as $CaCO_3$.	Total solids at 180° C.
15	2.9	0.0	4.9	44	42	94	[b] 292
19	.2	.0	48	34	8.2	84	169
20	1.5	.0	18	20	6.8	33	99

[a] See Plate III, in pocket; also record of wells on p. 66. [b] Much organic matter present.

PUBLIC WATER SUPPLY.

The city engineer reported that the works include three reservoirs, two of which, Wigwam and Morris reservoirs, on West Branch of Naugatuck River, have areas of 105 and 150 acres and capacities of 750,000,000 and 2,000,000,000 gallons, respectively. The water is supplied to about 70,000 people, the average daily consumption being about 7,500,000 gallons. The Morris reservoir was begun in 1909 and was practically complete at the close of 1913. (See Pl. III.)

The average condition of the water of Fenn and Morris brooks at Waterbury is indicated in the following table, which gives the averages of tests of 36 samples from each source examined by the State Board of Health between 1898 and 1901.

Average quality of surface waters near Waterbury.[a]

[Parts per million.]

Source.	Color.	Total solids at 100° C.	Organic and volatile matter.	Total hardness as $CaCO_3$.	Chlorine.
Fenn Brook	43	48	14	11	1.7
Morris Brook	32	48	13	15	2.3

[a] Compiled from annual reports of the State Board of Health of Connecticut, 1898–1901.

According to Baker[1] the Waterbury waterworks were built by the city in 1868, and an additional supply was introduced in 1895. The supply is obtained from East Mountain Brook and West Branch of Naugatuck River. For the fiscal year ending December 31, 1895, there is reported 38 miles of mains, 4,023 taps, 270 meters, and 230 public and 50 private hydrants; and the consumption is given as 4,000,000 gallons.

The census report for 1911 gives the following financial data for 1911:

Revenue receipts	$203, 952
Payments for expense	32, 133
Payments for outlays	320, 624
Value of land, building, and equipment	2, 791, 720
Debts incurred	1, 560, 000

The following statement in regard to future developments is quoted from the annual report of the city engineer of the city of Waterbury for the year 1912 (p. 26):

During the winter of 1911–12 some surveying was done on a proposed reservoir above the one (Morris) now being constructed. It was determined that such a reservoir could be made in the valley of Pitch Brook, which with a depth of water of 90 feet would store about 1,200,000,000 gallons and have an area of about 100 acres.

Borings were made at an assumed site for a dam, and ledge was located all across the valley. Conditions favor the same type of construction as is being used at Morris dam. These surveys will probably be completed this winter and more accurate information obtained.

During the past year the city has again very narrowly escaped a water famine, necessitating restrictions which were highly uncomfortable and inconvenient. Fortunately the immediate future will be free from these unpleasant experiences due to the bringing into use of Morris reservoir. The question to be considered, however, is for how long this increased supply will continue to be ample, and whether the construction of still another storage reservoir ought not to be undertaken in 1914, immediately after the completion of this one.

In a report to the board of aldermen, dated October 7, 1912, by a committee appointed by that body, figures were presented showing conclusively that the West Branch watershed could fill another such reservoir, even in a year of minimum rainfall. It was also pointed out that the city was growing rapidly; that the consumption of water would increase from other causes as well as on account of such

[1] Baker, N. M., The manual of American waterworks, p. 83, 1897.

growth; that it was very important for Waterbury to have reservoir capacity some years ahead of its actual needs and that the construction of reservoirs, including preliminary engineering studies, the removal of legal obstacles, etc., takes several years.

The conclusion reached by the committee was that a third reservoir on the West Branch watershed could wisely be undertaken as soon as Morris reservoir is completed. If such construction is to begin in 1914, it will be necessary to undertake the preparation of plans early in the coming year.

Assuming that three reservoirs are built on the West Branch with a combined storage of nearly 4,000,000,000 gallons, the city will have reached the limit of development on that watershed. It will then be necessary to obtain water from some other source. For various reasons it appears likely that the obtaining of rights to take water from new sources will hereafter be found increasingly difficult. It would be wise for Waterbury to give early attention to this matter and secure such rights now, without waiting until urgent necessity compels the acceptance of burdensome and expensive conditions.

RECORDS OF WELLS AND SPRINGS.

Information concerning the wells in Waterbury is presented in the following tables. The map referred to in the first column is Plate III, in pocket at end of volume.

Dug wells in Waterbury, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea level.	Cover.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
1	....	Slope....	600	28.7	4.3	596	Open....	
2	....	Slope....	530	....	9.0	521	....	
7	....	Hill.....	570	....	10.5	559	Open....	
10	....	Slope....	525	12.0	3.7	521	Open....	Not used.
14	....	Slope....	555	13.4	12.4	543	Open....	Not used.
15	....	Flat.....	570	....	9.8	560	....	
16	....	Hill.....	570	24.7	20.0	550	Open....	Not used.
17	....	Hill.....	900	13.0	4.9	895	Closed..	
18	....	Slope....	730	19.0	8.0	722	....	Fluctuation 13 feet; fails.
19	....	Slope....	655	13.7	5.5	649	....	
21	....	Slope....	475	20.4	9.1	486	Open....	
22	....	Flat.....	500	7.1	3.5	496	Closed...	
23	....	Slope....	600	15.2	9.8	590	Open....	
24	....	Slope....	500	11.8	6.5	493	....	
25	....	Hill.....	520	24.9	22.5	497	....	
26	....	Slope....	520	27.2	22.0	498	....	Not used.
27	....	Slope....	450	21.2	15.5	434	Open....	
28	....	Slope....	515	39.9	29.5	485	Lattice..	
29	....	Hill.....	490	25.0	18.6	473	Closed...	Not used.
30	G. H. Reed........	Slope....	530	14.8	4.0	526	Closed...	
32	....	Slope....	300	30.1	24.9	275	Closed...	Not used.
33	....	Slope....	260	33.5	32.2	228	Lattice..	

Drilled wells in Waterbury, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Diameter.	Yield per minute.	Cost.	Remarks.
			Feet.	*Feet.*	*Inches.*	*Gallons.*		
4	Chas. Doll	Slope	670	59	6	5		22 feet to rock.
5	Manufacturer's Foundry Co.	Flat	260	166	8	60	a $5	111 feet to rock.
6	Chas. Reed	Slope	670	63	6	4		
8	Henry Joy	Hill	560	55	6	7		
9	John Joy	Hill	540		6			
11	Waterbury Country Club.	Hill	560	550(?)				
12	R. A. Judd	Slope	540	200(?)	6			
13	Harry Waterworth	Flat	535	91	6	12		75 feet to rock; water pumped from 80 feet below surface.
20	Perkins	Slope	400	216	6	8		8 feet to rock; 14 feet of casing used.

a Per foot.

Springs in Waterbury, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Yield per minute.	Remarks.
			Feet.	*Gallons.*	
3		Slope	560	(a)	
31		Slope	515	4	Covered; supplies horse trough.

a Constant.

WATERTOWN.

POPULATION AND INDUSTRIES.

Watertown is in the southeastern part of Litchfield County, in the Naugatuck River valley. It is reached by the Watertown branch of the Naugatuck division of the New York, New Haven & Hartford Railroad, which has stations at Oakville and Watertown, and by trolley from Waterbury. Post offices are maintained at Oakville and Watertown. It was separated from Waterbury and incorporated in 1780. The area of the town is 30 square miles.

The population in 1910 was 3,850. The changes in population from 1782 to 1910 are shown in the following table. The principal industries are agriculture and the manufacture of silk thread, umbrella trimmings, mouse traps, and general hardware.

Population of Watertown, Conn., 1782–1910.

Year.	Population.	Increase.	Decrease.	Year.	Population.	Increase.	Decrease.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
1782	2,732			1850	1,533	6	
1790	3,170	16		1860	1,587	4	
1800	1,622		49	1870	1,698	7	
1810	1,714	6		1880	1,897	12	
1820	1,439		16	1890	2,323	23	
1830	1,500	4		1900	3,100	33	
1840	1,442		4	1910	3,850	24	

TOPOGRAPHY.

Elevations in Watertown range from about 280 feet to a little over 1,000 feet above sea level. The lowest point is on Naugatuck River in the southwest corner of the town, and the highest is in the northwest corner, about 1 mile north of Big Meadow Pond. The hilly character of the town and the distribution of woods is shown on Plate III.

Naugatuck River and its west branch, which form the east boundary of the town, receive all the drainage except that from a small area in the northwest which contains the headwaters of Pomeraug River.

WATER-BEARING FORMATIONS.

Bedrocks.—Crystalline rocks of two varieties—Waterbury gneiss and Thomaston granite gneiss (p. 9)—compose the rock floor of Watertown. They are very dense in texture and consequently poorly suited to furnish large quantities of water. But they have been intensely fractured, and fissures which contain water are sufficiently numerous to afford moderate supplies to drilled wells. The occurrence of water in crystalline rocks is discussed on page 17.

Glacial drift.—Till constitutes the rock cover in all parts of the town except a narrow strip along Naugatuck River where the stream deposits are found. Till consists of mixtures of clay, sand, gravel, and bowlders, and was deposited by the retreating ice sheets at the close of the glacial epoch. In some places the till is about 100 feet thick, but in other places, as shown on Plate III, the bedrocks are exposed. (See p. 11.)

GROUND-WATER SUPPLIES.

Forty-six dug wells, ranging in depth from 6 to 29 feet and averaging 16 feet, were examined. Depth to water in these wells ranges from 2 to 23 feet and averages 7 feet. All the wells pass through till but at least three end in rock. Only four were reported to go dry, although seven of those examined have been abandoned.

Springs are numerous along the brooks and hillsides throughout the town, but they are all gravity springs of low yield and the usual method of utilizing the flow is to dig a shallow well and install a pump or siphon. There has been little drilling in Watertown heretofore, but it is said that a considerable amount of this work is contemplated. A 6-inch well drilled for Albert Blakesley to a depth of 118 feet yields 2 gallons a minute. It is situated at an elevation of about 880 feet above sea level and reached bedrock at 96 feet below the surface. The records of drilled wells in other towns of this area will serve to indicate the prospects for drilled wells in Watertown, since the occurrence of water is uniform throughout the area.

The following analysis represents a moderately mineralized but rather hard water containing almost no iron:

Analysis of water from dug well of J. H. Atwood, Watertown, Conn.

[Sample collected June 24, 1915. No. 36 in record table (p. 70). R. B. Dole, analyst.]

	Parts per million.
Silica (SiO_2)	10
Iron (Fe)	Trace.
Calcium (Ca)	32
Magnesium (Mg)	5
Carbonate radicle (CO_3)	.0
Bicarbonate radicle (HCO_3)	60
Sulphate radicle (SO_4)	25
Chlorine (Cl)	48
Total hardness as $CaCO_3$	120
Total solids at 180° C	291

PUBLIC WATER SUPPLY.

The Watertown Water Co., of which A. W. Wheeler is superintendent, supplies the village of Watertown. The works include an impounding reservoir in Bethlehem, 22 feet deep, with a capacity of 20,000,000 gallons, and a distributing reservoir holding 500,000 gallons. Water is delivered by gravity through 13 miles of mains under pressures of 40 to 135 pounds. There are 53 hydrants belonging to the fire district, 4 private hydrants, and 278 service connections. There about 2,500 consumers and the average daily consumption is estimated to be 250,000 gallons. The following financial statement was furnished:

Total cost of construction, estimated	$68, 000
Cost of operation, estimated	2, 361
Gross income	6, 200

Four meters are in use, the rate being 10 to 40 cents per 1,000 gallons, but most of the supply is furnished at a flat rate, $8 a year being the minimum charge.

It is said that the present supply is inadequate and that it is occasionally necessary to pump water into the mains from brooks. A supply several times as large as that now available is needed.

According to tests made by the Connecticut State Board of Health of 12 samples from the city reservoir in 1901 the water supply has an average color of 57 parts per million, a total hardness of 20 parts, and an alkalinity of 23 parts and contains 63 parts of total solids, of which 25 parts is volatile matter.[1]

RECORDS OF WELLS AND SPRINGS.

Information concerning the wells and springs in Watertown is given in the following tables. The map cited is Plate III.

Dug wells in Watertown, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Depth to water.	Elevation of water table above sea level.	Cover.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
2	....	Slope....	910	14.1	6.6	903	Closed...	
5	E. H. Peck....	Hill.....	790	19.7	2.8	787	Open....	Fails.
6	....	Slope....	770	6.6	.9	769	Closed...	
7	....	Slope....	785	15.6	12.9	772	Open....	
8	....	Slope....	660	17.2	5.3	655	Closed...	
9	....	Slope....	750	14.8	4.7	745	Closed...	
12	....	Hill.....	910	12.8	3.2	907	Closed...	Not used.
13	E. B. Atwood.	Slope....	890	10.2	4.5	885	Closed...	
15	....	Flat.....	840	15.5	2.1	838	Closed...	Not used; fails.
16	....	Hill.....	860	26.8	3.0	857	Closed...	
17	M. J. Scott....	Slope....	780	....	7.3	773	Open....	
18	"Ruby Farms"	Slope....	670	....	12.0	658	Closed...	
20	....	Slope....	550	13.9	2.9	547	Closed...	Not used.
21	....	Slope....	740	11.6	3.0	737	Open....	
24	....	Hill.....	880	19.4	13.5	866	Closed...	17 feet to rock.
27	....	Slope....	840	....	8.0	832	Closed...	Depth to water reported.
28	....	Slope....	700	7.0	....	....	Closed...	
29	....	Hill.....	750	18.0	14.0	736	....	14 feet to rock.
30	....	Slope....	440	25.0	23.0	417	....	
32	....	Slope....	550	15.5	8.4	542	Closed...	
33	....	Hill.....	685	....	8.0	677	....	
34	....	Hill.....	670	....	8.7	661	....	
35	....	Slope....	550	11.9	5.0	545	Open....	Fails.
36	J. H. Atwood.	Hill.....	760	18.9	8.7	751	Open....	
38	....	Hill.....	590	22.0	6.0	584	Closed...	
39	....	Slope....	740	18.0	4.7	735	Closed...	
40	....	Slope....	680	16.3	9.3	671	Closed...	
41	....	Hill.....	700	25.1	7.1	693	Closed...	
42	....	Slope....	640	....	5.8	634	Closed...	Use city water.
44	....	Slope....	540	9.3	4.1	536	Open....	
45	....	Hill.....	605	16.1	8.7	596	Closed...	
48	....	Hill.....	650	18.0	13.0	637	Closed...	
49	....	Slope....	585	29.0	17.0	568	....	
50	....	Hill.....	765	17.7	5.6	759	Closed...	
52	....	Hill.....	740	....	12.0	728	....	
53	....	Hill.....	660	11.6	6.0	654	Closed...	11 feet to rock.
55	....	Slope....	560	16.7	10.1	550	Closed...	Not used.
58	....	Flat.....	755	17.7	11.5	743	Open....	Not used.
59	....	Hill.....	680	....	8.0	672	....	
63	....	Slope....	710	11.4	3.8	706	Closed...	
64	....	Slope....	680	7.0	4.0	676	Closed...	8 feet square.
65	....	Flat.....	590	10.9	7.2	583	Open....	
66	....	Slope....	.640	7.0	3.0	637	Closed...	
67	Thomas Lillis.	Slope....	625	12.5	3.7	621	....	Fails.
68	....	Flat.....	530	....	7.0	523	Closed...	
69	....	Slope....	570	17.6	9.0	561	....	Not used.
71	....	Slope....	620	17.5	7.5	612	Closed...	Not used.

[1] Connecticut State Board of Health Ann. Rept., 1901, p. 263.

Drilled wells in Watertown, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Depth.	Diameter.	Yield per minute.	Remarks.
			Feet.	*Feet.*	*Inches.*	*Gallons.*	
23	Albert Blakesley	Hill	880	118	6	2	96 feet to rock.
46	Preston	Slope	560				
47	Chas. Abbott	Slope	440				

Springs in Watertown, Conn.

Map No.	Owner.	Topographic position.	Elevation above sea level.	Temperature.	Yield per minute.	Remarks.
			Feet.		*Gallons.*	
1		Top of slope	920			Delivered to barn by ram.
3		Slope	755		[a] 2.5	
4		Slope	920		[a] .5	Not used; covered.
10		Top of slope	800	54	[b] 3.0	
11		Slope	800		1	Not used; covered.
14	E. B. Atwood	Foot of slope	800		2	
19		Foot of slope	685			
22		Slope	645			Covered.
25		Slope	850			
26		Foot of slope	880			5 feet deep; 0.8 foot to water; used.
31		Foot of slope	470		.5	Used.
37	J. H. Atwood	Foot of slope	755		[a] 1.0	
43		Foot of slope	655		.5	Not used; covered.
51		Slope	685	54	[b] .5	Open.
54		Slope	610			
56	Richenbach	Slope	725		([b])	Delivered to house and barn by gravity through 1,500 feet of pipe.
57		Top of slope	795		[a] Low.	Delivered to house and barn by siphon.
60		Foot of slope	615			No overflow.
61		Slope	675		([a])	
62		Slope	715		3	
70		Slope	660			

[a] Yield constant. [b] Yield varies.

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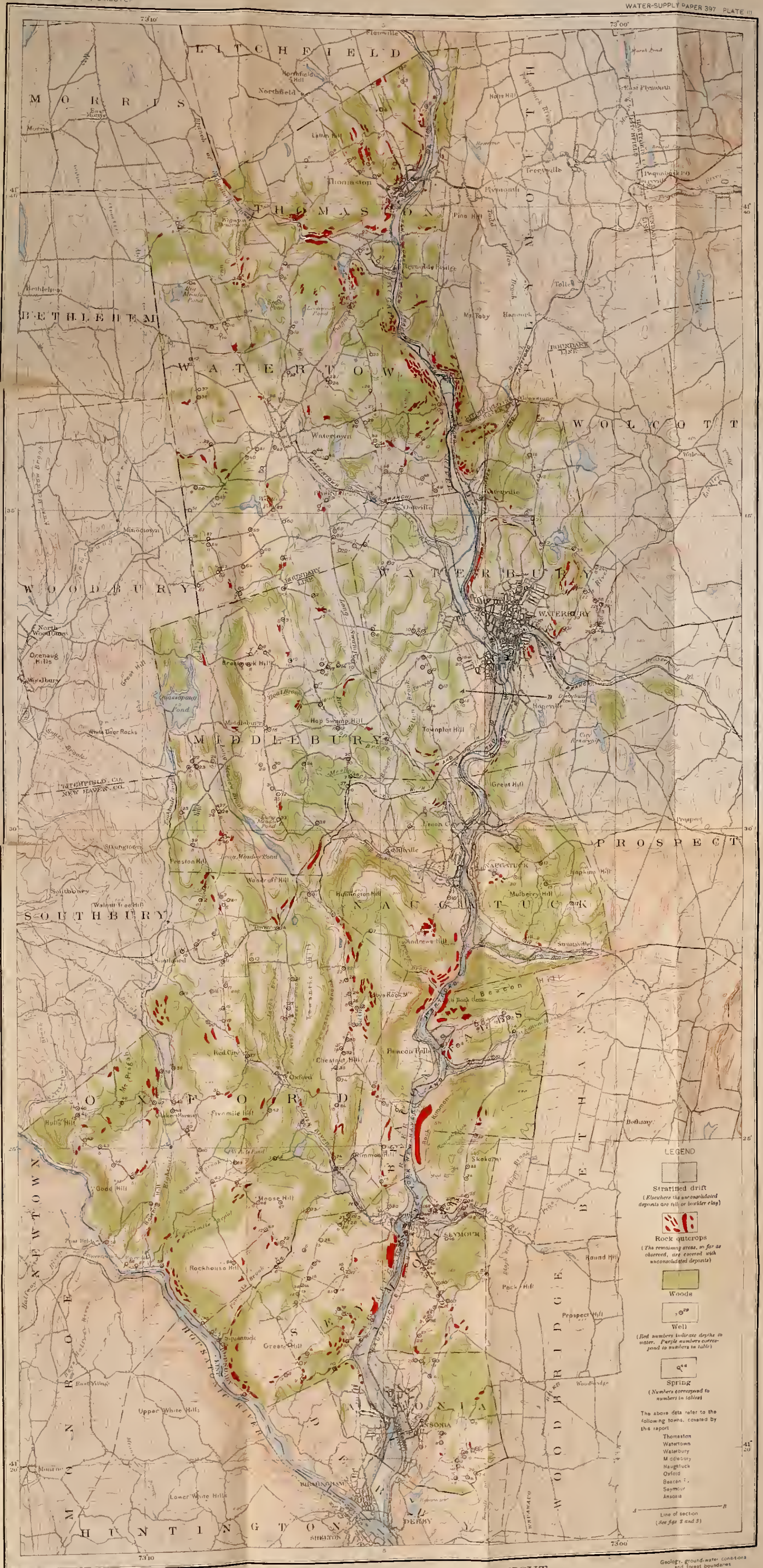

Base from Waterbury, Derby, Meriden and New Haven U S G S topographic atlas sheets

MAP OF WATERBURY AREA, CONNECTICUT

Showing rock outcrops, wooded areas, and ground-water conditions

Contour interval 20 feet
Datum is mean sea level
1915

Geology, ground-water conditions and forest boundaries by Arthur J. Ellis