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DEPARTMENT OF THE INTERIOR
Roy O. West, Secretary

U. S. GEOLOGICAL SURVEY
George Otis Smith, Director

Water-Supply Paper 597—B

A STUDY OF GROUND WATER IN THE POMPERAUG BASIN, CONNECTICUT

WITH SPECIAL REFERENCE TO INTAKE AND DISCHARGE

BY

OSCAR EDWARD MEINZER

AND

NORAH DOWELL STEARNS

Prepared in cooperation with the
CONNECTICUT STATE GEOLOGICAL AND NATURAL HISTORY SURVEY

Contributions to the hydrology of the United States, 1928
(Pages 73–146)
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CONTENTS

ILLUSTRATIONS

Arnold I. Johnson
Hydraulic Engineer
Hydrologic Laboratory

A STUDY OF GROUND WATER IN THE POMPERAUG BASIN, CONNECTICUT

WITH SPECIAL REFERENCE TO INTAKE AND DISCHARGE

By Oscar Edward Meinzer and Norah Dowell Stearns

INTRODUCTION

For a number of years the United States Geological Survey has cooperated with the Geological and Natural History Survey of Connecticut in a study of the ground-water resources of that State. A large number of towns have been surveyed, and water-supply papers covering these towns have been published, as shown on Plate 11. The present report covers the ground-water resources of the towns of Bethlehem, Woodbury, and Southbury. It includes also a critical study of the drainage basin of Pomperaug River, which lies chiefly in these three towns. (See pl. 12.) In this study, which is based on observations covering a period of more than three years, an attempt has been made to determine, month by month, what became of the water that fell on the drainage basin as rain or snow and especially to determine for each month the quantity of water that reached the zone of saturation and was added to the ground-water supply and the quantity that was discharged from the zone of saturation as ground-water run-off or by evaporation and transpiration.

The Pomperaug Basin was selected for quantitative study, not because its water resources are intensively developed or especially valuable, but because it presents ground-water conditions that are fairly representative of those throughout the State and because it is a convenient unit for quantitative study, with fewer complications than are found in most areas.

The quantitative study is, in a sense, a by-product of the regular ground-water work in Connecticut. The allotments for carrying on the investigation were small, and the number of observations made were inadequate to yield very accurate results. However, so little work of this kind has been done in the eastern, humid part of the United States and so many problems arise in which it is essential to make estimates of the ground-water recharge in specific areas that it seems worth while to publish the results that were obtained. It is believed also that a presentation of the methods used will be of value to others who may be required to make quantitative studies of ground-water supplies in humid regions.

The investigation was made under the general direction of H. E. Gregory, former superintendent of the Connecticut State Geological and Natural History Survey, and O. E. Meinzer, geologist in charge of the division of ground water in the United States Geological Survey. The general ground-water survey of the basin was made by Arthur J. Ellis, who also had charge of the regular observations that were begun in the summer of 1913 and were continued until about the end of 1916. Special observations were made by Kirk Bryan and H. S. Palmer and by Messrs. Gregory and Meinzer. The water analyses were made by Margaret D. Foster, except that of Nonewaug River, which was made by S. C. Dinsmore. The stream-gaging station at Bennetts Bridge, near the mouth of the Pomperaug, was established by C. H. Pierce, and the gage was read once or twice a day by W. H. Ingram. The three rain gages were read by S. P. Hayes, A. M. Mitchell, and H. M. Canfield, voluntary observers. Weekly measurements of the observation wells were made by Ernest W. and George A. Parkin and later by Ralph Wooden. Thanks are due to the local observers and also to the many owners of wells and springs and other inhabitants of the Pomperaug Basin who furnished information or gave assistance in other ways.

On account of war work and other important duties Mr. Ellis was obliged to postpone his study of the Pomperaug data, and at his untimely death in 1920 the investigation was left incomplete. In 1922 Norah E. Dowell (now Mrs. Stearns) took up the study and spent a few weeks in the Pomperaug Basin. In 1923 H. T. Stearns spent a short time in the basin and completed the geologic map (pl. 12).

The present report was carefully examined by the late H. H. Robinson, superintendent of the Connecticut State Geological and Natural History Survey, and David G. Thompson, both of whom gave much valuable criticism.

GEOGRAPHY

The drainage basin of Pomperaug River is situated in the central part of the western highland of Connecticut. (See pl. 11.) It is about 17 miles in length and 8 miles in maximum width and has an area of about 89 square miles. It comprises nearly all of the towns of Bethlehem and Woodbury, a large part of the town of Southbury, and small parts of the towns of Roxbury, Washington, Morris, Watertown, and Middlebury. (See pl. 12.) It contains the villages of Bethlehem, Woodbury, North Woodbury, Pomperaug, Southbury, and South Britain. The New York, New Haven & Hartford Railroad passes through the southeast corner of the area and has a station at Southbury. Woodbury and North Woodbury are reached by an electric line from Waterbury.

The Pomperaug Basin is one of the rural parts of Connecticut, where the population is relatively small and widely scattered. According to the census of 1920, the town of Bethlehem had 576 inhabitants, the town of Woodbury 1,698, and the town of Southbury 1,238. The density of population was 29 to the square mile in Bethlehem, 47 in Woodbury, and 31 in Southbury. In this, as in many other rural districts in Connecticut, the population is not increasing. From 1910 to 1920 there was a slight increase in Bethlehem and Southbury, but it was more than offset by a decrease of 162 in Woodbury.

Agriculture is the main industry and consists chiefly of general farming and dairying. There are also several small factories in the area. Cultivated fields and orchards are found in the valley bottoms, on the lower and gentler slopes of the hills, and on many of the flat or rounded hilltops. The rocky areas are largely in pasture, and the wet lands produce marsh hay. About a third of the drainage basin consists of woodland.

A meteorologic station has been maintained by the United States Weather Bureau at Waterbury, 10 miles east of this basin, for a period of 38 years. According to the records obtained at this station the mean annual temperature at Waterbury is 48.8° F., the mean annual precipitation 48.81 inches, the average date of the first killing frost October 14, and the average date of the last killing frost April 16.[1] In the Pomperaug Basin there is a long winter season. Spring usually comes so quickly that the snow melts rapidly and sometimes causes strong freshets. It soon gives way to summer, which is a pleasant season except for a few hot waves. Autumn is delightful and often has many weeks of Indian summer, with warm days and cool nights. The winds are prevailingly from the west, except in May and June, when east winds prevail.[2]

TOPOGRAPHY AND DRAINAGE

The Pomperaug Basin consists chiefly of rather rugged uplands, but in the south-central part of the basin there are extensive valley areas. The highest point in the basin, 1,150 feet above sea level, is at its northern extremity, near the village of Morris; the lowest point, only 100 feet above sea level, is at the mouth of Pomperaug River.

Most of the hills are well rounded and are covered with glacial drift. Some of the slopes, however, are very steep and are either entirely bare of soil or so thinly covered that bedrock is exposed at intervals of only a few feet. The valleys trend in a north-south

[1] Climatologic data, 1922 and 1923, United States Weather Bureau.

[2] Summaries of climatological data of the United States, by sections: U. S. Weather Bureau Bull. W, section 105, 1912.

direction. In the south-central part of the basin the valley of Pomperaug River and to some extent the tributary valleys have wide flat bottoms and are bordered by extensive terraces. Both the bottom lands and the terraces are underlain by stratified drift. The terraces generally have smooth surfaces, modified to some extent by kames and kettle holes. In the rest of the basin the valleys are usually narrow and have steep sides.

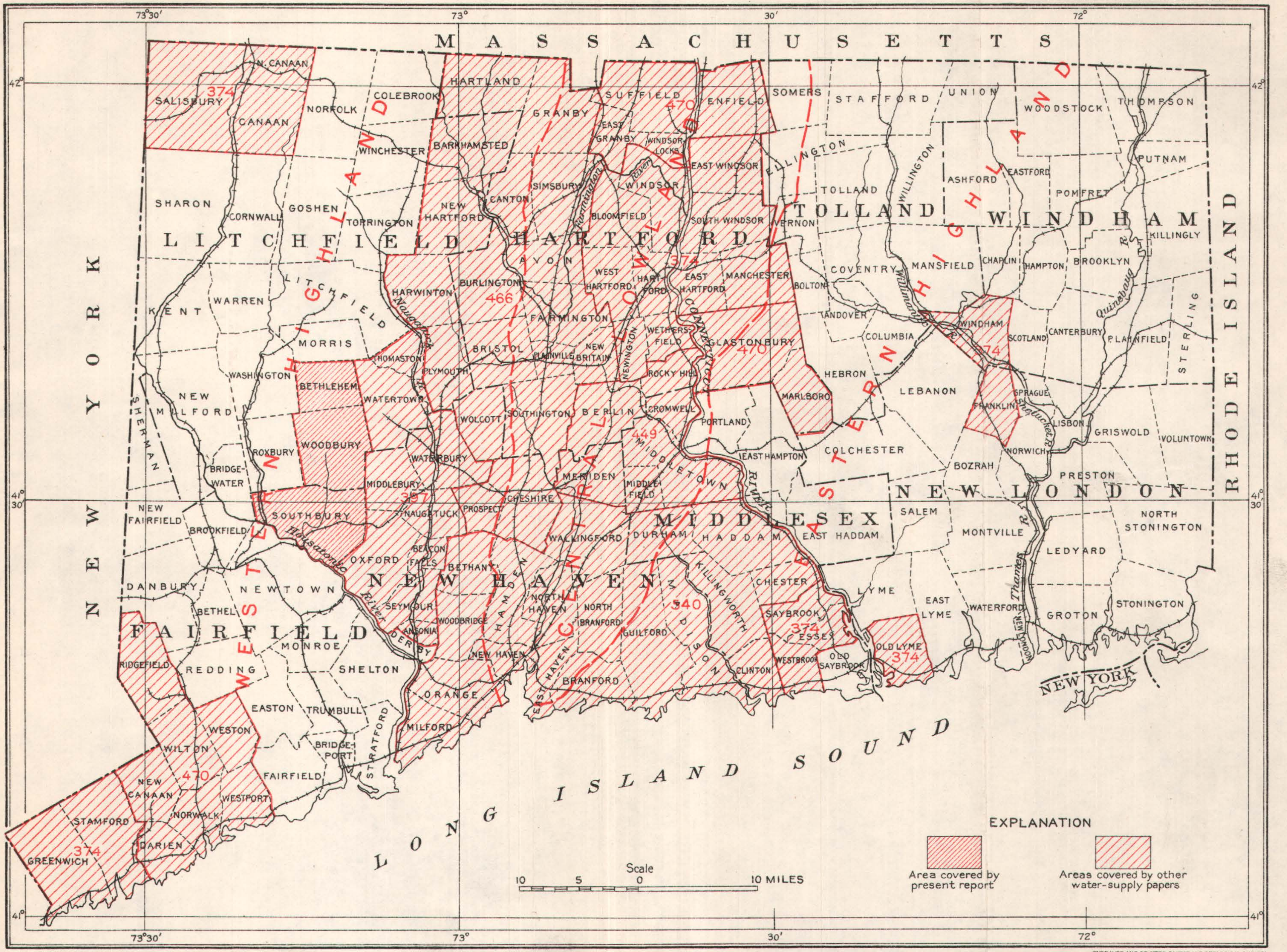
Pomperaug River flows in a generally southward course and discharges into the Housatonic just below Bennetts Bridge. It is formed by the confluence near North Woodbury of Nonewaug River, which drains the northeast quarter of the basin, and Weekeepeemee River, which drains the northwest quarter. (See pls. 12 and 13.)

There has obviously been some derangement of the drainage of Pomperaug River in the lower part of its course and of its tributaries, Hesseky and Transylvania Brooks. These brooks at one time probably formed a single stream that flowed southward. Later the upper part of this stream apparently became impounded by the deposition of glacial drift in the vicinity of the present divide and found an outlet toward the northeast. These changes in drainage are suggested by the abnormal angles that Hesseky Brook makes with the Pomperaug and that the tributaries make with Hesseky Brook, the insignificant divide that at present separates its headwaters from those of Transylvania Brook, the swampy character of its bottom lands, and the lake deposits that underlie its valley. (See pl. 12.) The narrow steep-sided valley of the Pomperaug below South Britain suggests that the river formerly drained directly southward through the low land east of Horse Hill.

Ponds and marshes are found in many parts of the basin. They were produced chiefly by glacial scour or deposition. (See pl. 14.) Long Meadow Pond, the largest pond, is about a mile south of Morris and empties into Weekeepeemee River. Big Meadow Pond lies about 2½ miles east of Bethlehem and empties into Nonewaug River. A small pond lies at the headwaters of Hesseky Brook, and there are a number of others near the villages of Woodbury and Southbury. Marshes are found at the head of Wood Creek, west of Todd Hill, along the course of Weekeepeemee River, south of Bethlehem, and along nearly the whole course of Hesseky Brook. The aggregate area of the ponds in the drainage basin of Pomperaug River is about half a square mile, and that of the marshes is also about half a square mile, not including many small wet tracts where the ground water lies near the surface and gives rise to seeps and springs.

GEOLOGIC SKETCH

The Pomperaug Basin is underlain by ancient crystalline rocks, such as schist, gneiss, granite gneiss, and diorite, except in the south-



MAP OF CONNECTICUT SHOWING PHYSIOGRAPHIC DIVISIONS AND AREAS TREATED IN THE PRESENT AND OTHER DETAILED WATER-SUPPLY PAPERS OF THE UNITED STATES GEOLOGICAL SURVEY central part, where Triassic trap and sedimentary rocks occur.[3] Spread over these rock formations is a mantle of glacial drift, which is generally thin and in many localities is entirely absent, leaving the rocks exposed. (See pl. 12.)

The ancient crystalline rocks have suffered so many changes that their history is difficult to decipher. In some remote period, probably in early Paleozoic time, sand and mud were deposited in the region, and eventually these materials became consolidated to sandstone and shale.[4] Later there were great mountain-building disturbances, characterized by compression of the earth's crust and intrusion of vast quantities of igneous material. The mashing and intrusion changed the old shale and sandstone into schist and gneiss. Much of the igneous rock also was crushed and converted into gneiss.[5]

During Triassic time the mountains were deeply eroded and much débris was deposited on the lower land. The deposits thus laid down were later consolidated and formed chiefly red sandstone, shale, and conglomerate, but also some dark bituminous shale and green and gray limy shales. In some places in the Connecticut Valley fossil footprints of reptiles and a few reptilian bones have been found in the Triassic rocks. In the Triassic rocks of the Pomperaug Basin remains of fishes and pieces of fossil wood have been found.[6] The Triassic history of the Pomperaug Basin is closely related to that of the central Connecticut lowland. According to one theory the Triassic rocks of this basin were once continuous with those of the greater Triassic area in the Connecticut Valley and were separated from them by erosion; according to another theory the Pomperaug Basin was a separate intermontane valley in which the Triassic sediments were deposited.[7]

The deposition of the Triassic sediments was interrupted throughout the region by eruptions of lava, which spread out in extensive sheets of basalt or trap. These lavas now form the trap ridges of Rattlesnake Hill, French Mountain, Ragland Hill, and Orenaug Hill. (See pls. 12 and 15, *A*.)

Subsequently, probably in Jurassic time, the flat-lying sedimentary rocks and interbedded trap sheets were broken into blocks by a series of faults that in general cut across the area in a northerly direction. Each block was rotated so that its southeast margin was depressed.[8]

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[3] Gregory, H. E., and Robinson, H. H., Preliminary geological map of Connecticut: Connecticut Geol. and Nat. Hist. Survey Bull. 7, 1907.

[4] Rice, W. N., and Gregory, H. E., Manual of the geology of Connecticut: Connecticut State Geol. and Nat. Hist. Survey Bull. 6, pp. 96–100, 1906.

[5] Idem, pp. 79, 109. 110.

[6] Hobbs, W. H., The Newark system of the Pomperaug Valley, Conn.: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 3, pp. 55–56, 161–162, 1901.

[7] Davis, W. M., The structure of the Triassic formation of the Connecticut Valley: U. S. Geol. Survey Seventh Ann. Rept., pp. 461–462, 1888.

[8] Davis, W. M., op. cit., figs. 98, 105; The Triassic formation of Connecticut: U. S. Geol Survey Eighteenth Ann. Rept., pt. 2, pl. 20, 1898. Hobbs, W. H., op. cit.

There is no sedimentary record of the interval between the Triassic period and the glacial epoch, either in the Pomperaug Basin or elsewhere in Connecticut, but erosion took place and left its mark. During the Cretaceous period, as has been shown by Davis,[9] the great block mountains formed by the faulting were almost completely worn away by the streams and a peneplain was developed which extended over the old crystalline rocks as well as the Triassic formations. In later periods, as has been shown by the work of Barrell,[10] the region was uplifted in successive stages and a series of terraces was cut by the sea into the elevated peneplain. Since the uplift the region has been deeply dissected, and only remnants of the original surface remain.

During the Pleistocene epoch the Pomperaug Basin was overridden at least once and probably several times by a thick continental ice sheet. As this ice sheet moved slowly southward it remodeled the topography by scraping away the decayed rock material that had accumulated at the surface, by breaking off and grinding down projecting ledges of rock, and by redepositing the débris. The major features of the topography were left unchanged, but the details were greatly altered. The mantle of residual soil was replaced by glacial drift of two types—unstratified drift, or till, and stratified drift, or glacial outwash. The till, which was deposited directly by the ice, forms a rather thin but irregular and frequently interrupted mantle over the bedrocks throughout the upland portions of the basin. The stratified drift was deposited by the streams that flowed out from the glacial ice and filled the valleys of Pomperaug River and of Hesseky and Transylvania Brooks to a considerable extent. The broad alluvial plains that resulted were later trenched by these streams, but remnants of the original plains remain and form terraces of stratified drift along the valley sides. In a few places silt and clay were deposited in temporary ponds or lakes formed where streams were dammed by the glacial ice and its deposits.

Since the Pleistocene epoch there has been no important change in the topography. Slight erosion has occurred over most of the region, and small amounts of alluvium have been deposited in the valleys. Some swamps have been filled, and some lakes have been changed to swamps by being filled with sediment and vegetation.

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[9] Davis, W. M., U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pp. 157-159, 1898.

[10] Barrell, Joseph, Piedmont terraces of the Appalachians and their origin: Geol. Soc. America Bull., vol. 24, pp. 688-691, 1913; The piedmont terraces of the northern Appalachians: Am. Jour. Sci., 4th ser., vol. 49, pp. 227-258, 327-362, 407-428, 18 figs., 2 pls., 1920.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES[11]

BEDROCK

PRE-TRIASSIC CRYSTALLINE ROCKS

In most of the Pomperaug Basin the glacial drift is underlain by crystalline rocks of pre-Triassic age, chiefly schist and gneiss. These rocks are so dense that the circulation of water through them is practically restricted to the joints. There are many joints in all these rocks, but in most of them the openings are too narrow, even at the surface, to allow much water to pass. However, the smaller joints are generally connected, either directly or indirectly, with larger ones into which they may drain. The joint openings in these rocks diminish rapidly in size from the surface downward, and most of them disappear entirely within a few hundred feet of the surface. Water-bearing fissures at greater depths are rare.

In the openings of this intricate system of joints ground water is stored in relatively small quantities and generally moves very sluggishly, if at all. Thus, although these rocks generally yield from 1 to several gallons a minute to drilled wells of moderate depth, they are not effective in transmitting much water any great distance, and it is safe to assume that they form a nearly impervious bottom, through which only small quantities of water escape from the Pomperaug Basin.

TRIASSIC ROCKS

The Triassic rocks, it is believed, underlie most parts of the valleys of Pomperaug River and Hesseky and Transylvania Brooks and the islandlike upland between these valleys. (See pl. 12.) They include sedimentary rocks and interbedded trap rocks. The sedimentary rocks consist chiefly of arkosic conglomerate and sandstone but include also some shale and limestone. The trap rocks, being the most resistant, have been etched into strong relief and form the prominent range of hills that extends from Woodbury to South Britain. Sandstone and conglomerate flank the outcrops of trap and probably underlie most of the valley lowlands, although they crop out in only a few places.

The sedimentary rocks are in general hard and dense. They are somewhat porous, but their pore spaces are so small that they yield little or no water from these spaces. Like the crystalline rocks, they are broken by numerous joints, which become tighter and less numerous with depth. The shale is generally less permeable than the sandstone, but it also is traversed by water-bearing joints. The trap rocks are as a rule even denser than the sedimentary rocks, but in some places they yield meager supplies of water from joints.

[11] For a more detailed discussion of water in the rocks of Connecticut see Gregory, H. E., and Ellis, E. E., Underground water resources of Connecticut: U. S. Geol. Survey Water-Supply Paper 232, 1919.

FAULTS

The rocks underlying the Pomperaug Basin are broken by many faults,[12] but it is believed that the fault fissures do not form water conduits large enough to allow ground water to escape in any considerable amounts, and there is no evidence of deep-seated waters appearing as springs. (See pp. 85–89.)

GLACIAL DRIFT

TILL

The till forms a mantle over the bedrock of most of the Pomperaug Basin. (See pls. 12 and 17, *A*.) It is an ice-laid deposit composed

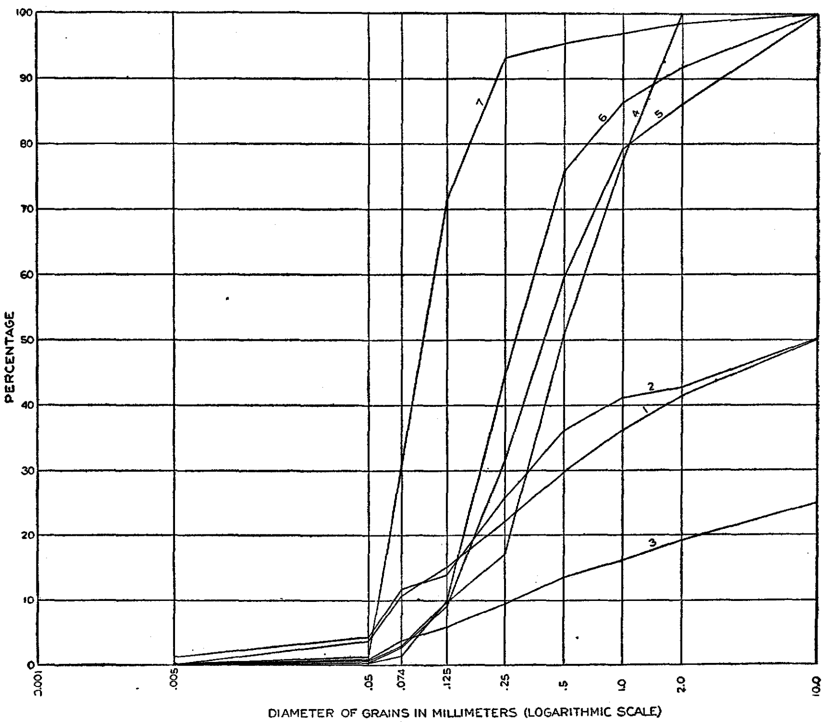


FIGURE 6.—Mechanical composition of glacial deposits in the Pomperaug Basin, Conn. 1, 2, 3, Till; 4, 5, 6, stratified drift of ordinary types; 7, glacial-lake deposit

of a matrix of the pulverized and granulated fragments of the rocks over which the ice sheet passed and of larger pieces of the same rocks embedded in the matrix. Its color in general is blue-gray, but near the surface, where the iron-bearing constituents of the matrix have been weathered, it is yellow or brown, and where the material is in large part derived from the red Triassic rocks it is reddish brown to

[12] Davis, W. M., op. cit. Hobbs, W. H., op. cit.

red. The boulders are very abundant and are scattered over the fields and exposed in the banks of cuts.

Some of the till, especially that part below the weathered zone, is very tough, as is indicated by the term "hardpan" often applied to it. The toughness of the till is due in part to the presence of clay, in part to its having been thoroughly compacted by the great weight of the ice sheets, and in part to the interlocking of the sharp, angular grains. It seems probable that the more soluble constituents of the matrix have to some extent been dissolved by the ground water and have been redeposited in such a way as to cement the particles together.

The relative amounts of the different sizes of material in till and in stratified drift as determined by mechanical analyses are shown in the following table and in Figure 6. The material smaller than 1 centimeter in diameter was tested practically according to the methods used by the United States Bureau of Soils.[13] The amounts of material larger than 1 centimeter in diameter were estimated in the field. The results shown in the table were calculated as percentages, including the coarse material, for which estimates were made.

Mechanical analyses of glacial deposits, Pomperaug Basin

[Analyzed by Norah E. Dowell]

Material	Diameter (millimeters)	Till			Stratified drift			
		1	2	3	4	5	6	7
Gravel to boulders [a]	Larger than 10	50.0	50.0	75.0	0	0	0	0
Gravel	10–2	8.7	4.7	5.9	0	13.8	7.3	1.5
Fine gravel	2–1	5.2	3.0	2.9	22.2	6.9	6.3	1.7
Coarse sand	1–0.5	6.4	6.1	2.7	26.9	19.4	10.8	1.6
Medium sand	0.5–0.25	7.7	10.3	4.0	33.9	28.2	31.0	2.0
Fine sand	0.25–0.125	7.0	9.5	3.7	13.5	22.6	35.2	21.9
Very fine sand	0.125–0.074	4.2	4.8	2.1	2.2	6.4	6.8	40.3
	0.074–0.05	7.0	7.4	2.9	1.0	2.2	2.3	29.9
Silt	0.05–0.005	3.8	2.9	.8	.3	.4	.3	1.0
Clay	Less than 0.005	.0	1.3	.0	.1	.1	.0	.1
Effective size [b] ...millimeters		.07	.07	.27	.13	.13	.13	.06
Uniformity coefficient [c]					4.9	3.8	2.8	1.9
Porosity ...per cent		16.3	15.8	8.7	31.8	37.1	38.5	41.9

[a] Estimated in field.

[b] The term "effective size" is here used to mean the diameter of grain which is just too large to pass through a sieve that allows 10 per cent of the material, by weight, to pass through (Meinzer, O. E., Outline of ground-water hydrology: U. S. Geol. Survey Water-Supply Paper 494, p. 45, 1923).

[c] The uniformity coefficient is the quotient of the diameter of a grain that is just too large to pass through a sieve that allows 60 per cent of the material, by weight, to pass through, divided by the diameter of a grain that is just too large to pass through a sieve that allows 10 per cent of the material, by weight, to pass through (Meinzer, O. E., op. cit., p. 45).

Samples 1 and 3 represent till derived chiefly from the gneiss and schist. Sample 2 represents till derived chiefly from Triassic sandstone, shale, and trap. There is no great difference in the mechanical analysis due to this difference in composition, except that No. 2 has a larger percentage of clay and No. 3 a larger percentage of boulders and pebbles.

[13] U. S. Dept. Agr. Bur. Soils Bull. 84, 1912.

The porosity was obtained in the laboratory by adding measured quantities of water to definite volumes of the material. The average porosity of the three samples of till is 13.6 per cent. In 1915 six samples of till were tested in the field by the senior author for porosity by adding measured quantities of water to definite volumes of the material. These tests gave porosities ranging from 21 to 11.5 per cent and averaging 14.7 per cent after corrections had been made for material of large size.

In most places the till yields only small supplies of water, but locally bodies of stratified sand and gravel within the till yield water freely. The till is of great value for domestic supplies because it is widely distributed and at most places will yield to inexpensive dug wells enough water for family uses. The till is also the reservoir which feeds most of the small springs that provide gravity supplies for many farms. Furthermore, it holds the water supplied by precipitation and yields it slowly to the streams, thus maintaining a perennial flow in streams that would otherwise be dry much of the time.

STRATIFIED DRIFT

In contrast with the till, which was laid down directly by the ice, the stratified drift is a water-laid deposit. (See pls. 17, *B*, and 18.) It consists of material that was derived chiefly from the ice but was well washed and sorted by the water that issued from the melting ice sheet. The stratified drift consists of beds laid one upon another in an intricate and irregular way. Some of the beds consist of clay, some of fine sand, some of coarse sand, others of gravel, and still others of cobbles, but the sands are the most abundant. The material of each bed is rather uniform in size, but there may be a great difference between adjacent lenses. In general the finer materials form more extensive beds than the coarser. Some of the beds of clay and silt, though only an inch or two thick, have a horizontal extent of hundreds of feet, whereas lenses of gravel may be 2 or 3 feet thick and yet not extend over 10 feet horizontally. The sand lenses are composed almost entirely of quartz grains, but in the gravel lenses there are pebbles of many kinds of rocks. The clay beds consist of true clay, thin flakes of mica, and minute particles of quartz and feldspar. All the deposits contain iron, which gives them brown colors.

The physical character of four samples of stratified drift is shown in the table on page 81 and in Figure 6. The mechanical analyses were made in the same way as those of the samples of till. Samples 4, 5, and 6 represent some of the finer material that was laid down by running water. All three samples consist of relatively well assorted material. Almost all the material is included within two or three sizes, whereas in the till there is a wider diversity of sizes, even exclusive of the boulders and cobbles that were taken out before the analyses were made. The strata of coarser stratified drift are also well assorted. Sample 7 is a very fine, well-assorted sand that was presumably deposited in a glacial lake.

The average porosity of samples 4, 5, and 6 is 35.8 per cent, and the porosity of sample 7 is 41.9. Field tests of porosity of eight samples of glacial outwash made by the senior author in 1915 gave results ranging from 18 to 37.6 per cent and averaging 28 per cent. One of these was a glacial-lake deposit with a porosity of 36 per cent, and another a recent stream deposit with a porosity of 48 per cent. As both the till and the stratified drift are variable even within short distances, a considerable range in mechanical composition and porosity is to be expected, even in deposits of the same class.

The best water-bearing material in the basin is the coarser stratified drift found in the valley of Pomperaug River and to some extent in the tributary valleys. These porous deposits of clean sand and gravel will yield water in large quantities to properly constructed wells, and their supplies are readily replenished when the rains come. They are valuable for obtaining large supplies from wells for municipal and industrial uses.

CIRCULATION OF GROUND WATER

The ground water in the Pomperaug Basin is virtually all derived from the rain and snow that fall on the drainage area. On the steep slopes the water runs off rapidly and relatively little enters the ground, but on the more gentle slopes and on the flat areas a larger portion of the precipitation is absorbed by the soil. Some of the water sinks through the pores of the unconsolidated material until it reaches the water table or the relatively impervious bedrock, and thence it moves laterally. Except in the stratified drift, however, lateral movement does not take place over great distances, largely because the unconsolidated materials occur in discontinuous areas interrupted by ledges of bedrock which cause the water to return to the surface.

Throughout most of the Pomperaug Basin the water table, or upper surface of the zone of saturation, is not far below the land surface, and in many places it appears virtually at the surface in springs, marshes, and seepage areas. Over a large part of the basin it is so near the surface that much of the ground water is dissipated through direct evaporation and through absorption by the roots of trees and other vegetation. The water table is commonly nearer the surface on the till-covered hills than in the stratified drift of the valleys, because the till, owing to its lower porosity and permeability, becomes saturated more quickly than the stratified drift. The greatest depth to ground water is found in the terraces underlain by the permeable stratified drift, in which the water table is nearly on a level with the streams.

WATER SUPPLIES

WELLS

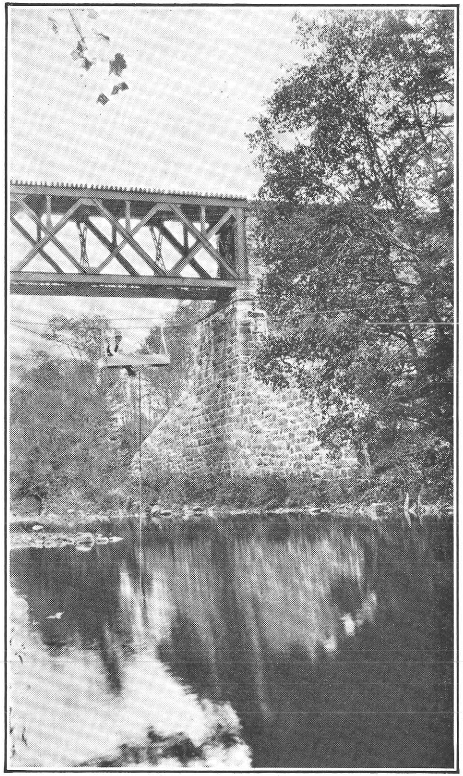
Practically all the domestic water supplies in the Pomperaug Basin are drawn from the glacial drift. Only a few wells penetrate bedrock, and these may draw water from the rock or from the overlying glacial drift. In the present investigation information was obtained in regard to about 160 wells in the area.

Most of the wells end in till, which underlies about nine-tenths of the area. These are nearly all dug wells, about 3 feet in diameter and curbed with stone. As a rule they furnish supplies of water adequate for domestic use, but if the well is unfavorably situated, as on a slope where the water drains quickly away, the supply may be inadequate or the well may be dry during summer droughts. Many of the wells investigated were reported to fail in dry seasons. Most of these are very shallow and fail because they are above the water table at its low stages or because they are on slopes where the ground water drains away completely.

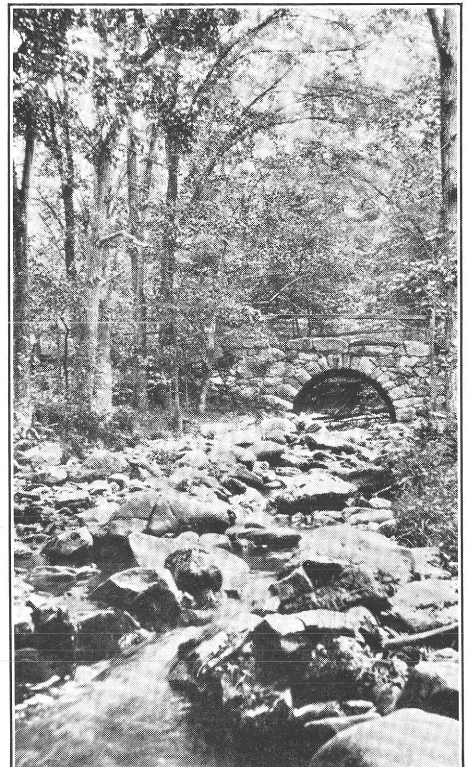
Most of the dug wells are between 15 and 30 feet deep. The deepest dug well examined was 40 feet deep, and the shallowest was only 7 feet. Many of the wells have either hand pumps or chain and sucker pumps, but some have only a rope and bucket equipment.

In parts of the valley bottoms of Pomperaug River and of Transylvania Brook and in the vicinity of North Woodbury the wells draw their supplies from the stratified drift. Most of these wells are dug wells, about 3 feet in diameter and curbed with stone, like the dug wells in till.

Only a few water supplies are obtained from drilled wells. These are of only moderate depth and obtain their water either from jointed bedrock or from the glacial drift overlying the rock. In Bethlehem the well of Homer Weldron was drilled in the bottom of a dug well 20 feet deep and ended in rock at a depth of 200 feet. However, the drilled hole has been abandoned, and only the dug well is used. In Southbury two drilled wells were reported, one, 25 feet deep, owned by Charles Hine and the other, 75 feet deep, owned by Mr. Hickock. Both of these wells are reported to end in sand and gravel. The Hickock well is said to have a good yield. In Woodbury three drilled wells were reported. The well of F. E. Warner is said to end in rock and to yield a supply of hard water. The well of C. B. Dakin, 3 inches in diameter and 296 feet deep, is reported to have passed through a few feet of drift and the rest of the distance through schist. It yields an unfailing supply. The well of C. M. Rowley is 60 feet deep and draws water from glacial materials.

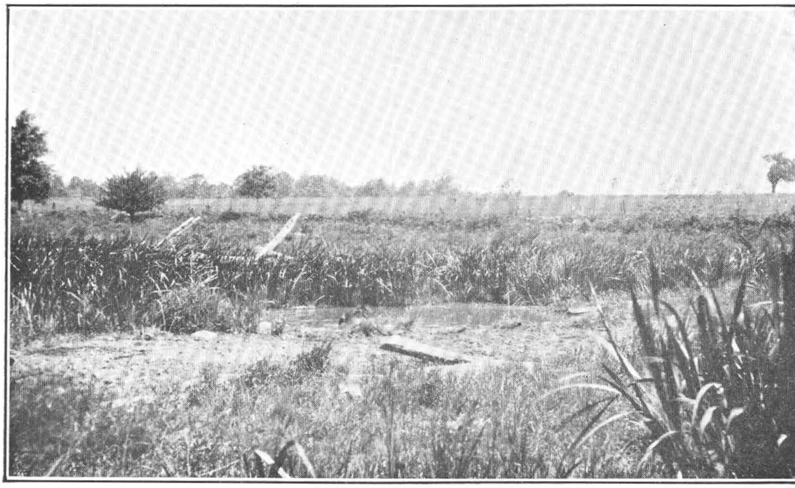


A. GAGING STATION ON POMPERAUG RIVER AT BENNETTS BRIDGE, CONNECTICUT

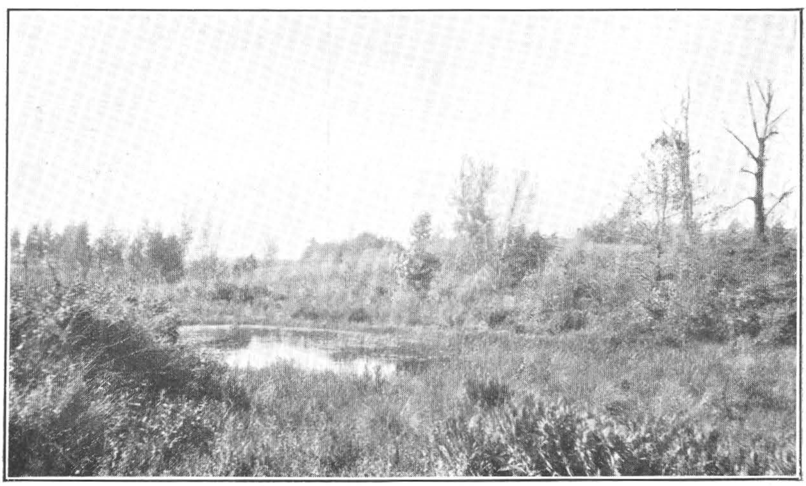


B. NONEWAUG RIVER 1½ MILES NORTH OF MINORTOWN, CONN.

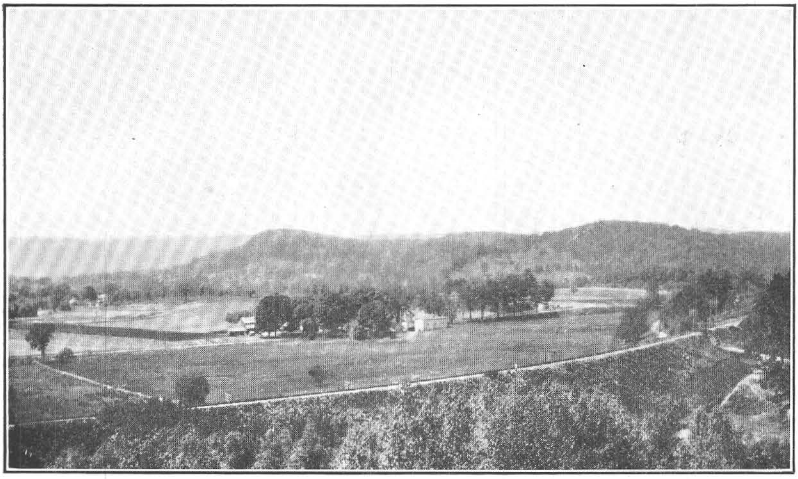
A typical stream bed in till



A. MARSH ON TOP OF HILL AT THE HEAD OF SPRUCE BROOK, 2 MILES EAST OF ROXBURY FALLS, CONN.

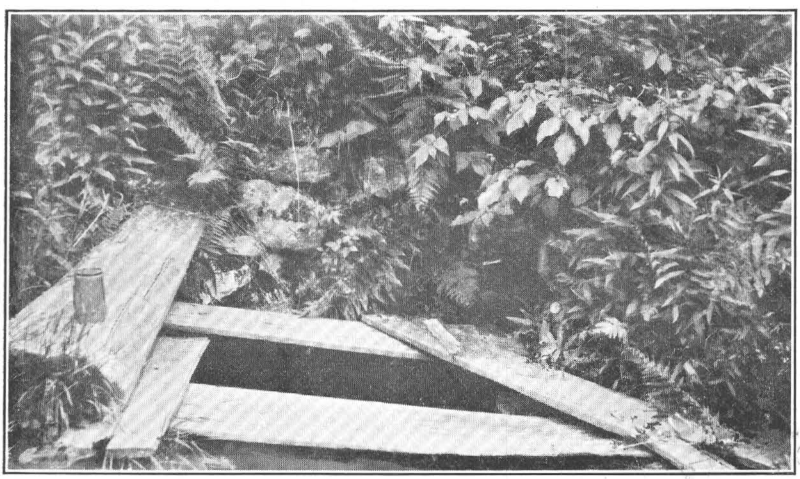


B. MARSH IN A ROCK-SCOURED BASIN, OR TARN, ON SOUTH SIDE OF FLAT HILL, WEST OF SOUTH BRITAIN, CONN.



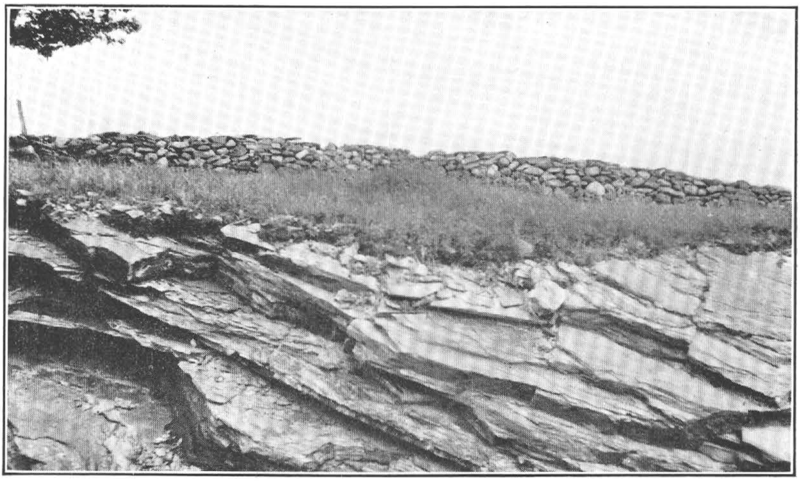
A. TRAP RIDGES OF RATTLESNAKE HILL, NEAR SOUTH BRITAIN, CONN.

View across Pomperaug Valley from Georges Hill

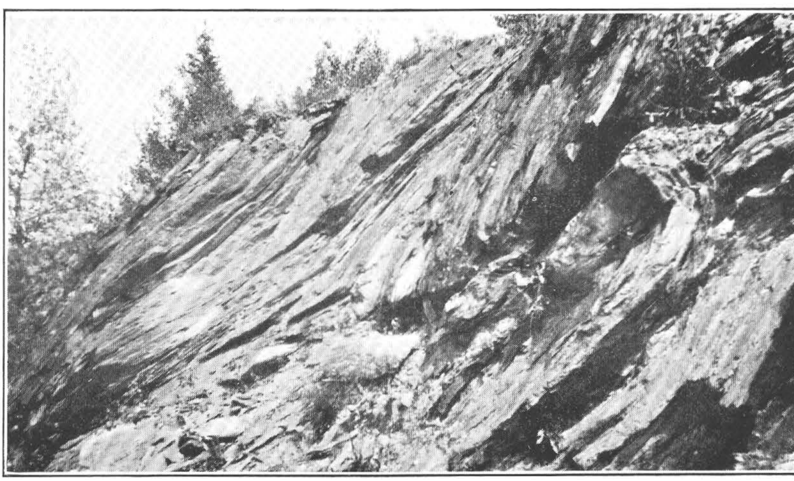


B. ROADSIDE SPRING NEAR MINORTOWN, CONN.

Shows vegetation typical of localities where the water table is very near the surface



A

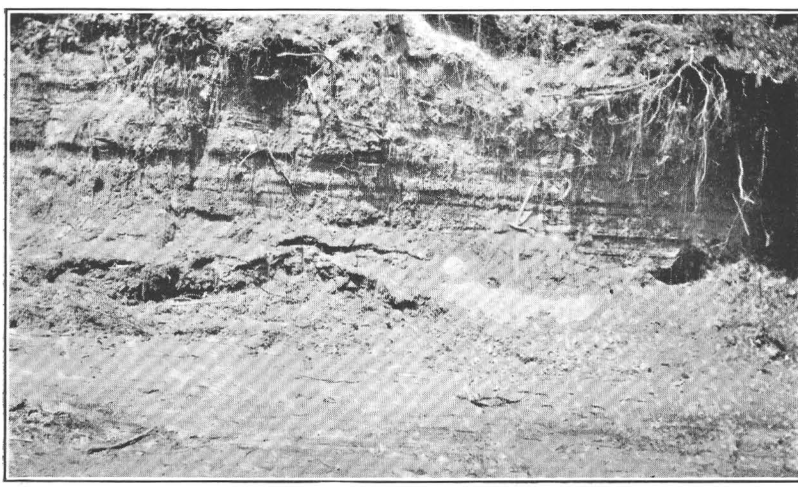


B

SCHIST SHOWING JOINTS AND PARTING PLANES IN WHICH GROUND WATER CIRCULATES

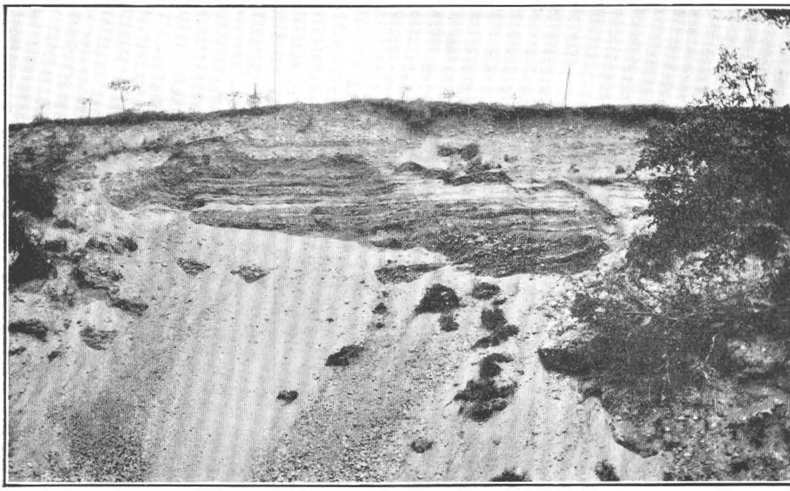
A. TILL 1 MILE NORTH OF SOUTHBURY CENTER, CONN.

The till is an unstratified glacial deposit that yields water in moderate amounts and supplies most of the domestic wells in the Pomperaug Basin



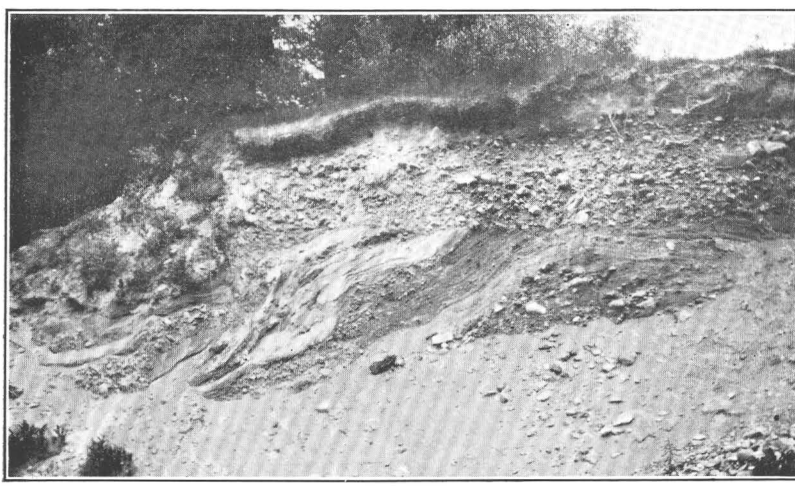
B. STRATIFIED GLACIAL-LAKE DEPOSIT ABOUT 1 MILE SOUTHEAST OF SOUTH BRITAIN, CONN.

Chiefly very fine sand. Material of this type yields practically no water to wells



A. STRATIFIED DRIFT NORTH OF NORTH WOODBURY, CONN.

Yields abundant supplies of water to wells



B. DISTORTED STRATIFIED DRIFT OVERLAIN BY TILL, MINORTOWN, CONN.

SPRINGS

In the present investigation records were obtained in regard to 74 springs in the Pomperaug Basin. Springs are very numerous, especially in the area of crystalline rocks, and many of them are used for domestic purposes. Some of the springs are in their natural condition, but many of them have been improved by enlarging and walling up the spring basins and building covers or small houses over them. The water from many of the springs flows by gravity through pipe lines to the houses and barns. Many of these houses have modern plumbing with toilet and laundry facilities, and some have hydrants with water under considerable pressure. Many watering troughs along the road are supplied by water piped from springs on the hillsides, and a few roadside springs have been enlarged and partly walled or covered. Plate 15, *B*, shows a roadside spring that is only slightly improved.

The abundance of springs in the Pomperaug Basin is probably due to the fact that the bedrock is exposed or lies very near the surface in so many places, expecially on the hillsides. In some places the water seeps out over large areas; in others the flow is more concentrated. Many of the hills have a north-south elongation with gently rounded tops, but steep east and west sides. The glacial drift is relatively thick on the tops of these hills, but the bedrock is likely to crop out on the steep sides, and here springs are commonly found. This mode of occurrence gives a linear arrangement to many of the springs. Other springs occur at the foot of slopes or along the streams.

No evidence was found that any of the springs are due to the rise of deep-seated water through fault fissures. In the following table are listed all the springs for which records of temperature were obtained. Most of the observations were made by H. T. Stearns in 1923. The observed temperatures of spring waters range from 47° to 62° F. Some of these temperatures are considerably above the mean annual air temperature of the area (49° F.), but examination of the springs made it evident that the relatively high temperatures were due not to the deep source of the water but rather to very shallow sources affected by the summer temperatures or to heating of the water after it seeped from the ground.

5673°—29——2

Records of springs in the Pomperaug Basin for which temperature was obtained

No. on map	Owner	Improvement	Temperature (°F.)	Flow (gallons per minute)	Date of measurement of temperature and flow	Remarks
S 1		Barrel and 1-inch pipe to house.	47	2	June 12, 1923	
S 2			54	½		
S 3	C. E. Beardsley	Stone casing and wooden curb.	49	20	June 28, 1923	See analysis, 3, p. 87.
S 4	James Hunt			1		Never fails; very little fluctuation.
S 5		Spring house, barrel, and pipe.	49	2	June 13, 1923	
S 6			46 52		Spring Fall	Never fails and never freezes in winter.
S 7		Horse tank	52	3-5	June 6, 1923	Two springs.
S 8			52	3	June 8, 1923	
S 9		1-inch pipe to house	47	2	June 13, 1923	Not in use.
S 10		Piped	60	8		
S 11		Horse tank	60			
S 12			55			Affected by rain.
S 13		Horse tank	57		June 6, 1923	Two springs.
S 14		Dug and cased	53	2	June 7, 1923	
S 15		Wooden spring house	52	6	June 2, 1923	Stock.
S 16	G. Sypher	Concrete basin	56-58		June 29, 1923	See analysis 4, p. 87.
S 17		Spring house. Piped to house.	55	Small	May 31, 1923	
S 18	J. R. Gilson	Spring house. Piped to house and barn. Depth 8 feet, diameter 7-8 feet.	51, 50	3, 8	June 2, 1923	Two springs. Never fail. Domestic and stock.
S 19		Spring house	54	4	do	
S 20		Shed	52	4		
S 21	Eugene Kerner	Enlarged. Pumped to house through tank.	49	15-20	June 27, 1923	See analysis 1, p. 87.
S 22		Walled and covered. Piped to house.	54	4-5	June 4, 1923	
S 23	Henry Shortt	Dug and walled; depth 2 feet, diameter 2 feet. Spring house.	47	4-5	June 28, 1923	See analysis 10, p. 87.
S 24	Geo. L. Curtis	Piped to house and barn	54	2-3	do	See analysis 8, p. 87.
S 25	Southbury Inn	Enlarged in the form of a well 20 feet deep.	58		June 21, 1923	
S 26		Wooden trough	51	5-6	June 1, 1923	Stock.
S 27			62		do	
S 28			50	2	1913	Constant flow.
S 29		Barrel	57	3	do	
S 30		Concrete box 6 by 2 feet	47	5-10	June 25, 1923	

MUNICIPAL SUPPLY

A private corporation supplies water to the Orenaug fire district, which comprises most of the villages of Woodbury and North Woodbury. In 1922 it was reported that about 700 inhabitants were served. The water flows by gravity from two reservoirs formed by the impounding of two branches of South Brook, south of Woodbury. One is a supply reservoir with a capacity of 800,000 gallons; the other is a storage reservoir with a capacity of 11,000,000 gallons.

QUALITY OF WATER

The chemical character of the ground water in the Pomperaug Basin is indicated by the analyses given in the following table. The wells and springs from which the samples were taken are shown on Plate 12. In general the analyses indicate that the ground water of this basin is similar to that of other parts of Connecticut where analyses have been made of water derived from till and stratified drift.

The amount of total solids in the samples analyzed is low, ranging from 40 to 106 parts per million. The waters are relatively soft, having a hardness ranging from 21 to 73 parts per million.

Analyses of ground water in the Pomperaug Basin

[Samples collected June 27 to 29, 1923. Analyzed by Margaret D. Foster. Parts per million]

Litchfield County

	1	2	3	4	5
Silica (SiO_2)	20	9.5	12	19	21
Iron (Fe)	.12	.08	.08	.12	.09
Calcium (Ca)	6.8	4.1	6.0	7.0	23
Magnesium (Mg)	2.4	2.6	1.6	2.8	3.8
Sodium and potassium (Na+K)	5.1	2.4	3.4	4.9	2.4
Bicarbonate radicle (HCO_3)	31	21	23	37	73
Sulphate radicle (SO_4)	6.7	7.7	8.0	6.6	12
Chloride radicle (Cl)	2.0	1.2	1.2	1.8	2.0
Nitrate radicle (NO_3)	.47	.13	1.3	.15	.78
Total dissolved solids at 180° C	58	40	46	61	106
Total hardness as $CaCO_3$ (calculated)	27	21	22	29	73

1. Spring at Woodbury; owned by Eugene Kerner. Water from till. Map No. S 21.
2. Dug well about 15 feet deep at Minortown; owned by L. S. Darrow. Water from stratified drift. Map No. W 30.
3. Spring at Bethlehem; owned by C. E. Beardsley. Water from till. Map No. S 3.
4. Spring at Woodbury; owned by G. Sypher. Water from till. Map No. S 16.
5. Dug well about 30 feet deep, at Woodbury; owned by W. M. Stiles. Water from till. Map No. W 25.

New Haven County

	6	7	8	9	10
Silica (SiO_2)	22	20	14	9.3	18
Iron (Fe)	.15	.12	.09	.24	.09
Calcium (Ca)	16	12	16	8.6	17
Magnesium (Mg)	6.2	4.7	2.3	3.7	2.4
Sodium and potassium (Na+K)	5.0	5.0	3.1	3.8	4.2
Bicarbonate radicle (HCO_3)	68	34	53	23	53
Sulphate radicle (SO_4)	12	8.9	8.5	10	7.2
Chloride radicle (Cl)	2.9	14	1.0	2.3	3.2
Nitrate radicle (NO_3)	.85	1.1	.48	13	4.4
Total dissolved solids at 180° C	101	99	75	62	84
Total hardness as $CaCO_3$ (calculated)	65	49	49	37	52

6. Dug well about 15 feet deep at White Oaks; owned by L. B. Holmes. Water from stratified drift. Map No. W 33.
7. Dug well 35 feet deep at Southbury; owned by Wm. Olson. Water from stratified drift. Map No. W 32.
8. Hillside spring at South Britain; owned by Geo. Curtis. Water from till. Map No. S 24.
9. Dug well about 25 feet deep at South Britain; owned by Charles Luff. Water from till. Map No. W 31.
10. Spring at Southbury; owned by Henry Shortt. Water from till. Map No. S 23.

The analysis of a composite sample of the water of Nonewaug River is given below. Samples were taken daily from July 11 to December 31, 1915, with the exception of August 20, October 11–12 and 14–18, and December 11, 13–20, and 31. For record of the discharge of Nonewaug River during this period see pages 103–104.

Analysis of composite sample of water from Nonewaug River at Alder Swamp bridge

[S. C. Dinsmore, analyst]

	Parts per million
Silica (SiO_2)	30
Iron (Fe)	.19
Aluminum (Al)	.15
Calcium (Ca)	5.1
Magnesium (Mg)	2.4
Sodium (Na)	8.2
Potassium (K)	1.8
Carbonate radicle (CO_3)	.0
Bicarbonate radicle (HCO_3)	37
Sulphate radicle (SO_4)	8.8
Chloride radicle (Cl)	2.6
Nitrate radicle (NO_3)	.38
Total solids at 180°C	79
Total hardness as $CaCO_3$ (calculated)	23

This analysis shows the river water to be very similar to the ground waters that have the smaller quantities of dissolved solids. According to tests of the daily samples made to determine the chloride, carbonate, and bicarbonate radicles, the chloride ranged during the period from 1.6 to 3.6 parts per million; the bicarbonate ranged from 11 to 47 parts per million; and the carbonate was reported absent except on 36 days, when the highest found was 15 parts per million.

INVENTORY OF THE WATER RESOURCES

GENERAL CONDITIONS

CIRCULATION

The source of the water in the Pomperaug drainage basin is essentially the precipitation—chiefly rain and snow—on the basin. This water may be temporarily stored, but it is eventually disposed of by evaporation and run-off. A part of it is intercepted by trees and other vegetation, from which it evaporates and is returned to the atmosphere without reaching the ground; a part is evaporated directly from the surface of the ground; a part flows directly into the streams and ponds and runs off, except a small amount that is lost by evaporation; a part percolates into the ground and becomes soil moisture, or penetrates to the water table, where it enters the zone of saturation and is called ground water. The soil moisture may be absorbed and transpired by plants or may be evaporated directly from the soil. The water in the zone of saturation may be transpired by plants or may evaporate where it comes near the surface, or it may seep into the ponds and streams eventually and be carried out of the basin by Pomperaug River as run-off.

It is believed that practically no water is lost by deep percolation out of the Pomperaug drainage basin and that practically no water enters the basin from deep-seated sources. (See below.) Therefore except as there is no increase or decrease in surface or subsurface storage within a given period, the difference between the amount of precipitation in the basin during the period and the amount of stream flow out of the basin is approximately the amount that is evaporated, directly or through the agency of plants.

STORAGE

The water that falls as rain or snow may be stored on the surface or below the surface. Surface storage includes the water that is held in the ponds and reservoirs, and for the purposes of this investigation it includes also the water in the streams. Moreover, surface storage includes the considerable quantities of water that accumulate on the surface in winter as ice or snow. The subsurface storage consists of the soil moisture, in the zone of aeration, and of the ground water, in the zone of saturation. The storage creates an interval of variable duration between the falling of the water as rain or snow and its exit from the basin by evaporation or as run-off, and it thereby greatly complicates the problem of determining what ultimately becomes of the water that falls as rain or snow.

PERCOLATION INTO OR OUT OF THE BASIN

Before an inventory of the water supply in the Pomperaug drainage basin was undertaken a careful investigation was made to determine whether there is any percolation into or out of the basin. It is recognized that the rocks in this basin have been faulted and that the fault fissures may carry water and bring it to the surface in the form of springs. However, no indication was found that any water comes from a deep-seated or distant source outside of the drainage basin. There are no thermal springs, and all the field evidence indicates that the fault openings are small and, like other joints in the bedrock, carry only small quantities of water, at shallow depths and through short distances. It is reasonably certain that the water discharged by springs in this basin is practically all supplied by precipitation on the basin.

Further, it is believed that there is practically no percolation of ground water out of the drainage basin by underflow through openings in the bedrock or through glacial drift. The borders of the drainage basin are in most places high areas underlain by bedrock. In the few places where there seemed to be a possibility of percolation out of the basin an inspection of the local conditions has led to the belief that percolation does not occur. For the purpose of this study, therefore, it may be assumed that there is no percolation into or out of the drainage basin.

PERIOD COVERED BY THE INVESTIGATION

In the present investigation records of precipitation, run-off, and water levels in wells were obtained during a period extending from the summer of 1913 to about the end of 1916. These records, with others, were used to estimate the amount of water that fell on the basin during the period and the rate at which it was disposed of by the different processes of circulation and storage. The daily, monthly, and annual records were analyzed. For making annual estimates it was advantageous to consider a year as extending from October 1 to September 30, chiefly because on October 1 the amount of water in storage is usually about at a minimum and there are usually fewer complications in estimating the storage than at other times during the year. On October 1 the ground water, the soil moisture, and the water in surface streams are usually near the minimum and there is no snow storage to complicate the problem, as there might be on January 1. The period covered by this investigation therefore covers three complete years—October 1, 1913, to September 30, 1916, and all annual averages are based on records of these three years.

PRECIPITATION

RECORDS OF PRECIPITATION

The United States Weather Bureau maintains no regular stations within the Pomperaug drainage basin but has maintained a station at Waterbury, about 10 miles east of this basin, for many years, including the entire period covered by this investigation. From July, 1913, to December, 1916, rain gages were maintained by the United States Geological Survey in Bethlehem, North Woodbury, and South Britain, and records of precipitation at these stations were obtained through the cooperation of public-spirited citizens who served without remuneration. The observations in Bethlehem were made by Samuel P. Hayes, those in North Woodbury by Asahel M. Mitchell, and those in South Britain by Henry M. Canfield. The assistance of these voluntary observers is gratefully acknowledged. The following table gives the daily and monthly records at each of the three stations:

Precipitation, in inches, in the Pomperaug Basin, July, 1913, to December, 1916

Bethlehem

Day	July	Aug.	Sept.	Oct.	Nov.	Dec.	Day	July	Aug.	Sept.	Oct.	Nov.	Dec.
1913							1913						
1	0	0	0	0	------	0	16	0	0	0	0	0	0
2	C	.14	0	2.17	------	0	17	0	0	0	0	.34	0
3	0	0	0	0	------	0	18	0	.02	.51	0	0	0
4	0	0	0	0	0.07	0	19	.25	0	.13	0	0	0
5	0	0	.20	0	0	0	20	0	0	.26	.54	.24	0
6	0	0	0	0	0	0	21	.05	0	.15	.42	0	0
7	0	.76	.01	0	0	.37	22	0	0	.54	0	0	.36
8	0	0	1.02	0	0	.77	23	0	.35	0	0	0	0
9	0	0	0	0	.43	0	24	.07	0	0	0	0	0
10	.23	0	0	.04	.54	0	25	.06	0	0	2.41	0	0
11	0	.03	0	0	0	0	26	0	0	0	2.49	0	.69
12	0	0	0	1.06	0	0	27	0	0	0	.92	0	0
13	1.22	0	0	0	0	0	28	0	0	0	.01	0	0
14	.22	.05	0	0	0	0	29	1.03	.46	0	0	.46	0
15	0	0	0	0	.12	0	30	0	1.09	0	0	------	0
							31	0	0	------	0	------	0
								3.13	2.90	2.82	10.06	[a] 2.20	2.19

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1914												
1	------	------	------	0	0	0	0	0	------	0	0	0
2	------	------	------	.24	0	.56	1.17	0	------	0	.17	0
3	------	------	------	0	0	0	0	.12	------	0	0	0
4	------	------	------	0	0	0	0	0	------	0	0	0
5	------	------	------	0	.43	.84	0	0	------	0	0	0
6	------	------	------	0	1.20	0	0	0	------	0	0	0
7	------	------	------	.19	0	0	.84	.03	------	0	0	0
8	------	------	------	.10	0	0	.23	0	------	0	0	.50
9	------	------	------	.72	.07	.09	0	0	------	0	.33	0
10	------	------	------	0	.11	0	0	0	------	0	0	0
11	------	------	------	0	0	0	.03	.71	------	0	0	0
12	------	------	------	.12	.55	0	.10	.49	------	0	0	0
13	------	------	------	0	.74	0	0	0	------	0	0	0
14	------	------	------	0	0	0	0	0	------	0	0	1.30
15	------	------	------	0	0	0	1.27	0	------	0	0	0
16	------	------	------	.76	0	.36	.03	0	------	.35	2.00	0
17	------	------	------	.02	0	0	0	0	------	2.66	.20	0
18	------	------	------	0	0	0	0	.25	------	.11	0	0
19	------	------	------	0	0	0	0	.15	------	.45	0	0
20	------	------	------	0	0	.61	0	.05	------	0	.44	.24
21	------	------	------	.75	0	0	0	.25	------	0	0	0
22	------	------	------	0	0	.28	2.8	1.11	------	0	0	.36
23	------	------	------	0	0	.08	0	0	------	0	0	0
24	------	------	------	0	0	0	.21	0	------	0	0	0
25	------	------	------	0	0	.08	0	0	------	0	0	.01
26	------	------	------	1.12	0	0	0	0	------	0	0	0
27	------	------	------	.25	0	0	0	0	------	0	0	0
28	------	------	------	.02	0	.28	.30	0	------	0	0	0
29	------	------	------	.02	0	.17	1.20	.25	------	0	0	0
30	------	------	------	.06	0	0	.04	.08	------	0	0	.41
31	------	------	------	------	.17	------	.03	0	------	0	------	0
	------	------	------	4.37	3.27	3.35	5.73	3.49	0.33	3.57	3.14	2.82
1915												
1	0	0.82	0	0	0.39	0	2.00	0	0	0	0	0
2	0	1.01	0	0	0	0	.10	0	0	.75	0	0
3	.05	.13	0	0	.05	0	.29	.25	0	.08	0	0
4	0	.05	0	.09	0	0	0	.07	0	0	0	0
5	0	0	0	0	.43	0	.58	3.10	0	0	0	0
6	0	.60	0	0	.05	0	0	.04	0	.22	.16	0
7	1.29	0	0	.13	0	.04	0	.25	0	0	0	0
8	0	0	0	0	.35	0	.12	.13	0	.88	0	0
9	0	0	0	0	0	0	0	.38	0	0	.15	0
10	0	0	0	0	0	0	0	.78	0	0	0	0

[a] Record not quite complete.

Precipitation, in inches, in the Pomperaug Basin, July, 1913, to December, 1916—Continued

Bethlehem—Continued

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1915												
11	0	0	0	.33	0	0	0	0	0	0	0	0
12	0	0	0	.81	0	.22	.08	0	0	0	0	0
13	1.41	0	0	0	.48	0	.01	0	0	0	0	0
14	0	0	0	0	0	0	0	.72	0	0	0	.75
15	0	.15	0	0	0	0	0	0	0	.10	.74	0
16	0	.47	0	0	0	.58	0	0	0	0	0	0
17	0	0	0	0	0	.18	.04	0	0	0	0	0
18	1.09	0	0	0	0	.02	0	0	.50	0	0	1.36
19	1.15	0	0	0	0	0	0	0	.20	0	0	.12
20	0	0	0	0	0	0	.27	0	0	0	.95	0
21	0	0	0	0	0	.28	.02	0	0	.34	0	0
22	0	0	0	0	1.02	0	.23	.56	3.50	0	0	0
23	0	0	0	.31	.10	.30	0	.52	0	0	0	0
24	1.12	0	0	0	0	0	0	0	0	0	0	.02
25	0	2.29	0	0	.27	0	0	.61	0	0	0	0
26	.08	.19	.02	0	0	.20	0	0	0	0	0	.86
27	0	0	0	0	.26	0	.35	0	.23	.43	.15	0
28	0	0	0	0	0	.07	0	0	0	0	0	0
29	0	------	0	.09	0	0	.60	.22	0	0	0	0
30	0	------	0	0	0	0	0	.22	0	0	.16	.21
31	0	------	0	------	0	------	.01	.02	------	0	------	0
	6.19	5.71	.02	1.76	3.40	1.89	4.70	7.87	4.53	2.80	2.31	3.32
1916												
1	0	0	0	0	0	0	0	0	0	0	0	1.60
2	.43	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	.15	.55	0	0	.25	.35	0	0	0	0	0	0
5	0	0	0	.11	0	0	.75	0	0	0	0	0
6	0	0	0	0	0	.60	0	0	0	0	.60	0
7	.04	0	0	0	0	0	0	1.23	0	0	0	0
8	0	0	.30	0	0	.40	0	0	0	0	0	0
9	0	0	0	0	.41	.05	0	.68	0	0	0	0
10	0	0	.67	.23	0	0	.35	0	0	0	0	0
11	.50	0	.04	0	0	0	0	.52	0	0	0	0
12	0	0	0	0	0	0	.25	0	0	0	0	0
13	0	.85	0	.16	0	0	.47	0	0	0	0	0
14	.14	0	0	0	0	0	.98	0	0	.30	0	0
15	0	0	0	.77	.45	0	0	0	0	0	0	.82
16	0	0	.85	0	.07	.48	0	0	1.36	.03	0	0
17	0	0	0	0	1.21	1.20	0	0	0	0	0	0
18	0	0	0	0	.10	0	0	0	0	0	0	0
19	0	0	0	.10	0	.25	0	0	.56	0	0	0
20	0	0	0	0	0	0	0	0	0	1.06	0	0
21	0	0	0	0	0	.32	.23	0	0	0	0	0
22	0	0	0	.60	0	.10	0	0	0	0	0	0
23	0	0	.33	0	0	0	0	0	0	0	0	1.49
24	0	0	0	0	.16	0	.09	1.13	0	0	1.44	0
25	0	.80	0	0	0	.40	0	0	0	0	0	0
26	0	1.40	0	0	0	0	.61	0	0	.04	0	0
27	0	0	0	0	0	0	0	.09	0	0	0	0
28	.06	0	0	.04	0	0	0	.55	0	0	0	0
29	0	0	0	0	1.07	0	0	0	0	0	0	.49
30	0	------	.34	0	0	0	0	0	1.52	0	0	0
31	0	------	0	------	.57	------	0	0	------	0	------	0
	1.32	3.60	2.53	2.01	4.29	4.15	3.73	4.20	3.44	1.43	2.04	4.40

Precipitation, in inches, in the Pomperaug Basin, July, 1913, to December, 1916—Continued

North Woodbury

Day	July	Aug.	Sept.	Oct.	Nov.	Dec.	Day	July	Aug.	Sept.	Oct.	Nov.	Dec.
1913							1913						
1	0	0	0	0	0	0	16	0	0	0	------	0	0
2	0	.15	.01	2.05	0	0	17	0	0	Tr.	0	.65	0
3	.01	Tr.	Tr.	.04	0	0	18	.14	0	.58	0	0	0
4	0	0	0	0	.06	0	19	.03	------	.06	------	0	0
5	0	0	.46	0	0	0	20	0	------	.29	.42	.24	Tr.
6	.05	0	0	0	0	0	21	.01	------	.13	.35	0	.44
7	0	.79	Tr.	0	0	.14	22	0	------	.74	0	0	0
8	0	0	.44	Tr.	0	.77	23	0	------	.58	0	0	.79
9	.05	0	.24	.03	.46	0	24	0	------	0	0	0	0
10	.23	Tr.	0	0	1.08	0	25	.01	------	0	2.80	0	0
11	0	.03	0	0	0	0	26	0	------	0	2.00	0	.34
12	0	0	0	1.04	0	0	27	0	------	0	.90	0	.24
13	.63	0	0	0	0	0	28	0	.56	0	0	0	0
14	.07	.03	0	0	0	0	29	.57	.50	0	.03	.56	0
15	0	0	0	0	0	0	30	0	1.13	0	0	0	0
							31	0	0	------	0	------	0
								1.80	------	3.53	[a]9.66	3.05	2.72

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1914												
1	0	1.33	0	0	0	0	0	0	------	0	0	------
2	0	0	3.87	.31	0	.25	1.27	0	------	0	0	------
3	0	0	0	Tr.	0	0	.27	.06	------	0	0	------
4	.16	0	0	0	0	0	.01	.31	------	0	0	------
5	.21	0	0	0	.44	.85	0	.05	------	0	0	------
6	0	0	0	0	1.47	0	0	0	------	0	0	------
7	0	[b].30	([b])	0	0	.06	.67	0	------	0	0	------
8	0	0	0	.21	0	0	.19	0	------	0	0	------
9	0	0	0	.72	.12	0	0	0	------	0	0	------
10	0	0	0	0	.03	0	0	0	------	0	0	------
11	0	0	0	0	0	0	0	.32	------	0	0	------
12	0	0	0	.15	.59	0	.19	1.54	------	0	0	------
13	0	0	0	0	.54	0	.02	.02	------	0	0	------
14	0	([b])	0	0	0	0	0	0	------	0	0	------
15	0	0	.03	0	0	0	1.18	0	------	0	0	------
16	0	[b].51	0	.83	0	.33	0	0	------	.30	2.50	------
17	[b].34	0	0	.02	0	0	0	0	------	2.38	0	------
18	0	0	.16	0	0	0	.09	0	------	.07	0	------
19	0	0	.50	0	0	0	0	.28	------	.51	0	------
20	0	0	0	0	0	.61	0	.35	------	0	[b].87	------
21	.50	0	0	.50	0	0	.25	.13	------	0	0	------
22	0	0	0	.02	0	.31	.21	.30	------	0	0	------
23	0	0	0	0	0	.10	0	0	------	0	0	------
24	0	0	0	0	0	0	0	0	------	0	0	------
25	.83	0	0	0	0	.06	0	0	------	0	0	------
26	0	0	.12	1.22	0	0	0	0	------	0	0	------
27	0	0	0	.29	0	0	0	0	------	0	0	------
28	.08	0	.42	0	0	.07	.58	0	------	0	0	------
29	0	------	.41	0	0	.19	.87	.21	------	0	0	------
30	.03	------	.12	.08	0	0	.06	.09	------	.05	0	------
31	0	------	0	------	0	------	.05	0	------	0	------	------
	2.15	------	5.63	4.35	3.19	2.83	5.91	3.66	------	3.31	3.37	------
1915												
1	0	2.00	------	0	0.36	0	2.00	0	0	0	0	0
2	0	0	------	0	0	0	0	.05	0	.82	0	0
3	0	0	------	0	.03	0	.18	.21	0	0	0	0
4	0	0	------	0	0	0	.17	.07	0	0	0	0
5	0	0	------	0	.35	0	.03	3.10	0	0	.12	0

[a] Record not quite complete. [b] Snow.

Precipitation, in inches, in the Pomperaug Basin, July, 1913, to December, 1916—Continued

North Woodbury—Continued

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1915												
6	0	1.06	-------	0.09	0.06	0	0.46	0	0	0.22	0	0
7	1.31	0	-------	.21	0	0	0	.50	.11	0	0	0
8	0	0	-------	0	.28	0	.60	.14	0	.83	0	0
9	0	0	-------	0	0	.07	1.20	.40	0	.06	.17	.09
10	0	0	-------	0	0	0	0	.63	0	0	0	0
11	0	0	-------	.20	0	0	0	0	0	0	0	-------
12	.29	0	-------	.62	.45	.12	.10	0	0	0	0	-------
13	1.60	0	-------	0	.05	0	0	.90	.14	0	0	-------
14	0	0	-------	0	0	0	.04	0	.22	0	0	-------
15	0	.15	-------	0	0	0	0	0	0	.09	0	-------
16	0	.28	-------	0	0	.65	0	0	0	0	.73	-------
17	0	0	-------	0	0	.20	0	.02	0	0	0	-------
18	.91	0	-------	0	0	0	0	-------	-------	0	0	2.00
19	1.10	0	-------	0	0	0	.06	-------	-------	0	0	0
20	0	0	-------	0	0	0	.22	-------	.69	0	0	0
21	0	0	-------	0	0	.36	.06	-------	1.60	.30	1.32	0
22	0	0	-------	0	1.25	0	.39	-------	0	0	0	0
23	0	0	-------	.29	.10	.36	0	-------	0	0	.10	0
24	1.00	0	-------	0	0	.03	0	-------	0	0	0	.09
25	0	2.00	-------	0	.25	0	0	-------	0	0	0	0
26	0	.21	-------	0	0	.06	0	-------	0	0	0	.98
27	0	0	-------	0	.19	0	.23	-------	.18	.29	0	0
28	0	0	-------	0	0	.16	0	1.51	0	0	.06	0
29	0	-------	-------	.05	0	0	.57	.37	0	0	.15	0
30	0	-------	-------	.13	0	0	0	.19	0	0	0	0
31	0	-------	-------	-------	0	-------	0	0	-------	0	-------	0
	6.21	5.70	-------	1.59	3.27	2.01	6.31	-------	-------	2.61	2.65	-------
1916												
1	0	0.22	0	0	0	0	0	0	0	0	0.16	0
2	-------	-------	0	0	0	0	0	0	0	0	0	0
3	.65	-------	0	0	0	0	.60	0	0	0	0	0
4	0	-------	0	.07	.22	.24	0	0	0	0	0	0
5	-------	-------	0	0	0	0	0	0	0	0	0	.04
6	.20	-------	0	0	0	0	0	0	0	0	.39	0
7	0	-------	0	.10	0	0	0	0	0	0	0	0
8	0	-------	0	0	.47	0	0	0	0	0	0	0
9	0	-------	0	0	0	.50	0	1.29	0	0	0	0
10	0	-------	.50	.40	0	0	.71	.69	0	.11	0	.43
11	.45	-------	0	0	0	.06	0	-------	0	0	0	0
12	0	-------	0	0	0	.22	0	.06	0	0	0	0
13	.19	-------	0	0	0	0	0	0	0	0	0	.90
14	0	-------	0	0	0	0	1.24	0	0	.25	0	0
15	0	-------	0	.92	0	0	0	0	0	0	0	0
16	0	-------	0	0	.30	0	0	0	1.21	0	0	.13
17	0	-------	0	0	1.35	1.36	0	0	0	0	0	0
18	0	-------	0	.09	0	0	0	0	0	0	.12	0
19	0	-------	0	0	0	0	0	0	.86	0	0	0
20	0	-------	0	.11	0	.46	0	0	0	.96	0	0
21	0	-------	0	0	0	.26	.30	0	0	.03	0	.12
22	0	-------	0	0	0	0	0	0	0	0	0	0
23	.03	-------	0	.47	.50	0	0	0	0	0	1.44	1.18
24	0	-------	0	0	.06	.56	0	1.00	.20	0	0	0
25	0	-------	0	0	0	0	0	0	0	0	0	0
26	0	-------	0	0	0	0	.80	0	0	0	0	0
27	0	-------	0	0	0	0	.55	.15	0	0	0	0
28	.10	-------	0	0	.50	0	.35	0	0	0	0	.50
29	0	-------	0	.09	.39	0	0	.82	0	0	0	0
30	0	-------	.42	0	0	0	0	0	1.45	0	.82	0
31	0	-------	0	-------	.02	-------	0	0	-------	0	-------	-------
	-------	(c)	.92	2.25	3.81	3.66	4.55	-------	3.72	1.35	2.93	[a] 3.30

[a] Record not quite complete.   [c] Number of light snows. Heavy rain last of month.

Precipitation, in inches, in the Pomperaug Basin, July, 1913, to December, 1916—Continued

South Britain

Day	1913				1914				1915			
	July	Aug.	Sept.	Oct.	May	June	July	Aug.	Aug.	Sept.	Oct.	Nov.
1	0	0	0	2.05	1.12	0	Tr.	0	0	0	0	0
2	0	.33	0	.06	.52	0	1.52	0	.02	0	.75	0
3	0	0	0	0	0	0	.04	.04	.70	0	.05	0
4	0	0	.07	0	0	.08	0	.17	.30	0	0	0
5	0	0	.02	0	0	.69	0	.04	.24	0	Tr.	.07
6	0	0	0	0	0	0	.48	0	0	0	.15	0
7	0	.92	1.17	0	0	0	.12	0	.47	.13	0	0
8	0	Tr.	0	0	0	.04	.04	0	.07	0	.90	0
9	.11	0	0	.05	.10	0	.01	0	.38	0	0	.11
10	.18	0	0	0	.05	0	0	.01	.17	0	0	0
11	0	0	0	.02	0	0	0	.29	0	0	0	0
12	0	0	.26	1.05	.60	0	.35	.29	0	0	0	0
13	.62	0	0	0	.42	0	0	0	.68	.10	0	.03
14	.04	.08	0	0	0	0	0	0	0	.03	0	0
15	0	0	0	0	.02	0	.86	0	0	0	.16	.84
16	0	0	0	0	0	.39	.02	0	0	0	.03	.11
17	0	0	0	0	0	0	.02	0	0	0	0	0
18	.08	0	.49	0	0	0	.10	.02	0	0	0	0
19	.02	.73	.11	.11	0	0	0	.27	0	.36	0	Tr.
20	0	0	.35	.06	0	.47	0	1.39	0	0	0	1.16
21	.13	0	.16	.02	0	.02	0	.52	0	0	.21	0
22	0	0	1.15	0	0	.60	0	.45	.84	.89	0	0
23	0	.22	.23	0	0	.01	.02	0	.54	0	0	0
24	Tr.	0	0	0	0	Tr.	.19	0	0	0	0	.02
25	.13	0	0	0	0	.04	0	0	.71	0	Tr.	0
26	0	.06	0	2.65	0	0	0	0	0	0	Tr.	0
27	0	0	Tr.	1.12	.05	0	0	0	0	.13	.23	.05
28	0	0	Tr.	1.05	0	.26	.42	0	0	0	Tr.	0
29	.67	.29	0	0	0	.37	.52	.36	.51	0	0	.09
30	0	1.63	0	0	.05	-------	.07	.11	.14	0	0	0
31	0	0	-------	.04	.02	-------	.27	-------	0	-------	0	-------
	1.98	4.26	4.01	8.28	2.95	[a] 2.97	5.05	[a] 3.96	5.77	1.64	2.48	2.48

[a] Record not quite complete.

Summaries of the monthly and annual precipitation at each station in the Pomperaug Basin and at the Waterbury station are given in the tables below. The average for these stations for each month, including the Waterbury station, is taken to be the precipitation in the Pomperaug Basin during that month. As the whole record for Waterbury to 1923 covers a period of 38 years, the average monthly and average annual precipitation at that station is nearly the actual average or so-called normal. It is also doubtless nearly the normal for the Pomperaug Basin and is therefore used in computing the departures from normal given in the tables.

Normal monthly and annual precipitation at Waterbury, in inches

October	4.15	May	3.95
November	3.75	June	3.20
December	4.29	July	4.68
January	4.23	August	4.48
February	3.97	September	3.86
March	4.43		
April	3.82	Annual	48.81


PRECIPITATION IN INCHES
MEAN DAILY TEMPERATURE IN DEGREES
MEAN DAILY TEMPERATURE
PRECIPITATION
3.87
DEPTH OF WATER LEVEL IN FEET
DAILY RUN-OFF IN SECOND-FEET
AVERAGE WATER LEVEL IN WELLS
GROUND-WATER RUN-OFF
TOTAL RUN-OFF
JULY
1913
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
1914
1915
1916

Monthly precipitation, in inches, in the Pomperaug Basin and at Waterbury, July, 1913, to December, 1916

Month	Bethlehem	North Woodbury	South Britain	Waterbury	Average [a]	Departure from normal [b]
1913						
July	3.13	1.80	1.98	1.36	2.07	−2.61
August	2.90	(c)	4.26	2.93	3.35	−1.13
September	2.82	3.53	4.01	3.37	3.43	−.43
October	10.06	9.66	8.28	8.83	9.21	+5.08
November	2.20	3.05		2.92	2.72	−1.03
December	2.19	2.72		2.84	2.58	−1.71
1914						
January		2.15		3.87	3.01	−1.22
February		(c)		3.10	3.10	−.87
March		5.93		6.09	6.01	+1.58
April	4.37	4.35		3.87	4.20	+.38
May	3.27	3.19	2.95	2.81	3.06	−.90
June	3.35	2.83	2.97	3.29	3.11	−.09
July	5.73	5.91	5.05	6.04	5.68	+1.00
August	3.49	3.66	3.96	3.55	3.67	−.81
September	.33			.29	.31	−3.55
October	3.57	3.31		3.18	3.35	−.80
November	3.14	1.37		2.98	2.50	−1.25
December	2.82			5.38	4.10	−.19
1915						
January	6.19	6.21		7.08	6.49	+2.26
February	5.71	5.70		5.49	5.63	+1.66
March	.02			.17	.10	−4.33
April	1.76	1.59		2.30	1.88	−1.94
May	3.40	3.27		2.78	3.15	−.80
June	1.89	2.01		1.73	1.88	−1.32
July	4.70	6.31		6.30	5.77	+1.09
August	7.87	(c)	5.77	7.82	7.87	+3.39
September	4.53	(c)	1.64	1.15	2.56	−1.30
October	2.80	2.61	2.48	2.55	2.61	−1.54
November	2.31	2.65	2.48	2.58	2.51	−1.24
December	3.32	(c)		6.37	4.86	+.57
1916						
January	1.32	(c)		1.05	1.48	−2.75
February	3.60	(c)		5.88	4.77	+.80
March	2.53	.92		3.84	2.43	−2.00
April	2.01	2.25		2.34	2.20	−1.62
May	4.29	3.81		3.40	3.83	−.12
June	4.15	3.66		5.01	4.27	+1.07
July	3.73	4.55		5.19	4.49	−.19
August	4.20	(c)		5.08	4.67	+.19
September	3.44	3.72		2.97	3.38	−.48
October	1.43	1.35		1.10	1.29	−2.86
November	2.04	2.93		2.98	2.65	−1.10
December	4.40	3.30		2.87	3.52	−.77

[a] Including Waterbury.
[b] The normal is that for Waterbury, based on a record of 38 years at that station.
[c] Record not quite complete.

Annual precipitation, in inches, in the Pomperaug Basin for the period of three years, October 1, 1913, to September 30, 1916

	Average [a]	Departure from normal
October, 1913, to September, 1914	46.66	−2.15
October, 1914, to September, 1915	45.28	−3.53
October, 1915, to September, 1916	41.50	−7.31

[a] Based on the monthly averages given in the preceding table.

DISTRIBUTION OF PRECIPITATION

The daily precipitation in the Pomperaug Basin, based on the averages for the three stations in the basin, is shown diagrammatically in Plate 19, and the monthly precipitation, as given in the preceding tables, is shown in Figure 7. The long-term monthly averages for Waterbury show a notably even distribution of precipitation through-

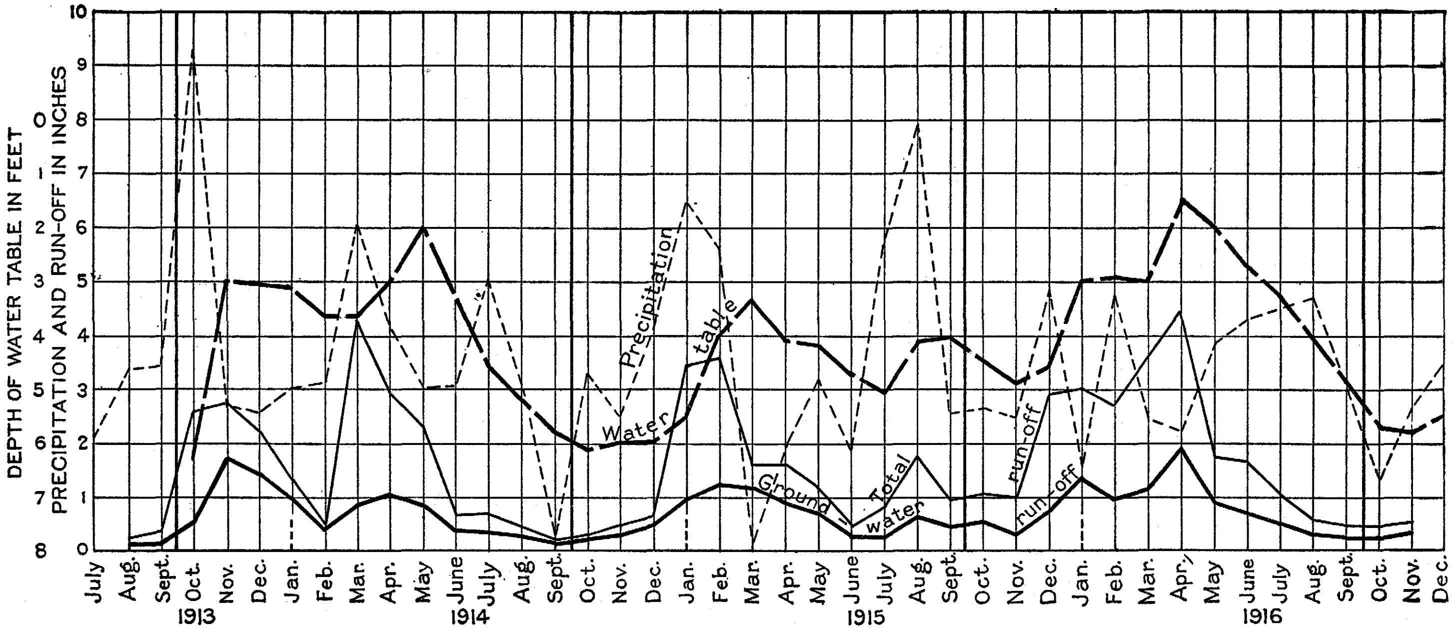


FIGURE 7.—Monthly precipitation, total run-off, ground-water run-off, and stage of the water table in the Pomperaug Basin, Conn., July, 1913, to December, 1916

out the year, which indicates that there are no definite rainy or dry seasons, as, for example, in California. There is, however, a great variation from month to month in the precipitation, as is shown in Figure 7.

A comparison of the daily precipitation at the three stations in the Pomperaug Basin shows a wide variation on certain days. These local differences indicate that the average of the three stations is not always representative of the amount of precipitation in the basin. This conclusion is in accord with results obtained by Marston [14] on local variations in precipitation in the vicinity of Boston, Mass.

SNOWFALL

The snowfall at Waterbury in the three winters under investigation is shown in the following table:

Snowfall at Waterbury, 1913–1916

Month	Inches (unmelted)			Percentage of total precipitation [a]		
	1913–14	1914–15	1915–16	1913–14	1914–15	1915–16
November	2.0	3.0	0.5	7	10	2
December	4.0	6.0	35.0	14	11	55
January	9.0	11.0	1.2	23	16	11
February	26.5	2.0	24.0	85	4	41
March	6.0	Trace.	39.0	10	0	[b] 100
April	Trace.	10.0	6.0	0	43	26
	47.5	32.0	105.7			

[a] Based on the assumption that 10 inches of snow, when melted, produced 1 inch of water.
[b] Calculated value is 102 per cent.

In the Pomperaug Basin during December, January, and February the average daily temperature is below freezing on most days, and the ground is generally frozen; consequently, the conditions are favorable for snow storage. However, in any of these months there may be warm days with rains and extensive thaws. All the snow may disappear and the ground may be bare for considerable periods. From December to February the number of days at Waterbury that had average temperatures below freezing amounted to 55 out of 90 in the winter of 1913–14, 50 out of 90 in 1914–15, and 61 out of 91 in 1915–16. In each winter there were two of these three months in which more than half the days had average temperatures below freezing. November of each year had very few days that averaged below freezing. March was variable, having only 7 such days in 1915, 11 in 1914, and 22 in 1916. Even when the mean daily temperature is below freezing the temperature during a part of the day may be well above the freezing point. Moreover, the recorded temperatures are those of the air in a place sheltered from the sun, whereas much of the snow is subjected to the direct rays of the sun. However, the water that results from the thawing on days when the mean temperature is below

[14] Marston, F. A., The distribution of intense rainfall and some other factors in the design of storm-water drains: Am. Soc. Civil Eng. Proc., vol. 50, pp. 19–46, 543–558, 1924.

freezing is largely refrozen before it has percolated far. Even in the coldest weather there is a slight loss of snow by direct evaporation.

Number of days with average temperature below freezing at Waterbury, 1913–1916.

Month	1913–14	1914–15	1915–16	Month	1913–14	1914–15	1915–16
November	1	6	1	March	11	7	22
December	10	21	24	April	0	0	0
January	22	17	15				
February	23	12	22		67	63	84

TOTAL RUN-OFF

RECORDS OF RUN-OFF

POMPERAUG RIVER

In connection with this investigation a gaging station was maintained on Pomperaug River at Bennetts Bridge, near its mouth, from July 30, 1913, to December 15, 1916, with some interruptions, especially in winter. (See pl. 13, *A*.) In the following tables are given the results of current-meter measurements made to establish the relation between gage height and discharge, also the daily, monthly, and annual discharge of the river as determined from daily gage heights according to the standard methods of the United States Geological Survey. (See also pl. 19 and fig. 7.)

POMPERAUG RIVER AT BENNETTS BRIDGE, CONN.[15]

LOCATION.—About one-fifth mile above confluence of the Pomperaug with Housatonic River, a quarter of a mile north of Bennetts Bridge, New Haven County, and 1 mile east of Sandy Hook railroad station.

DRAINAGE AREA.—89.3 square miles (measured on topographic maps).

RECORDS AVAILABLE.—July 30, 1913, to December 15, 1916, when station was discontinued.

GAGE.—Inclined staff in three parts, attached to rock ledge and to tree on right bank; read by W. H. Ingram.

DISCHARGE MEASUREMENTS.—Made from cable at gage or by wading.

CHANNEL CONTROL.—Channel irregular; bed covered with gravel and boulders. Control is formed by large rocks about 100 feet below the gage, sharply defined.

EXTREMES OF DISCHARGE.—1913–1916: Maximum stage recorded, 7.4 feet March 2, 1914 (discharge, 2,520 second-feet); minimum stage recorded, 0.68 foot September 20, 1914 (discharge, 7.7 second-feet).

ICE.—Stage-discharge relation affected by ice which forms on control and river below the gage.

REGULATION.—Operation of power plants at South Britain, 2½ miles above the station, causes a small diurnal fluctuation at low stages.

ACCURACY.—Control has been changed by obstructions at various times in previous years. Rating curve well defined below 400 second-feet; above that the curve for 1915 and 1916 is parallel to 1913 and 1914 curves. Gage read to quarter-tenths twice daily except in winter, when it was read once a day. Daily discharge ascertained by applying mean daily gage height to rating table. Records good.

[15] U. S. Geol. Survey Water-Supply Papers 351, pp. 107–108; 381, pp. 114–116; 401, pp. 102–104; 431, pp. 119–121; 451, p. 111.

Discharge measurements of Pomperaug River at Bennetts Bridge, 1913–1916

Date	Gage height	Discharge	Date	Gage height	Discharge	Date	Gage height	Discharge
1913	*Feet*	*Sec.-ft.*	1914	*Feet*	*Sec.-ft.*	1915	*Feet*	*Sec.-ft*
July 31	1.10	15.6	Jan. 14	[a] 2.90	21.6	Mar. 3	2.42	202
Oct. 16	1.59	39.7	Jan. 27	[a] 2.40	53.8	Apr. 10	2.06	126
Oct. 17	1.58	39.2	Mar. 2	6.80	2,080	Do	2.07	129
Do	1.58	38.6	Do	6.33	1,750	June 22	1.23	33.2
Oct. 27	4.71	801	Aug. 16	1.22	25.7	Dec. 21	[a] 2.74	223
Oct. 28	3.80	482	Do	1.22	25.3			
Do	3.78	472	Sept. 11	1.10	20.3	1916		
Oct. 29	3.46	382	Nov. 3	[b] 2.68	24.2	Jan. 22	[a] 3.11	161
Do	3.44	380	Nov. 18	[b] 3.05	60.6	Mar. 27	2.80	295
Do	3.44	381	Dec. 19	[b] 3.48	[a] 93.9	Do	2.86	318
Oct. 31	3.00	276				Aug. 17	1.26	385
Nov. 3	2.66	237						

[a] Stage-discharge relation affected by ice.
[b] Stage-discharge relation affected by temporary dam below the gage.

Daily discharge, in second-feet, of Pomperaug River at Bennetts Bridge, July 30, 1913, to December 15, 1916

Day	July	Aug.	Sept.	Day	July	Aug.	Sept.	Day	July	Aug.	Sept.
1913				1913				1913			
1	------	17	24	11	------	18	21	21	------	21	29
2	------	18	22	12	------	18	21	22	------	19	56
3	------	17	21	13	------	17	22	23	------	22	83
4	------	16	20	14	------	18	20	24	------	19	39
5	------	16	21	15	------	19	20	25	------	20	32
6	------	15	20	16	------	20	20	26	------	18	28
7	------	18	21	17	------	18	24	27	------	18	28
8	------	20	37	18	------	20	22	28	------	19	24
9	------	18	34	19	------	23	22	29	------	19	23
10	------	17	26	20	------	23	27	30	16	39	23
								31	16	30	------

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1913–14												
1	24	250	180	125	------	------	250	200	62	41	36	24
2	190	230	166	109	------	1,730	385	170	74	144	32	23
3	109	210	158	118	------	610	280	149	59	95	31	22
4	58	200	146	130	------	550	230	144	81	62	35	22
5	43	190	143	143	------	430	200	325	133	48	32	20
6	38	170	136	109	------	355	190	550	73	41	31	19
7	34	162	152	105	------	250	180	370	54	51	28	18
8	35	152	310	107	------	190	200	250	57	95	25	20
9	34	355	210	113	------	190	400	240	48	67	24	19
10	32	460	180	124	------	156	260	220	50	47	27	19
11	32	290	180	107	------	138	230	190	57	42	67	18
12	92	250	162	------	------	118	210	270	46	51	47	18
13	92	230	150	------	------	106	190	385	40	41	35	17
14	54	230	154	------	------	120	166	290	31	35	31	18
15	43	220	154	------	------	180	156	230	35	101	30	14
16	40	210	136	------	------	300	370	190	47	97	26	14
17	35	260	136	------	------	370	250	170	48	64	26	13
18	34	240	130	------	------	310	190	159	32	60	24	14
19	34	210	113	------	------	250	170	139	30	44	26	14
20	48	250	99	------	------	180	170	133	57	38	49	7.7
21	115	220	112	------	------	128	230	127	43	34	45	16
22	64	200	170	------	------	134	200	113	49	31	97	14
23	43	190	158	------	------	127	170	102	56	36	47	18
24	46	170	430	------	------	138	149	94	45	35	36	16
25	760	166	230	------	------	170	138	85	38	31	30	11
26	1,520	158	290	------	------	290	400	78	35	29	28	12
27	1,040	148	210	------	------	400	355	73	32	28	25	------
28	520	141	154	------	------	760	270	68	31	31	26	------
29	385	220	143	------	------	760	250	58	35	63	28	------
30	310	200	132	------	------	490	230	45	42	56	28	------
31	270	------	130	------	------	290	------	35	------	45	26	------

Daily discharge, in second-feet, of Pomperaug River at Bennetts Bridge, July 30, 1913, to December 15, 1916—Continued

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1914–15												
1	-------	22	45	-------	-------	272	70	148	54	195	21	71
2	-------	22	40	-------	-------	231	71	110	49	104	27	64
3	-------	26	40	-------	-------	209	76	97	46	76	32	55
4	-------	26	35	-------	-------	155	66	85	43	55	246	52
5	-------	22	35	-------	-------	151	107	114	40	50	392	50
6	-------	22	35	-------	-------	166	144	112	39	93	184	50
7	-------	19	45	-------	-------	163	189	91	37	53	203	49
8	-------	19	40	-------	-------	159	159	104	43	71	141	50
9	-------	26	45	-------	-------	134	144	104	40	257	193	49
10	-------	22	45	-------	-------	134	128	82	37	101	355	42
11	-------	22	45	-------	-------	127	182	70	32	70	189	36
12	-------	22	-------	-------	-------	122	420	64	33	60	137	35
13	-------	22	-------	-------	-------	120	224	98	30	52	235	40
14	-------	26	-------	-------	-------	114	176	91	29	55	159	44
15	-------	26	-------	-------	-------	114	153	71	28	50	118	39
16	-------	112	-------	-------	-------	114	135	61	46	32	103	35
17	105	91	-------	-------	-------	106	127	66	42	36	84	32
18	66	55	-------	-------	-------	97	118	77	38	31	76	36
19	55	50	-------	-------	-------	93	110	63	34	34	65	36
20	50	66	-------	-------	-------	97	104	56	32	30	61	37
21	35	66	-------	-------	-------	93	93	56	37	36	54	355
22	30	55	-------	-------	-------	96	89	213	32	46	120	280
23	30	45	-------	-------	-------	107	107	159	31	37	211	155
24	26	45	-------	-------	-------	106	120	112	40	32	112	97
25	26	45	-------	-------	-------	96	101	127	30	27	182	84
26	26	45	-------	-------	-------	91	93	101	29	28	141	75
27	26	55	-------	-------	-------	85	89	118	28	30	85	80
28	22	55	-------	-------	-------	78	80	85	29	24	72	65
29	22	45	-------	-------	-------	87	85	72	27	44	78	58
30	22	45	-------	-------	-------	77	89	58	26	40	117	55
31	26	-------	-------	-------	-------	72	-------	56	-------	31	96	-------
1915–16												
1	48	54	72	220	257	282	1,100	135	109	62	48	33
2	78	54	67	245	220	232	1,050	126	87	57	42	29
3	112	51	65	232	208	208	800	118	84	144	40	27
4	84	48	58	175	220	197	605	126	106	115	38	27
5	77	51	56	197	197	175	470	118	100	83	36	28
6	89	51	56	605	175	165	380	115	164	72	36	23
7	77	47	51	270	208	154	350	110	103	64	36	25
8	197	47	47	245	165	154	308	109	135	54	45	25
9	165	48	47	220	154	154	350	154	118	61	97	25
10	106	50	47	208	154	154	365	110	115	96	61	22
11	87	47	47	197	144	144	320	101	115	92	96	20
12	77	47	47	197	135	135	295	87	126	92	66	20
13	70	46	47	208	126	165	282	79	96	87	50	20
14	67	45	47	220	118	154	440	75	83	232	41	21
15	74	60	47	197	118	135	410	95	75	106	37	22
16	65	97	47	175	118	135	295	112	75	79	33	106
17	61	71	56	175	118	154	270	500	470	68	35	41
18	57	61	154	175	118	154	258	258	258	67	32	33
19	54	88	535	165	118	118	220	175	220	57	30	61
20	62	257	270	165	110	118	197	135	245	51	28	44
21	78	135	245	154	110	110	197	116	154	51	27	33
22	70	112	197	154	103	106	220	106	154	54	27	30
23	61	97	175	154	103	106	258	144	116	55	27	30
24	56	89	175	154	103	106	220	154	101	50	61	30
25	55	84	175	208	103	103	197	126	118	47	41	29
26	52	79	2,010	270	1,520	115	175	103	175	91	33	27
27	82	72	680	425	570	295	164	91	110	126	32	26
28	78	74	500	410	380	605	164	112	96	115	41	24
29	70	75	425	282	320	950	164	175	83	71	62	25
30	61	78	320	245	-------	1,730	144	144	70	58	41	175
31	57	-------	220	245	-------	1,270	-------	144	-------	55	34	-------

1913: Gage read twice daily at about 7 a. m. and 6 p. m. Discharge determined from a rating curve well defined below 2,600 second-feet.

1913–14: Discharge determined from a rating curve well defined below 2,600 second-feet. Mean discharge Sept. 27–30 estimated at 12 second-feet; Jan. 12–31, 95 second-feet; Mar. 1, 152 second-feet. Discharge during winter determined from discharge measurements and climatic records.

1914–15: Discharge determined as follows: Oct. 17 to Dec. 11 from a rating curve not well defined; Mar. 1 to Sept. 30 from a well-defined rating curve. No estimates of discharge determined for the winter. For the period Oct. 1–16, on account of uncertainty as to backwater, no estimates have been made.

1915–16: Stage-discharge relation affected by ice Dec. 6–25, Jan. 8–24, and Feb. 12–25. Discharge ascertained from gage heights corrected for backwater by means of two discharge measurements, observer's notes, and weather records.

Daily discharge, in second-feet, of Pomperaug River at Bennetts Bridge, July 30, 1913, to December 15, 1916—Continued

Day	Oct.	Nov.	Dec.	Day	Oct.	Nov.	Dec.	Day	Oct.	Nov.	Dec.
1916				1916				1916			
1	61	30	118	11	23	31	52	21	60	29	
2	43	30	78	12	23	29	72	22	44	30	
3	36	29	64	13	25	29	103	23	38	39	
4	32	28	57	14	27	30	67	24	33	258	
5	30	32	56	15	30	29	60	25	31	83	
6	29	52	52	16	28	29		26	30	57	
7	28	38	47	17	26	32		27	29	47	
8	27	34	42	18	24	31		28	28	46	
9	25	33	43	19	41	28		29	28	43	
10	25	32	70	20	95	27		30	28	78	
								31	28		

Monthly discharge of Pomperaug River at Bennetts Bridge, August, 1913, to November, 1916

[Drainage area, 89.3 square miles]

Month	Discharge in second-feet				Run-off (depth in inches on drainage area)
	Maximum	Minimum	Mean	Per square mile	
1913					
August	39	15	19.7	0.221	0.25
September	83	20	27.7	.310	.35
October	1,520	24	199	2.23	2.57
November	460	141	219	2.45	2.73
December	430	99	173	1.94	2.24
1914					
January			[a] 103	1.15	1.33
February			[a] 49.9	.559	.58
March	1,730	106	[a] 335	3.75	4.32
April	400	138	236	2.64	2.94
May	550	35	182	2.04	2.35
June	133	30	50.7	.568	.63
July	144	28	54.3	.608	.70
August	97	24	34.8	.390	.45
September	24	7.7	[a] 16.3	.183	.20
October	105	[a] 12	[a] 24.5		[a] .31
November	112	19	40.6	.455	.51
December			[a] 48.5		.62
1915					
March	272	72	125	1.40	1.61
April	420	66	128	1.43	1.60
May	213	56	94.2	1.05	1.21
June	54	26	36.0	3.40	.45
July	257	24	60.6	.678	.78
August	392	21	138	1.55	1.79
September	355	32	73.5	.823	.92
October	197	48	78.3	.877	1.01
November	257	45	73.8	.826	.92
December	2,010	47	225	2.52	2.90
1916					
January	605	154	232	2.60	3.00
February	1,520	103	224	2.51	2.71
March	1,730	106	283	3.17	3.66
April	1,100	144	356	3.99	4.45
May	500	75	137	1.53	1.76
June	470	70	135	1.51	1.68
July	232	47	81.0	.907	1.05
August	97	27	43.6	.488	.56
September	175	20	36.0	.403	.45
October	95	23	34.0	.381	.44
November	258	27	44.8	.502	.56
December 1-15	118	42	65.4	.732	.41

[a] Estimated.

Annual discharge of Pomperaug River at Bennetts Bridge

Period	Discharge in second-feet				Run-off (depth in inches on drainage area)
	Maximum	Minimum	Mean	Per square mile	
October, 1913, to September, 1914	1,730	7.7	140	1.57	21.04
October, 1914, to September, 1915					16.79
October, 1915, to September, 1916	2,010	20	159	1.78	24.15
3-year period, October, 1913, to September, 1916	[a] 2,010	[a] 7.7			[b] 20.66
Entire period, July 30, 1913, to Dec. 15, 1916	[a] 2,010	[a] 7.7			

[a] No record for January and February, 1915. [b] Annual average.

NONEWAUG RIVER

A gaging station was maintained on Nonewaug River at Alder Swamp Bridge, near its mouth, from July 13 to December 31, 1915. The results of current-meter measurements and the daily discharge in second-feet for the period are given in the following table. (See also fig. 10.) The record is discussed on pages 108–113.

NONEWAUG RIVER AT ALDER SWAMP BRIDGE

LOCATION.—Short distance above Alder Swamp Bridge.
DRAINAGE AREA.—About 25 square miles.
RECORDS AVAILABLE.—July 13 to December 31, 1915.
GAGE.—Staff gage nailed to tree.
EXTREMES OF DISCHARGE.—Maximum, 300 second-feet on December 26; minimum, 6.0 second-feet on August 2.

Discharge measurements of Nonewaug River at Alder Swamp Bridge

Date	Gage height	Discharge
	Feet	*Sec. ft.*
July 9, noon	1.11	66.02
July 10, 9.30 a. m.	.68	27.37
July 12, 10 a. m.	.46	14.30
July 14, noon	.40	11.26

Daily discharge, in second-feet, of Nonewaug River at Alder Swamp Bridge, July to December, 1915

Day	July	Aug.	Sept.	Oct.	Nov.	Dec.
1		6.6	18.9	11.3	13.5	17.8
2		6.0	14.3	40.1	12.9	17.1
3		7.0	11.3	28.8	12.9	17.1
4		7.5	8.8	28.8	11.3	17.1
5		173.5	7.8	28.8	13.5	17.1
6		54.0	8.4	27.4	12.9	17.1
7		82.5	8.0	26.0	11.8	13.5
8		50.8	8.0	123.5	11.3	14.0
9		[a] 122.0	7.8	54.0	21.6	14.3
10		97.0	7.8	39.2	12.3	14.3
11		57.0	7.8	34.1	11.8	14.3
12		122.0	8.0	22.3	11.3	11.8
13	12.3	150.0	8.8	20.0	12.3	
14	10.9	54.0	9.0		11.8	
15	9.5	34.1	8.8		34.1	
16	8.8	30.9	8.8		27.4	Obstructed by snow.
17	8.4	27.4	8.4		20.0	
18	8.0	22.3	9.5		15.9	
19	7.5	18.3	9.5	13.5	21.6	
20	8.4	14.3	9.0	15.4	214.7	
21	[b] 9.8	11.8	12.9	24.8	39.2	77.9
22	13.5	10.5	129.3	17.8	30.0	54.0
23	9.5	76.6	32.0	14.8	24.2	50.9
24	7.8	54.0	18.9	14.3	20.5	49.0
25	7.0	45.0	16.5	14.0	19.5	42.6
26	6.3	36.9	14.8	12.9	19.5	300.0
27	7.0	23.7	14.0	33.0	19.5	181.0
28	6.8	21.0	14.0	20.5	20.0	76.8
29	13.5	19.5	12.9	17.1	20.5	101.0
30	8.4	34.1	11.8	15.9	20.0	79.0
31	7.0	27.4		14.3		Reading stopped.

[a] 70.5 second-feet before rain. [b] 7.8 second-feet 2 hours before rain.

DISTRIBUTION OF RUN-OFF

The daily discharge of surface water from the Pomperaug Basin for the period August 1, 1913, to December 15, 1916, is shown by means of a curve in Plate 19. Two features of the run-off are conspicuous—sharp peaks, coinciding with heavy rainfall or, in winter, often with high temperatures and rapid thaws; and general seasonal fluctuation, the high run-off normally occurring in winter and spring and the low run-off in summer and fall.

The monthly run-off from the Pomperaug Basin from August, 1913, to November, 1916, in relation to the monthly precipitation, is shown in Figure 7; and the average monthly run-off, in relation to the average monthly precipitation for the same period, is shown in Figure 8. During the summer the run-off is small in comparison to the precipitation, but during some winter months it is greater than the precipitation. In the summer much of the rainfall is evaporated directly or used by plants, and very little reaches the streams. In the winter a large part of the precipitation falls as snow and may remain on the ground from one month to another. When the accumulated snow melts it may produce a monthly run-off that is greater than the precipitation for that month. This is clearly shown by the records for March, 1915, when the run-off was 1.61 inches but the precipitation as recorded was only 0.10 inch, and for April, 1916, when the run-off was 4.45 inches and the precipitation only 2.20 inches. It

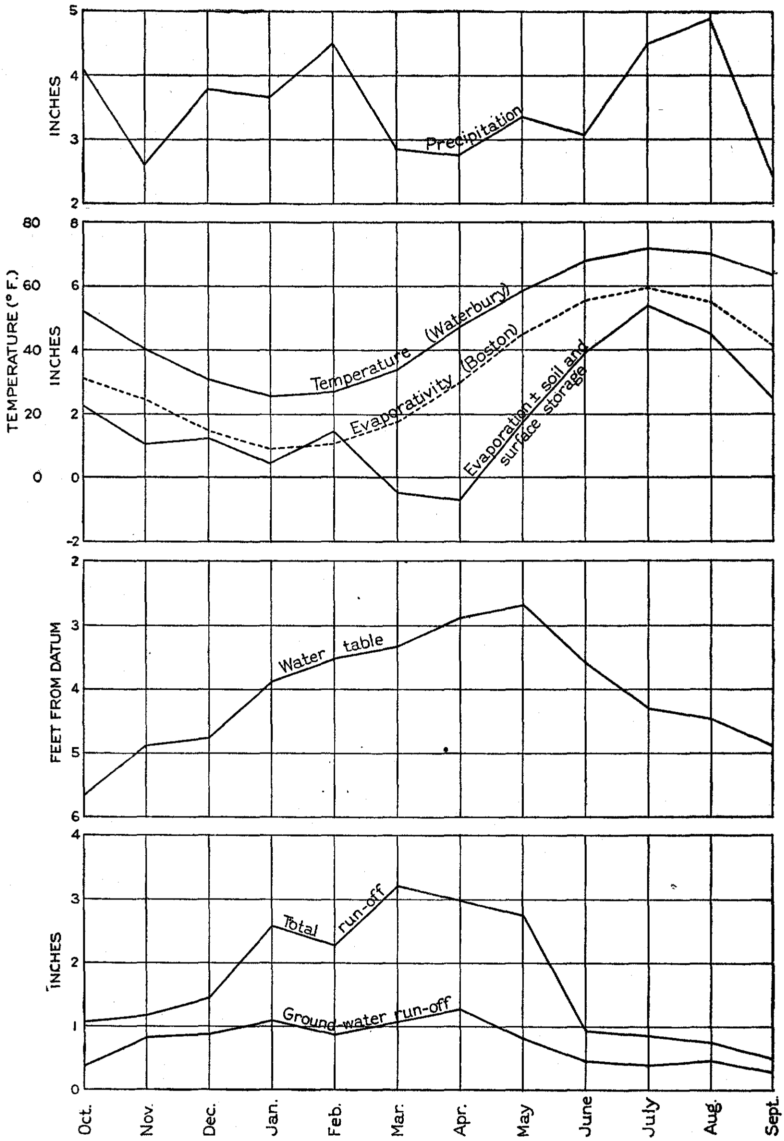


FIGURE 8.—Average monthly weather and water conditions in the Pomperaug Basin, Conn., August, 1913, to December, 1916. The precipitation curve is based on the monthly averages for the Pomperaug Basin during the period, not the Waterbury normal

sometimes happens that heavy precipitation occurs near the end of a month, producing disproportionately high run-off in the following month. In October, 1913, the precipitation was abnormally high, and there were very heavy rains in the last week of the month; the precipitation in November was low, but as a result of the October rains the run-off in November exceeded the precipitation.

In the year October, 1913, to September, 1914, the annual precipitation was 46.66 inches, which was only slightly below normal, and the run-off was 21.04 inches. At the beginning of this water year, in October, 1913, dry conditions evidently prevailed. The water table was low, the soil was probably dry, and the run-off was low. The heavy precipitation of October supplied soil moisture, raised the water table, and caused a high run-off. However, at the end of the water year, in September, 1914, dry conditions again prevailed, the soil moisture was depleted, and the water table receded to about the level it had in the preceding autumn. This year therefore approximated average conditions, and the run-off is probably not very far from the average annual run-off from the basin. The discharge records for January and February were, however, unsatisfactory because of the effects of backwater produced by ice, and the estimates for these two months may be somewhat low.

In the year October, 1914, to September, 1915, the precipitation was 45.28 inches and the run-off only 16.79 inches. Several conditions tended to make the run-off relatively low. Dry conditions prevailed at the beginning of the water year, but at the end of the year, in September, 1915, there was relatively abundant soil moisture and the water table averaged about 1.7 feet higher than in the preceding October. Some of the precipitation was evidently stored as soil moisture or as ground water, and there was correspondingly less run-off in proportion to the precipitation than in the preceding water year. Further, the very dry spring of 1915, especially in March, reduced the amount of annual run-off below normal, as spring is the season of usual heavy run-off. March and April in both 1914 and 1916 had high run-off. Moreover, in July and August, 1915, there was heavy precipitation, but it was well distributed and produced little run-off. This precipitation, together with that in September, left the soil moist and the ground-water supply replenished at the end of September. All these conditions resulted in a low run-off during the year in spite of nearly normal precipitation.

In the year October, 1915, to September, 1916, the precipitation was only 41.5 inches, whereas the run-off was 24.15 inches—the highest of the three years under investigation. The year began with moist soil and a high water table, and hence there was relatively large run-off in spite of the rather small precipitation. At the end of the water year, in September, 1916, the usual dry conditions prevailed. However, for several of the winter months the precipitation at Waterbury was much heavier than that recorded at some of the stations in the Pomperaug Basin, which suggests that there were either larger local differences in precipitation than would be expected in winter or else considerable errors due to the difficulties in obtaining measurements of snowfall and of converting these into depth of water. The actual precipitation on the basin was probably greater than is indicated by the average of the available records.

It should be recognized that for the entire period both precipitation and run-off data may have rather large percentages of error because not enough precipitation stations were maintained to make the average results entirely representative and because of interruptions in the discharge records, especially in the winter, when ice in the river interfered with accurate work.

GROUND-WATER RUN-OFF

GENERAL CONDITIONS

The run-off from the Pomperaug Basin shown in the preceding tables consists of direct run-off and ground-water run-off. The direct run-off is the water that reaches the streams by flowing over the surface; the ground-water run-off is the water that reaches the streams by traveling underground, first forming a portion of the ground-water supply in the zone of saturation and later seeping out along the stream channels. After a rain the direct run-off reaches the streams quickly, and nearly all of it is discharged from the basin within a few days. That part of the rain which becomes ground water, however, reaches the streams much later and during a longer period because of its retardation in its underground course. Thus the soil and the underlying deposits act as a reservoir, receiving a part of the water from rains and snows and yielding it slowly and gradually to the streams. Consequently, there is generally a small but steady stream flow throughout the summer, when very little of the precipitation reaches the ground water and when for considerable periods there is virtually no direct run-off.

METHOD OF ESTIMATING GROUND-WATER RUN-OFF

An effort was made to determine the quantity of ground water that percolates into the streams and is carried out of the basin by Pomperaug River. The general method applied is that used by Houk [16] in his investigations of flood control in Ohio. It is based on the facts that the direct run-off from any rain is nearly all carried out of the basin within a few days of the time it falls and that in the later part of any protracted period of fair weather the water discharged by the trunk stream is nearly all ground water.

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[16] Houk, I. E., Rainfall and run-off in Miami Valley, State of Ohio: Miami Conservancy District Tech. Repts., pt. 8, 1921.

Curves were drawn by Houk[17] showing both total and ground-water run-off from the drainage basin of Mad River above Wright, Ohio, for the period 1915 to 1919. (See fig. 9.) The curves showing ground-water run-off were drawn so as to pass through the low points only of the hydrograph for total run-off. They are very smooth, and the resulting estimates of ground-water run-off seem to be conservative.

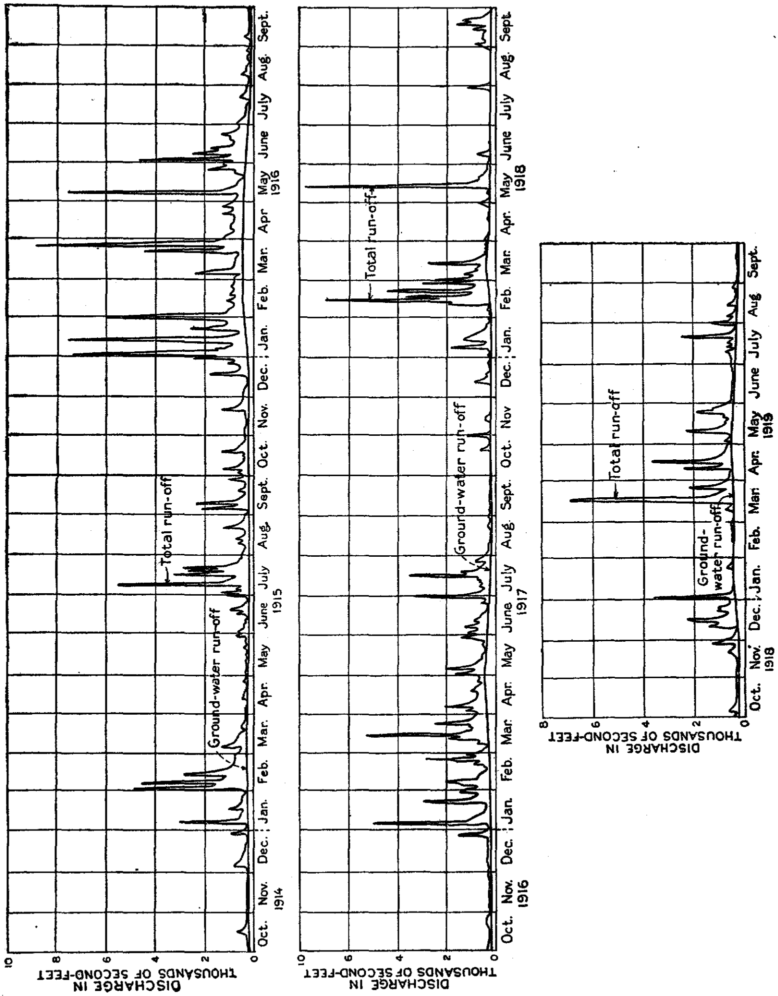

FIGURE 9.—Total and ground-water run-off from the drainage basin of Mad River above Wright, Ohio, 1915 to 1919. (After Houk)

The diagrams in Plate 19 and Figure 10 show that the crest of a flood reaches the mouth of the Pomperaug very promptly after the rain that causes it. Generally the crest reaches the mouth of the Nonewaug on the same day that the rain occurs and the mouth of the Pomperaug on the same or the following day. Special observa-

[17] Houk, I. E., op. cit.

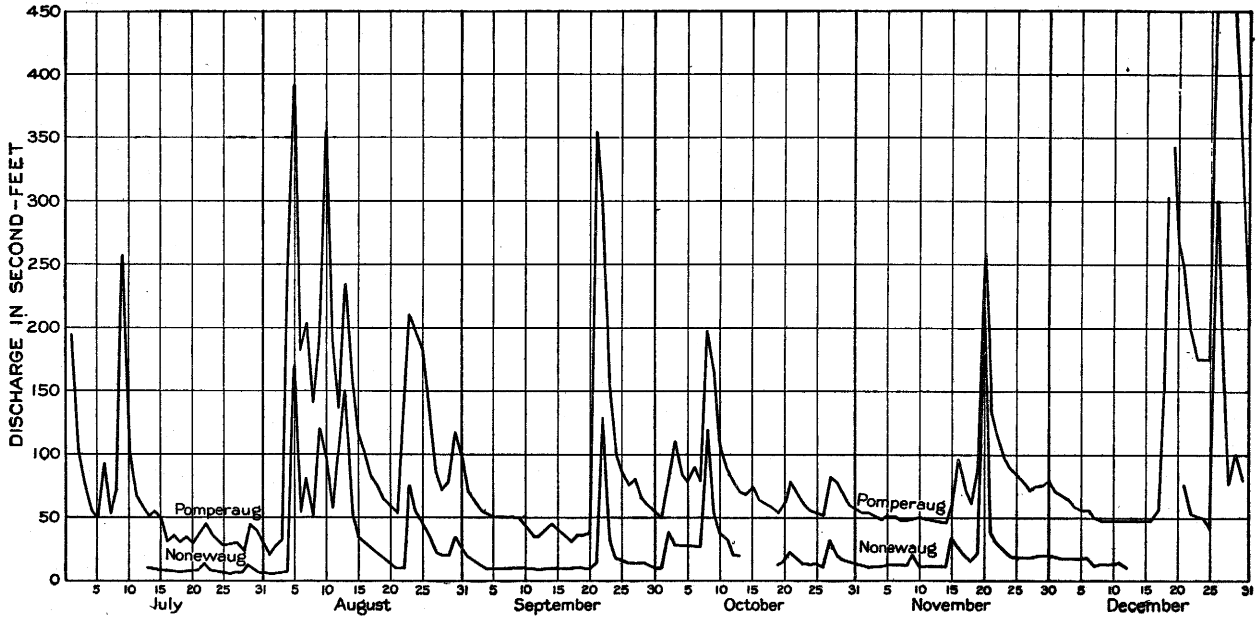

Figure 10.—Hydrographs of Pomperaug River at Bennetts Bridge and of Nonewaug River at Alder Swamp Bridge, Conn., July to December, 1915, showing the brief interval that elapses between the crests of floods at the two stations

tions were made of the flood that resulted from the rain on July 8, 1915. On that day there was only a slight rain at the Bethlehem station, but at North Woodbury about 0.60 inch of rain fell early in the forenoon and about 1.20 inches during the afternoon—mostly during the middle of the afternoon. No rain fell at North Woodbury after 7 p. m. The crest of the flood reached the Alder Swamp Bridge, on Nonewaug River, some time in the evening of July 8, and the river had subsided somewhat by the morning of July 9. The Pomperaug at Bennetts Bridge had not yet felt any effects of the rain when the gage was read on the evening of July 8, but it had risen slightly by the morning of July 9, and it reached its crest about the evening of July 9, about one day after the crest had passed the Alder Swamp Bridge. The Nonewaug was nearly though not entirely back to its pre-storm condition by the morning of July 10, about a day and a half after it had been at its highest stage; the Pomperaug had subsided nearly to normal by July 11, within two days after it had been at its highest stage.

At noon July 9, when the Nonewaug was still in flood, it was flowing at the Alder Swamp gaging station at an average velocity of fully 1½ feet a second, or 24 miles a day; at noon July 14, when it was again at a low stage, it was flowing at an average rate of fully 9 inches a second, or about 12 miles a day. The cross-section area of the stream at this point is more or less normal, indicating that the velocities given can be taken as a rough measure of the rate at which the water moves toward its exit from the basin.

Rough calculations indicate that the entire volume of water in the Pomperaug and its tributaries at a given stage, exclusive of a few of the largest ponds, is only equal to the volume that is discharged by the stream in a short period—probably not more than two days. The large ponds, which have considerable storage capacity, introduce some uncertainty. However, it is a matter of common observation that at all stages of the Pomperaug its water is drawn from numerous brooks, draining all parts of the basin, and that the ponds do not notably increase the flow of the streams on which they are situated. No rain of sufficient consequence to have much effect on the streams occurred until July 20, when the volume of water in the Pomperaug and its tributaries was not very much less than on July 11, although practically no direct run-off had been received in this period of 10 days. Evidently from July 11 to 20 the discharge recorded at Bennetts Bridge was only a little greater than the discharge of ground water into the Pomperaug River system. Similar analysis of other storms and succeeding periods of fair weather will give approximately the ground-water run-off for those periods.

The total run-off as measured at the gaging station near the mouth of Pomperaug River was plotted in second-feet by days for the period from October 1, 1913, to December 15, 1916. (See pl. 19.) On this diagram was drawn a ground-water run-off curve, in general connecting the troughs of the total run-off curve. The drawing of the ground-water run-off curve was a somewhat arbitrary process in several respects:

1. Although most of the direct run-off from a given storm is discharged within a day or two after the storm, a good many days probably elapse before the last of the direct run-off has passed under Bennetts Bridge. Thus although it is certain that within a few days after a storm the ground-water run-off curve approaches close to the total run-off curve, yet no data are available for determining just how close it approaches on a given day or just where the two virtually come together. In general it was assumed that during the parts of the year when there was no snow the direct run-off was discharged from the basin within a week after a rainstorm.

2. There is uncertainty as to the amount of ground-water run-off during the flood stage of a stream, and the longer the stream is kept at an abnormal stage by successive rains at short intervals the greater becomes the uncertainty. During the flood stage the discharge of ground water is probably checked because the water levels of the streams are likely to be higher than the adjacent water table. However, periods of flood run-off are commonly also periods of ground-water recharge, when the water table is built up. Hence the discharge of ground water is usually greater after a flood stage than it was before the flood, and accordingly the curve showing ground-water run-off was brought up somewhat to meet the descending curve that shows total run-off.

3. In winter and early spring the situation is complicated by the snowfall, the uncertainty as to when the snow melts, and the protracted periods of heavy discharge due in part to direct run-off but in part also to a high stage of the water table and the resulting large discharge of ground water. For this season a study as detailed as possible was made of the daily weather conditions to determine the periods of melting snow, and then about the same rule was applied as for the parts of the year when there was no snow.

Thus, in November, 1913, the ground-water run-off was computed to be 1.73 inches, which is nearly the monthly maximum for the period covered by the investigation. The ground-water run-off curve for that month was controlled by two troughs of the total run-off curve, one of which reached its lowest point on November 8 and the other on November 28. The low point of the first trough occurred at the end of a period of 11 days with virtually no precipitation at any station; the low point of the second at the end of a period of 8 days. The conclusion can therefore not be avoided that the ground-water run-off curve should approach close to the total run-off curve on these dates and should have approximately the position and form shown in Plate 19. As only 2 inches of snow (unmelted) fell during the month there can be no appreciable error due to the inclusion of melted snow with the ground-water run-off. In like manner the position of the ground-water run-off curve in December is approximately determined by the troughs of November 28 and December 20.

For a month such as April, 1914, there is more uncertainty as to the position of the ground-water run-off curve, because there was no period of more than four or five days between rainstorms that affected the run-off, and because some run-off may have been produced by the melting of snow. For such a month the position of the curve was determined by projecting the downward-trending segments of the total run-off curve, giving these projections as nearly as possible the form that is characteristic of the parts of the curve that represent long intervals of fair weather.

An attempt was made to estimate the proportion of daily run-off that is derived from ground water by comparing the chemical composition of the stream water each day with that of average well water. The gaging station on Nonewaug River (see p. 103) was established in part for this purpose, and daily samples were taken, with slight interruptions, during the period in which a record of daily discharge was obtained, July 13 to December 30, 1915. For comparison one sample was taken from each of 14 wells in the vicinity.

The constituents chosen for this experiment were the chloride radicle (Cl), the bicarbonate radicle (HCO_3), and the carbonate radicle (CO_3), because of the simple volumetric methods that could be used in determining the quantities of these radicles in the samples of well water and in the daily samples taken from Nonewaug River.

The method proved to be inapplicable in the Pomperaug Basin, at least for these constituents, because of the small amounts of each that occur in the average well water—hardly more than in the direct run-off. Thus the chloride in the 14 samples of well water averaged 3.7 parts per million. Two of the samples contained 12 and 14 parts per million, which may have been due to pollution. If these two are disregarded the chloride in the remaining 12 samples averaged only 2.1 parts per million. On the other hand, the chloride in the stream water ranged from 1.6 to 3.6 parts per million and averaged 2.6 parts. Thus, also, the bicarbonate in the 14 samples of well water averaged 50 parts per million, whereas in the daily samples of stream water it ranged from 11 to 47 parts and averaged 37 parts.

Changes in the stage of the stream generally produced small changes in both chloride and bicarbonate concentration, but they were altogether too small to be useful in estimating the quantity of ground-water run-off. In the first part of the period the chloride content regularly decreased in high stages and increased in low stages, suggesting that the ground water received by Nonewaug River contained slightly more chloride than was normal for the direct run-off. Later in the period, however, the chloride content showed a tendency to increase slightly in high stages and to decrease in low stages, as if the ground water received by the stream in that part of the period contained a little less chloride than was normal for the direct run-off. The bicarbonate evidently occurred in somewhat greater amount in the average ground water than in the direct run-off, for it generally increased in low stages and decreased in high stages. However, any differences that may have existed between the average ground water and the average direct run-off, in respect to concentration of either constituent, were so small and variable that they produced only slight and erratic changes in the concentration of the mixture from which the daily samples were taken.

ESTIMATES OF GROUND-WATER RUN-OFF

The curve in Plate 19 that shows ground-water run-off is probably as accurate as can be drawn with the available data, but greater accuracy would have been possible if more gaging stations had been maintained. A check on the accuracy of this curve is found in the closeness with which it follows the trend of the curve that shows the fluctuation of the water table. (See pl. 19 and pp. 127–129.) From the curve showing the ground-water run-off were obtained the monthly and annual ground-water run-off as given in the following table. (See also figs. 7 and 8.)

Estimated ground-water run-off and direct run-off, in inches, from the Pomperaug Basin, August, 1913, to November, 1916

Month	Total run-off	Ground-water run-off	Direct run-off	Month	Total run-off	Ground-water run-off	Direct run-off
1913				1915			
August	0.25	0.13	0.12	March	1.61	1.19	0.42
September	.35	.17	.18	April	1.60	.90	.70
October	2.57	.52	2.05	May	1.21	.67	.54
November	2.73	1.73	1.00	June	.45	.28	.17
December	2.24	1.42	.82	July	.78	.24	.54
				August	1.79	.60	1.19
1914				September	.92	.44	.48
January	1.33	[a] 1.00	[a] .33	October	1.01	.55	.46
February	.58	[a] .40	[a] .18	November	.92	.36	.56
March	4.32	.86	3.46	December	2.90	.73	2.17
April	2.94	1.03	1.91				
May	2.35	.85	1.50	1916			
June	.63	.39	.24	January	3.00	1.34	1.66
July	.70	.38	.32	February	2.71	.99	1.72
August	.45	.29	.16	March	3.66	1.16	2.50
September	.20	.18	.02	April	4.45	1.90	2.55
October	.31	.22	.09	May	1.76	.89	.87
November	.51	.34	.17	June	1.68	.69	.99
December	[a] .62	[a] .50	[a] .12	July	1.05	.54	.51
				August	.56	.29	.27
1915				September	.45	.25	.20
January	[b] 3.41	[a] .95	[a] 2.46	October	.44	.25	.19
February	[b] 3.58	[a] 1.20	[a] 2.38	November	.56	.32	.24

[a] Estimated on inadequate data.
[b] Run-off from drainage basin of Farmington River, above New Boston, Mass., area 92.7 square miles (Water-Supply Paper 401, p. 95). No records available for the Pomperaug Basin.

Estimated annual ground-water run-off, in inches, from the Pomperaug Basin, 1913–1916

October, 1913–September, 1914	9.05
October, 1914–September, 1915	7.53
October, 1915–September, 1916	9.69
Average	8.76

DISTRIBUTION OF GROUND-WATER RUN-OFF

During a period usually lasting from about November or December until about April or May the ground-water flow is large and generally reaches a maximum for the year. During this period evaporation is low and the demands of plant life are nearly zero; hence a large part of the water that falls as rain or snow is added to the soil moisture or percolates into the ground-water reservoir when the ground is not frozen. The water table generally rises and stands high during this period. Because of the high head of the ground water the flow of the springs is increased and the amount of ground-water run-off is large. Beginning about April or May, however, the amount of direct evaporation and the demands of plant life increase and the water table begins to lower. With decreased amount of ground water there is decreased head and hence decreased ground-water flow. Throughout the summer the ground-water run-off is usually small, and unless there are exceptionally heavy or persistent rains it decreases as the season advances.

Ground-water run-off in Pomperaug Basin in relation to precipitation and to total run-off

Month	Precipitation (inches)	Total run-off		Ground-water run-off		
		Inches	Per cent of precipitation	Inches	Per cent of precipitation	Per cent of total run-off
1913						
August	3.35	0.25	7	0.13	4	52
September	3.43	.35	10	.17	5	49
October	9.21	2.57	28	.52	6	20
November	2.72	2.73	100	1.73	64	63
December	2.58	2.24	87	1.42	55	63
1914						
January	3.01	1.33	44	[a] 1.00	33	75
February	3.10	.58	19	[a] .40	13	69
March	6.01	4.32	72	.86	14	20
April	4.20	2.94	70	1.03	25	35
May	3.06	2.35	77	.85	28	36
June	3.11	.63	20	.39	13	62
July	5.68	.70	12	.38	7	54
August	3.67	.45	12	.29	8	64
September	.31	.20	6	.18	6	90
October	3.35	.31	9	.22	7	71
November	2.50	.51	20	.34	14	67
December	4.10	[a] .62	15	[a] .50	12	81

[a] Estimated.

Ground-water run-off in Pomperaug Basin in relation to precipitation and to total run-off—Continued

Month	Precipitation (inches)	Total run-off		Ground-water run-off		
		Inches	Per cent of precipitation	Inches	Per cent of precipitation	Per cent of total run-off
1915						
January	6.49	[b] 3.41	53	[a] .95	15	28
February	5.63	[b] 3.58	54	[a] 1.20	21	34
March	.10	1.61		1.19	1,200	74
April	1.88	1.60	85	.90	48	56
May	3.15	1.21	38	.67	21	55
June	1.88	.45	24	.28	15	62
July	5.77	.78	14	.24	4	31
August	7.87	1.79	2	.60	8	34
September	2.56	.92	36	.44	17	48
October	2.61	1.01	39	.55	21	54
November	2.51	.92	37	.36	14	39
December	4.86	2.90	60	.73	15	25
1916						
January	1.48	3.00	203	1.34	91	45
February	4.77	2.71	57	.99	21	37
March	2.43	3.66	151	1.16	48	32
April	2.20	4.45	202	1.90	86	43
May	3.83	1.76	46	.89	23	51
June	4.27	1.68	39	.69	16	41
July	4.49	1.05	23	.54	12	51
August	4.67	.56	12	.29	6	52
September	3.38	.45	13	.25	7	56
October	1.29	.44	34	.25	19	57
November	2.65	.56	21	.32	12	57

[a] Estimated. [b] Run-off from drainage basin of Farmington River above New Boston, Mass.

Average monthly ground-water run-off in Pomperaug Basin in relation to precipitation and to total run-off, August, 1913, to December, 1916

Month	Precipitation (inches)	Total run-off		Ground-water run-off		
		Inches	Per cent of precipitation	Inches	Per cent of precipitation	Per cent of total run-off
October	4.12	1.08	26	.39	9	36
November	2.60	1.18	45	.69	27	59
December	3.77	1.92	38	.88	23	46
January	3.66	2.58	70	1.10	30	43
February	4.50	2.29	51	.86	19	38
March	2.85	3.20	112	1.07	38	33
April	2.76	3.00	109	1.28	46	43
May	3.35	1.77	53	.80	24	45
June	3.09	.92	30	.45	15	49
July	4.50	.84	19	.39	9	46
August	4.89	.76	16	.33	7	43
September	2.42	.48	20	.26	11	54

Annual ground-water run-off in Pomperaug Basin in relation to precipitation and to total run-off

Month	Precipitation (inches)	Total run-off		Ground-water run-off		
		Inches	Per cent of precipitation	Inches	Per cent of precipitation	Per cent of total run-off
October, 1913, to September, 1914	46.66	21.04	45	9.05	19	43
October, 1914, to September, 1915	45.28	16.79	37	7.53	17	45
October, 1915, to September, 1916	41.50	24.15	58	9.69	23	40
Three-year average	44.48	20.66	46	8.76	20	42

In the drainage basin of Miami River above Dayton, Ohio, according to Houk,[18] in a period of 26 years, from 1894 to 1919, the annual precipitation ranged from about 24 to more than 46 inches, the total annual run-off from less than 4 to more than 24 inches, and the annual ground-water run-off from about 2 to 7 inches. (See fig. 11.) These data indicate how widely the ground-water run-off may vary from year to year, both in actual amount and in percentage of total run-off. They show that short-time records may be misleading because the few years which they cover may occur in an exceptionally wet or in an exceptionally dry period or may be abnormal in other respects.

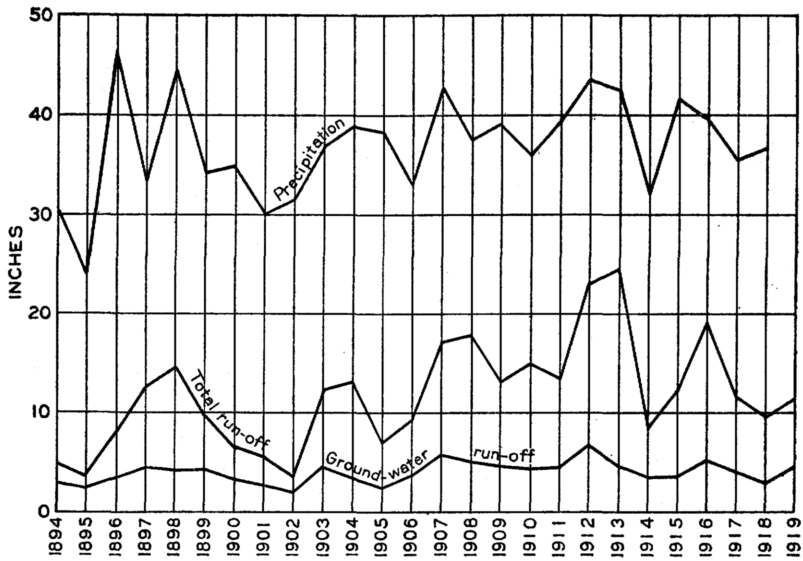

FIGURE 11.—Precipitation, total run-off, and ground-water run-off in the drainage basin of Miami River above Dayton, Ohio, 1894 to 1919. (After Houk)

FLUCTUATION OF THE WATER TABLE AND ITS RELATION TO GROUND-WATER STORAGE

RECORDS OF WATER LEVELS IN WELLS

Weekly measurements of depth to the water level were made on a number of selected wells during the period from October, 1913, to December, 1916, in order to obtain data on the fluctuation of the water table. These measurements were made chiefly by Ernest W. and George A. Parkin and Ralph Wooden, all of North Woodbury. Their faithful and careful work was of much value in the investigation and is much appreciated. The location of the wells is shown on Plate 12, and the records are given in the following tables.

Originally there were 29 wells under observation, but measurements in some of these were discontinued before the end of the investi-

[18] Houk, I. E., op. cit., p. 166.

gation. Nearly complete data for the period are available for 22 wells, of which 11 are in till and 11 in stratified drift.

Records of observation wells in the Pomperaug Basin

No.	Owner	Topographic position	Depth (feet)	Water-bearing material	Remarks
W 1	Ed. Smith	Flat	34.2	Stratified drift	Cement curb. 2-bucket rig. Water used to some extent.
W 2	Frank Chatfield	do	27.9	do	2-bucket rig. Water used to some extent. Dry every summer.
W 3	F. A. Dillingham	do	36.8	do	Observations discontinued after April, 1914.
W 4	Lant. Bennett	Slope	28.5	do	Used for washing only.
W 5		do	25+	do	Observations discontinued after August, 1914.
W 6	William Morris	Flat	16.9	do	Considerable water used.
W 7	——— Russell	Slope	28.7	Till with thin cover of stratified drift.	Not used in 1915.
W 8	Thomas Sullivan	do	30.2	do	Considerable water used.
W 9	Charles Beardsley	Flat	22.8	Stratified drift	Used in 1915. Observations discontinued October, 1913.
W 10	Henry M. Canfield	Slope	33.3	do	Not used in 1915. Records incomplete.
W 11	James Fleming	do	23.0	Till	Considerable water used.
W 12	Pine Tree House	Flat	22.5	Stratified drift	Not used in 1915. Observations discontinued in April, 1914, but resumed in July, 1915.
W 13	V. Markham	do	18.0	Till	Not used in 1915.
W 14	Oliver Towles	do	20.5	Stratified drift	2-bucket rig. Considerable water used.
W 15	S. L. Capewell	do	28.0	Till	2-bucket rig.
W 16	G. W. Drakley	do	20.6	Stratified drift	Do.
W 17		Foot of hill	24.8	Till	2-bucket rig. Observations discontinued in November, 1913, but resumed in August, 1914.
W 18	T. Comber	Flat at foot of hill.	12.9	Stratified drift	2-bucket rig.
W 19	Herbert Someset	Top of hill	22.6	Till with thin cover of stratified drift.	Do.
W 20	Old Lodge	Flat at foot of hill near river.	10.4	Stratified drift	2-bucket rig. Not used in 1915.
W 21	Edward Crane	Flat	22.9	do	Two-bucket rig. Used in 1915.
W 22	John Minor	do	41.4	do	2-bucket rig.
W 23	F. C. Parkin	Slope	26.2	Till with thin cover of stratified drift; red sandstone at bottom.	2-bucket rig and house pump.
W 24	——— Chatfield	do	25.5	Till	Pump.
W 25	W. C. Stiles	Flat	24.2	do	Windlass. Water used for drinking.
W 26	——— Baten	do	29.8	Stratified drift	Observations discontinued in October, 1913.
W 27	——— Kiel	Foot of hill	32.1	Till	Observations discontinued in April, 1914.
W 28	F. Gilbert	Slope	27.4	do	2-bucket rig.
W 29	J. Cassidy	Flat	34.5	Till with thin cover of stratified drift.	Records incomplete.

Weekly records of the depth, in feet, to the water level in the observation wells

[Records of wells 3, 5, 9, 12, 17, 26, and 27, which were under observation for only a short time, are omitted from this table]

	1	2	4	6	7	8	10	11	13	14	15	16	18	19	20	21	22	23	24	25	28	29
1913																						
Oct. 4	32.4	25.9	27.5	16.8	27.5	27.7	30.35	19.7	17.65	18.5	23.8	19.4	11.5	20.12	9.6	20.7	34.15	25.1	22.9	18.95	24.95	------
Oct. 11	32.4	26.0	27.45	16.4	27.5	27.8	30.5	19.4	17.5	18.45	------	19.4	11.7	20.3	10.0	20.95	34.3	24.85	23.45	18.8	25.0	------
Oct. 18	32.45	26.0	27.45	16.3	27.6	27.95	30.6	19.2	17.1	18.4	20.1	19.0	11.8	20.2	10.0	21.0	34.3	24.9	23.5	18.4	24.9	------
Oct. 25	32.5	25.8	26.4	13.0	27.6	28.15	30.95	19.2	16.55	18.4	20.2	19.0	9.7	20.2	7.1	21.0	34.1	24.2	23.15	------	24.7	------
Oct. 26	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	20.2	------	------	------	------
Oct. 27	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	14.65	------	------	------	------
Oct. 30	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	14.1	------	------	------	------
Nov. 1	29.95	24.4	25.85	9.1	25.6	27.6	30.4	18.2	9.2	17.8	22.95	13.55	------	------	7.55	17.9	------	14.65	21.25	18.7	16.9	------
Nov. 8	29.1	24.45	25.2	9.4	25.45	27.8	30.2	18.3	9.45	16.85	21.45	15.55	10.4	19.65	7.7	18.25	24.05	16.65	19.4	18.4	18.1	------
Nov. 15	28.5	24.1	25.6	------	30.15	26.5	30.2	18.0	9.2	16.2	21.25	------	10.6	19.9	8.1	18.15	33.65	16.0	16.5	18.5	17.5	------
Nov. 22	28.1	24.45	24.65	9.15	24.8	26.6	30.05	17.9	9.15	16.0	21.85	19.4	10.55	18.15	7.95	18.3	33.9	16.5	19.1	18.8	17.55	------
Nov. 29	26.8	24.1	24.5	9.4	24.65	26.5	30.1	18.0	9.6	16.2	20.5	19.1	10.1	18.5	7.85	18.7	34.1	16.15	19.1	18.75	17.1	------
Dec. 6	26.5	24.15	24.55	9.9	24.5	------	29.9	18.2	9.4	------	20.6	17.6	10.85	18.3	7.0	18.6	33.5	16.8	19.4	18.4	18.7	------
Dec. 13	26.3	24.1	24.5	9.95	24.5	26.9	29.9	18.0	9.3	16.3	20.4	17.6	10.7	18.2	7.0	17.5	33.4	17.6	19.5	18.5	18.3	------
Dec. 20	26.7	24.1	24.6	10.2	24.8	27.15	29.9	18.1	9.4	16.3	20.5	17.9	11.4	18.4	7.2	17.8	33.3	18.1	19.7	18.75	18.8	------
Dec. 27	26.4	23.9	24.65	9.6	24.35	27.1	29.9	18.1	8.8	16.4	20.7	17.5	10.8	18.05	7.0	17.7	33.4	18.15	19.8	18.4	18.0	------
1914																						
Jan. 3	26.15	23.9	24.35	9.45	24.4	26.9	29.85	18.15	9.4	16.2	20.6	17.4	11.2	18.3	7.2	17.9	33.4	18.0	19.9	18.5	18.4	------
Jan. 10	25.9	24.0	24.4	9.55	24.1	------	29.75	18.0	9.6	16.25	20.55	17.95	11.0	18.3	7.3	17.95	33.6	17.55	19.5	18.55	18.9	31.35
Jan. 17	26.1	24.3	24.6	10.0	24.4	26.8	29.8	18.1	10.0	16.4	20.9	18.15	11.2	18.5	7.15	18.1	33.4	17.6	19.7	18.6	20.0	------
Jan. 24	26.6	24.3	25.0	10.9	24.4	26.6	29.8	18.3	9.6	16.45	21.3	18.35	11.3	18.85	7.3	18.4	33.8	19.3	20.0	18.1	20.3	31.2
Jan. 31	26.7	24.1	24.7	11.2	24.6	26.6	29.4	18.6	9.7	16.6	21.4	18.3	11.3	18.8	7.5	18.1	33.2	19.5	20.2	18.4	19.6	------
Feb. 7	26.1	24.0	24.6	9.8	25.0	26.4	29.6	18.5	9.4	16.5	21.5	18.4	11.1	18.6	7.0	17.9	32.9	21.3	20.1	18.4	18.3	------
Feb. 21	26.1	24.15	25.4	9.4	25.5	27.2	29.8	18.1	10.6	16.6	22.0	18.5	11.0	18.5	7.6	18.3	33.15	21.8	19.6	18.5	18.9	------
Feb. 28	26.3	24.3	25.5	9.5	24.4	27.1	29.6	18.4	10.2	16.4	22.3	18.8	10.7	18.5	7.8	18.8	33.2	21.8	20.1	18.6	18.14	------
Mar. 7	27.0	24.0	25.0	10.0	24.3	27.35	29.7	18.8	9.9	16.6	22.4	17.9	10.4	18.0	6.7	17.4	32.5	19.7	19.95	18.7	19.5	------
Mar. 14	26.6	24.1	25.0	12.5	25.3	27.3	29.75	18.6	9.6	16.6	22.7	18.0	10.65	18.2	7.2	18.0	32.1	21.0	20.8	18.4	18.45	------
Mar. 21	26.1	23.9	24.8	11.8	25.3	27.3	29.7	18.7	9.4	16.5	22.9	17.8	10.4	18.05	6.9	17.7	32.3	21.3	20.7	18.5	17.9	------
Mar. 28	26.0	23.8	24.6	11.1	25.5	26.7	29.7	18.3	9.3	16.6	22.9	18.0	10.6	18.0	7.0	17.8	32.4	21.1	20.1	18.3	17.6	------
Apr. 4	25.9	23.7	24.75	11.25	25.2	26.6	29.65	18.3	9.05	16.3	23.0	17.2	10.2	17.8	7.0	17.85	32.6	22.45	20.3	18.4	17.35	------
Apr. 11	26.0	23.6	24.3	10.85	24.9	26.6	29.75	18.25	8.8	16.3	23.0	16.85	10.0	17.7	6.8	17.4	32.5	21.7	20.1	18.4	17.3	------
Apr. 18	26.1	23.5	24.0	9.75	24.6	26.3	29.6	17.9	8.95	16.0	22.55	16.35	10.0	17.6	6.65	17.25	32.4	19.85	19.1	18.3	17.3	31.1
Apr. 25	25.9	23.75	23.9	9.8	24.1	26.2	29.6	17.85	9.2	15.85	22.25	16.65	10.2	17.8	6.9	17.2	32.3	18.45	18.5	18.2	18.0	31.1
May 2	25.55	23.5	23.6	9.2	23.65	26.5	27.6	17.6	9.4	15.65	21.8	16.1	10.2	17.6	6.2	16.5	32.5	16.6	17.7	17.6	17.2	31.1
May 9	25.3	23.35	23.3	9.75	23.25	25.9	29.6	17.8	8.6	15.6	21.4	15.3	10.45	17.4	5.9	15.9	32.3	14.3	17.1	17.4	16.8	31.0
May 16	25.1	23.4	22.9	8.6	22.95	25.65	29.5	17.5	8.85	15.2	21.45	15.85	10.05	17.55	5.6	15.65	32.5	13.8	16.7	17.5	16.9	31.05
May 23	24.95	23.65	23.0	9.5	22.95	25.5	29.6	17.8	9.45	15.6	20.0	16.95	10.5	17.9	6.6	17.05	32.5	14.35	26.85	18.75	18.6	31.15
May 30	25.15	23.6	23.15	9.3	23.45	25.55	29.7	17.9	10.0	15.65	19.95	17.85	10.9	18.1	------	------	------	16.0	18.1	18.4	18.8	31.15
June 6	25.5	23.9	25.6	9.4	23.3	25.6	29.6	18.0	10.85	15.5	20.1	18.4	10.95	18.0	6.5	17.0	32.4	18.2	19.1	18.1	18.5	31.1
June 13	25.1	24.0	25.5	11.2	23.2	25.7	29.6	18.6	11.4	15.4	19.9	18.7	11.4	18.7	7.0	17.7	32.4	18.6	19.5	18.3	22.7	31.2
June 20	25.9	24.0	24.3	12.3	23.3	25.6	29.7	18.8	12.2	16.4	20.2	18.75	10.6	18.95	7.7	18.1	32.4	19.9	19.95	18.45	22.2	31.2

June 27	26.4	24.3	24.5	12.85	23.3	25.5	29.7	19.1	12.4	16.1	20.6	19.0	11.1	19.0	7.6	18.4	32.45	20.6	20.1	18.4	23.2	31.2
July 1	26.7	24.5	24.7	13.4	26.1	26.5	29.75	18.5	13.0	16.8	21.4	18.9	11.2	19.6	7.6	18.2	34.5	21.4	20.45	18.4	23.1	31.3
July 11	26.9	24.5	25.1	13.8	25.9	26.45	29.8	18.9	13.2	17.3	21.3	19.0	12.0	19.4	8.0	19.0	34.5	22.1	20.8	18.45	23.65	31.3
July 18	27.8	24.5	25.3	13.8	25.35	26.5	29.85	19.2	13.3	17.3	21.55	19.0	11.4	19.35	8.1	19.2	34.55	22.7	21.0	18.5	23.85	31.3
July 25	28.5	24.7	25.6	13.9	25.4	26.5	29.75	19.4	13.3	17.5	21.7	19.1	11.45	------	------	------	------	23.3	21.2	18.5	------	31.3
Aug. 1	29.3	24.7	25.9	14.5	------	26.7	30.0	19.6	13.9	17.6	21.95	19.2	11.4	19.4	8.7	19.75	33.0	23.75	21.2	18.4	23.8	31.0
Aug. 8	30.4	25.0	26.1	15.0	25.9	27.2	30.2	20.0	14.5	17.8	22.45	19.4	11.8	19.6	9.0	19.9	33.3	23.8	21.3	18.6	24.3	31.1
Aug. 15	30.7	24.9	26.3	------	25.7	------	30.1	20.1	14.7	17.7	22.55	19.3	11.9	19.45	9.0	20.0	33.2	23.75	21.6	18.5	24.6	31.1
Aug. 22	31.2	25.0	26.4	15.4	26.1	25.7	29.7	20.1	14.8	17.4	22.8	19.4	11.9	19.4	9.2	20.1	32.8	23.6	21.75	18.5	24.4	31.1
Aug. 29	32.9	25.0	26.6	15.7	26.4	27.6	30.25	20.0	14.7	17.7	22.9	19.5	11.7	19.2	9.8	20.4	33.3	23.7	22.0	18.6	24.0	31.45
Sept. 5	32.2	25.5	26.5	15.55	27.9	26.3	30.65	20.2	15.0	17.9	22.7	19.6	11.8	19.6	9.8	20.5	33.5	23.65	22.05	18.7	24.45	31.5
Sept. 12	32.3	25.4	26.6	15.5	27.7	27.8	------	20.4	15.15	18.00	23.45	19.65	12.05	19.65	10.0	20.9	32.75	23.9	22.15	19.0	24.25	31.2
Sept. 19	32.5	25.6	26.7	16.5	26.8	28.1	30.9	20.5	15.55	18.2	23.5	19.9	12.7	19.8	10.2	21.0	33.5	24.25	22.3	19.2	24.95	32.6
Sept. 26	32.3	25.7	27.5	15.85	26.85	28.1	29.7	20.7	15.9	18.7	23.9	20.0	12.65	20.3	10.3	21.55	33.7	24.65	22.5	19.3	25.0	32.0
Oct. 3	33.2	27.9	27.5	16.2	26.8	28.1	29.1	20.5	16.25	18.3	23.8	20.5	12.5	20.6	10.0	21.7	33.25	24.7	22.9	19.6	25.5	31.8
Oct. 10	33.5	27.9	27.0	16.0	26.9	28.1	29.0	21.0	16.0	18.5	24.15	20.0	12.7	20.0	10.0	21.3	33.7	25.1	22.5	19.2	25.6	31.7
Oct. 17	33.1	27.9	26.7	16.0	26.9	27.4	28.2	20.6	15.9	18.6	24.0	20.0	12.2	19.5	9.8	20.9	33.5	25.7	22.7	19.0	25.5	31.2
Oct. 24	33.0	26.9	26.7	16.0	26.9	28.2	29.1	20.5	16.0	18.3	24.2	19.7	12.3	19.0	9.6	20.5	33.2	25.7	22.5	18.8	25.4	31.1
Oct. 31	33.0	26.8	26.6	16.0	25.7	28.2	30.1	20.7	16.3	18.3	24.4	19.3	12.3	19.5	10.2	20.2	33.0	25.5	22.6	18.6	25.55	31.0
Nov. 7	33.0	26.85	26.6	16.2	25.5	28.2	30.5	20.7	16.5	18.2	24.5	19.2	12.4	18.9	9.9	20.0	29.9	25.4	22.7	18.7	25.6	31.3
Nov. 14	33.2	26.5	26.9	16.5	25.7	28.0	30.5	20.9	16.6	18.2	24.7	19.5	12.4	19.2	9.9	20.0	30.2	25.7	22.8	18.6	25.7	31.6
Nov. 21	33.1	26.5	26.3	16.2	25.7	28.0	30.1	20.7	16.6	18.1	24.7	19.2	12.2	19.9	9.7	20.3	30.1	25.7	22.3	18.5	25.7	31.5
Nov. 28	33.0	26.6	26.3	16.1	25.7	28.1	30.0	20.8	16.2	18.0	24.9	19.7	12.55	19.1	9.75	20.1	30.5	25.3	22.0	18.7	25.25	31.3
Dec. 6	33.0	26.4	26.9	16.15	25.2	28.7	30.0	20.9	16.25	18.1	24.7	19.1	12.7	19.1	10.4	20.0	30.3	24.7	22.4	18.6	25.1	31.1
Dec. 12	33.1	26.4	26.1	16.4	25.5	28.05	30.0	20.3	16.0	18.3	24.3	19.3	12.1	19.9	9.4	20.3	30.1	24.4	23.1	18.2	25.6	31.6
Dec. 19	33.2	26.0	26.0	16.3	25.5	28.0	------	20.0	16.25	18.1	24.3	19.0	11.9	19.7	9.2	20.3	30.0	23.4	23.0	18.4	25.4	------
Dec. 26	33.2	25.9	26.0	16.3	25.1	28.0	------	20.05	16.2	18.0	24.65	19.0	11.7	19.8	9.1	20.3	30.0	22.6	23.4	18.4	25.2	------
1915																						
Jan. 2	33.3	25.7	26.05	16.1	25.2	28.0	------	20.0	16.2	18.0	24.3	19.0	11.1	19.8	9.1	20.3	30.2	22.6	23.1	18.2	25.2	------
Jan. 9	33.1	25.2	26.0	16.0	25.0	28.05	------	20.0	16.1	18.0	24.2	19.0	10.6	19.4	9.05	20.2	30.0	22.6	23.9	18.2	25.1	------
Jan. 16	33.0	25.5	26.0	16.0	25.0	27.85	------	19.9	16.1	17.9	24.1	19.0	10.4	19.1	8.7	20.0	29.8	21.7	23.4	18.2	25.0	------
Jan. 23	29.9	25.6	26.0	15.9	24.9	27.7	------	19.7	16.0	17.8	24.1	18.7	9.2	19.1	8.3	20.0	29.7	18.65	23.1	18.2	25.0	------
Jan. 30	29.9	25.4	26.0	15.7	24.7	27.7	------	19.7	16.7	17.7	24.0	18.0	9.2	19.1	8.0	19.7	29.5	18.05	20.7	18.0	------	------
Feb. 6	29.7	25.4	25.8	15.6	24.45	27.5	------	19.6	16.2	17.4	23.8	18.0	9.2	19.0	8.05	19.4	29.5	17.8	20.1	18.0	------	------
Feb. 13	29.7	25.6	25.8	------	25.6	27.7	------	20.2	9.0	17.2	23.5	18.0	9.0	19.0	8.0	19.1	29.4	18.15	20.0	18.0	------	------
Feb. 20	29.7	25.7	25.5	------	25.8	27.5	------	20.4	9.0	17.0	23.4	18.0	9.2	18.9	8.0	19.1	29.9	18.7	20.0	18.05	------	------
Feb. 27	29.5	25.7	25.2	------	25.8	27.1	------	20.2	9.0	17.0	23.0	18.2	9.0	18.6	8.0	19.0	29.7	18.6	19.8	18.0	18.4	------
Mar. 6	25.1	23.5	22.9	------	24.6	26.55	------	20.2	9.15	15.5	23.4	18.2	10.7	17.95	5.7	15.7	29.6	17.9	19.05	18.3	17.4	------
Mar. 13	25.1	23.2	22.9	------	24.6	26.5	30.0	20.2	9.1	15.4	23.7	18.2	10.7	17.95	5.7	15.6	29.4	17.75	18.9	18.1	------	------
Mar. 20	25.4	23.2	22.9	------	24.9	26.85	------	20.4	9.1	15.4	23.7	18.7	10.6	17.95	5.7	15.6	29.9	18.2	19.2	18.1	------	------
Mar. 27	25.7	23.1	22.9	------	24.9	26.8	------	20.6	9.2	15.4	23.9	18.9	10.9	17.9	5.7	15.7	29.95	19.9	19.0	18.1	------	------
Apr. 3	25.65	24.3	24.25	------	25.4	25.7	------	21.4	10.0	16.6	20.2	18.6	10.6	19.6	6.9	17.9	29.9	20.8	21.7	18.4	------	------
Apr. 10	25.6	24.2	24.2	------	25.4	25.9	------	21.0	10.0	16.2	20.4	18.8	10.9	19.6	6.9	17.9	29.4	21.6	21.7	18.0	------	------
Apr. 17	25.9	24.4	24.9	------	25.55	25.9	------	21.5	10.0	16.4	20.6	18.8	10.9	19.6	6.95	17.6	29.5	21.7	21.7	18.6	------	------
Apr. 24	26.9	24.4	24.6	------	25.6	25.9	------	21.5	10.0	16.4	20.8	16.7	10.9	19.95	6.9	17.9	29.8	20.9	20.5	18.6	------	------
May 1	26.45	24.3	24.95	------	25.8	25.9	------	21.5	10.4	16.4	20.9	16.8	10.95	19.9	6.95	17.7	29.7	21.7	20.9	18.7	------	------
May 8	26.1	24.0	24.7	------	25.5	25.8	------	21.3	10.2	16.2	20.9	16.6	10.7	19.5	6.7	17.6	29.5	20.6	20.9	18.6	------	------
May 15	26.5	24.4	24.7	------	25.55	25.8	------	21.4	10.6	16.4	20.9	16.9	10.9	19.7	6.7	17.6	29.8	20.8	20.7	18.6	------	------
May 22	26.4	24.6	24.7	------	25.4	25.8	------	21.6	10.4	16.7	20.9	16.9	10.9	19.7	6.4	17.6	29.9	21.0	20.9	18.5	------	------
May 29	28.35	24.6	24.9	------	25.6	27.65	------	19.9	9.7	17.0	23.0	18.75	11.2	18.1	7.9	18.85	33.25	21.45	20.5	18.5	------	------

Weekly records of the depth, in feet, to the water level in the observation wells—Continued

	1	2	4	6	7	8	10	11	13	14	15	16	18	19	20	21	22	23	24	25	28	29
1915																						
June 6	29.3	24.5	25.4	------	25.4	28.0	------	20.5	10.4	17.4	23.3	18.8	11.6	18.6	8.4	18.9	33.6	22.1	20.6	18.7	------	------
June 13	29.6	24.7	25.1	------	24.5	28.0	------	20.5	10.8	17.6	23.4	18.9	11.7	18.4	8.4	18.8	33.7	22.3	20.9	18.6	------	------
June 20	29.4	25.0	25.2	------	25.1	27.9	------	20.5	10.8	17.9	23.8	18.95	11.9	18.7	8.8	18.95	33.8	22.8	20.95	18.6	------	------
June 26	30.05	25.0	25.55	14.5	25.9	28.0	31.0	21.0	12.0	17.4	23.4	19.2	12.35	19.0	9.0	19.9	33.8	23.3	21.0	18.5	23.15	31.1
July 3	30.4	24.95	25.0	14.6	25.9	28.6	31.2	21.4	12.5	18.7	23.0	19.0	11.7	19.2	8.6	19.8	33.7	23.5	20.05	18.4	23.2	31.4
July 10	30.9	24.9	25.8	14.7	26.1	28.3	31.5	21.0	11.9	17.45	23.9	18.3	11.25	18.5	8.2	19.4	33.75	23.8	21.1	18.5	22.75	31.3
July 17	31.1	25.0	25.9	14.2	26.2	28.2	31.0	20.9	11.2	18.1	23.6	18.4	12.6	18.5	9.2	19.8	31.5	23.6	21.0	19.6	22.7	31.9
July 24	31.55	25.2	26.0	13.8	26.3	28.3	31.8	21.0	12.0	17.8	23.9	18.9	12.2	18.85	9.2	20.0	34.0	23.3	21.4	18.6	21.7	31.5
July 31	31.45	25.2	26.1	13.9	26.2	28.4	31.9	21.4	12.0	17.6	23.9	18.95	12.4	18.9	9.6	20.0	34.1	23.0	21.6	18.7	21.8	31.6
Aug. 7	31.1	25.0	26.0	12.8	25.4	27.5	31.4	20.3	11.6	17.2	23.4	18.05	12.1	18.4	8.3	20.0	34.0	22.4	21.0	18.6	20.9	30.9
Aug. 14	31.0	25.2	26.2	12.8	25.1	27.6	31.6	20.3	11.2	17.4	23.3	18.0	12.1	18.5	8.4	20.1	32.9	22.0	21.05	18.6	20.7	30.4
Aug. 21	30.8	25.1	26.0	12.1	25.0	27.0	31.1	20.0	11.0	17.1	23.05	17.6	12.0	18.3	8.1	20.0	31.9	19.6	20.4	18.7	20.4	30.1
Aug. 28	30.9	24.6	26.5	12.7	25.0	27.3	------	20.1	11.2	17.15	23.3	17.85	12.1	18.3	8.6	20.4	31.0	18.3	20.4	18.3	20.6	30.7
Sept. 4	30.8	24.7	26.6	12.7	25.2	27.6	------	20.3	11.2	17.2	23.1	17.7	12.4	18.5	8.6	20.4	31.1	18.5	20.1	18.3	20.4	30.2
Sept. 11	30.3	24.6	26.7	13.0	25.3	27.8	------	20.1	11.3	17.3	23.0	17.6	12.4	18.5	8.4	20.5	31.2	18.8	21.0	18.4	20.5	30.3
Sept. 18	30.0	24.4	26.8	13.0	25.2	27.7	------	20.0	11.1	17.6	23.3	17.3	12.2	18.5	8.9	20.7	31.0	19.2	21.0	18.6	20.7	30.5
Sept. 25	30.0	24.5	26.9	12.9	25.2	27.8	------	20.3	11.0	17.6	23.4	17.2	12.3	18.4	8.9	20.5	30.8	19.8	20.9	18.5	20.6	30.4
Oct. 2	29.9	24.5	26.7	12.85	25.4	27.7	------	20.2	10.6	17.2	23.5	17.1	12.1	18.5	8.4	20.3	30.7	21.2	20.8	18.5	20.3	30.1
Oct. 9	29.6	24.4	26.8	12.6	25.4	28.1	------	20.4	10.5	17.2	23.3	17.1	12.1	18.5	8.4	20.5	30.3	20.8	20.7	18.6	20.4	30.0
Oct. 19	29.2	24.7	25.8	15.4	26.3	28.2	------	20.0	11.1	17.3	22.2	18.6	11.4	18.7	8.8	19.7	34.1	21.3	21.1	18.7	22.8	31.8
Oct. 23	29.5	24.7	25.8	15.65	26.4	28.3	------	20.9	11.1	17.3	22.1	18.8	11.4	18.9	8.85	19.7	34.0	21.4	21.0	18.7	22.8	31.9
Oct. 30	29.65	24.6	25.9	15.7	26.3	28.1	------	20.8	11.25	17.2	22.2	18.8	11.2	18.9	8.7	19.6	34.0	21.2	20.95	18.5	22.7	31.7
Nov. 6	30.2	24.75	26.1	15.75	26.3	28.2	------	21.0	11.3	17.2	22.2	18.9	11.3	18.9	8.7	19.8	34.0	21.35	21.1	18.5	22.9	31.9
Nov. 13	30.65	24.95	26.3	16.0	26.5	28.3	------	21.1	11.4	17.3	22.5	18.9	11.45	19.0	9.0	20.0	34.0	21.9	21.2	18.6	23.0	32.0
Nov. 20	30.8	24.8	26.5	16.0	26.6	28.6	------	21.1	11.15	17.4	22.6	19.1	10.6	18.7	8.6	19.8	34.0	22.0	21.1	18.6	23.0	32.1
Nov. 27	31.3	24.8	26.45	16.0	26.5	28.4	------	21.0	10.6	17.2	22.6	19.1	11.0	18.3	8.75	19.8	34.15	22.6	21.3	18.5	22.1	32.2
Dec. 4	31.4	24.6	26.5	16.0	26.6	28.45	------	20.6	10.75	17.3	23.0	19.15	11.2	18.3	8.9	19.85	34.1	22.7	21.4	18.6	20.45	32.3
Dec. 13	31.5	25.0	26.7	16.1	26.65	28.5	------	20.9	11.0	17.4	23.2	19.2	11.45	18.4	9.1	20.0	34.3	22.7	21.7	18.6	20.7	34.3
Dec. 20	31.6	24.9	26.8	15.75	26.8	28.6	------	21.0	10.4	17.1	23.2	18.0	10.0	17.8	8.2	19.5	34.3	22.3	21.0	17.4	18.7	32.4
Dec. 25	31.5	24.6	26.5	13.3	26.1	28.6	------	20.4	10.0	16.8	23.2	18.0	10.5	18.0	8.25	19.1	34.2	21.6	21.2	18.6	17.5	32.3
1916																						
Jan. 1	29.7	23.7	25.35	10.55	25.3	28.0	------	20.0	9.2	16.3	23.0	16.35	9.8	17.6	7.3	17.9	34.0	15.8	19.8	18.5	16.7	32.1
Jan. 8	28.65	23.5	25.0	9.9	25.0	27.5	------	19.8	9.3	16.0	22.5	16.1	9.95	17.6	7.2	17.85	34.0	15.2	19.2	18.35	17.0	32.0
Jan. 17	27.8	23.6	24.65	9.6	24.8	27.3	------	19.8	9.6	15.9	22.1	16.4	10.2	17.8	6.8	17.5	33.8	15.1	18.9	18.3	17.6	32.0
Jan. 22	27.0	23.7	24.4	9.8	24.8	27.2	------	19.7	------	16.0	21.7	17.2	10.4	18.0	6.65	17.4	33.8	16.0	19.0	18.0	18.5	32.3
Jan. 29	25.9	23.45	23.8	9.75	24.65	27.2	------	19.6	------	15.85	21.5	16.8	9.8	17.5	5.9	16.2	33.5	15.9	18.5	18.3	17.2	31.9
Feb. 7	25.1	23.6	23.7	10.0	24.35	27.1	------	19.5	------	15.8	21.0	16.85	10.15	17.8	6.25	19.7	33.4	17.0	18.7	18.3	17.6	31.8
Feb. 12	24.9	23.7	23.9	10.25	24.25	27.2	------	19.6	------	15.9	20.8	17.4	10.4	18.0	6.5	16.85	33.0	17.6	19.2	18.3	18.4	31.5
Feb. 21	24.8	24.0	24.0	10.5	24.5	27.3	------	19.7	------	16.1	20.7	17.9	10.6	18.1	6.7	17.15	33.1	18.5	19.4	18.3	19.1	31.7
Feb. 28	24.2	23.1	23.4	8.7	24.0	27.1	------	19.5	------	15.55	21.0	15.1	9.35	16.9	5.6	15.7	33.15	12.5	17.85	18.3	17.2	31.6
Mar. 4	24.3	23.2	23.0	8.4	23.8	26.5	------	19.4	------	15.35	20.4	16.1	10.0	17.8	6.1	16.4	33.0	14.5	17.8	18.3	17.4	31.5
Mar. 13	21.4	23.4	23.3	8.45	23.8	26.8	------	19.5	------	15.7	20.0	17.3	10.6	18.2	6.5	17.3	33.0	17.35	18.35	18.4	19.0	31.2
Mar. 20	24.8	23.7	23.6	8.9	24.15	26.85	------	19.6	------	16.1	20.4	17.7	10.6	19.2	6.6	17.3	32.7	18.5	19.4	18.3	19.2	31.4

Mar. 27	24.8	23.8	23.85	9.4	24.3	27.0	-------	19.8	-------	16.0	20.5	18.0	10.7	18.2	6.9	17.5	32.8	18.7	19.55	18.3	19.8	31.3
Apr. 1	22.85	22.6	19.8	8.3	23.1	25.6	-------	19.15	-------	14.8	19.8	12.8	8.4	16.55	4.35	13.0	22.7	11.0	14.2	16.5	16.4	31.0
Apr. 8	23.1	22.7	20.7	8.3	22.45	23.9	-------	19.0	-------	14.15	18.25	14.15	9.6	17.6	5.1	14.6	32.15	13.85	14.4	17.3	17.0	30.6
Apr. 15	23.3	22.8	20.9	8.3	21.9	24.1	-------	18.8	-------	14.2	17.7	15.0	9.5	17.7	5.2	15.2	31.8	15.0	15.0	17.3	17.0	30.5
Apr. 24	23.35	23.1	21.4	8.3	21.75	23.7	-------	19.1	-------	14.5	17.3	15.9	10.1	17.8	5.5	15.9	31.55	15.1	16.0	18.0	17.8	30.2
May 1	23.5	23.3	21.7	8.4	21.8	23.9	-------	18.7	-------	14.75	17.4	16.8	10.3	18.9	5.8	16.0	31.8	15.6	16.9	18.3	18.5	29.9
May 8	23.7	23.35	22.2	8.4	22.2	24.2	-------	18.6	-------	15.2	17.8	17.4	10.6	17.9	6.1	16.6	31.85	16.3	17.7	18.3	19.3	29.8
May 13	24.1	23.6	23.65	8.9	22.6	24.3	-------	18.7	10.4	15.6	18.3	17.9	10.9	18.0	6.5	17.1	31.8	17.2	18.5	18.4	20.3	29.6
May 21	24.1	23.6	23.0	8.75	22.9	24.45	-------	18.6	9.95	15.8	18.4	18.0	10.55	17.9	6.6	17.3	31.8	18.0	18.8	18.4	19.1	29.5
May 29	24.4	23.75	23.3	9.3	23.1	24.6	-------	18.6	10.2	15.9	17.8	18.2	10.85	17.9	7.0	17.7	32.0	-------	19.2	18.4	18.7	29.35
June 3	24.7	23.9	23.6	9.7	23.3	24.6	-------	18.7	10.35	16.0	19.0	18.5	10.85	18.0	7.3	18.2	32.0	-------	19.4	18.3	18.7	29.5
June 10	25.0	24.1	24.0	10.3	23.8	24.8	-------	18.7	10.6	16.2	19.2	18.6	10.8	18.0	7.2	18.2	32.2	19.3	19.6	18.4	20.1	29.4
June 19	25.3	23.95	24.3	9.7	24.0	25.0	-------	18.8	10.7	16.4	19.5	18.6	10.4	18.1	7.4	18.3	32.3	19.8	19.7	18.4	20.7	29.7
June 26	25.5	24.1	24.4	9.9	24.0	25.3	-------	19.0	10.2	16.5	19.9	18.5	10.7	18.0	7.4	18.7	32.7	20.4	19.9	18.5	19.7	29.6
July 1	25.8	24.1	24.5	10.3	24.1	25.2	-------	18.9	10.5	16.6	19.9	18.7	11.0	18.2	7.6	18.6	32.5	20.0	20.0	18.4	20.6	29.65
July 8	26.1	24.25	24.65	10.1	24.3	25.1	-------	19.5	11.0	16.65	20.25	18.8	11.1	18.6	7.7	18.8	32.5	20.3	20.0	18.4	21.8	29.6
Aug. 1	27.6	24.2	25.15	10.3	24.5	25.2	-------	19.6	11.3	16.8	20.6	18.5	11.0	18.8	7.9	19.0	32.7	21.2	20.5	18.2	22.8	30.1
Aug. 5	27.9	24.4	25.3	11.1	24.8	25.2	28.0	19.8	11.6	16.8	20.9	18.8	11.6	19.0	8.2	19.4	32.9	21.3	20.7	18.4	22.9	30.3
Aug. 12	28.3	24.5	25.4	11.4	24.8	25.4	28.0	19.9	11.8	17.2	21.5	18.8	11.4	19.0	8.4	19.5	33.0	22.3	20.9	18.6	23.0	30.4
Aug. 19	28.7	24.4	25.55	12.1	24.9	25.3	28.0	20.2	12.0	17.1	21.0	18.9	11.75	19.1	8.8	19.7	33.2	22.4	21.0	18.4	23.1	30.25
Aug. 26	29.3	24.5	25.9	13.0	25.25	25.8	28.0	20.3	12.6	17.1	21.4	19.35	11.8	19.4	9.0	20.4	33.5	22.5	21.1	18.4	23.4	30.45
Sept. 2	29.7	24.7	25.8	13.7	25.5	25.9	28.2	20.4	12.8	17.3	21.4	19.0	11.8	19.5	9.0	20.0	33.4	21.9	21.2	18.6	23.7	30.6
Sept. 9	29.8	24.85	26.0	14.0	25.45	25.8	28.3	20.35	13.45	17.3	21.6	19.1	11.9	19.35	9.4	20.1	33.3	22.25	21.4	18.6	23.6	30.8
Sept. 16	30.4	25.0	26.2	14.5	25.7	26.4	28.4	20.7	13.9	17.6	21.8	19.2	12.0	19.5	9.4	20.4	33.4	22.9	21.4	18.5	23.9	30.4
Sept. 23	31.0	25.0	26.35	14.9	25.8	26.5	28.55	20.8	14.3	17.8	22.1	19.1	11.75	19.8	9.6	20.5	33.6	23.3	21.6	18.4	24.0	30.7
Sept. 30	31.5	25.0	26.5	15.1	25.9	26.6	28.5	20.9	14.6	17.7	22.3	19.35	11.45	19.7	9.35	20.55	33.75	23.9	21.65	18.6	24.2	31.2
Oct. 7	32.0	25.4	26.55	15.6	26.15	27.3	28.65	21.3	15.0	18.0	22.75	19.4	11.9	19.95	9.65	20.7	34.3	24.5	21.9	18.6	24.75	32.8
Oct. 14	32.0	25.2	26.6	15.4	26.0	27.0	28.55	21.7	14.7	17.8	22.55	19.3	11.8	20.5	9.7	20.6	33.6	25.1	22.0	18.4	24.3	33.2
Oct. 21	31.9	25.3	26.6	15.6	25.9	27.1	-------	20.7	15.0	17.9	23.0	19.1	11.55	19.8	9.6	20.6	33.8	25.4	22.0	18.8	24.3	31.35
Oct. 28	31.9	25.4	26.7	16.0	26.2	27.25	28.8	20.8	14.6	17.9	23.0	19.3	11.8	20.2	9.9	20.9	34.0	25.7	22.5	18.7	25.1	31.65
Nov. 4	32.0	25.5	26.9	16.4	26.4	27.4	28.8	20.7	14.5	18.0	23.2	19.35	11.9	20.0	-------	20.7	34.1	25.4	22.2	18.8	24.7	31.8
Nov. 11	32.7	25.6	26.9	16.3	26.4	27.6	28.9	20.9	14.2	17.9	23.4	19.4	11.8	20.1	10.0	20.7	34.3	25.6	22.35	18.8	24.8	32.0
Nov. 18	25.6	27.1	26.9	16.5	26.55	27.7	29.2	20.9	14.2	18.1	23.6	19.5	11.8	20.1	-------	20.9	34.4	25.5	22.5	18.9	24.75	32.1
Nov. 25	31.95	25.5	27.4	16.4	26.5	27.6	29.0	20.8	13.8	17.9	23.7	19.25	11.3	20.0	9.6	20.75	34.0	24.7	22.5	18.8	24.8	32.0
Dec. 2	31.9	25.6	27.3	16.3	26.4	27.8	29.1	20.6	13.1	17.8	24.0	19.1	11.4	20.0	9.6	20.7	34.3	25.5	22.7	18.9	24.0	32.0
Dec. 9	31.9	25.6	27.3	15.7	26.2	28.0	29.1	20.3	12.4	17.9	24.1	18.95	11.5	18.8	9.6	20.6	34.3	24.4	22.8	18.7	24.7	32.2
Dec. 17	32.0	25.5	27.3	15.4	26.3	28.0	29.25	20.4	11.9	17.8	24.2	19.0	11.4	19.5	9.6	20.6	34.8	25.5	23.1	18.7	24.9	32.3
Dec. 24	32.0	25.6	27.0	14.7	26.1	28.0	29.1	20.2	11.3	17.7	24.6	18.0	10.8	19.0	9.0	20.4	34.6	24.8	22.4	18.7	-------	-------
Dec. 30	31.8	25.4	26.8	13.2	25.6	28.2	29.4	20.0	10.7	17.6	24.2	18.0	11.1	18.3	9.3	20.3	34.7	24.0	23.1	18.6	23.9	32.5

INTERPRETATION OF THE RECORDS

As a rule the fluctuations in the observation wells were of the same general character, although each well has individual characteristics. The chief factors in the variations in fluctuation seem to be the depth of the well, or, more precisely, the depth to the water table; the location of the well, whether on a flat area, on a hill slope, or near the foot of a hill; and the kind of water-bearing material, whether till or stratified drift. The wells in stratified drift are on a flat area, whereas the wells in till are on hill slopes or at the foot of hills, and almost all the wells in stratified drift are deeper than those in till; therefore it is difficult to separate the factors that influence any individual well.

In general the shallow wells show greater range in fluctuation than the deep wells, and the wells on hill slopes or at the foot of hills show wider fluctuations and greater flashiness than those on plains. The same amount of water will cause a greater rise of the water level in till than in stratified drift, but the rise and subsequent fall in stratified drift will probably occur more quickly because the water moves through stratified drift more rapidly than through till. In other words, after a rain some of which percolates to the water table the wells in till will show a greater but perhaps less prompt rise than the wells in stratified drift.

When the ground is frozen and there is not much recharge the water table on hilltops and slopes declines, but because of the general movement of the ground water toward the valleys the water table in the lowlands may remain stationary or even rise during the same period of frozen ground. Thus in upland-till wells the water level is likely to decline during prolonged periods of severe winter weather, whereas in the stratified-drift wells, which are on the lowlands, the water table is much less likely to decline. This difference in the behavior of till and stratified-drift wells occurred during the winter of 1913–14, as is shown in Figure 12.

The fluctuation of the water table during the period from October, 1913, to December, 1916, is shown in Plate 19 by means of a composite curve based on the averages of the weekly measurements recorded in the preceding table. In constructing this curve the highest water level in each well during the period was used as the zero datum for that well, and the fluctuations of the water level in that well were expressed in depths below this datum. This method allowed a fair comparison of the fluctuations of the water levels in the wells. The altitude of the wells above sea level was not determined. As about 90 per cent of the drainage basin is covered by till and only about 10 per cent by stratified drift, the average figures for the wells in till were given a relative value of 90 and those for the wells in stratified drift were given a relative value of 10. The curve based on this weighted

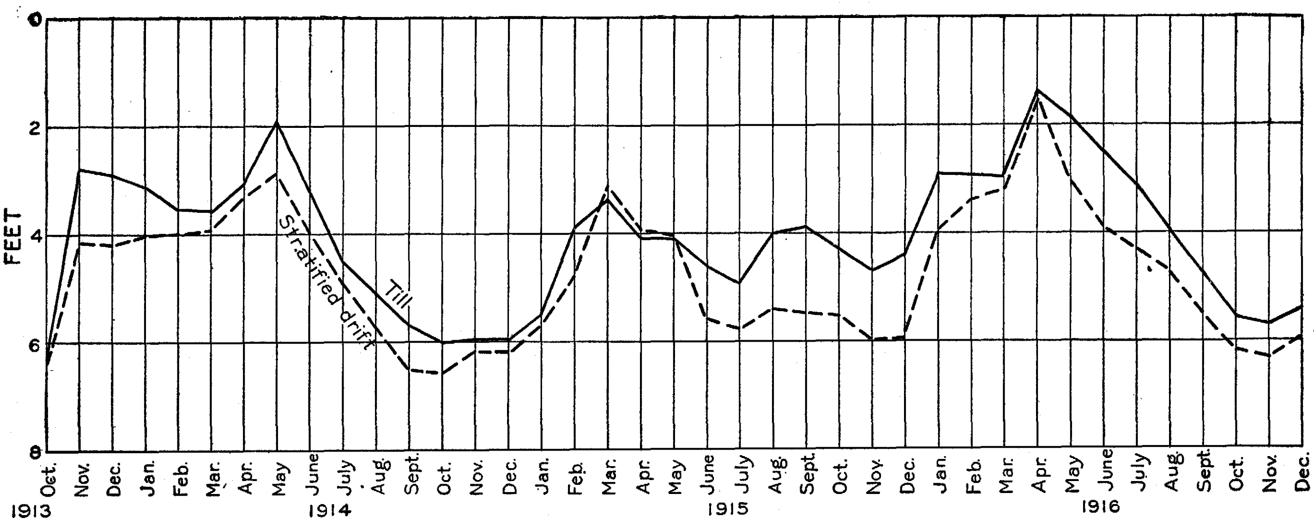

FIGURE 12.—Fluctuation of water table in till and in stratified drift in the Pomperaug Basin, Conn., by months, October, 1913, to December, 1916

average is regarded as showing average conditions for the entire drainage basin.

The following table gives the average monthly depths to the water level in the wells in till and in stratified drift and the weighted average of these two for the period covered by the investigation. (See also fig. 8.)

Average stage of the water table in the Pomperaug Basin, October, 1913, to December, 1916, as indicated by the position of the water levels in the observation wells

[Figures indicate feet below the highest water levels in these wells during the period]

Month	Till	Stratified drift	Weighted average	Month	Till	Stratified drift	Weighted average
1913				1915			
October	6.34	6.35	6.34	May	4.14	4.07	4.13
November	2.81	4.17	2.95	June	4.63	5.55	4.72
December	2.86	4.21	3.00	July	4.94	5.76	5.02
				August	3.97	5.41	4.11
1914				September	3.84	5.44	4.00
January	3.06	4.03	3.16	October	4.32	5.55	4.44
February	3.58	4.04	3.63	November	4.72	6.04	4.85
March	3.57	3.93	3.61	December	4.41	5.97	4.57
April	3.06	3.50	3.10				
May	1.89	2.89	1.99	1916			
June	3.22	3.97	3.30	January	2.87	3.91	2.97
July	4.55	4.90	4.59	February	2.86	3.41	2.92
August	5.10	5.72	5.16	March	2.94	3.22	2.97
September	5.73	6.50	5.81	April	1.42	1.49	1.43
October	6.04	6.59	6.10	May	1.84	3.05	1.96
November	5.97	6.15	5.99	June	2.55	3.91	2.69
December	5.92	6.17	5.95	July	[a] 3.13	[a] 4.27	3.24
				August	3.99	4.73	4.06
1915				September	4.76	5.54	4.84
January	5.49	5.70	5.51	October	5.64	6.16	5.69
February	3.88	4.75	3.97	November	5.72	6.33	5.77
March	3.39	3.11	3.36	December	5.43	5.98	5.49
April	4.09	3.94	4.08				

[a] Only 2 sets of records.

FLUCTUATION OF THE WATER TABLE IN RELATION TO PRECIPITATION AND OTHER WEATHER CONDITIONS

The fluctuations of the water table, as shown by fluctuations of the water levels in the wells, indicate a seasonal emptying and refilling of the ground-water reservoir. The filling of the ground-water reservoir occurs when water derived from rain or snow percolates into the zone of saturation. The discharge of ground water is effected chiefly through ground-water run-off and through evaporation, including transpiration.

The water table usually begins to rise in the fall, as soon as evaporation and plant growth become slight, and it rises rapidly whenever there is a heavy rain or when the snow melts on ground that is not frozen. There may also be a retardation in the rate of ground-water discharge due to lower temperature, and hence greater viscosity of the ground water at the points of discharge, but this effect is probably slight. There is considerable variation from one year to another in the time when the principal recharge takes place, owing to differences in snow and frost conditions as well as to irregularities in precipitation.

However, in early spring the water table usually reaches its highest stage for the year. As soon as the weather becomes warm and plant growth becomes active the water table begins to decline unless this is prevented by unusually heavy rains. All through the summer soil evaporation and the demands of vegetation are so great that but little water percolates to the zone of saturation, whereas ground-water run-off continues and water is also discharged from the zone of saturation by soil evaporation and transpiration. Hence the water table usually declines persistently throughout the summer and reaches its lowest stage in the fall. During the summer only exceptionally heavy or prolonged rains cause any considerable rise in the ground-water level.

A detailed study of the fluctuations of the water table shows some interesting facts regarding the filling and emptying of the ground-water reservoir during the period of observation. The rains of October, 1913, amounted to 9.21 inches, which was 5.06 inches above normal, whereas the demands of soil evaporation and plant growth so late in the season were doubtless low. The direct run-off during the month was high, and there was a large addition to the supply of soil moisture, but a large part of the rain also entered the zone of saturation. About October 11 the water table began to rise slightly, then more rapidly, and from October 25 to November 1 the rise amounted to about 3 feet. Most of the replenishing was accomplished in this last week of October, as the water table rose only half a foot higher by November 15 and no higher during December. A slight lowering of the water table occurred during January and February, 1914, and a rise of 1.8 feet during April and the first part of May. The highest stage of the water table was reached about May 16. The growing period, or period of depletion, then began, and the water table declined steadily, reaching its lowest stage for 1914 and for the entire period of the investigation in the first part of October—following a drought of several weeks at the end of the growing period. At this low stage the water table averaged about 4½ feet below the high stage of May, showing a considerable emptying of the ground-water reservoir.

The rains in the middle of October, 1914, checked the depleting process and caused a slight rise of the water table. However, from that time until the later part of December the water table remained nearly stationary. More rapid replenishment began in January, 1915, and continued practically without interruption until early in March, the total rise being about 3 feet. The large rise during the middle of the winter was due to high temperature and heavy precipitation, partly in the form of warm rains, which took the frost out of the ground and thus allowed the water to reach the zone of saturation. On account of the exceptionally dry spring, especially in March, the water table began to decline unusually early, and by the middle of April it was about 1 foot below its high stage early in March. Owing to rains later in the season, however, the decline was not nearly so great in the summer of 1915 as it had been in the summer of 1914, and in August, when there is usually severe depletion, there was actually a rise of about 1 foot due to excessive and protracted rains following the abundant rainfall of July. This higher level was fairly well maintained throughout the rest of August, all of September, and the early part of October. Then followed a few weeks of deficient rainfall during which the water table descended nearly a foot. Thus in 1915 the water table reached two low stages—one at the end of July and another in November or December—but at neither time did it go to nearly as low a level as in the fall of 1913 and the fall of 1914. At the low stage in November, 1915, the water table stood less than 2 feet below its high stage of March. The water year October, 1914, to September, 1915, closed with more than the usual amount of water in storage.

The replenishing period began about the middle of December, 1915. The water table rose quickly as a result of heavy precipitation, and by January 8, 1916, it had risen about 2 feet. Throughout January, February, and March the water table fluctuated somewhat but maintained a high level. This was a winter of heavy snowfall, with temperatures below normal in February and especially in the first three weeks of March, resulting in large snow storage. The rapid and large rise of the water table during the last week in March was due to unseasonably high temperatures which melted the snow and took the frost out of the ground, thus permitting water to reach the zone of saturation. This rise, occuring at a time when the water table already stood high, brought the water table by April 8 to the highest point it reached during the entire period covered by the investigation. Depletion began early in April, and except for a temporary rise during a rainy period in the later part of May the water table continued to descend until the middle of November, when it was about 4.8 feet below the high point of the preceding April. In the low stage of November, 1916, the water table stood lower than it had in the low stage of 1915 and at about the same level as in the low stage of 1914, but not quite so low as in October, 1913, when the observations were begun.

Thus, in spite of somewhat deficient precipitation during the period of investigation, the supply of ground water was not depleted—that is, the quantity of water stored in the zone of saturation at the end of the period was fully as great as the quantity stored at the beginning of the period.

The decline from the high stage in the spring to the low stage in the fall, representing depletion of the ground-water supply, was 4.5

feet in 1914, 1.85 feet in 1915, and 4.8 feet in 1916. The depletion was probably nearest to the normal in 1914. The rise of the water table from fall to spring, representing replenishment of the ground-water supply, was 4.8 feet in 1913–14, 3.1 feet in 1914–15, and 3.85 feet in 1915–16. For the 3-year period the average decline of the water table from spring to fall was 3.72 feet, and the average rise from fall to spring was 3.92 feet, the small difference between average decline and average rise being due to the fact that the water table stood a little higher at the end of the period than at the beginning.

FLUCTUATION OF THE WATER TABLE IN RELATION TO GROUND-WATER RUN-OFF

As shown in Plate 19 and Figure 7, the ground-water run-off fluctuates with the water table. Almost without exception, when the water table rises the ground-water run-off increases, and when the water table declines the ground-water run-off decreases. However, in the summer the decrease in ground-water run-off is disproportionately great (see fig. 8), because much of the ground-water that appears at or near the surface evaporates instead of being carried away by the river.

In Figure 13 an effort is made to establish a ground-water rating curve for the Pomperaug drainage basin. Numbers indicate months of the year in which observations were made, "1" standing for January, "2" for February, etc. A dot represents a set of observations made in the period from October to April, when evaporation is at a minimum; a cross represents a set of observations made in the period from May to September, when there is active evaporation of ground water. This rating curve, based only on observations when evaporation was not great, doubtless lies to the right of the broken line and is approximately represented by the continuous line. It is comparable to the rating curves that are developed in gaging surface streams, the coordinates being (1) the average depth, in feet, of the water levels in the observation wells below the zero datum for each well, and (2) the ground-water run-off, in second-feet, as determined from the curve in Plate 19. The average depth of the water levels, or average stage of the water table, was as a rule determined once a week by measurements of the observation wells. Hence, the dots and crosses in Figure 13 show the weekly positions of the water table plotted against the corresponding ground-water run-off.

It is evident from the data presented in Figure 13 that from May to September evaporation of ground water is a process which is very effective in reducing the amount of ground-water run-off. Thus, with the water table at the same altitude the ground-water run-off will be much less in August than in January because in August a part of the ground water that is returned to the surface or near to the surface is disposed of by evaporation. Hence, it is not feasible to make a single rating curve that will be applicable in all seasons. If, however, only the months are considered in which not much evaporation takes place a curve can be drawn that will represent approximately the ground-water run-off during these months. Thus, in drawing the rating

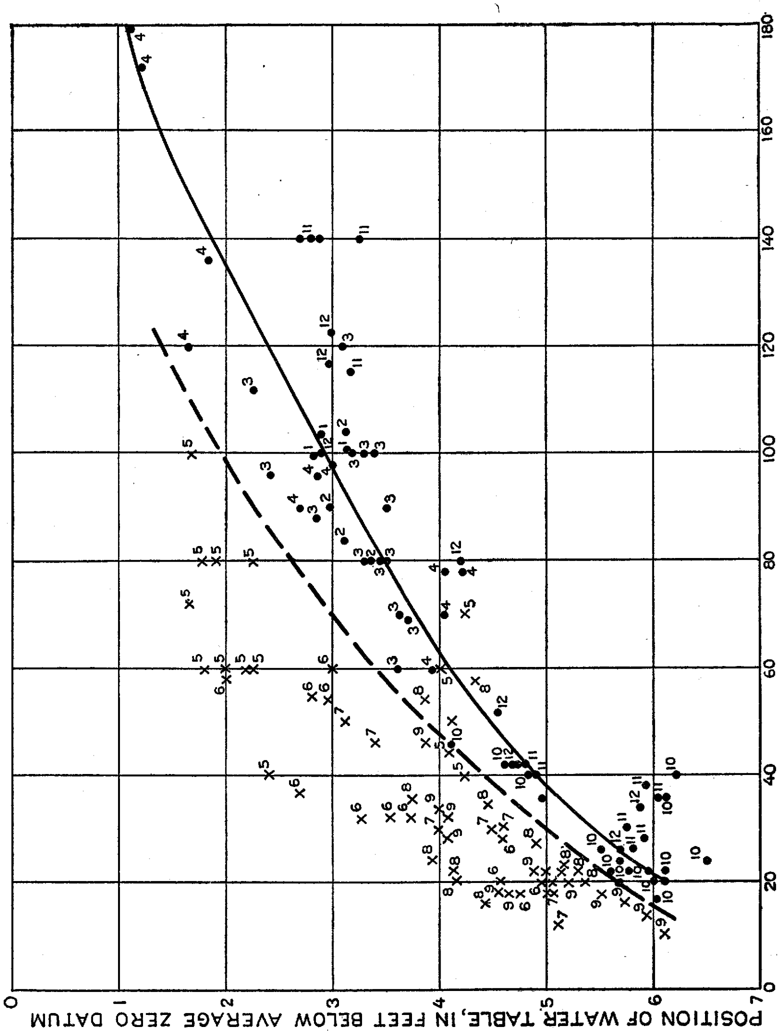

FIGURE 13.—Rate of ground-water run-off in relation to stage of water table in the Pomperaug Basin, Conn., based on water-level data given in the table on pages 117–121 and ground-water run-off as shown in Plate 19. (See p. 127)

curve shown by the continuous line in Figure 13, only the observations from October to April (represented by dots), were taken into consideration, and some allowance had to be made for evaporation in the early part of October. Although the dots are not perfectly alined, they fall into about as narrow a zone as could be expected with the imperfect data that were used. This curve probably represents somewhat less than the total ground-water discharge in the summer, because the roots of plants and the soil capillaries do not wait for the water to appear at the surface but pump it up from some depth. Further research is required to determine the characteristic type of ground-water rating curves.

Considerable interest attaches to the question what is the "point of zero flow," or how much farther the water table would have to descend below the low stages reached in the fall of 1913 and the fall of 1914 before stream flow would cease. As the water table comes near this point the ground-water run-off approaches zero, and therefore the actual arrival of the water table at the point of zero flow would be indefinitely delayed were it not for the fact that evaporation of ground water would continue and might easily carry the water table below this point—a condition that is common in arid regions. Meager ground-water run-off would probably continue in certain localities long after most parts of the basin had ceased to contribute to the stream flow. The inference from this line of reasoning is that a small amount of water would continue to flow in the principal streams of the Pomperaug River system even after a much more protracted drought than any that occurred in 1913 or 1914.

Even after ground-water run-off from a given area ceases there generally remains a supply of ground water that is stored in the zone of saturation, somewhat as a supply of surface water remains in a reservoir after there is no more water to go over the spillway. This water can be recovered by wells. Usually in times of severe drought many dug wells fail. In some localities the ground-water reservoir may at such times actually be drained except for the water in the crevices of the bedrock, and no remedy is available except to drill into the rock. Commonly, however, the trouble is due merely to the fact that the well is not deep enough to extend to the water table at its lowest stages, and the flow into the well can be restored by digging the well a little deeper.

CHANGES IN GROUND-WATER STORAGE REPRESENTED BY FLUCTUATIONS OF THE WATER TABLE

The changes in the quantities of water held in storage in the zone of saturation can be calculated from the fluctuations in the water table if the average specific yield of the glacial materials in the belt of fluctuation is known. For example, if a material whose specific yield is 20 per cent were saturated and then allowed to drain it would yield a volume of water equal to one-fifth of the volume of the material. Obviously, if in such material the water table declines 5 inches the quantity of water removed from the zone of saturation during the decline amounts to a layer of water 1 inch deep.

No direct data are available regarding the specific yield of the water-bearing materials in the Pomperaug Basin. However, the specific yield is equal to the porosity minus the specific retention, and the specific retention approximates the moisture equivalent expressed in percentage by volume. These terms have been defined as follows:[19]

The *specific yield* of a rock or soil, with respect to water, is the ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume.

The *specific retention* of a rock or soil, with respect to water, is the ratio of (1) the volume of water which, after being saturated, it will retain against the pull of gravity to (2) its own volume.

The *moisture equivalent* of a soil is the ratio of (1) the weight of water which the soil, after saturation, will retain against a centrifugal force 1,000 times the force of gravity to (2) the weight of the soil when dry. It can also be expressed as the ratio of (1) the volume of water retained under the specified conditions to (2) its own volume.

The moisture equivalent by weight can be roughly calculated from the mechanical analyses according to the following formula developed by Briggs and Shantz:[20]

$$\text{Moisture equivalent} = 1.84\ (0.01\ \text{sand} + 0.12\ \text{silt} + 0.57\ \text{clay}).$$

The percentages of sand, silt, and clay in three samples of till and three samples of ordinary stratified drift in the Pomperaug Basin are given in the table on page 81. The material larger than sand is considered as having a moisture equivalent of 0. The moisture equivalents by weight are changed to moisture equivalents by volume by multiplying by the specific gravity of the materials.

The average porosity of the samples of till is 14 per cent, and that of the samples of stratified drift is 36 per cent (p. 81). The calculated average moisture equivalent (by volume) of the till is 3.4 per cent, and that of the stratified drift is 3 per cent. If these are used as specific retentions the specific yield of the till is 10.6 per cent and that of the stratified drift 33 per cent. As about 90 per cent of the basin is covered with till and 10 per cent with stratified drift the average specific yield of the glacial materials in the Pomperaug Basin is computed to be 12.8 per cent.

The monthly increase or decrease in the quantity of water stored in the zone of saturation was determined by obtaining from Plate 19 the rise or decline of the water table between the first and last day of each month, and multiplying this rise or decline by 12.8 per cent, the computed average specific yield. The results are given in the tables on pages 143–144.

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[19] Meinzer, O. E., Outline of ground-water hydrology, with definitions: U. S. Geol. Survey Water-Supply Paper 494, pp. 25, 28–29, 1924. See also Meinzer, O. E., Occurrence of ground water in the United States, with a discussion of principles: U. S. Geol. Survey Water-Supply Paper 489, pp. 50–63, 1924.

[20] Briggs, L. J., and Shantz, H. L., The wilting coefficient for different plants and its indirect determination: U. S. Dept. Agr. Bur. Plant Industry Bull. 230, 1912.

EVAPORATIVITY

RECORDS OF EVAPORATIVITY

No records of evaporativity, or evaporation from a free water surface, are available for the Pomperaug Basin. The averages for Boston, Mass., as computed by Fitzgerald,[21] are given in the following table and are shown graphically in Figure 8. These averages are based on observed rates of evaporation from Chestnut Hill Reservoir, at Boston, corrected and supplemented by a formula which Fitzgerald derived from other observations and experiments.

Average evaporativity

Month	Precipitation [a] (inches)	Evaporativity		Month	Precipitation [a] (inches)	Evaporativity	
		Inches [b]	Per cent of precipitation [c]			Inches [b]	Per cent of precipitation [c]
October	4.15	3.16	76	May	3.95	4.46	113
November	3.75	2.25	60	June	3.20	5.54	173
December	4.29	1.51	35	July	4.68	5.98	128
January	4.23	.96	23	August	4.48	5.50	123
February	3.97	1.05	26	September	3.86	4.12	107
March	4.43	1.70	38				
April	3.82	2.97	78		48.81	39.20	80

[a] Waterbury normal, based on record covering 38 years.
[b] Evaporation at Boston, Mass.
[c] On the assumption that the evaporativity is the same in the Pomperaug Basin as at Boston.

RECORDS OF DAILY TEMPERATURE

It is not necessary here to discuss the various weather conditions that control the rate of evaporation from a free water surface. One of the most influential of these conditions is the temperature of the air that comes into contact with the water, and hence the temperature may be taken as a more or less reliable indication of the rate of evaporation. The maximum and minimum daily temperature and the average monthly and annual temperature at Waterbury, as recorded by the United States Weather Bureau during the period covered by this investigation, are given in the following tables. The average daily temperature at Waterbury is shown on Plate 19, and the average monthly temperature in relation to evaporation and evaporativity is shown in Figure 14.

[21] Fitzgerald, Desmond, Evaporation: Am. Soc. Civil Eng. Trans., vol. 15, pp. 581–646, 1886; corrected in vol. 17, p. 275, 1892.

Daily maximum and minimum temperatures for Waterbury, Conn., July, 1913, to December, 1916 [a]

Month		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1913																																
July	Max.	97	90	92	92	93	92	82	83	80	84	82	81	87	83	82	84	85	79	90	88	86	89	87	79	82	83	86	86	94	97	91
	Min.	66	73	61	60	66	72	54	45	53	62	53	46	64	63	51	55	52	62	60	65	57	52	60	66	62	48	53	59	70	65	65
August	Max.	83	89	91	83	83	85	84	85	88	94	84	80	73	80	83	92	96	96	83	82	79	77	83	83	79	82	79	85	77	85	85
	Min.	64	64	55	60	51	54	62	58	66	72	53	49	55	56	49	58	62	70	64	49	47	47	54	54	54	44	64	55	66	65	55
September	Max.	85	88	83	86	68	78	69	84	78	72	72	71	74	66	68	71	72	80	70	62	69	71	70	70	78	78	70	70	77	70	----
	Min.	65	68	65	68	57	57	56	66	50	39	41	48	48	39	33	38	45	63	55	53	59	61	43	40	42	49	51	36	47	46	----
October	Max.	63	61	70	72	80	74	66	69	74	79	68	67	58	62	63	67	74	66	61	63	63	60	60	60	64	63	65	71	69	59	49
	Min.	52	51	45	51	56	56	60	62	64	64	61	53	36	39	43	51	46	46	51	52	43	32	30	42	58	52	51	46	45	43	30
November	Max.	49	55	57	57	51	65	65	61	63	55	40	49	55	51	46	39	45	58	58	70	64	60	69	50	44	50	44	36	39	43	----
	Min.	25	34	31	45	32	26	28	33	51	37	24	30	34	39	38	32	32	30	44	51	52	49	46	32	23	33	24	29	34	34	----
December	Max.	46	51	54	49	52	52	54	52	36	39	38	38	50	54	49	45	57	46	41	45	51	43	40	47	43	36	33	30	35	37	40
	Min.	32	35	41	35	40	38	34	25	20	20	26	17	22	24	27	27	25	30	18	22	28	34	28	34	30	32	17	11	14	14	16
1914																																
January	Max.	35	29	32	33	45	38	38	37	42	39	34	30	18	13	24	36	39	32	31	36	34	36	36	47	43	27	40	55	51	55	46
	Min.	18	16	25	30	32	12	19	30	14	34	27	14	−6	−10	8	14	28	11	11	27	29	10	1	28	15	11	14	36	34	39	30
February	Max.	42	38	50	53	45	34	44	44	23	33	28	12	21	27	27	15	24	28	30	28	28	34	32	19	29	42	46	46	----	----	----
	Min.	34	24	23	38	25	20	20	22	10	15	9	−10	−6	13	5	−11	0	−7	23	16	13	−7	12	0	−5	−5	9	11	----	----	----
March	Max.	44	46	44	42	45	39	40	42	33	35	32	35	37	42	57	54	55	45	36	31	32	38	42	46	51	64	72	66	40	36	60
	Min.	33	25	27	28	25	31	29	29	24	19	19	14	13	14	34	28	32	30	24	17	12	22	18	22	22	38	45	35	34	30	32
April	Max.	58	52	45	45	43	48	47	63	59	50	52	61	56	56	54	39	63	76	83	63	55	69	69	65	60	46	54	59	59	51	----
	Min.	27	41	33	21	31	23	37	38	35	27	31	39	25	22	35	34	34	32	49	52	42	38	34	29	42	38	41	46	50	39	----
May	Max.	60	66	74	69	61	74	76	71	70	78	75	73	47	68	67	72	72	80	84	87	82	84	75	74	76	91	94	85	82	80	84
	Min.	31	31	40	42	49	48	42	49	46	44	49	46	39	41	39	39	40	40	46	48	54	50	58	45	45	62	70	63	55	45	49
June	Max.	82	75	78	75	72	74	83	89	70	86	90	87	84	79	79	69	76	76	68	71	75	68	73	90	92	88	78	69	77	74	----
	Min.	56	48	43	58	51	42	44	64	54	55	55	56	56	53	55	51	42	48	52	44	44	57	37	60	67	61	58	59	55	54	----
July	Max.	77	75	69	80	76	75	65	83	81	78	79	91	88	79	78	84	88	90	83	80	79	81	77	82	82	88	87	78	76	67	73
	Min.	46	58	54	57	57	57	55	59	63	61	65	63	68	60	63	69	76	71	61	49	56	55	53	61	63	64	57	58	53	55	54
August	Max.	85	85	81	76	74	81	84	94	93	91	81	77	83	79	85	84	87	80	92	85	83	85	85	84	79	78	78	71	65	81	85
	Min.	57	57	61	61	60	60	64	66	64	67	71	68	61	60	65	54	63	59	68	69	66	66	54	67	51	51	53	62	61	60	54
September	Max.	87	92	87	81	80	78	74	76	67	72	67	72	78	78	81	88	92	92	82	87	95	97	93	88	78	62	69	62	65	68	----
	Min.	56	70	65	63	49	48	62	54	40	39	45	41	39	39	39	40	44	46	59	44	52	53	56	59	55	45	40	34	28	48	----
October	Max.	67	78	84	83	81	72	64	79	77	79	83	76	70	62	64	64	67	71	65	73	80	77	67	58	57	62	56	53	56	54	55
	Min.	46	34	38	42	50	48	50	52	50	55	62	48	49	40	43	59	60	48	49	43	40	47	39	41	42	41	35	23	39	40	34
November	Max.	73	65	58	71	66	51	52	56	45	41	54	51	62	58	45	62	48	32	34	38	34	48	35	36	48	57	58	46	50	47	----
	Min.	35	44	37	37	35	37	29	40	32	22	27	29	29	38	32	43	32	84	26	32	22	20	20	15	28	38	42	22	20	30	----
December	Max.	62	64	62	52	38	34	33	33	33	40	42	38	35	51	32	29	29	29	39	42	32	37	26	22	25	13	21	36	32	45	42
	Min.	36	38	48	32	32	27	29	29	27	27	27	22	17	32	9	11	11	6	15	25	24	24	13	8	9	−4	−9	8	16	32	20
1915																																
January	Max.	33	30	28	31	39	42	57	47	37	35	32	37	44	43	46	47	45	55	56	45	37	31	41	48	33	37	35	36	35	21	23
	Min.	11	20	18	11	7	26	40	30	22	20	14	29	34	22	34	29	30	43	45	32	25	15	20	23	26	25	28	30	10	4	6
February	Max.	40	32	19	33	31	53	48	37	52	28	39	49	43	41	51	51	37	41	45	55	53	51	51	58	53	39	29	32	----	----	----
	Min.	22	11	10	17	10	30	33	26	23	8	12	34	24	27	36	37	30	16	20	23	23	22	34	41	38	25	14	16	----	----	----

March	Max	37	44	39	45	45	39	47	48	43	44	46	42	51	49	48	49	43	41	50	51	45	50	50	57	59	54	41	51	44	37	48
	Min	19	24	19	13	28	28	29	29	22	25	27	21	20	26	21	22	22	22	20	26	28	30	33	29	29	33	16	29	28	18	21
April	Max	50	50	46	50	49	51	52	68	70	70	62	66	61	63	68	69	64	72	80	77	69	63	73	74	92	84	92	89	74	68	----
	Min	31	25	27	27	23	37	32	33	37	44	49	49	35	32	32	33	45	46	50	50	41	31	44	45	50	44	54	46	44	48	----
May	Max	62	61	64	60	67	71	72	74	72	69	73	73	70	68	70	63	50	62	66	71	66	76	67	63	77	69	62	72	73	63	80
	Min	41	39	44	41	44	47	41	55	56	41	45	56	44	41	45	35	44	39	35	38	49	49	53	47	44	54	36	46	43	37	35
June	Max	84	75	67	74	75	75	81	75	81	75	74	82	78	90	83	77	80	85	77	76	79	70	66	73	78	80	80	83	86	78	----
	Min	45	47	43	45	47	54	60	59	54	53	51	59	48	58	60	62	62	59	64	61	52	49	55	51	46	55	49	49	53	61	----
July	Max	79	76	83	85	76	77	78	73	81	84	84	71	86	88	90	84	90	87	88	81	80	73	80	79	85	85	83	86	86	87	89
	Min	65	62	59	64	65	56	50	63	56	53	56	60	53	60	59	64	70	64	64	64	60	60	52	58	52	57	61	55	60	62	71
August	Max	89	84	79	71	75	65	80	83	85	82	85	80	89	88	85	89	84	71	76	83	79	77	85	86	83	78	69	74	66	73	72
	Min	67	70	59	56	56	57	58	61	63	57	57	59	69	65	62	64	66	48	48	50	56	57	65	60	67	54	47	48	54	57	55
September	Max	75	85	90	88	82	80	75	83	95	90	88	83	84	91	93	94	92	82	76	82	72	64	70	71	73	68	66	66	72	75	----
	Min	49	49	50	57	65	65	62	69	68	68	56	60	64	68	68	70	66	63	61	53	60	45	36	45	44	48	43	40	41	38	----
October	Max	68	52	68	71	66	60	62	60	60	61	64	75	77	74	80	68	76	74	73	66	78	70	56	54	59	64	69	63	65	60	60
	Min	41	46	37	42	51	50	41	48	37	34	29	41	42	52	64	51	37	43	52	60	59	40	38	31	27	36	50	34	39	44	40
November	Max	69	68	51	48	48	51	55	62	62	51	55	61	59	51	52	45	43	45	58	58	50	44	38	40	48	54	51	56	49	43	----
	Min	45	50	40	28	38	33	26	27	39	30	33	42	32	27	43	31	27	25	30	38	38	30	22	31	24	24	28	33	33	28	----
December	Max	39	39	37	35	36	32	32	33	39	32	27	36	31	32	26	32	31	51	38	34	34	34	39	42	49	54	37	39	35	30	31
	Min	20	27	24	19	20	23	27	19	24	16	16	12	18	25	15	16	17	31	30	25	17	10	14	29	25	27	19	32	25	18	10
1916																																
January	Max	39	36	37	33	41	50	27	25	31	40	46	42	45	39	21	33	32	19	24	36	53	56	55	42	55	61	67	63	46	35	50
	Min	16	28	29	14	27	26	16	7	6	20	34	26	26	11	3	18	11	5	10	17	35	36	31	24	29	41	49	45	19	24	34
February	Max	54	41	30	26	35	44	40	23	35	32	28	22	22	17	29	32	40	38	34	22	21	39	38	36	42	42	33	25	29	----	----
	Min	40	24	22	5	12	25	22	10	18	18	11	18	15	−8	−13	3	27	26	6	−1	−3	−5	27	24	29	30	16	7	9	----	----
March	Max	32	27	33	28	32	22	39	39	29	41	40	35	45	39	35	25	26	19	31	29	38	37	36	38	54	66	58	55	48	63	68
	Min	10	17	13	14	15	7	17	28	16	19	10	4	28	22	18	12	5	2	14	11	24	24	18	13	28	23	29	33	38	39	32
April	Max	63	56	55	45	57	55	50	44	40	54	61	55	50	49	58	70	64	53	60	63	63	61	49	55	60	57	54	49	70	71	----
	Min	37	41	33	33	34	33	31	30	30	30	27	41	42	39	35	31	42	41	38	44	43	41	40	41	40	43	41	38	37	40	----
May	Max	69	72	67	69	69	74	71	75	65	64	79	75	73	69	56	56	56	56	56	67	76	67	57	70	84	80	76	68	83	76	73
	Min	44	45	47	48	48	53	48	44	51	40	51	49	44	40	45	50	49	44	36	40	42	42	43	50	57	51	47	35	59	60	57
June	Max	75	80	74	75	76	77	73	59	58	55	59	76	77	71	68	69	67	81	72	74	72	71	73	76	71	81	80	83	80	80	----
	Min	43	44	54	50	49	49	54	54	54	47	49	54	54	54	53	50	61	60	56	54	45	48	47	51	56	54	61	65	57	56	----
July	Max	83	84	84	73	68	85	89	91	82	74	81	92	91	81	77	80	83	87	87	89	85	85	83	79	78	77	87	80	77	80	93
	Min	49	55	63	57	57	52	56	63	65	64	67	70	71	68	56	55	67	70	61	69	70	70	70	68	70	70	71	63	49	60	68
August	Max	88	80	83	84	82	94	90	95	87	74	73	87	80	79	84	83	89	87	88	89	93	96	91	81	86	84	85	69	77	83	85
	Min	62	54	63	65	69	72	69	73	80	69	59	63	57	50	50	57	63	57	58	57	55	68	66	65	52	60	63	55	44	53	54
September	Max	88	80	72	77	80	80	82	92	78	80	75	76	83	92	78	73	72	74	69	75	75	74	71	70	66	73	85	78	77	68	----
	Min	51	67	42	55	58	56	63	71	60	45	45	41	54	50	68	58	39	41	47	37	44	52	63	48	45	42	53	57	68	46	----
October	Max	69	72	77	72	80	81	78	84	84	73	64	68	66	59	62	69	65	55	58	69	68	59	60	62	62	62	56	63	63	66	63
	Min	32	35	35	46	40	57	54	42	60	34	32	34	43	38	30	50	49	28	40	57	54	34	34	32	53	53	29	33	32	53	47
November	Max	63	62	55	55	50	56	57	60	67	62	50	48	46	59	37	36	38	44	50	50	40	42	55	58	38	32	52	50	60	57	----
	Min	52	37	33	30	38	32	26	32	39	43	38	26	36	32	24	21	23	31	23	27	21	14	26	38	27	18	32	29	40	43	----
December	Max	43	45	47	52	56	53	45	46	45	42	39	36	33	31	28	22	26	26	28	32	36	40	38	32	38	25	33	43	37	22	25
	Min	32	32	27	38	48	40	34	32	30	25	21	32	24	19	19	18	11	4	20	9	24	32	29	20	24	15	17	33	21	13	12

[a] From U. S. Weather Bureau records.

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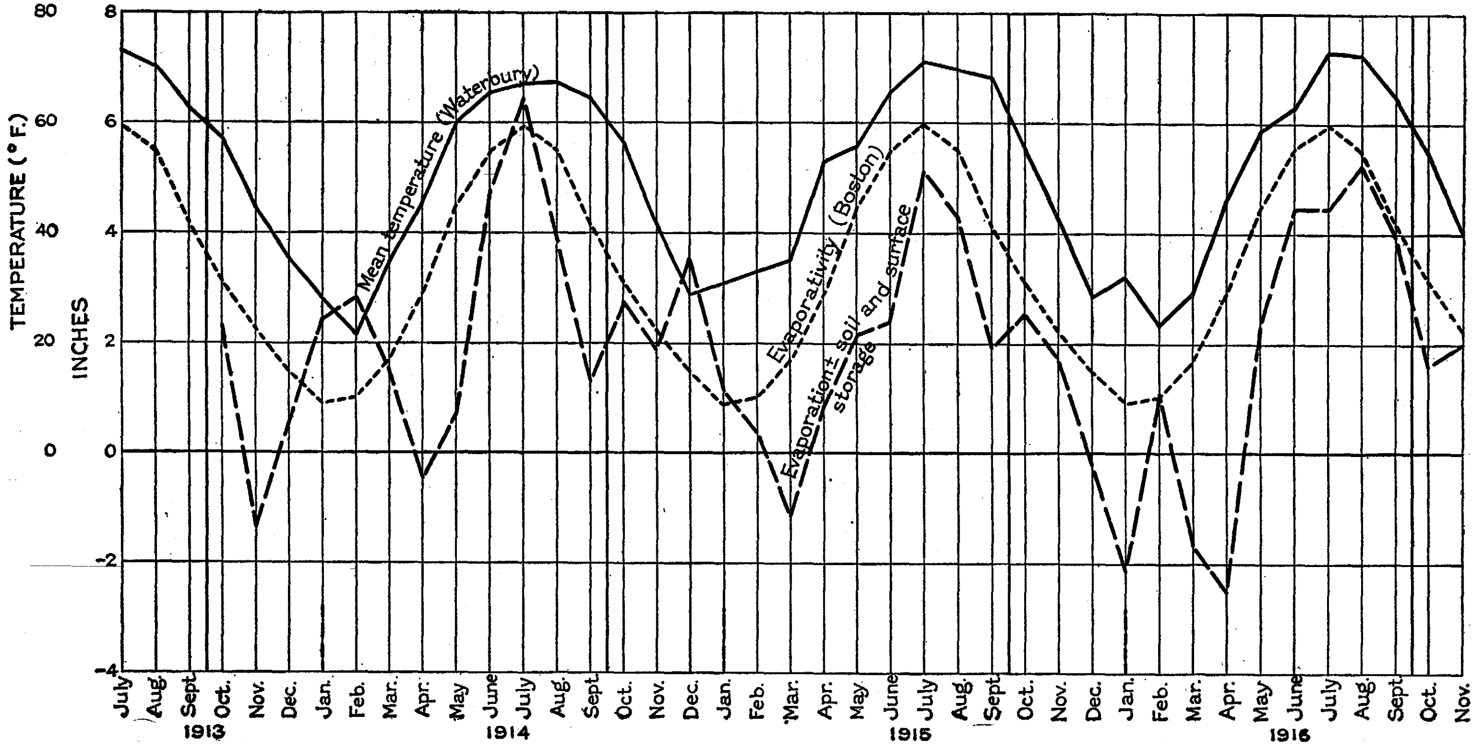

FIGURE 14.—Monthly temperature, evaporativity, and evaporation plus or minus changes in soil and surface storage in the Pomperaug Basin, Conn., July, 1913, to November, 1916

Average monthly and annual temperatures at Waterbury, July, 1913, to December, 1916, and normal temperatures at the same station (°F.)

	1913	1913–14	1914–15	1915–16	1916	Normal
October		57.2	56.8	54.6	54.5	52.2
November		44.0	40.6	42.4	41.0	40.6
December		35.4	28.8	28.5	30.6	31.0
January		28.0	31.2	32.2		25.5
February		21.8	33.0	23.5		26.7
March		35.2	35.4	28.8		33.5
April		46.0	53.2	46.8		47.0
May		60.9	55.9	58.6		58.1
June		65.4	65.8	62.8		67.6
July	73.0	69.4	71.1	73.0		71.7
August	70.7	71.8	69.0	72.6		69.6
September	62.4	64.0	68.0	64.6		63.2
Annual		49.9	50.9	49.0		48.8

RELATION OF EVAPORATIVITY TO PRECIPITATION

The evaporativity has a great seasonal fluctuation, ranging each year from a very slow rate in winter to a rapid rate in summer, but the differences in evaporativity from day to day or from month to month are not so great and erratic as the corresponding differences in precipitation. Moreover, for the same month in successive years the range of evaporativity is not nearly so great as the range in precipitation.

If the records for evaporativity at Boston can be regarded as approximately correct for the Pomperaug Basin, it follows that the evaporation from a free water surface in this basin is slightly less than the precipitation, although it may be greater in certain dry years. In general, the evaporation from a free water surface is greater than the precipitation during the summer and less than the precipitation during the winter, but occasionally there are summer months in which the precipitation is in excess of the evaporation.

EVAPORATION

TOTAL EVAPORATION

It is believed that the Pomperaug Basin does not lose any notable quantity of water by subterranean percolation. If this is true practically all the water that falls on the basin as rain or snow ultimately either evaporates or escapes through Pomperaug River. During any given period, however, some of the water may be stored as snow or ice, as surface water in ponds and streams, as soil moisture, or as ground water in the zone of saturation; on the other hand, water may be drawn from storage in the melting of snow and ice, the shrinking of ponds and the dwindling of streams, the drying out of the soil, or the lowering of the water table. Obviously, therefore, for any month, year, or other designated period, the total evaporation is about equal to the precipitation minus the total run-off and minus the net increase in storage, or to the precipitation minus the total run-off and plus the net decrease in storage.

The table on page 143 shows the difference between the precipitation and the total run-off minus any increase in ground-water storage or plus any decrease in ground-water storage for each month and year covered by the investigation. As no definite data were obtained concerning increase and decrease in the other forms of storage no allowances could be made for them. Thus this table shows the monthly and annual evaporation without corrections for changes in surface and soil storage. Even without these corrections the figures show in general the variations in monthly evaporation from one season to another. (See also fig. 14.) However, they are too large to represent evaporation alone in months when the soil became wetter (usually in late fall but also in occasional months of excessive rainfall in other seasons) and in months when snow accumulated on the ground. On the other hand, they are too small to represent all of the evaporation in months when the soil moisture was depleted (as in most months of late spring and in some months of summer and early fall) and in months when the snow that fell earlier in the winter disappeared. In some spring months the loss in snow storage is counterbalanced by increase in soil storage.

In the annual estimates the correction for increase or decrease in storage would be relatively much smaller, and in the 3-year average it would be still smaller. In other words, the figures given in this table show approximately the annual evaporation in the successive years, and the figure given for the annual average is a closer approximation to the average annual evaporation during the period of the investigation.

The evaporation opportunity is the actual evaporation expressed as a percentage of the evaporativity—that is, of the evaporation that would occur from a free water surface. If the average annual evaporativity at Boston represents fairly the evaporativity in the Pomperaug Basin during the years covered by the investigation the evaporation opportunity was about 64 per cent in the year ending September, 1914, about 64 per cent in the year ending September, 1915, and about 50 per cent in the year ending September, 1916—an average of about 59 per cent for these three years. If the run-off records for the first of these years and the precipitation records for the third year are a little too low, as is suspected, the actual evaporation opportunity may have been a little less than computed in the first year and a little more in the third year.

The records seem to indicate that in midsummer, when plant growth is most active, the evaporation opportunity is not far from 100 per cent. According to the records, average evaporativity and average evaporation both reach their maximum in July, when the average evaporativity is given as 5.98 inches and the average evaporation plus or minus storage is given as 5.34 inches. As July is usually a month when soil moisture is depleted, rather than increased, this figure for evaporation is apparently not too large.

Studies of relative amounts of precipitation, run-off, and evaporation have recently been made by Houk [22] in the drainage basin of Miami River above Dayton, Ohio, and by Bates and Henry [23] in the Wagonwheel Gap area, Colo. The average annual results derived from these investigations are given in the following table for comparison with the results obtained in the Pomperaug Basin. The records for the Miami Basin cover a period of 25 years, and those for Wagonwheel Gap 7 years, whereas those of the Pomperaug Basin cover only 3 years.

Comparison of average annual precipitation, run-off, and evaporation in the Pomperaug drainage basin, Conn., the Miami drainage basin above Dayton, Ohio, and drainage basin A of the Wagonwheel Gap area, Colo.

		Pomperaug	Miami	Wagonwheel Gap
Length of record	years	3	25	7
Precipitation	inches	44.48	37.07	21.00
Run-off	do	19.53	11.87	6.08
Evaporation [a]	do	23.20	25.20	14.92
	percentage of precipitation	52	68	71

[a] For the Miami Basin and the Wagonwheel Gap area this figure is precipitation minus run-off; for the Pomperaug Basin it is precipitation minus run-off and ground-water storage. (See table, p. 144.)

In the Miami Basin the precipitation is considerably less than in the Pomperaug Basin, but the evaporation appears from the data available to be slightly greater, leaving much less water to be carried off by the streams. In the Wagonwheel Gap area the precipitation is notably less, hence there is less water available either for evaporation or for discharge by the streams, but the proportion of evaporation to precipitation is greater.

Evaporation proceeds in two ways—by transpiration, or the evaporation from the pores or stomata of plants, and by evaporation that takes place without the agency of plants. Transpiration is limited to the growing season, which in the Pomperaug Basin extends from about April to October. Quantitative studies of transpiration have been made by numerous investigators, but most of these studies have been concerned primarily with irrigation and with the water requirement of plants. The results have commonly been expressed in pounds of water required to produce a pound of dry matter. The rate of transpiration depends upon many factors, such as temperature,

[22] Houk, I. E., Rainfall and run-off in the Miami Valley: Miami Conservancy District Tech. Repts., pt. 8, 1921.

[23] Bates, C. G., and Henry, A. J., Stream-flow experiment at Wagonwheel Gap, Colo.: Monthly Weather Rev. Suppl. 17, 1922.

humidity, wind velocity, light, soil moisture, and kind of vegetation. The subject is summarized as follows by Meyer:[24]

> For tentative purposes the following normal seasonal transpiration may be used as a base value in estimating water losses for the north-central portion of the United States: 9 to 10 inches for grains, grasses, and agricultural crops; 8 to 12 inches for deciduous trees; 6 to 8 inches for small trees and brush; 4 to 6 inches for coniferous trees. These quantities represent inches depth of water over the entire area occupied by the given form of vegetation.

Only a very general estimate can be made of the rate of transpiration in the Pomperaug Basin. About 32 per cent of the basin is wooded, and most of the woodland is in small deciduous trees and brush. On the basis of Meyer's figures 9 inches seems a conservative estimate of the average amount of transpiration from both the wooded and the nonwooded areas.

If the total evaporation in the Pomperaug Basin was about 23 inches a year during the three years covered by the investigation and the transpiration was about 9 inches, it follows that about 14 inches a year was evaporated in other ways—chiefly from the moisture in the soil, but in part from the rain and snow intercepted by trees and other plants, in part from rain and snow lying on the surface of the ground, and in part from the water of ponds and streams.

EVAPORATION OF WATER DERIVED FROM THE ZONE OF SATURATION

Part of the water evaporated from the soil or transpired from plants is derived from the zone of saturation and hence from the supply of ground water. The amount of this ground-water evaporation was estimated in the following manner:

From November to April, each year, when the temperature is low, plant life nearly dormant, and the ground frozen much of the time, only small quantities of ground water are lost by evaporation. Moreover, no feasible method was available for estimating these small quantities. Therefore, the ground-water evaporation during these months was considered negligible.

Estimates of monthly ground-water evaporation for the period from May to October each year were computed from the monthly ground-water recharge, change in ground-water storage during the month, and monthly ground-water run-off. These quantities are given in the summary table on page 143. The methods of obtaining ground-water run-off and changes in ground-water storage are explained on pages 107 to 113 and 129 and 130; the methods of estimating the ground-water recharge on pages 140 and 141. For any month during the period from May to October in which there was a decrease in the

[24] Meyer, A. F., The elements of hydrology, p. 262, New York, John Wiley & Sons, 1917.

amount of ground water in storage, the recharge plus the net withdrawal from storage gives the total discharge of ground water, and this total discharge minus the ground-water run-off gives the ground-water evaporation. For example, in May, 1914, the recharge was estimated to be 1.84 inches, the net withdrawal from storage 0.08 inch, and the ground-water run-off 0.85 inch. Therefore, the total discharge of ground-water during the month was computed to be 1.92 inches and the ground-water evaporation 1.07 inches. In June, 1914, there was no recharge or, more precisely, the amount of recharge was so small that it was regarded as negligible. In the same month the net withdrawal from storage was 2.30 inches and the ground-water run-off was 0.39 inch. The total discharge of ground water was therefore taken to be 2.30 inches, and the ground-water evaporation 1.91 inches.

For certain months during the evaporation period in which there was considerable recharge no method was available for estimating the recharge independently of the ground-water evaporation (p. 141). Hence, there was no way of computing the ground-water evaporation.

For these exceptional months the best that could be done was to obtain the average ground-water evaporation for corresponding months in other years and to assume that this average represented the evaporation for this month. Thus the ground-water evaporation could not be computed for October, 1913, and October, 1914, but it was computed to be 0.87 inch in October, 1915, and 0.82 inch in October, 1916, and therefore the somewhat unsatisfactory assumption was made that the ground-water evaporation in October, 1913, and October, 1914, was the average of these two figures, or 0.85 inch. The only other months for which averages from other years had to be used were May, August, and September, 1915.

The average annual ground-water evaporation for the three years covered by the investigation, according to the computations that were made, was 6.21 inches, or about 27 per cent of the total evaporation. This includes transpiration of trees and other plants that feed upon water from the zone of saturation and also evaporation from soil in low places where the soil is kept moist by rising ground water. It also includes evaporation from springs, seepage areas, and streams.

The table on page 144 shows that although the total evaporation, like the evaporativity, does not reach its maximum until July, the ground-water evaporation reaches its maximum in June. The table also indicates that the ground-water evaporation amounts to about 66 per cent of the total in May and to about 36 per cent of the total in June, whereas for the entire year it amounts to only 27 per cent of the total. Although these monthly averages are believed to be subject to large errors they are probably correct in showing that the ground-water evaporation is relatively large in the first part of the evaporation season, when the water table stands high.

GROUND-WATER RECHARGE

It remains to consider the quantity and distribution of the ground-water recharge—that is, the water that percolates down to the water table and enters the zone of saturation.

There was some recharge in every month or nearly every month from October to May in each year covered by this investigation, as is shown by the fact that in every one of these months, with a few possible exceptions, the water table either rose or else declined only moderately—not enough to provide the amount of ground water that was disposed of by run-off and evaporation. The monthly recharge varied greatly in amount, however, being largest in months in which there was heavy rainfall or in which much snow melted and least in months with meager precipitation or with frozen ground and accumulating snow.

During the summer months (June to September) the consumption of water by plants and the evaporation from the soil are so great that not much of the rain escapes to the water table except at times of especially heavy rainfall. As is shown in Plate 19, most ordinary summer rains have no noticeable effect on the water table. In August, 1915, when the water table rose conspicuously, there was obviously heavy recharge, and some recharge is also indicated by the water-level data in July and August, 1914, July and September, 1915, and June and July, 1916.

The monthly recharge was computed as follows: For the period from November to April, when ground-water evaporation is regarded as negligible, the recharge in any month is equal to the ground-water run-off plus the net increase in ground-water storage as indicated by the rise of the water table, or minus the net decrease in ground-water storage as indicated by decline of the water table. In most of these months there was a rise in the water table and hence some storage to be added to the run-off. The greater part of the recharge occurs during this cold period, when the problem is not seriously complicated by evaporation.

In the remaining months of the year, when evaporation has to be taken into account, the simple method used for the colder months is not applicable. For these months it was necessary to compute the recharge, so far as possible, directly from the fluctuations of the water table. The regular decline of the water table in some months shows that there was little or no recharge in these months, and hence in making the computations recharge in these months was regarded as zero. In those summer months in which the water levels were appreciably affected by precipitation the amount of recharge was estimated, if possible, directly from the water-table curve in Plate 19. For example, in August, 1914, the water table declined gradually until at least August 15, but between the measurements made on the 15th and those made on the 22d there were several rains which not only stopped the decline but raised the water table 0.18 foot. The recharge between these dates was estimated not on the rise of the water table, but on the vertical interval between the level at which it stood on August 22 and the level at which it would have stood if the gradual decline prior to August 15 had continued until August 22. This interval is about 0.3 foot and represents a recharge of about 0.45 inch. After August 22 the water table resumed its decline and no further allowance was made for recharge in this part of the month.

In a few of the summer months with large recharge it was impossible to make a satisfactory estimate of recharge by inspection of the water-table curve in Plate 19. These months were October, 1913, October, 1914, and May, August, and September, 1915. For these months average figures for ground-water evaporation were used, as explained on page 143, and the recharge was then computed as the sum of ground-water run-off and ground-water evaporation plus or minus change in storage. The estimates of recharge for these months are in error to the extent that the quantities used for ground-water evaporation are inaccurate.

According to the methods of computation explained above, the annual ground-water recharge during the three years ranged from 14.04 to 16.84 inches and averaged 15.57 inches, or 35 per cent of the precipitation.

It was not practicable to make an inventory of the water in the stratified drift as distinct from that in the entire basin. However, as the stratified drift yields water more freely than the till, large ground-water developments in this region are generally made by sinking wells in the stratified drift, and hence it is of practical importance to have information on the rate of recharge in deposits of this kind. The data given in the table on page 124 show that the fluctuations of the water table in the stratified drift are comparable in magnitude to those in the till. As the specific yield of the stratified drift is much greater than that of the till, it is obvious that the fluctuations of the water table in the stratified drift represent much greater quantities of ground water than the average fluctuations for the entire basin, as shown in the summary table on page 143. Much of this water comes from precipitation on the areas of stratified drift, but some comes as surface or ground water from adjacent areas that are underlain by till.

SUMMARY

The water in the drainage basin of Pomperaug River is nearly all derived from precipitation—that is, from the rain and snow which fall on the basin. It is nearly all disposed of as run-off or by evaporation—that is, it is either carried out of the basin by Pomperaug River or else is evaporated directly or through the agency of plants. In the three full years covered by this investigation, October, 1913, to September, 1916, according to the data that were obtained, the precipitation averaged 44.48 inches, the run-off 20.66 inches, and the evaporation 23.20 inches a year (plus or minus a slight unknown difference in stream and soil storage). Moreover, there was during the 3-year period a net increase in ground-water storage (that is, in the quantity of water stored in the zone of saturation) which amounted to 1.85 inches, or an average of 0.61 inch a year, as is shown by the higher position of the water table at the end than at the beginning of the period.

During the 3-year period the ground-water recharge, or quantity of water that percolated from the surface to the water table and entered the zone of saturation, averaged 15.58 inches a year. Of this amount, an average of 8.76 inches seeped into Pomperaug River and its tributaries and was carried out of the basin by the river, 6.21 inches evaporated either directly or through the agency of plants, and 0.61 inch remained in storage in the zone of saturation.

According to these results, in the 3-year period the total run-off amounted to about 46½ per cent and the total evaporation to about 52 per cent of the precipitation, about 1½ per cent of the precipitation being stored in the zone of saturation. The ground-water recharge amounted to about 35 per cent of the precipitation, of which somewhat more than half was disposed of as run-off and somewhat less than half by evaporation. More precisely, the ground-water run-off amounted to about 19½ per cent of the precipitation, the ground-water evaporation to about 14 per cent, and the net increase in ground-water storage to about 1½ per cent.

There was no marked seasonal distribution of the precipitation but a very pronounced seasonal distribution of the evaporation. Consequently, each year was divided into a replenishing and a depleting season. In the replenishing season, from late fall to early spring, an average of approximately 7 inches of water was stored in the zone of saturation, over and above the withdrawals as run-off and by evaporation; in the depleting season, from late spring to early fall, nearly a like average amount was withdrawn from storage, in addition to the contributions that were occasionally received by the zone of saturation during this season. Most of the water withdrawn from storage during the depleting season was utilized by the vegetation or otherwise evaporated; only a small part ran off through Pomperaug River. In any long period of years the average seasonal depletion will, of course, be very nearly equal to the average seasonal replenishment.

In the following tables are given a summary of the monthly and annual inventories of the water supply of this basin during the period covered by the investigation:

Inventory of the water supply of the Pomperaug Basin, July, 1913, to December, 1916, in depth in inches over the drainage area

	Precipitation	Increase or decrease of ground water in storage	Ground-water run-off	Ground-water recharge	Ground-water evaporation	Total run-off	Total evaporation plus increase or minus decrease in surface and soil storage	Principal changes in surface and soil storage or other conditions that make the figures given in last column greater or less than total evaporation
1913								
July	2.07	-------	-------	-------	-------	-------	-------	
August	3.35	-------	0.13	-------	-------	0.25	-------	
September	3.43	-------	.17	-------	-------	.35	-------	
October	9.21	+4.30	.52	5.67	[a] 0.85	2.57	2.34	Increase in stream and soil storage.
November	2.72	+1.38	1.73	3.11	([b])	2.73	−1.39	Decrease in soil storage.
December	2.58	−.23	1.42	1.19	([b])	2.24	.57	
1914								
January	3.01	−.77	[c] 1.00	.23	([b])	1.33	2.45	Estimate of total run-off probably too low.
February	3.10	−.31	[c] .40	.09	([b])	.58	2.83	Increase in snow storage; estimate of total run-off probably too low.
March	6.01	+.23	.86	1.09	([b])	4.32	1.46	
April	4.20	+1.69	1.03	2.72	([b])	2.94	−.43	Decrease in snow storage.
May	3.06	−.08	.85	[d] 1.84	1.07	2.35	.79	Decrease in soil and stream storage.
June	3.11	−2.30	.39	([e])	1.91	.63	4.78	
July	5.68	−1.46	.38	[d] .45	1.53	.70	6.44	
August	3.67	−.77	.29	[d] .45	.93	.45	3.99	
September	.31	−1.23	.18	([e])	1.05	.20	1.34	Decrease in soil storage.
October	3.35	+.31	.22	1.38	[a] .85	31	2.73	Increase in soil storage.
November	2.50	+.15	.34	.49	([b])	.51	1.84	
December	4.10	−.08	[c] .50	.42	([b])	[c] .62	3.56	Increase in soil storage and perhaps in snow storage; estimate of total run-off may be too low.
1915								
January	6.49	+2.00	[c] .95	2.95	([b])	[c] 3.41	1.08	
February	5.63	+1.69	[c] 1.20	2.89	([b])	[c] 3.58	.36	
March	.10	−.38	1.19	.81	([b])	1.61	−1.13	Decrease in stream and snow storage.
April	1.88	−.614	.90	.29	([b])	1.60	.89	
May	3.15	−.23	.67	1.61	[a] 1 17	1.21	2.17	
June	1.88	−1.00	.28	([e])	.72	.45	2.43	
July	5.77	−.15	.24	[d] .60	.51	.78	5.14	
August	7.87	+1.84	.60	3.34	[a] .90	1.79	4.24	
September	2.56	−.31	.44	1.05	[a] .93	.92	1.95	Decrease in soil storage.
October	2.61	−.92	.55	[d] .50	.87	1.01	2.52	
November	2.51	−.15	.36	.21	([b])	.92	1.74	
December	4.86	+2.30	.73	3.03	([b])	2.90	−.34	Records for precipitation probably too low.
1916								
January	1.48	+.61	1.34	1.95	([b])	3.00	−2.13	Decrease in snow storage.
February	4.77	+1.00	.99	1.99	([b])	2.71	1.06	Increase in snow storage; records for precipitation probably too low.
March	2.43	+.38	1.16	1.54	([b])	3.66	−1.61	Decrease in snow storage; records for precipitation probably too low.
April	2.20	+.31	1.90	2.21	([b])	4.45	−2.56	Decrease in snow storage.
May	3.83	−.31	.89	[d] 1.84	1.26	1.76	2.38	
June	4.27	−1.84	.69	[d] .40	1.55	1.68	4.43	
July	4.49	−1.00	.54	[d] .40	.86	1.05	4.44	
August	4.67	−1.15	.29	([e])	.86	.56	5.26	
September	3.38	−1.06	.25	([e])	.81	.45	3.99	
October	1.29	−.77	.25	[d] .30	.82	.44	1.62	
November	2.65	+.08	.32	.40	([b])	.56	2.01	Increase in soil storage.
December	3.52	+.84	-------	-------	([b])	-------	-------	

[a] Unsatisfactory estimate based on average of corresponding months in other years.
[b] Ground-water evaporation is regarded as negligible.
[c] Estimated on inadequate data.
[d] Estimated from irregularity in water-table curve in Plate 19.
[e] Ground-water recharge was apparently negligible in amount.

Inventory of the average monthly water conditions in the Pomperaug Basin, July, 1913, to December, 1916, in depth in inches over the drainage area

[Based on all data in the preceding table]

Month	Precipitation [a]	Increase or decrease of ground water in storage	Ground-water run-off	Ground-water recharge	Ground-water evaporation	Total run-off	Total evaporation plus increase or minus decrease in surface and soil storage
October	4.12	+0.73	0.39	1.96	0.85	1.08	2.36
November	2.60	+.33	.69	1.05		1.18	1.05
December	3.77	+.71	.88	1.55		1.92	1.26
January	3.66	+.61	1.10	1.71		2.58	.47
February	4.50	+.79	.86	1.66		2.29	1.42
March	2.85	+.08	1.07	1.15		3.20	−.43
April	2.76	+.46	1.28	1.74		3.00	−.70
May	3.35	−.21	.80	1.76	1.17	1.77	1.78
June	3.09	−1.71	.45	.13	1.39	.92	3.88
July	4.50	−.87	.39	.48	.96	.84	5.34
August	4.89	−.03	.33	1.27	.90	.76	4.50
September	2.42	−.87	.26	.35	.93	.48	2.43

[a] Based on monthly precipitation during the period; not Waterbury normal.

Inventory of the annual water supply of the Pomperaug Basin, October, 1913, to September, 1916, in depth in inches over the drainage area

[Based on all data in the preceding table]

Month	Precipitation	Increase or decrease of ground water in storage	Ground-water run-off	Ground-water recharge	Ground-water evaporation	Total run-off	Total evaporation plus increase or minus decrease in surface and soil storage
October, 1913, to September, 1914	46.66	+0.45	9.05	16.84	7.34	21.04	25.17
October, 1914, to September, 1915	45.28	+3.23	7.53	15.83	5.07	16.79	25.26
October, 1915, to September, 1916	41.50	−1.83	9.69	14.07	6.21	24.15	19.18
Average	44.48	+.61	8.76	15.58	6.21	20.66	23.20

DISCUSSION OF METHODS AND RESULTS

In arid regions so many quantitative investigations of ground-water supplies have been made that the methods of work are relatively well understood. In humid regions, however, much less quantitative work has been done, the methods that are employed in arid regions are largely inapplicable, and the problem of making quantitative estimates is inherently more difficult. The method used in this investigation is a composite of several available methods and has doubtless led to more reliable results than could have been obtained by the application of any single method. The observations made, however, were not adequate in number nor sufficiently refined to lead to very accurate results, and the period of observation was too short to give average conditions. With the same general method much more accurate results can be obtained if sufficient funds and time are available to make more numerous and more detailed observations.

The precipitation records show that many of the rains and snows are local or vary in intensity within short distances, and that an accurate measure of the quantity of water that falls upon an area so large as the Pomperaug Basin can not be obtained from three rain gages, even though they are well distributed and there are no gaps in the records. Where so few gages are used the daily records are the most likely to be unrepresentative, but even the monthly and annual records may show considerably more or less precipitation than the true average for the basin. It should be noted, however, that with the method that was used the records of precipitation do not enter directly into the ground-water estimates.

In such an investigation the record of total run-off, as determined by the gaging station near the mouth of the trunk stream, is very important, and more money should be spent than was available for the station at Bennetts Bridge, to make this record accurate and complete. Instead of a staff gage read by a local observer once or twice a day, an automatic gage, or water-stage recorder, should be installed. In winter, when the relation of discharge to stage is disturbed by ice in the river, a sufficient number of current-meter measurements should be made to obtain a complete and reliable record.

In this investigation the estimates of ground-water run-off were based on the discharge of the Pomperaug at Bennetts Bridge—that is, on the discharge during the periods between rains, when there was virtually no direct run-off left in the stream system. Much better results could be obtained by basing the estimates on periods beginning as soon after rains as all of the direct run-off has reached the streams. With this method the ground-water run-off during any particular day would be the total run-off minus the decrease in stream storage. The decrease in stream storage could be estimated by maintaining gages at several points on the trunk stream and on selected tributaries and making surveys of the stream system showing the approximate water areas of different parts of the system at different gage heights. Calculations show that in a drainage basin which is not larger than the Pomperaug the total quantity of water stored in the stream system at any time is rather small compared with the rate of discharge and hence that errors in the measurement of decrease in storage will introduce relatively small errors in the estimates of ground-water run-off. The proposed method would have the advantage over the method used in this investigation in that the record would cover a much larger part of each period between rains and that the entire process would be one of observation and measurement without the intangible feature of the present method. It would not be necessary to make current-meter measurements to develop rating curves at the subsidiary stations, as only change in storage, indicated by change in gage-height, is involved, not rate of discharge.

Records should be obtained in regard to snow storage and soil storage. The precipitation records should show whether the precipitation occurred as rain or snow, and there should be a record of the days when the snow contributed to the direct run-off, when it did not thaw sufficiently to contribute to the run-off, when the ground was virtually free of snow, and when the ground was frozen. Soil storage is an important item in the monthly inventory and could be estimated on the first of each month by making a number of moisture determinations of soil samples collected in fairly typical locations. Large numbers of moisture determinations are made in connection with dry-farming and irrigation investigations, and some are now made in the laboratories of the Geological Survey in connection with hydrologic investigations.

There should be a larger number of observation wells, they should be more widely distributed over the basin, and so far as possible they should be equipped with automatic water-stage recorders. Much more work should be done to determine the specific yield of the different kinds of material in which the water table occurs, because the specific yield is a factor in the estimates of ground-water recharge and ground-water evaporation. In recent investigations it has been found feasible to obtain columns of the undisturbed materials and to make direct tests of the specific yield of these materials in their natural state. The columns are taken directly above the water table at a low stage.

Records of evaporation from a free water surface should be obtained for the entire period covered by the investigation. Work could also be done in determining transpiration and soil evaporation by tank experiments and from daily fluctuations of the water table shown by water-stage recorders over wells. Indeed, with the methods that have been outlined, the accuracy of the results in a quantitative study of the water resources of an area will be largely a function of the funds and time available for making the investigation.

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