Ground-Water Resources of North-Central Connecticut

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1752

Prepared in cooperation with the Connecticut Water Resources Commission

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By ROBERT V. CUSHMAN

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GROUND-WATER RESOURCES OF NORTH-CENTRAL CONNECTICUT

By Robert V. Cushman

ABSTRACT

The term "north-central Connecticut" in this report refers to an area of about 640 square miles within the central lowland of the Connecticut River basin north of Middletown. The area is mostly a broad valley floor underlain by unconsolidated deposits of Pleistocene and Recent age which mantle an erosional surface formed on consolidated rocks of pre-Triassic and Triassic age. The mean annual precipitation at Hartford, near the center of the area, is 42.83 inches and is uniformly distributed throughout the year. The average annual streamflow from the area is about 22 inches or about half the precipitation.

The consolidated water-bearing formations are crystalline rocks of pre-Triassic age and sedimentary and igneous rocks of the Newark group of Triassic age.

The crystalline rocks include the Middletown gneiss, the Maromas granite-gneiss, the Glastonbury granite-gneiss of Rice and Gregory (1906), and the Bolton schist which form the basement complex and the Eastern Upland of north-central Connecticut. Enough water for domestic, stock, and small commercial use generally can be obtained from the crystalline rocks. Recoverable ground water occurs in the interconnected joints and fracture zones and is yielded in amounts ranging from ¼ to 35 gpm (gallons per minute) to wells ranging in depth from 29 to 550 feet.

The sedimentary rocks of Triassic age underlie all the Connecticut River Lowland and are predominantly arkosic sandstone and shale. Water supplies sufficient for domestic, stock, and small commercial use can be obtained from shallow wells penetrating these rocks, and larger supplies sufficient for industries and smaller municipalities can probably be obtained from deeper wells. Reported yields range from ½ to 578 gpm; the larger yields are generally obtained from wells between 300 and 600 feet in depth. Yields are larger where the overlying material is sand and gravel or where the rocks are well fractured. The igneous rocks of Triassic age are basalt and have water-bearing characteristics similar to the crystalline rocks.

The unconsolidated deposits comprise ground-moraine and drumlin deposits, ice-contact deposits, outwash-plain and valley-train deposits, and glaciolacustrine and associated delta deposits of Pleistocene age, as well as dune deposits, flood-plain deposits, and swamp deposits of Recent age. Ground-moraine deposits occur throughout the area but yield only small quantities of water.

The ice-contact deposits consisting mostly of sand and gravel form kames, kame terraces, and crevasse fillings and are the surface deposits in three ex-

tensive areas along the eastern margin of the Connecticut River Lowland. The deposits in most places are saturated and, where they consist of well-sorted material, are highly permeable, yielding as much as 750 gpm to properly constructed wells.

Outwash-plain and valley-train deposits and bodies of undifferentiated outwash underlie the surface in the eastern and southern parts of the area. These deposits consist of well-sorted sand and silt and some pebble gravel ranging in thickness from nearly zero to more than 225 feet in places. The thicker deposits are an important source of moderate supplies of ground water. Screened wells of moderate depth commonly yield about 150 gpm, but some yield as much as 400 gpm. Bodies of buried outwash deposits of irregular size and shape occur in the bottoms of some of the filled bedrock valleys. They seldom are more than 20–30 feet thick. Their permeability is generally low because of the high percentage of silt; yields as much as 30 gpm to domestic wells are reported. Under most favorable conditions, these deposits yield as much as 500 gpm.

The glaciolacustrine and associated delta deposits occur in nearly all parts of north-central Connecticut and are potential sources of moderate supplies of ground water. They consist of well-sorted sand which generally grades downward into varved clay and silt. The deposits of sand are thickest—more than 100 feet thick in places—where they occur in deltas, but generally they are less than 20 feet thick. The permeable sand beds commonly yield 80–100 gpm to properly constructed wells; the thick deposits yield as much as 400 gpm. The clay and silt of the glaciolacustrine deposits are virtually impermeable. They form a barrier which retards the downward movement of ground water in the overlying sand deposits and confines water in the underlying buried outwash deposits.

The flood-plain, dune, and swamp deposits are mostly thin, discontinuous bodies of sand and silt and are relatively unimportant as sources of water. The larger dune deposits may store some water, but for the most part they lie above the water table and are unsaturated.

The shape and slope of the water table are controlled by the topography, local differences in the permeability and thickness of the aquifer, and local differences in recharge and discharge. The slope of the water table is greatest in the areas of till-mantled bedrock because the lesser permeability of the till causes greater retardation of movement of water. The smallest slopes are in the glaciolacustrine deposits.

Depths to water are greatest in tracts of outwash deposits, particularly in areas of ice-contact and valley-train deposits having steep slopes, and are most shallow in the till-covered bedrock upland or in areas of glaciolacustrine deposits. Water in the buried outwash probably is confined and has a hydrostatic head that is lower than the head of the unconfined water above.

Changes in water level in wells in north-central Connecticut show seasonal fluctuations, due in large part to variation in rate of evapotranspiration, but little overall change in water levels for the period of record since 1935. The largest seasonal fluctuations are noted in wells in the till-mantled bedrock uplands.

The ground water is mostly of the calcium bicarbonate type, has a low mineral content, and is suitable for most purposes. Water from the Newark group of sedimentary rocks is moderately hard to very hard and may be of the calcium sulfate type containing objectionable amounts of sulfate and chloride; water from some pre-Triassic crystalline rocks contains objectionable amounts of iron. Water from the buried outwash deposits is unusual in the area because it is of the sodium bicarbonate type and has a relatively high concentration of sodium and sulfate.

Pumpage of ground water averaged 17.7 million gallons per day in 1958. The largest use was by industry. Fifteen of the 19 public and semipublic water systems in north-central Connecticut are supplied solely from ground water.

INTRODUCTION

LOCATION AND GENERAL FEATURES OF THE AREA

North-central Connecticut, as the term is used in this report, is within the part of the central lowland of the Connecticut River basin which is north of Middletown. It includes the central and eastern part of Hartford County, the towns of Somers and Vernon and part of the town of Ellington in western Tolland County, and the towns of Cromwell and Portland in northern Middlesex County. The area lies approximately between lat 41°35′ and lat 42°02′ N. and between long 72°25′ and long 72°45′ W. The area has about 640 square miles and a north-south length of 38 miles and a maximum east-west width of 21 miles (fig. 1).

Most of the area is a broad lowland plain or valley floor eroded to a late mature stage in weak stratified rocks and flanked by low rolling hills. On the east, the lowland is bordered for the most part

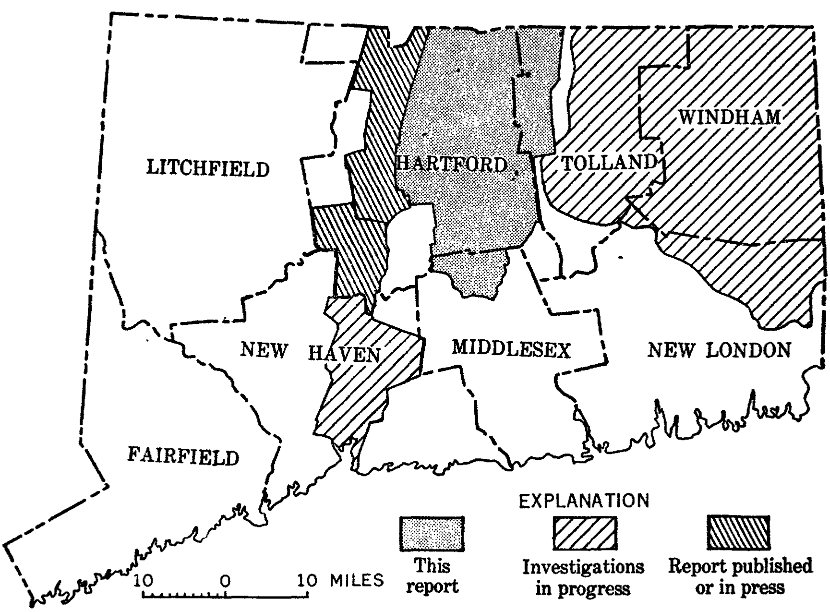

FIGURE 1.—Index map of Connecticut showing area of report and status of ground-water investigations.

by the highland area of eastern Connecticut, a rolling plateau underlain by resistant crystalline rocks. On the west it is bordered for the most part by a linear range of prominent hills and ridges known locally as "trap ridges." The most impressive of these is Talcott Mountain, a ridge that forms the western boundary of the towns of Bloomfield and West Hartford.

Hartford, near the center of the report area, is the largest city in Connecticut and the capital of the State. Together with East Hartford and West Hartford, it is an important industrial area for the manufacture of aircraft engines and propellers, brushes, firearms, mechanical counters, precision machines, turbine and marine engines, and typewriters. The city of Hartford is the home office of 44 insurance companies and is nationally known as "the insurance city." The total population of the north-central Connecticut area as of July 1, 1957, according to the estimate of the Connecticut Department of Health is about 457,500. Of the total, about 65 percent resides in the towns of Hartford, West Hartford, Wethersfield, and East Hartford.

The area outside the industrial centers around Hartford and Manchester includes the most intensively developed farming areas in the State. Tobacco and potatoes are the major crops. The soil and climate of the Connecticut River valley are especially adapted to the growing of cigar-leaf tobacco; in 1959 about 7,800 acres of tobacco was grown in the north-central Connecticut area.

PURPOSE OF THE INVESTIGATION

The present investigation of ground-water conditions in north-central Connecticut is part of a statewide study of the ground-water resources of Connecticut carried on by the U.S. Geological Survey in cooperation with the Connecticut Water Resources Commission. The overall purpose of the investigation in this area, as well as the statewide cooperative program, is to provide basic information on the principal water-bearing formations, their ability to yield water to wells, the quality of the ground water, and the methods for recovery of ground water. Water from wells constitutes the principal source of water supply for small municipalities and rural homes and farms in all north-central Connecticut outside of the urban areas supplied by the water systems of Hartford, Manchester, Portland, and Windsor Locks. Ground water is also the source of water for many industries. The investigation was designed to provide information for locating wells or expanding existing water-supply installations owned by industries, municipalities, and individuals.

Another important purpose was to provide information on the availability of large supplies of ground water for the irrigation of tobacco and potatoes. Growers of these crops have learned that peak yields can be obtained by use of supplemental irrigation to prevent retardation of growth during periods of deficient rainfall. At present, most of the water used for irrigation is taken from nearby surface sources, such as lakes, ponds, and streams; however, some cultivated lands that are remote from a surface water supply are irrigated from wells. In view of the prospects of increasing use of water for irrigation, this investigation is intended to serve as a guide for sound development and conservation of ground water.

METHODS OF STUDY AND SCOPE OF INVESTIGATION

Fieldwork in the area was done during parts of 1948, 1949, 1950, and 1952. The geology of the area was studied chiefly as it relates to the occurrence of ground water. Most of the work consisted of mapping the surficial deposits because they are the most important water-bearing units in the area and previously had not been mapped adequately. The geologic studies included the determination of the thickness and general areal extent of the surficial deposits, the outcrop areas of consolidated rock formations, and the relation of the water-bearing units to potential sources of recharge. Locations of nearly all wells and test holes having detailed logs were plotted, and geologic sections and thickness maps were constructed. The bedrock and surficial geology of the Hartford North quadrangle was mapped in detail for publication in the series of Geologic Quadrangle maps of the U.S. Geological Survey.

Basic data collected for this investigation but not incorporated in the report include records for more than 958 wells, test holes, and springs, and logs for about 170 wells and test holes. These data may be examined at the office of the U.S. Geological Survey, Ground Water Branch, room 204, Post Office Building, Middletown, Conn. The locations of wells, test holes, and springs are shown on plates 1 and 2 accompanying this report. Well and test-boring data for the area were collected from the files of industrial concerns, municipalities, water-well contractors, State agencies and by interviewing well owners and others. The well depth and depth to water could not be measured in some wells because the pump was sealed to the top of the casing. For these wells such information was reported by drillers and owners, and commonly the records are incomplete. Because most drillers in the area are concerned principally with the construction of wells in bedrock, the nature of the overlying surficial material is generally not reported in detail. In general, the records of domestic wells contain specific information regarding the depth to bedrock, whereas test wells and borings are the best source of information regarding the character of the surficial deposits. The records of completed wells filed with the Connecticut Water Resources Commission by drillers since 1955 were of great value in keeping the well inventory up to date.

The water levels in selected observation wells were measured periodically, usually at monthly intervals. Scattered measurements were taken at wells where water levels had been measured during previous investigations. Data on water levels used in this report have been published in Works Progress Administration for Connecticut (1938 a, b), LaSala (1960), and in the annual series of Water-Supply Papers of the Geological Survey (1946–57).

Detailed chemical analyses were made by the U.S. Geological Survey Quality of Water Branch laboratory of 43 water samples from selected wells tapping the principal water-bearing units. Other partial analyses were furnished by the Connecticut State Department of Health and by well owners.

PREVIOUS GROUND-WATER AND GEOLOGIC INVESTIGATIONS

The earliest study of the ground-water resources of the north-central Connecticut area was begun in 1903 by Prof. H. E. Gregory for the U.S. Geological Survey. A preliminary report prepared by Prof. Gregory (1904) contained records of wells and analyses of natural waters in this area.

In 1905 a report on the Triassic rocks of the Connecticut Valley as a source of water supply was prepared by M. L. Fuller and W. H. C. Pynchon of the U.S. Geological Survey. The study of the ground-water resources of Connecticut was continued at intervals during 1904 and 1905 and a report discussing the fundamental ground-water problems relating to the State was prepared by H. E. Gregory and E. E. Ellis in 1909. This paper included basic data on the ground-water resources of the Connecticut River valley and served as a guide for later studies.

Because of the importance of these studies, a cooperative agreement was made between the U.S. Geological Survey and the Connecticut Geological and Natural History Survey for the purpose of obtaining information on the occurrence, quantity, and quality of underground water available for industrial, municipal, and private use. As a part of this cooperative agreement, reconnaissance field investigations on ground water were carried on from 1911 to 1916 in a large part of the north-central Connecticut area and adjoining areas. Reports summarizing the work were prepared by Gregory and Ellis (1916), Waring (1920), and Palmer (1920). These reports discussed the occurrence of ground water in the several towns and included records of wells and springs and analyses of water samples.

Ground-water investigations were made in part of north-central Connecticut in 1934–38 as a Works Progress Administration project sponsored by the State Water Commission, now the Water Resources Commission. The work consisted primarily of inventories of wells and springs and the periodic measurement of water levels in a number of selected observation wells. Records of wells, springs, and ground-water levels in Cromwell and Portland were published as a part of Bulletin GW 4 of the Connecticut Ground Water Survey (1938a). Records of water levels in wells in a number of other towns in north-central Connecticut were published in Bulletin GW 6 of the Connecticut Ground Water Survey (1938b). Other records of wells and springs collected by the Works Progress Administration in the north-central Connecticut area have not been published but are on file at the U.S. Geological Survey office at Middletown, Conn.

Considerable geologic work of a descriptive nature has been done in the north-central Connecticut area, particularly on the Triassic rocks. The main features of the bedrock geology of the area are shown on the geologic map of Connecticut (Gregory and Robinson, 1907; Rodgers and others, 1959) and were described in detail in the manual of the geology of Connecticut by Rice and Gregory (1906). The early work on the pre-Triassic rocks was carried on by Gregory and his assistants during the years 1899 to 1902. The results were first published as a part of the above-mentioned geologic map and manual and later were partly revised by Foye (1949). Recently, detailed maps of the crystalline rocks in parts of the north-central Connecticut area have been completed by Collins (1954) in the Ellington quadrangle, by Herz (1955) in the Glastonbury quadrangle, by Aitken (1955) in the Rockville quadrangle, and by Stugard (1958) in the Middle Haddam quadrangle. A detailed study of the lithology, structure, and metamorphic features of the crystalline rocks of the Middle Haddam quadrangle is being carried out currently by J. L. Rosenfeld and G. P. Eaton, of Wesleyan University.

Most of the present knowledge of the Triassic rocks has been the result of such outstanding investigators as Silliman, Percival, Hitchcock, Dana, Russell, and Davis in the 19th century and Barrell, Lull, Longwell, Thorpe, and Krynine in recent years. A detailed survey of the Triassic rocks of Connecticut was made by W. M. Davis during the period 1879–98. A description of the stratigraphy based on field relations was presented in the monograph by Davis (1898) and was later refined by Thorpe (1929), Longwell (1933), and Krynine (1950).

A systematic study of the complicated structural relationships of the Triassic area was made by Longwell (1922, 1928). Krynine (1950) presented a detailed discussion of the stratigraphy, petrography, and origin of these rocks in southern Connecticut, which includes the southern part of the north-central Connecticut area. The geology of the Triassic rocks of the Middletown quadrangle was mapped recently by Lehmann (1959).

The glacial deposits of the area received considerable attention from students in the 19th century, but were not studied systematically until the present century. Loughlin (1905) made a detailed study of the clays of Connecticut and recognized the importance of the narrows at Rocky Hill and the channel at New Britain in controlling the level of the glacial Lake Hitchcock to the north. Antevs (1922, 1928) studied and described clay sections in this area as a part of his classic investigation of the varve series in northeastern North America. Systematic mapping of the glacial deposits of this area was begun in 1927 by Professor R. F. Flint of Yale University with the financial support of the Connecticut Geological and Natural History Survey. The distribution of the major units of glacial deposits in north-central Connecticut was shown on the first map of the glacial geology of the State (Flint, 1930). Subsequent additions to the map and descriptions and discussions of later findings in north-central Connecticut have been published at intervals by Flint (1932, 1933, 1953). A study of the glacial deposits of the Connecticut River lowland in Massachusetts north of the report area was made by Jahns and Willard (1942). Prof. R. E. Deane, with financial support of the Connecticut Geological and Natural History Survey, mapped the surficial deposits of four quadrangles centering about the Portland area during the summers of 1952–56. All the mentioned works have been consulted freely in the preparation of the report. In 1955, the Engineering and General Geology Branches of the U.S. Geological Survey began a long-range program of geologic mapping in Connecticut in cooperation with the State Geological and Natural History Survey. Maps of the surficial deposits of the Avon, New Britain, and Windsor Locks quadrangles have been published (Schnabel, 1962; Simpson, 1959; and Colton, 1960, respectively), and maps of the surficial deposits of the Broad Brook, Hartford North, Springfield South, and Tariffville quadrangles are being prepared. All these quadrangles include parts of the north-central Connecticut area.

ACKNOWLEDGMENTS

The work resulting in this report was conducted under the immediate supervision of M. L. Brashears, Jr., and J. E. Upson and was completed under the supervision of G. C. Taylor, Jr., former district geologists, Mineola District. The work was done in cooperation with the Connecticut Water Resources Commission, whose director, Mr. William S. Wise and staff gave valuable assistance.

The writer is grateful for the cooperation and assistance given by many well owners, well contractors, drillers, and governmental agencies—local, State, and Federal—in the north-central Connecticut area. The owners of domestic, farm, and industrial wells furnished useful data on wells, springs, and local ground-water conditions, and were most cooperative in allowing their wells to be used for hydrologic observations. Drillers' logs, details of well construction, and formation samples were provided through the generous cooperation of the many local well contractors, and were invaluable in the preparation of this report. The owners and operators of all municipal water-supply systems in the area provided data on well construction and pumpage. Particular thanks are offered to the Manchester Water Department, and to Mr. Fred Thrall, Superintendent, for generous cooperation in helping to obtain data on aquifer performance at Manchester. Information on the subsurface geology of the City of Hartford was obtained from numerous logs of test borings supplied by Mr. Charles W. Cooke, Deputy Director, Hartford Department of Public Works. Mr. Philip Keene, Soils Engineer, Connecticut Highway Department, and his staff provided outstanding assistance to the investigation by furnishing detailed logs of highway and bridge borings and formation samples from the files of that department. Records of chemical analyses of ground-water samples in the files of the Connecticut Department of Health were made available for study by Mr. Warren Scott, Director, Bureau of Sanitary Engineering. Helpful information on the characteristics of soils in the north-central Connecticut area was furnished by Dr. C. L. W. Swanson, Chief Soil Scientist, Connecticut Agricultural Experiment Station.

Grateful acknowledgment is made for the helpful assistance of Profs. R. F. Flint of Yale University, New Haven, and R. E. Deane, of the Connecticut Geological and Natural History Survey, who accompanied the writer in the field on several occasions and generously made available unpublished maps on the surficial geology of the southern half of the report area. These maps were used in part in compiling plate 1 of this report, but because the work of these men had not been completed and the maps were unpublished, many details have been generalized and some modifications have been made for convenience in describing ground-water conditions. The author assumes full responsibility for such generalizations, which he trusts will not be attributed to Profs. Flint and Deane. Acknowledgment

also is made of the helpful assistance of R. B. Colton, J. H. Hartshorn, R. W. Schnabel, and H. E. Simpson, all of the Branch of Regional Geology in New England, U.S. Geological Survey, who were doing geologic mapping in the area and with whom the writer has compared field maps and discussed local geologic problems.

WELL-NUMBERING SYSTEM

In this and other reports on ground-water resources in Connecticut each well described is numbered serially within the town in which it is situated. A letter or combination of several letters, which precedes the well number, is the abbreviation of the town name. For example, well SW 1 is in the town of South Windsor and was the first well inventoried in that town. The locations of all wells for which records are available are shown on plate 1 by serial number, in which the letter prefixes designating the town have been omitted for ease in reading. The names and boundaries of towns are also shown. The letter prefixes which correspond to the towns are listed below:

Name of town	*Letter prefix*	*Name of town*	*Letter prefix*
Bloomfield	Bl	Portland	P
Cromwell	Cr	Rocky Hill	RH
East Granby	EG	Somers	So
East Hartford	EH	South Windsor	SW
East Windsor	EW	Suffield	Su
Ellington	El	Vernon	V
Enfield	Ef	West Hartford	WH
Glastonbury	Gl	Wethersfield	Wf
Hartford	H	Windsor	W
Manchester	M	Windsor Locks	WL

As an aid in reporting a well location anywhere in Connecticut, the U.S. Geological Survey 7½-minute quadrangles have been lettered consecutively in an easterly direction from "A" through "R", beginning with the Glenville, N.Y.-Conn., quadrangle. Similarly, the quadrangles have been numbered from south to north, beginning with "1" and ending with "9". The coordinate letters and numbers applying to the quadrangles in the north-central Connecticut area are shown on plate 1. Each 7½-minute quadrange is divided into nine 2½-minute rectangles designated by the numbers 1 to 9, beginning with 1 in the upper left and ending with 9 in the lower right, as shown in the accompanying diagram. Each of the 2½-minute quadrangles is similarly subdivided into nine 50-second quadrangles; each of these subdivisions is similarly designated by a lower-case letter from "a" through "j"; the letter "i" is omitted for clarity.

TOPOGRAPHY

The State of Connecticut includes parts of three principal physiographic divisions—the Eastern Upland, the Western Upland, and the Connecticut Valley Lowland, or Triassic lowland. The north-central Connecticut area is mostly within the Connecticut Valley Lowland but extends into the Eastern Upland for several miles along its eastern border. The lowland in this area is sharply delineated from the upland along a major fault zone, known locally as the Great Fault (plate 1).

The Eastern Upland extends the entire length of the report area and slopes gently to the east and south. It consists of a broad, gently undulating upland surface which rises eastward from an altitude of about 350 feet near the Great Fault to a general summit altitude of about 800 feet. Some peaks rise to more than 800 feet, and the maximum altitude, 1,121 feet, is at Bald Mountain in Somers. The surface is maturely dissected, has moderate relief, and some of the stream valleys have relatively steep slopes.

The lowland, which includes most of the report area, has a nearly flat floor ranging in altitude from about 50 feet near the center to 200 feet near its borders. The floor is formed on easily eroded, tilted sedimentary rocks of Triassic age, which in most places are covered by thick unconsolidated deposits. In the area north of Hartford, the valley floor ends abruptly on the west at a series of prominent ridges of resistant trap rock that rise to a general level of 700 feet. The most impressive of the ridges is Talcott Mountain, whose crest rises to 950 feet near the Heublein Tower in southwestern Bloomfield. Other prominent ridges and hills of traprock (basalt flows) interrupt the flat floor in the area south and west of Hartford. The eastern part of the lowland, from the Massachusetts boundary south to Manchester, includes low rolling hills of lesser prominence that rise to altitudes of as much as 350 feet, and are underlain by a resistant facies of the sedimentary rocks. Similar hills rising to 200 feet mark the western part of the lowland south from Hartford. Scattered individual hills and knobs of unconsolidated deposits occur throughout the remaining parts of the valley floor. They are common in the area north of Hartford, particularly in the towns of Suffield and Bloomfield.

Irregular areas of low-lying meadows and swamps flank the Connecticut River and the lower reaches of the Farmington, Hockanum, Park, and Scantic Rivers. The meadows and swamps are the river terraces and flood plains of the Connecticut Valley Lowland, and represent the part of the valley that has been inundated by flood waters in Recent geologic time. They lie below the general level of the valley

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floor. The flood plain bordering the Connecticut River is relatively wide in the area below Windsor Locks, having a maximum width of about 2½ miles, opposite the village of Glastonbury.

STREAMS

The Connecticut River drains the entire area of north-central Connecticut. (See pl. 1.) It flows southward through the center of the lowland to Portland where it leaves the lowland through a relatively narrow gorge carved in the more resistant rocks of the Eastern Upland. It has a nearly flat gradient in the lowland area, the mean water surface falls only about 40 feet in the 43 miles between the points where the river enters and leaves the area. The river flows through a narrow bedrock valley in the short stretch between Thompsonville and Windsor Locks, but elsewhere in its course it flows upon a considerable thickness of unconsolidated deposits in a relatively broad valley. The tidal effects from Long Island Sound are felt as far north as Windsor Locks, the range in the tide at Portland during low flow being about 2½ feet.

Between the Massachusetts boundary and Portland, the Connecticut River is joined by four important tributaries—the Scantic, Farmington, Park, and Hockanum Rivers. The Scantic and Hockanum Rivers join the Connecticut River from the east at East Windsor Hill and East Hartford, respectively. The upper reaches of these streams drain a part of the Eastern Upland. In these reaches the streams flow upon bedrock; their gradients are steep, and the valleys are narrow and steep walled. In the lowland area the streams flow on thick unconsolidated deposits and their gradients are nearly flat. The Farmington River drains a large area outside of north-central Connecticut and joins the Connecticut River from the west at Windsor; only a small part of its drainage area is within north-central Connecticut. It enters the report area through a break in the main ridge of traprock forming the western border of the area and drains an extensive sand plain, into which it has cut a narrow steep-sided valley. The valley floor is on bedrock for several miles above Poquonock but elsewhere rests upon thick deposits of unconsolidated material. The Park River enters the Connecticut River from the west at Hartford and drains much of the lowland west of the Hartford area as well as the eastern slopes of the ridges of traprock.

The flow of a number of streams in north-central Connecticut has been gaged for 30 years by the U.S. Geological Survey. Gaging stations equipped with continuous water-stage recorders are operated on the Connecticut River and on each of the important tributaries in cooperation with the Connecticut Water Resources Commission, the Hartford Department of Public Works, and the Corps of Engineers, U.S. Army. A total of eight stations are now in operation. Table 1 is a summary of the basic hydrologic data obtained at each of the stations. The records of daily flow are not included in this report. They may be found in the regular series of Water-Supply Papers entitled "Surface Water Supply of the United States, Part 1–A, North Atlantic Slope Basins, Maine to Connecticut," which are published annually by the Geological Survey.

TABLE 1.—*Summary of streamflow data in north-central Connecticut*

[Records furnished by Hartford, Conn., office, U.S. Geol. Survey]

Stream-gaging station	Period of record	Drainage area above gage (sq mi)	Drainage area (sq mi)	Average flow (mgd)	Maximum flow		Minimum daily flow (mgd)
					Quantity (cfs)	Date	
Connecticut River at Thompsonville	1928–60	9,661	23.4	[1] 10,750	282,000	Mar. 20, 1936	[2] 685
Scantic River at Broad Brook	1928–60	98.4	79.8	93.7	13,300	Aug. 19, 1955	10.3
Farmington River at Rainbow [3]	1928–60	591	30.8	[1] 704	69,200	do	[2] 3.3
South Branch Park River at Hartford	1936–60	40.6	20.6	47.4	5,000	do	4.5
North Branch Park River at Hartford	1936–60	25.3	25.3	24.9	10,000	do	0.3
Park River at Hartford	1936–60	74.0	52.5	79.5	14,000	do	7.1
Hockanum River near East Hartford	1919–21, 1928–60	74.5	63.1	[1] 76.3	5,160	Sept. 21, 1938	[2] 0.8
Connecticut River near Middletown [4]	1948–58	10,870	480	11,800	267,000	Mar. 21, 1936	([5])

[1] Adjusted for storage and diversion.
[2] Flow regulated.
[3] At Tariffville prior to September 1939.
[4] Affected by tidal action except at flood stage.
[5] Flow regulated; minimum daily indeterminate; minimum weekly flow, 1,850 mgd.

Table 1 indicates that the discharge from streams in the north-central Connecticut area has a wide range and that the average annual discharge for the area, based on records of the tributary streams, is 1.62 cfsm (cubic feet per second per square mile), or 22.00 inches of water, which is 51 percent of the mean annual precipitation of 42.83 inches for the area. The annual mean discharge per square mile ranges from 1.46 to 1.84 cfs and is the result of differences in precipitation, topography, and geology in the drainage area or watershed.

The following pertinent hydrologic information is summarized from the records of daily flow furnished by the Hartford District office of the Surface Water Branch:

1. The seasonal distribution of runoff is less uniform than the distribution of precipitation. The normal seasonal runoff is about 3 inches in summer, 3 inches in autumn, 6 inches in winter, and nearly 10 inches in spring. Thus, about 30 percent of the total annual runoff flows down the streams in the summer and autumn months, and nearly one-half runs off in the spring.

2. The monthly flow of the streams varies widely from a low in August to a high in March. About 3 percent of the flow occurs in August, and about 18 percent in March.
3. The Connecticut River and the lower reaches of its tributaries reach flood stage nearly every spring and overflow part or all their flood plains.

Floods have occurred on the Connecticut River in every month of the year, but they occur most frequently in the spring. Outstanding floods occurred in the Connecticut River Lowland in May 1854, November 1927, March 1936, September 1938, and August 1955; the 1936 flood reached a record stage of 37 feet above mean sea level at Hartford.

CLIMATE

The following description of the climate of north-central Connecticut is condensed from reports of the U.S. Weather Bureau. The climate of the area is humid and temperate and is characterized by cool winters, warm summers, and frequent weather changes. The area lies between the southerly winter position and the northerly summer position of the "polar front." As a result, the weather is influenced by cold and dry continental air in winter and warm, maritime air in summer; it is characterized by day-to-day variability. Abrupt weather changes are also a result of the area being close to the ocean and to the path of coastal storms. Heavy precipitation and persistent northeast winds, or "northeasters," frequently accompany the coastal storms. Exceptionally heavy precipitation results when these storms take the form of tropical hurricanes. Many of the large monthly rainfalls recorded in recent years during late summer or early autumn are due to the passage of these hurricanes across or near Connecticut. During the summer the area also is subject to frequent and heavy thunderstorms that form over the Berkshire Mountains to the west and move across the Connecticut Valley.

The U.S. Weather Bureau maintains a complete climatological station for the Hartford area at Bradley Field near Windsor Locks. In 1954 the location of this station was shifted to Bradley Field from Hartford, where it had been since 1905. The meteorological data obtained at Bradley Field are representative of the north-central Connecticut area and are summarized in table 2. Data for precipitation stations at Bloomfield, Hartford, West Hartford, Manchester, and Rockville also are available but are not included in this report.

TABLE 2.—*Summary of meteorological data at Hartford, Conn.*

[From U.S. Weather Bureau (1956). Length of record is 52 years unless otherwise indicated. Mean date of last killing frost, Apr. 19; mean date of 1st killing frost, Oct 17; mean length of growing season, 181 days]

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Precipitation:													
Normal [1] ....inches..	3.15	2.66	3.81	3.56	3.66	3.62	3.56	3.54	3.44	2.80	3.48	3.29	40.57
Mean [2] ....do....	3.61	3.21	3.78	3.64	3.61	3.50	3.71	4.07	3.42	3.01	3.68	3.59	42.83
Maximum in 24-hr. period..do....	3.32	3.04	2.92	3.73	3.68	2.52	2.87	12.12	6.72	5.19	3.55	2.35	12.12
Mean number of days with 0.01 in. or more of precipitation......	12	11	12	12	12	11	10	10	9	8	10	11	128
Temperature:													
Normal [1] ....°F..	27.0	28.1	37.2	48.0	59.7	68.9	73.8	71.4	63.8	52.9	41.3	29.6	50.1
Mean [2] ....do....	28.0	27.9	37.3	47.8	59.0	67.6	73.2	70.8	63.7	53.6	42.2	31.0	50.2
Mean maximum........do....	35.8	36.2	46.0	57.5	69.4	77.8	83.1	80.6	73.8	63.8	50.4	38.5	59.4
Mean minimum........do....	20.2	19.6	28.6	38.1	48.5	57.4	63.2	60.9	53.6	43.4	33.9	23.5	40.9
Absolute maximum........do....	70	72	86	91	94	100	101	101+	101	91	83	67	101+
Absolute minimum........do....	−16	−24	−4	11	28	40	48	38	30	18	6	−18	−24

[1] Normal values are based on the period 1921–50, and are means adjusted to represent observations taken at the present standard location.

[2] Mean values are long-term means based on the period of record beginning in 1905. Values have not been corrected for changes in instrument location.

The precipitation is uniformly distributed throughout the year, and no distinction can be made between wet and dry seasons. Thus water from precipitation is potentially available for recharge throughout the year. For the period 1921–50, the precipitation averaged slightly more than 40 inches per year, or several inches less than the average for the State. About 32 percent was in the form of snow, which averaged about 40 inches per year. The annual precipitation ranged widely, from 33 inches in 1941 to 62.94 inches in 1955.

The temperature at Hartford in north-central Connecticut varies widely throughout the year; the record high is 101°F in August 1955 and the record low is −24°F in February 1943. During the summer, temperature and humidity usually are high; during the winter they are low. The normal annual temperature is 50.1° F, and ranges from a normal monthly low of 27.0°F in January to a normal monthly high of 73.8°F in July. The length of the frost-free season ranges from 130 to 214 days and averages 181 days. The ground is usually frozen during the months of January and February when the average depth of frost penetration is less than 2 feet.

Evaporation records, obtained during the late spring and summer months by the Water Bureau of the Hartford Metropolitan District since 1918 at its Reservoir 1 in West Hartford, are summarized in the following table:

Mean evaporation at Reservoir 1, West Hartford, 1918–56

[Data from Hartford Metropolitan District Commission and are based on daily measurements of evaporation from a floating pan 48 in. in diameter, 8 in. deep, filled daily to a level of 4 in. from the bottom]

Month	Mean evaporation (inches)	Years of record
May	4.65	34
June	5.61	37
July	6.11	38
August	5.42	37
September	4.10	35
October	2.95	28

PHYSIOGRAPHIC DEVELOPMENT

A knowledge of the development of the physiography of north-central Connecticut and the geologic formations that make up the landforms is essential to an understanding and interpretation of the occurrence of ground water. Seemingly obscure relationships between geology and hydrology often become apparent when the succession of events leading to the formation of the present landscape is known. For example, the areal distribution of the relatively impermeable lacustrine clay and silt in the Connecticut River Lowland is not evident everywhere from surface and subsurface data but can be interpreted from the geologic history of the lake in which the deposits were formed.

The following sections summarize the history of the present landscape from the time of formation of the earliest known rocks to the present.

PRE-PLEISTOCENE HISTORY

The events in geologic time that resulted in the formation of the rocks, deposits, and topographic features of north-central Connecticut probably began during the first half of the Paleozoic era when sediments were deposited in a shallow inland sea. After deposition, the sediments were intruded by igneous magmas and later altered and metamorphosed to form gneiss and schist, the most abundant crystalline rocks in the Eastern Upland. Large-scale pegmatitic intrusions into the crystalline rocks took place late in the period of metamorphism. Radioactive minerals in these pegmatites have furnished the only reliable means of age determination of the rocks. The average age of several pegmatites in Portland is reported to be about 260 million years (Rodgers, 1952, p. 414). This determination dates the instrusions at about the beginning of the Mississippian period of the Paleozoic era. Erosion and mountain building undoubtedly occurred during the interval between the Mississippian and Triassic periods, but little evidence of these events remains.

At the beginning of the Triassic north-central Connecticut was a mountainous area underlain largely by metamorphosed rocks. During the Triassic period the mountains were eroded and several thousand feet of sediments were deposited under generally nonmarine oxidizing conditions. The deposition took place in a basin that was probably created and maintained by recurrent differential downwarping along an extensive major fault in the metamorphosed crystalline rocks. This fault, which is known locally as the Great Fault, separates the area of crystalline rocks from the area of Triassic rocks in north-central Connecticut. The position of the Triassic border fault shown on plate 1, is adapted from Aitken (1955), Collins (1954), Herz (1955), and Stugard (1958). The deposition was interrupted by periods of igneous activity during which three distinct flows of basaltic lava poured out upon the surface of the sediments. Diabasic magma intruded fractures in the nearby crystalline rocks and cooled to form dikes. The later events of Triassic time included tilting and block faulting of the sedimentary rocks and lava flows. As a result, the sediments and several lava flows were tilted an average of 15° eastward and were broken into blocks by a series of faults. These faults caused the displacement of the outcrops of the lava sheets that form such conspicuous features of the local landscape.

Between the Triassic and the Pleistocene several periods of uplift and erosion reduced the area of crystalline rocks to a rounded, maturely dissected upland, and a wide, flat-bottomed valley was carved nearly to present sea level in the relatively soft Triassic sediments. In response to the final uplift, the ancestral Connecticut River gradually entrenched itself about 100 feet into the broad valley floor, and tributary streams cut deep valleys along weak zones in the rocks of the crystalline upland. The present course of the Connecticut River occupies this preglacial channel in the stretch of river from Middletown north to Wethersfield. In the 25-mile stretch from Wethersfield north to the State line, however, logs of deep wells and borings reveal that the present course of the Connecticut River lies as much as 2 miles west of its former course. Furthermore, the present river channel at an altitude of about 40 feet is almost continuously rock walled in the 6-mile stretch from Thompsonville to Windsor Locks, whereas the borings indicate that the surface of the bedrock in the former channel in this same stretch is more than 100 feet below mean sea level. This buried channel is filled with concealed sediments of late Pleistocene age. It was recognized and described by Flint (1933), who prepared a generalized contour map of the bedrock surface showing the approximate trend and configuration of the channel. Although based on the few test-boring records that were available at the time, Flint's map is similar to plate 2 prepared from more abundant subsurface data gathered during the ground-water investigation.

At the close of the period of erosion preceding the advent of the Ice Age the principal features of the present topography of north-central Connecticut were formed. The eastern area of crystalline rocks was a broad upland plateau whose surface was broken by numerous stream valleys. The belt of weak Triassic rocks was reduced by erosion to a broad, generally smooth lowland broken only by the deep valleys of the Connecticut River and its main tributaries. A broken line of trap ridges projected above the surface of the lowland at its western edge.

PLEISTOCENE GLACIATION

The passage of one or more ice sheets across north-central Connecticut greatly altered the preglacial topography. An extensive blanket of residual soil and rotted rock was removed and the exposed bedrock surface was smoothed, polished, and locally scoured. The more resistant rocks, such as the crystalline gneiss of the uplands and the Triassic basalt, were mostly rounded, smoothed, and polished, whereas the less resistant Triassic sediments were abraded and scoured. The most notable evidence of glacial scour in north-central Connecticut is the apparent overdeepening of the preglacial channel of the Connecticut River. Numerous test wells and borings show that the bedrock surface in the center of the buried channel between Thompsonville and East Hartford slopes southward and is more than 100 feet below sea level. The bedrock surface is a maximum of more than 200 feet below mean sea level in the East Hartford area. It rises toward the south to an altitude of about 100 feet below mean sea level at Middletown. The elongate rock basin in the East Hartford area is probably due to glacial overdeepening. The location was especially favorable for deep erosion by ice. The southward moving ice was constricted immediately to the south of the East Hartford deep by a resistant wall of Triassic basalt at Rocky Hill on the west and by the upland of crystalline rock on the east. This restriction probably favored faster movement and greater thickness of ice, resulting in greater erosion locally.

Debris from the melting ice mass was deposited generally over the bedrock as a veneer of ground moraine. It filled existing minor depressions in some areas and formed drumlins or elongated hills in others.

According to more recent views (Flint, 1933; Jahns and Willard, 1942), the ice sheet eventually disappeared from the area by stagnation and then by downward melting. These views are tenable with the evidence in north-central Connecticut and are followed in this report. The early stages of ice wastage were acompanied by flow of melt water through interconnected openings in the ice or between the ice and the valley walls. This flow resulted in the deposition of several types of stratified glaciofluvial deposits at successively lower levels. The streams on the east side of the area were larger than those on the west side and the bulk of the glaciofluvial deposits were formed along the eastern side of the Connecticut River Lowland and at its southern end. A part of this drift, consisting mostly of outwash-plain and valley-train deposits, filled the Connecticut River trench below Rocky Hill and formed an effective dam to the drainage in the southern part of the area. This dam strongly influenced the later geologic history of the region.

As the ice melted back to the north, a large body of melt water accumulated in the lowland basin between the receding ice front and the drift dam at Rocky Hill. The basin probably resulted partly from glacial erosion and partly from a regional northward downwarping of the earth's crust under the weight of the ice sheet. The latter theory was discussed by Daly (1920). The body of water that formed behind the dam, glacial Lake Hitchcock of Lougee (1939), eventually extended over half of the north-central Connecticut area and persisted for several thousand years (Antevs, 1922, p. 47). The level of the water in the lake was held constant by a spillway, the New Britain channel of Flint (1933, p. 975), that bottomed on bedrock. The channel is in the low divide between the Park and Mattabesset Rivers in New Britain just west of the north-central Connecticut area in the latitude of Rocky Hill and Wethersfield. Glacial Lake Hitchcock received a great volume of sediment from many tributary streams, the finer grained sediments accumulating in deep water in the lake bottom as varved clay and silt and the coarser sand and gravel in shallow water along the shore. The lake-bottom deposits are more than 300 feet thick in the East Hartford area. In the areas where tributary streams entered the lake, deltas composed of relatively thick deposits of sand and gravel were built out into the body of open water, where they commonly overlie or grade into varved clay. The draining of Lake Hitchcock was eventually accomplished by a breaching of the drift dam at Rocky Hill. As the lake level dropped, tributary streams cut into the soft sediments of the delta and shore areas, carrying sand farther out in the lake and distributing it as a blanket over the clay. In some places the shoaling and braiding streams disturbed and eroded some of the clay layers before the sand was deposited.

The draining of Lake Hitchcock may have been aided by an upwarping of the earth's crust during readjustment due to the removal of the ice. The amount of upwarping can be measured roughly from the position of the former lake-surface plane and the altitude of the upper surface of the lake-bottom deposits. Neither method can be used to furnish an exact figure because only meager evidence of the altitude of the lake surface remains in the area and because the altitude of the lake-bottom deposits is not a measure of the depth of water covering them. Flint (1933, p. 973–974) summarized the difficulties in determining the level of the former lake in Connecticut and obtained a rough measure of the tilt from the slope of the upper surface of the lake-bottom deposits. He concluded that the data roughly indicate a plane that rises from an altitude of about 70 feet in the district south of Hartford to more than 200 feet in the vicinity of Amherst, Mass., about 40 miles north. This gives a slope of about 3.2 feet per mile. Jahns and Willard (1943, p. 272–274) determined a slope of 4.2 feet per mile between Northfield, Mass., and the Connecticut boundary line from measurements at the line of contact between delta topset and foreset beds. They show the altitude of the lake surface rising from 186 feet near Porter Lake in Longmeadow, Mass., to 365 feet near Northfield, Mass. Observations in north-central Connecticut on poorly preserved wave-cut benches along the eastern edge of the lake and wave-cut benches and beach deposits on the slopes of the higher drumlins in Bloomfield, Suffield, and Windsor made during this investigation show that the altitude of the former lake surface rises from about 135 feet in the Hartford-East Hartford area to 180 feet near Bradley Field, Windsor Locks, a slope of about 4 feet per mile.

POST-PLEISTOCENE HISTORY

By the close of the Pleistocene epoch Lake Hitchcock had drained and the Connecticut River began its most recent cycle of development. The preglacial topography was partly buried by the deposition of sediments on the lake bottom, and as a result the postglacial Connecticut River was unable to return exactly to its former channel. The river followed the lowest parts of the lake bottom, which corresponded closely with the former river course in the southern part of the area below East Hartford, but was widely divergent in the region north of East Hartford. In this region, the river was forced westward by the deltaic deposits of the glacial Chicopee River to occupy the bedrock channel between Thompsonville and Windsor Locks. (See p. 18.) It maintained a relatively straight course in this area but followed a more sinuous path to the south, eroding the lake-bottom deposits into several low terraces and benches, whose surfaces were veneered with reworked parts of the original mantle of sand. The river has gradually adjusted to its present course by cutting across and abandoning old meanders. In most recent times the flood plain has been veneered with alluvial deposits of fine sand and silt; the surfaces of the erosional terraces, the lake-bottom deposits, and some of the glaciofluvial deposits have been veneered with eolian deposits ranging from a thin layer of fine silt or loess to typical dunes of medium to fine sand.

GEOLOGY

DESCRIPTIONS AND WATER-BEARING PROPERTIES OF THE GEOLOGIC FORMATIONS

In terms of their capacity to contain and to yield water to wells, the rock units of the north-central Connecticut area can be divided into two main classes—those that are consolidated and yield water mostly from fractures and other small discontinuous openings, and those that are unconsolidated and have continuous interstices or pore spaces which may yield appreciable quantities of water. From oldest to youngest, the consolidated water-bearing rocks are crystalline rocks of pre-Triassic age, and the Newark group of sedimentary and igneous rocks of Triassic age. The unconsolidated water-bearing deposits overlie the consolidated rocks and are of Pleistocene and Recent age.

From oldest to youngest, the units are: (a) ground-moraine deposits; (b) ice-contact deposits; (c) outwash-plain and valley-train deposits; (d) glaciolacustrine and associated delta deposits, all of Pleistocene age; (e) flood-plain deposits; (f) dune deposits; and (g) swamp deposits of Recent age.

The rocks that underlie the area all contain some pore spaces or other openings called interstices, which may contain air or water. The number, size, and arrangement of the openings vary with the character of the rock, and thus the occurrence of ground water is controlled in part by local geologic conditions. The interstices in unconsolidated deposits are generally interconnected, whereas the openings in the consolidated rocks consist mostly of fractures that may or may not be interconnected. Water is stored in the interstices, and moves through them from points of recharge to points of discharge, such as stream beds, swamps, springs, or wells. A rock is saturated when all its interstices are filled with water.

The percentage of the total volume of a rock that is occupied by interstices is called "porosity." The porosity indicates only the amount of water that a rock can hold or store, not the amount that it will yield to a well. Some rocks, such as clay, may be highly porous but will yield only a small amount of water to a well. The specific yield is a measure of yield of a water-bearing formation, or aquifer, and is the percentage of the total volume of the rock occupied by ground water that will drain by gravity. The permeability of a water-bearing formation in part determines the rate of movement of ground water and is expressed as the number of gallons per day that flows through a section of aquifer 1 foot wide and 1 foot thick, oriented at right angles to the direction of flow, and under a hydraulic gradient of 1 foot per foot.

Table 3 (p. 24–25) summarizes the general physical character and water-bearing properties of each of the stratigraphic units. The areal distribution and general relations of the units are shown on plates 2 and 3.

CONSOLIDATED ROCKS

CRYSTALLINE ROCKS OF PRE-TRIASSIC AGE

GENERAL CHARACTER AND EXTENT

The term "crystalline rocks" is used in this report to describe metamorphosed sedimentary and igneous rocks of pre-Triassic age. This term includes several groups of rocks which generally have a crystalline texture and which have been studied, named, and described in detail in earlier geologic reports. However, because many problems concerning the correlation of these rocks still remain and because their water-bearing properties are virtually the same, the crystalline rocks are considered collectively as a hydrologic unit in this report.

The rocks include the Middletown gneiss, the Maromas granite-gneiss, the Glastonbury granite-gneiss of Rice and Gregory (1906), and the Bolton schist. They are the oldest rocks in the region and form the basement complex. They form the Eastern Upland of north-central Connecticut, and extend north in an elongated belt from Portland through the towns of Glastonbury, Manchester, Vernon, Ellington, and Somers into Massachusetts. The belt is widest in the town of Glastonbury. The crystalline rocks mostly are overlain by deposits of Pleistocene and Recent age. The rocks are separated from the Triassic sedimentary basin to the west by one or more large faults. Doubtless, they underlie unconformably the sedimentary rocks of Triassic age, although no drill holes have been known to penetrate the full thickness of the Triassic rocks. The distribution of the generalized crystalline rock unit is shown on plate 1 as the area east of the large fault. The rocks are not shown on plate 1, except as isolated outcrops. The distribution of individual units of crystalline rocks is shown on the detailed maps of Stugard (1958), Herz (1955), Aitken (1955), and Collins (1954).

The age of the crystalline rocks is unknown except that they are pre-Triassic. Studies of radioactive minerals from pegmatites associated with crystalline rocks in Portland and Glastonbury indicate an average age of 260 million years (Rodgers, 1952, p. 415) and therefore suggest that their age is at least pre-Mississippian.

Although the rocks all have crystalline texture, the detailed lithologic characteristics of the rock groups differ considerably. The Middletown gneiss is predominantly a gray (shades of gray vary with the amount of hornblende and biotite) medium- to fine-grained hornblende and biotite gneiss. It occurs in an elongate belt about a quarter of a mile wide along the western border of the crystalline rocks from the southeastern corner of Portland to South Glastonbury. It includes abundant pegmatite intrusions. The border facies of the rock is a fine-grained light-gray to light-brown rock having a sugary texture and containing garnet.

The Maromas granite-gneiss is a gray fine-grained banded gneiss containing abundant microcline, biotite, or hornblende. Because of its massive character, it was quarried by earlier residents of the area. In north-central Connecticut this rock crops out only in the southeast corner of the town of Portland where it is closely associated with the Middletown gneiss.

TABLE 3.—*Stratigraphic units in north-central Connecticut and their water-bearing properties*

System	Age	Stratigraphic unit	Thickness (feet)	General character	Water-bearing properties
Quaternary	Recent	Swamp deposits	1–10	Chiefly peat and muck overlying flood-plain and glaciolacustrine deposits.	Generally saturated but have low permeability and are unimportant as sources of water.
		Dune deposits	0–40	Chiefly sand with some silt; stratified and well-sorted. Occur as dunes overlying older deposits.	Occur generally above the saturated zone and are not tapped by wells. Highly permeable and transmit water from precipitation downward to underlying deposits.
		Flood-plain deposits	0–15	Chiefly silt and fine sand containing organic material; usually overlie varved clay and silt.	May yield small supplies to shallow dug wells; not utilized as a source of water because areas are subject to floods.
	Pleistocene	Glaciolacustrine and associated delta deposits	0–255	Upper unit of well-sorted coarse to fine sand and a little gravel grading downward into or conformably overlying lower unit of varved clay and silt; upper unit of glaciolacustrine deposits consists of coarse to fine sand as much as 30 ft thick; deltaic deposits are as much as 85 ft thick and consist of sand and a little gravel.	Where sufficiently thick, upper unit and delta deposits yield as much as 100 gpm to wells; lower clay and silt have low permeability and prevent downward movement of water from upper sand unit or confine water in buried gravel lenses.
		Outwash-plain, valley-train, and undifferentiated outwash deposits.	0–225+	Coarse to fine sand with some silt and gravel; deposits are well sorted and stratified. Gravel beds occur usually in upper unit that is less than 30 ft thick; lower unit consists of fine sand and silt.	An important aquifer where coarse materials are present; upper unit yields domestic supplies to shallow dug and driven wells; lower unit generally yields only small supplies but where coarse sand and gravel beds are included may yield moderate supplies to wells.
		Buried outwash deposits	0–20	Poorly sorted gravel and silt. Generally occur as discontinuous beds or lenses near the bottom of preglacial channel.	Where present, may yield large supplies of water to properly constructed wells if silt fraction is small. Water under artesian pressure.
		Ice-contact deposits	0–110	Largely coarse to fine sand with some gravel and silt; show marked difference in grain size and sorting between beds, and broad areal and vertical variation. Overlie bedrock and ground moraine.	Potentially the most important aquifer in area. Yield water now to only a few large-capacity wells and many small wells. Water moderately hard but otherwise satisfactory.
		Ground-moraine and drumlin deposits.	0–110	Heterogeneous mixture of unstratified material ranging in size from clay to boulders; usually well compacted and known locally as "hardpan"; include sorted material locally. Overlie bedrock throughout the area.	Generally a poor aquifer because of predominance of clay and silt. Because of widespread occurrence in upland areas, they supply water to a large number of rural wells. Yield small and sometimes unreliable supplies to dug wells of large diameter.

Triassic	Late Triassic	Igneous rocks (Part of Newark group and of Meriden formation of Krynine, 1950.)	0–800	Massive crystalline basalt occurring in three lava flows separated by sedimentary beds. Jointing well defined; columnar jointing most common. Underlie ridges.	Generally yield small supplies to drilled wells intercepting water-bearing openings along joint planes and other fractures. Most wells yield some water, but generally less than 10 gpm. Quality of water is satisfactory for most uses.
		Sedimentary rocks undifferentiated. (Part of Newark group. Includes Portland arkose, and Meriden formation of Krynine, 1950.)	0–4,000	Consolidated fine- to coarse-grained sedimentary rocks of fluvial origin. Consist of conglomerate arkose, sandstone, siltstone, and shale, in beds of variable thickness. Predominantly reddish-brown. Joints well defined. Underlie most of lowland area.	Generally yield moderate supplies of water for domestic and small municipal and industrial uses from openings along bedding planes and joints. An important source of water because of large areal extent. May yield as much as 500 gpm. Water is hard in most places.
	Pre-Triassic	Consolidated rocks of pre-Triassic age undifferentiated. (Includes Bolton schist, Glastonbury granite gneiss of Gregory (1906), Maromas granite gneiss, and Middletown gneiss.)	Unknown	Consolidated crystalline rocks consisting predominantly of schist and granite gneiss. Rocks are highly folded and joints are numerous. Underlie most of upland area. Overlain by till.	Yield small, generally less than 10 gpm, but reliable supplies of water to drilled wells penetrating openings along joints. Water is moderately hard but otherwise satisfactory.

The Glastonbury granite-gneiss of Rice and Gregory (1906) is the most extensive of the crystalline rocks. It underlies a lenticular area from southern Portland to the Massachusetts boundary. For the most part it is a dark well-foliated medium-grained schistose gneiss containing a large quantity of the black biotite and hornblende. The fact that the biotite and hornblende are alined parallel with lighter colored feldspars gives a distinct banded appearance to the rock. In the eastern part of its outcrop area, the Glastonbury granite-gneiss grades into a light-colored fine-grained biotite gneiss or granite. This rock is much more massive than the well-foliated western facies and has in the past been quarried in blocks as much as 3 feet thick which show no signs of fractures.

The Bolton schist is silvery- to dark-gray medium-grained mica schist containing abundant biotite and garnet. It shows considerable variation in character and includes gneissoid bands as well as beds and lenses of quartzite and limestone. It is dark gray where freshly exposed, but weathered outcrops usually have a rusty-brown appearance. The Bolton schist occurs generally east of the main mass of the Glastonbury granite-gneiss in north-central Connecticut, but in the towns of Portland and southern Glastonbury, it encloses the granite-gneiss body in a large synclinal fold and crops out in a narrow band along the eastern, southern, and western border of the granite-gneiss. The Bolton schist also crops out along the eastern border of the Triassic rocks in northern Somers.

WATER-BEARING PROPERTIES

Because the crystalline rocks in north-central Connecticut underlie a large area and because all other rocks in this area are nearly impermeable, crystalline rocks are important as a source of water for rural use. The amount of water supplied to an individual well is usually small, however, and crystalline rocks are therefore unimportant as a source of water for industrial and public supply.

The percentage of pore space in consolidated crystalline rocks is probably 1 percent or less, and is small compared to the porosity of unconsolidated sand and gravel deposits. The pore spaces are so small that little or no water is transmitted through them, and wells probably obtain no significant amounts of water from pores in crystalline rock in north-central Connecticut. Several wells have been drilled 200–300 feet deep in these rocks and have yielded only small supplies which enter the well from a single level in the hole. Most recoverable ground water occurs in interconnected joints and fracture zones. The permeability of the crystalline rocks is determined largely by the size and extent of the fractures. Spacing between individual joints of parallel sets ranges from a few inches to several feet. Because appreciable water is yielded to a well only where there is a sufficient number of joints and because the location of joints is not known in detail, the success or failure of a well in crystalline rock cannot be predicted with certainty.

YIELDS OF WELLS

The yield and depth of wells in crystalline rock vary areally, both widely and locally from well to well, depending on the number and size of openings and on the topography. Therefore, data for a single well or a group of wells may be applied only in a general way to indicate the probability of obtaining a required yield in any given locality. Records of 123 wells penetrating pre-Triassic crystalline rocks are available for the north-central Connecticut area. Most wells are 6 inches in diameter. Their reported yields range from ¼ to 35 gpm (gallons per minute). The average yield is about 10 gpm and the median is 7 gpm. These wells are from 29 to 550 feet deep; the average depth is 145 feet and the median is 125 feet. Most wells in crystalline rock are less than 200 feet in depth and most supply some water. A review of the available data on the yield of the two main types of pre-Triassic rocks, schist and granite-gneiss, suggests that the average drilled wells in granite-gneiss have slightly higher yields than wells in schist. The average and median yield of 108 wells in granite-gneiss is about 11 and 7 gpm, and the average and median yield of 15 wells in schist is about 7 and 6 gpm. This is reasonable because the fracturing of the coarser grained and more brittle rocks, such as granite-gneiss, generally has produced wider and more continuous joint openings than fracturing in the finer grained rocks, such as schist. Similar results were obtained from a study of records of drilled wells in crystalline rock in southern New England by Cushman, Allen, and Pree (1953).

The rock openings, such as joints and other fractures, become more widely spaced and narrower with increasing depth. The depth below which joints are too tightly closed to contain recoverable water is not known precisely, and it probably varies somewhat from place to place. Experience of drillers indicates that, if a sufficient supply of water is not obtained after drilling through 250 feet of pre-Triassic crystalline rocks, the chances of getting the needed water by drilling deeper are poor. Where more water is required after drilling to about 250 feet, the yield may be increased by further developing the well by means of surging or wire brushing before drilling deeper or by moving to a new location. Where no water is found in crystalline rock above the 250-foot depth, it is common practice to move to a different location.

SEDIMENTARY ROCKS OF TRIASSIC AGE

GENERAL CHARACTER AND EXTENT

The sedimentary rocks of the north-central Connecticut area have been assigned to the Newark group of Triassic rocks. The term "Newark" was applied by Redfield (1856) as a convenient name for the beds of red sandstone, shale, and conglomerate of the Connecticut River valley and those extending from New Jersey to Virginia. The Triassic sedimentary rocks in Connecticut are similar in lithology and structure to the Newark group in New Jersey and Virginia. They unconformably overlie the pre-Triassic crystalline rocks and are considered to be Late Triassic in age. They are the youngest consolidated rocks recognizable in the area and are overlain locally by unconsolidated deposits of Pleistocene and Recent age.

The Triassic sediments in north-central Connecticut consist of arkosic sandstone, feldspathic sandstone, conglomerate, shale, and subordinate limestone and siltstone. These rocks will be referred to generally in this report as Triassic sandstone and shale because the predominating rock types are arkosic sandstone and shale and because these terms are commonly used by drillers and engineers in the area. All the Triassic rocks have a continental origin. They were deposited chiefly as coalescing alluvial fans or streams which flowed westward from the eastern highlands. The rocks now form a homocline that strikes about north and dips eastward; the average angle of dip is 15° but ranges from nearly 0° to 25°. The present eastward dip is the result of downward movement of the Triassic basin along the Triassic border fault during and subsequent to the time of deposition.

The sedimentary rocks underlie nearly all of north-central Connecticut west of the eastern highlands area of crystalline rocks. They underlie all the valley area west of the major fault shown on plate 1 and are found beneath the basalt flows which form the ridges on the west side of the valley. They are shown on plate 1 only as isolated outcrops. The rocks crop out on the flanks and crests of scattered oval-shaped hills, in the beds of some streams, and on the sides of some of the trap (basalt) ridges, but because of their general lack of resistance to weathering and erosion, the outcrops are few. The more resistant rocks, such as the coarse sandstone and conglomerate in the eastern part of the area have more numerous outcrops. Except in the hilly sections, the sedimentary rocks are concealed by stratified glacial deposits and younger alluvium. The rocks underlying most hills are concealed by a thin covering of unstratified glacial drift known as till.

The age of the Newark group is Late Triassic. The most common fossil remains are plants, a small number of species of fishes, a few reptilian bones, and abundant dinosaur tracks.

Krynine (1950) divided the Newark group in Connecticut into three formations: the New Haven arkose, which includes all rocks below the lava flows; the Meriden formation, which includes the three lava flows and the sedimentary strata between them; and the Portland arkose, which includes the entire sequence of sedimentary strata above the lava flows. Of the three, the Portland arkose and the upper sedimentary member of the Meriden formation are the sedimentary rock units that occur within the north-central Connecticut area.

The upper member of the Meriden formation of Krynine (1950) is composed predominantly of the finer grained sediments—shale, mudstone, and fine- to medium-grained arkosic and feldspathic sandstone. The shale and mudstone range from grayish black to red and the sandstone from pinkish gray to reddish brown. They originated probably as lacustrine and swamp deposits. The upper member occurs between the middle and upper lava flows, and as the middle flow for the most part forms the western boundary of the report area, the upper sedimentary member occurs in this part of the area. It underlies a narrow, elongate belt extending northward from the western part of West Hartford to the Massachusetts border in central Suffield. Outcrops are few in this belt, but the location of the sedimentary rock is easily determined from its position between the ridge-forming lava flows. These rocks also underlie broader areas in central and western Rocky Hill and Wethersfield and the southern part of Hartford, where they crop out in a number of places; the best exposure is along a deep roadcut of the Wilbur Cross Highway, where it passes under Ridge Road in Wethersfield. Here the contact of the upper sedimentary member with the overlying upper lava flow is well exposed. About 1 foot of the fine-grained sedimentary rock immediately below the basalt flow has been recrystallized and has a baked appearance. A similar exposure of the contact is found in Rock Ridge Park, just west of Trinity College campus in Hartford. Lehmann (1959, p. 15) calculated the thickness of the upper sedimentary member of the Meriden formation (the East Berlin formation of Lehmann, 1959) to range between 550 and 600 feet in the Middletown area. This is also probably the thickness in north-central Connecticut.

The upper unit of the Newark group, the Portland arkose, is the most widespread bedrock unit in north-central Connecticut. It includes all sedimentary rocks above the upper lava flow and underlies a large part of the report area and is penetrated by the greatest number of wells. The lithology of the Portland arkose is highly variable, consisting of reddish-brown conglomerate, reddish-brown to purplish-brown coarse arkosic sandstone, red fine-grained micaceous mudstone, and red to dark-gray shale. Arkosic sandstone is the predominant rock type. The rocks are poorly exposed, and the pattern of distribution of the several rocks types within the Portland arkose is difficult to establish. In general, the grain size becomes coarser from west to east. Well logs indicate that alternating beds of shale and sandstone are prevalent in the western part of the area, whereas in the eastern part, in the vicinity of the border fault, the formation consists of coarse arkosic sandstone and conglomerate. The thickest exposed section of shale and sandstone, totaling 319 feet, crops out for more than one thousand feet along the south bank of North Branch of Park River in the northeast corner of the town of West Hartford. The following log of well Bl 34 also exemplifies the lithology of these rocks.

Driller's log of well Bl 34 near Bloomfield

	Feet
Topsoil	2
Ground-moraine deposits:	
Clay hardpan	8
Fine sand and clay	5
Gravel hardpan	4
Boulders and hardpan	5.5
Sedimentary rocks of Triassic age:	
Red rock	53.5
Red shale	32
Red rock	24
Red shale	31
Sedimentary rocks of Triassic age—Continued	
Red rock	23
Red shale	72
Red shale (much harder)	158
Dark red shale with hard streaks	47
Red shale mixed with layers of gray sandstone and gray shale	135
Total	600

The arkosic sandstone is well displayed in the abandoned "brownstone" quarries in Portland. The conglomerate facies crops out in the steep roadcuts along State Route 17 near the border fault in Portland.

In a narrow zone immediately adjacent to the border fault the sedimentary rocks have been brecciated, silicified, and otherwise altered by the grinding action and compression of rock movement. Collins (1954) and Aitken (1955) described a number of exposures along the position of the fault in the area from Talcottville north to the Massachusetts boundary, where the rocks have been made more resistant to erosion by intense silicification and brecciation. Collins noted that this zone is more than 1,000 feet wide in places. Fewer exposures are noted in the southern part of the area, and it is possible that the brecciated zone is narrower here. Records are available for a few wells in this area; for example, wells Gl 105 and Gl 123 penetrated the crystalline rocks below Triassic sedimentary rocks, and the drillers noted no difference in the color of the cuttings or the drilling character of the rock in the transition zone between the two rock types. The log of well Gl 105 follows:

Driller's log of well Gl 105, 3.6 miles south of Glastonbury

	Feet
Valley-train deposits:	
Red sand, gravel, and silt	40
Sedimentary rocks of Triassic age:	
Red coarse conglomerate	120
Crystalline rocks of pre-Triassic age:	
Gray hard granitic rock	60
Total	220

The thickness of the Portland arkose can be only approximated. Krynine (1950, p. 69) reported an estimate of 4,000 feet for the thickness in central Connecticut. Lehmann (1959, p. 26) estimated the thickness in the Middletown area to be 3,000–3,500 feet. Numerous cross faults in the sedimentary rocks increase the difficulties of estimating the thickness of the Portland arkose. Because the source of the sediments was probably to the east, the depth to the crystalline basement and the thickness of the Portland arkose probably is greatest in this direction. Few wells in the area covered by this report are known to have penetrated the crystalline rock beneath the Triassic sediments, and those that do are drilled in the immediate vicinity of the Triassic border fault. The deepest well on record in the area underlain by the Portland arkose is only 973 feet deep (well SW 107). A log of this well follows:

Driller's log of well SW 107, 1.5 miles east of East Windsor Hill

	Feet
Glaciolacustrine deposits:	
Yellow medium to fine sand	16
Gray clay	60
Red clay and silt	88
Ground-moraine deposits:	
Red silt and fine sand with a few pebbles	10
Sedimentary rocks of Triassic age:	
Red shale and sandstone	799
Total	973

WATER-BEARING PROPERTIES

Sedimentary rocks of Triassic age are an important source of water for rural homes, industries, and smaller municipalities in north-central Connecticut because they underlie a large part of the area. Water is contained in and moves along intergranular pore spaces, bedding-plane partings, and secondary openings, principally joints and faults. The openings along joints and bedding planes probably are the most important avenues for the movement and storage of water in the sedimentary rocks.

The percentage of pore space in these rocks is small in comparison to that in glacial sand and gravel. Much of the intergranular pore space in the sedimentary rocks is occupied by a carbonate cement, chiefly calcite, which further reduces the original porosity. Gregory (1909, p. 105) reported on an experiment wherein a dried sample of sandstone from the Portland quarry was immersed in water for 3 months and was found to have absorbed an equivalent of about 2 quarts of water for every cubic foot, indicating a porosity of about 7 percent. In contrast, Meinzer (1923, p. 11) obtained a porosity ranging from 20.9 to 37.6 percent for sand and gravel by adding water to samples of glacial outwash from the Pomperaug Valley, Conn. Owing to the small primary porosity, water is transmitted slowly through intergranular pores in sedimentary rocks.

The permeability of the sedimentary rocks in north-central Connecticut is probably due to the number and size of openings along bedding planes and joints. The relative importance of each is not definitely known but both types of openings store and transmit water. For example, water may be observed to seep from openings at the intersection of steeply dipping joints in the walls of the abandoned "brownstone" quarry at Portland. Fuller (1905, p. 97) reported that when this quarry was being worked, water was noted to emerge everywhere from along bedding planes, especially along the shaly partings. Drillers frequently reported that all or part of the yield of a well drilled in sandstone and shale is obtained from a specific depth or depths, which implies widely spaced narrow openings. The permeability of the rock is dependent upon the amount of jointing and parting and the size of the openings along these fractures, which in turn are related to the type of rock and the depth of burial. The openings intersect at many different angles, with the result that percolating ground water can move in many directions.

Where saturated sedimentary rocks are not buried beneath an impermeable material, the water is probably under water-table conditions.

Because the location of water-filled openings at depth is not known in detail, the yield of an individual well tapping sedimentary rocks probably cannot be predicted with any degree of certainty. Usually a well drilled into these rocks will penetrate at least a few water-bearing joints or bedding-plane partings and yield at least a small supply of water. Many wells drilled in sandstone and shale in this area are reported to penetrate three or more water-filled joints before a sufficient supply is obtained. The depth and yield of wells varies widely, depending on the number and size of openings. Records of 688 drilled wells in sandstone and shale are available for the north-central Connecticut area. Reported yields range from ½ to 578 gpm. The average and median yield of all wells are about 34 and 16 gpm. The depth of these wells ranges from 40 to 973 feet, and averages 203 feet. The median depth is 158 feet. Gregory (1909) reported that wells penetrating Triassic sandstones in Connecticut had an average depth of 144 feet and an average yield of 27 gpm. Wells in Triassic sedimentary rocks in southern New England as reported by Cushman, Allen, and Pree (1953, p. 88) had an average yield of about 20 gpm and an average depth of 199 feet.

Most of the data described in this report, and those mentioned above, are for wells drilled to obtain a small amount of water for rural home use. Generally, when a supply sufficient for domestic use was obtained, drilling was stopped. A much smaller number of wells were drilled to obtain large yields sufficient for industrial and air-conditioning uses. In these wells, drilling was probably continued until either the desired yield was furnished or the funds allotted for drilling were exhausted. The figure of average yield from sandstone and shale given above is probably lower than might actually be expected because it is weighted by an excessive number of wells whose yields do not measure the capacity of the aquifer. Most wells in sedimentary rocks of Triassic age would yield more water if they were drilled deeper and developed more fully than is done for domestic or rural wells. This conclusion is substantiated by data for 64 industrial wells that tap sandstone and shale in Hartford and in neighboring towns in north-central Connecticut. These wells have an average and median yield of 169 and 103 gpm, and an average and median depth of 485 and 500 feet. The most productive group of these are the 10 wells drilled for the Connecticut General Life Insurance Co. in Bloomfield (wells 32, 34, 79–84, 96, and 97 shown in pl. 1). When tested individually for 24 hours, these wells yielded from 179 to 578 gpm. All were drilled to about 600 feet.

The depth-yield relation of wells in the Newark group is indicated in figure 2, which shows the probability of obtaining a well whose yield is equal to or more than a specified amount. The lower curve is the cumulative frequency curve of yield of 388 wells penetrating sedimentary rocks which were drilled for all types of uses and in locations selected largely for convenience by the owners or drillers. The upper curve is based on yields of industrial and commercial wells only. The curves show that the yield of 20 percent of the 388 wells equals or exceeds 48 gpm, whereas the yield of 20 percent of the industrial and commercial wells equals or exceeds 290 gpm. The industrial and commercial wells were drilled to greater depths to obtain larger yields. Drillers have reported that additional water-

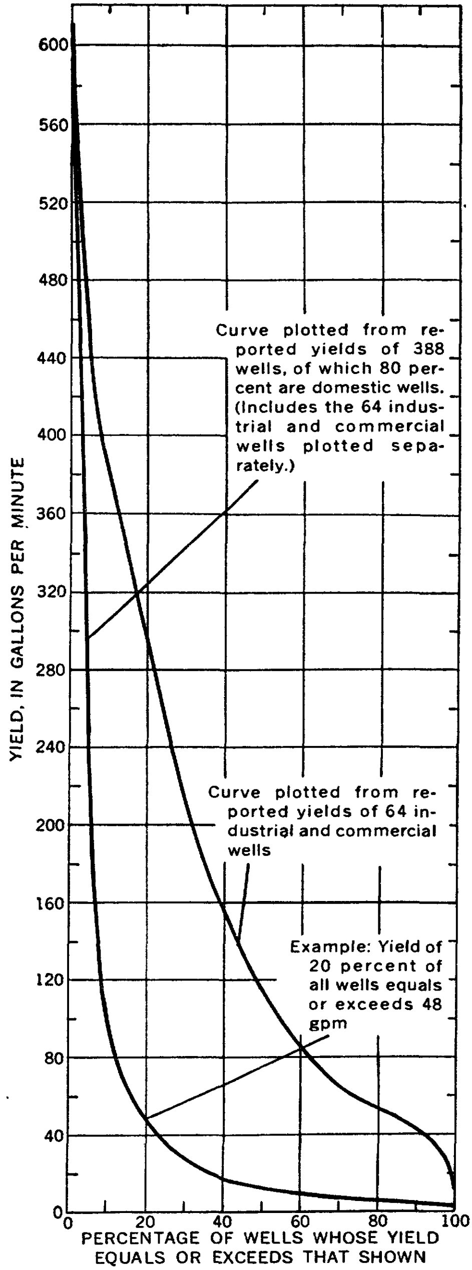


FIGURE 2.—Cumulative frequency curves of yield of wells in sedimentary bedrock. Wells yielding 80 gpm or less were grouped in units of 4 gpm, and their percentage was plotted at the upper end of the group. For example, the percentage of wells having yields of from 4 to 8 gpm were plotted at 8 gpm. Wells yielding more than 80 gpm were grouped in units of 20 gpm, and their percentage was plotted at the upper end of the group.

bearing zones have been penetrated as deep as 450 feet in some sedimentary rocks. Thus it appears that water-bearing openings exist to considerably greater depth in sedimentary rocks than in crystalline rocks in north-central Connecticut. If a desired yield is not obtained at shallower depths, the available data suggest that drilling should be continued until a well has reached a depth of at least 450 feet.

Specific capacity, or the number of gallons per minute per foot of drawdown, is a better measure of well performance than yield because it relates yield to changes in the water level or pumping lift. The specific capacity of a well is dependent primarily on the well's effective diameter, the efficiency of the well, and the water-transmitting capacity of the rock formation. Specific capacity could not be calculated for most wells in sedimentary rocks owing to the inadequacy of testing procedures, lack of data on the drawdown, or change in water level during the pumping test. The specific capacity of 44 industrial and commercial wells for which reliable information is available ranges from less than 0.1 to 10 gpm per ft; the median is 1 gpm per ft, which is considerably smaller than that for wells obtaining water from glacial sand and gravel. The relatively low specific capacity of wells in sedimentary bedrock has special significance to the well owner because it indicates that a large yield is generally accompanied by a sizeable drawdown of the water level in the well. If the median specific capacity (1 gpm per ft) is used, a drawdown of 250 feet should be anticipated when a well is pumped continuously at a rate of 250 gpm for a period of several hours. A marked lowering of the water level at a well also can be expected to affect water levels in the vicinity of the well, but probably in a lesser amount.

FACTORS CAUSING AREAL VARIATION IN YIELD

As noted from the previous discussion, variations in yield among wells in sedimentary rocks are common. In north-central Connecticut, some variations seem to have an areal pattern which can be related to one or more geologic or hydrologic factors. For example, wells of large capacity are seldom found in areas where the rocks are covered by a considerable thickness of lacustrine clay and silt. These areas generally include the deep bedrock valleys in the lowland east of the Connecticut River and in the eastern part of Bloomfield and Windsor, shown in plate 2. In marked contrast, many wells of large yield are concentrated in several areas in Hartford, West Hartford, western Bloomfield, and in Manchester. The areal variations in yield are probably mostly related to (a) the nature and thickness of the overlying unconsolidated material, and (b) the degree to which the rocks are fractured or contain other openings.

In much of the Connecticut River Lowland north of Glastonbury and Rocky Hill, the sedimentary rocks are overlain by relatively impermeable clay and silt of lacustrine origin. Where the bedrock is deepest, as shown by the contours on plate 2, and where the impervious covering is thick, the average yield of wells is low and the largest number of failures are reported. The low yields are probably related to the imperviousness of the unconsolidated covering which limits downward movement of water and, hence, recharge to the bedrock. Similarly, a large number of failures (wells which yielded a negligible amount of water) are reported from the areas of thick clay and silt. Well SW 67 in South Windsor, for example, yielded only 4 gpm after being drilled to a depth of 915 feet. The rock in this area is overlain by 100 feet or more of lacustrine clay and silt. Well SW 107 yielded only 6–7 gpm after being drilled to a depth of 973 feet. Bedrock at the site was overlain by about 150 feet of lacustrine clay and silt. (See log of this well on p. 31.)

In contrast, a number of wells with high yields have been developed in areas where the bedrock is close to the surface or where it is covered by relatively thick deposits of permeable sand and gravel. For example, the wells at the Connecticut General Life Insurance Co. property in Bloomfield (see p. 33) are developed in sandstone and shale which is covered by only 25 feet of till. Besides being thin, the till probably is somewhat more permeable than clay and conducts somewhat larger quantities of water into the underlying rock. Wells of large yield developed in sedimentary rocks in Manchester are in areas where the rock is overlain by permeable sand and gravel. The infiltration capacity of these materials is generally high, and they transmit substantial quantities of water from precipitation downward to openings in the bedrock. The specific capacity of these wells, more than 6 gpm per ft is generally high for wells in the Newark group; one well, M 60, has a specific capacity of about 9 gpm per ft.

The degree to which the sedimentary rocks in north-central Connecticut have been fractured or contain other openings may have an important effect on their water-yielding capacity also. The effect of fracturing and other small openings on the yield of wells is difficult to evaluate apart from other factors such as type and thickness of overburden. The degree of fracturing may be a function of the type of bedrock and as such can be related to well yield. The detailed character of the Portland arkose of the Newark group, which underlies most of north-central Connecticut, is not known; but as stated in the preceding section, the gross character changes to the east from predominantly fine-grained to predominantly coarse-grained material. The coarser grained and thicker bedded rocks should support more continuous and open fractures, and therefore it is postulated that they would yield large amounts of water to drilled wells. The evidence from north-central Connecticut, however, is not conclusive in this respect. The wells having large yields in Manchester obtain water from the coarse-grained facies of the Portland arkose, where this facies is overlain by permeable sand and gravel. Thus the large yields may be related to either of these factors, or both. The highly productive wells in the Hartford-West Hartford-Bloomfield area probably obtain water from alternating beds of fine-grained sandstone and shale. Detailed study of the relation of fractures to the water-yielding capacity of sedimentary rocks may provide information that will be helpful in predicting the yield from fractured rocks in north-central Connecticut.

In summary, the present evidence suggests that larger yields from the Newark group may be obtained where the rocks probably are well fractured and either are overlain by permeable materials or are close to the surface. Information given on plates 1 and 2 may be of use in locating favorable areas.

IGNEOUS ROCKS OF TRIASSIC AGE

GENERAL CHARACTER AND EXTENT

Igneous rock of Triassic age, known locally as traprock, is the principal ridge-forming rock in the Connecticut River Lowland. Traprock underlies and forms the elongate ridges along the western border of the area extending from West Hartford to the Connecticut-Massachusetts line and underlies many of the smaller discontinuous ridges in the area extending from Cromwell to Hartford. Outcrops are numerous on the flanks of these ridges. Krynine includes the traprock in his Meriden formation and, therefore, it is of Late Triassic age.

The traprock is a fine-grained extremely hard basalt, which is bluish gray on a fresh surface and buff or brown on a weathered surface. It flowed out at the surface forming three successive compound lava flows—designated lower, middle, and upper. The lower and upper flows mark the limits of the Meriden formation of Krynine (1950). The middle lava flow is 300–500 feet thick in north-central Connecticut, and the upper flow is 50–150 feet thick. The lower flow crops out only to the west of the area. The middle lava flow is the principal ridge-forming member and delineates the western boundary of the report area in the towns of Suffield, East Granby, Bloomfield, West Hartford, and Rocky Hill. The upper flow is overlain by the

Portland arkose. The top and bottom of the basalt flows often contain irregular or elongated vesicles formed by the expansion of contained gasses during the cooling process. The vesicles range in diameter from microscopic dimensions to several inches and usually are filled by secondary minerals deposited from percolating waters.

The joints in the basalt are well defined and are of two types, oblique joints similar to those formed in other consolidated rocks in Connecticut and joints formed perpendicular to the top and bottom of the flows during the cooling and shrinkage of the molten lava. The latter joints intersect one another to divide the rock into rough hexagonal blocks or columns, forming the characteristic columnar structure exhibited in many exposures of basalt in north-central Connecticut. Examples of columnar structure are seen in many of the steep west faces of the ridges and are especially well exposed in a bluff west of Trinity College in Hartford. The combination of the two well-defined joint patterns breaks the traprock into numerous angular blocks for a considerable depth. Although the fracturing is probably greatest near the surface, the basalt is also well fractured at depth. Angular blocks often break off during drilling and wedge the tools.

The basalt was erupted in the form of lava flows, which are conformable with the bedding of the sediments and, therefore, dip generally to the east. Erosion of the bordering soft sedimentary rocks has made the hard basalt stand out in ridges that have steep erosion slopes on the west side and gentle dip slopes on the east. Displacement along major faults has caused abrupt terminations and offsets of parts of the ridges. These breaks in the basalt are especially evident in the area between Cromwell and Hartford and in the western part of West Hartford and Bloomfield. Where the faults are parallel to the strike of the beds, the displacement causes a repetition of the outcrop pattern, and double ridges of basalt separated by sandstone may result. A repetition of this type gives rise to the two broad ridges east of Talcott Mountain in West Hartford. The ridges are underlain by basalt and are separated by a narrow band of sandstone that underlies the depression occupied by reservoirs 2, 3, and 6 of the Hartford Metropolitan Water Bureau.

WATER-BEARING PROPERTIES

Ground water in traprock occurs in and moves principally through intersecting sets of fractures. Little if any water is obtained from pore spaces between crystal grains or from vesicles. In this respect, the water-bearing characteristics of basalt are similar to those of pre-Triassic crystalline rock. Most drilled wells in basalt obtain adequate supplies for domestic and farm use at depths ranging from 60 to 500 feet. The average depth of 53 wells is 153 feet and the median depth is 140 feet. The yield of these wells ranges from 1½ to 50 gpm; the average yield is about 13 gpm and the median is about 10 gpm.

Because the basalt occurs in flows or layers between beds of sandstone and shale, drillers sometimes report drilling through basalt and finding water in the sandstone immediately below. In fact, water is found at the contact of the Triassic sedimentary rocks and basalt more often than not, and drillers look for such a contact as a source of water. An example is the well at the Hartford Times Tower on Talcott Mountain in Bloomfield (well Bl 78). The driller reported finding water in sandstone below the middle lava flow at a depth of 160 feet. Because an insufficient supply was obtained at this level, the well was deepened further, passing out of the sandstone and into the lower lava flow at a depth of 268 feet. Drilling was discontinued at a depth of 310 feet because the supply was considered adequate.

The depth below which joints in basalt are too tightly closed to contain recoverable water is not known precisely and probably varies from place to place. If a sufficient supply of water is not obtained after drilling to a depth of 250 to 300 feet, the chances of obtaining the needed water by drilling deeper are poor. In general, where a well is drilled about 200 feet into rock and more water is required, it may be wise to attempt to increase the yield by developing the well before drilling deeper or moving to a different location. Generally, a well should not be drilled deeper if it has reached a depth of 300 feet in basalt and has an insufficient yield after surging.

WELL CONSTRUCTION

Because the basalt consistently shows a high degree of fracturing near the surface, water in small amounts commonly enters the well within a few feet below the bedrock surface. Drillers generally find it advisable to prevent this flow from entering the well because fine sand and silt filling the fractures enter the well and make the water muddy. This water may be contaminated where the surface of the rock is near the land surface. The hardness of the rock sometimes causes considerable difficulty in casing off contaminated water because it prevents the casing from being properly driven into the rock. In a properly constructed well in traprock, the drill hole has a larger diameter than the casing so that the casing may be firmly seated in the rock for several feet and that the annular space may be filled with cement. Drilling the open hole in the rock is completed with a smaller bit, commonly 6 inches in diameter.

UNCONSOLIDATED DEPOSITS

The unconsolidated deposits of north-central Connecticut were deposited on bedrock by the action of glacial ice, streams, and wind. They are different in physical characteristics from the bedrock because they are unconsolidated and, therefore, contain more open pore spaces. From oldest to youngest they are: (a) ground-moraine and drumlin deposits, ice-contact deposits, outwash-plain and valley-train deposits, and glaciolacustrine and associated delta deposits, all of Pleistocene age, and (b) dune deposits, flood-plain deposits, and swamp deposits, all of Recent age. The deposits of Pleistocene age may be separated on the basis of their lithology into unstratified and stratified deposits. Ground-moraine and drumlin deposits are composed of unstratified material and the remaining deposits are stratified. Some of the stratified deposits contain the principal water-bearing beds.

Plate 1 shows the principal areas underlain by the Pleistocene and Recent deposits in north-central Connecticut. The thickness and character of the unconsolidated deposits may be estimated from records of wells. Where well data are lacking, the thickness in some areas may be estimated from the contours of the buried bedrock surface (pl. 2) if the altitude of the land surface is known.

GROUND-MORAINE DEPOSITS

GENERAL CHARACTER AND EXTENT

Ground moraine is a morphologic unit typifying a glacial deposit of relatively wide areal extent that was deposited by direct action of glacial ice moving across an area. Ground moraine is deposited by lodgement on the surface of the bedrock and built up in thickness by progressive accumulation of material. Ground-moraine deposits generally form the oldest phase of a sequence of glacial sediments and are composed chiefly of till. Till ranges widely in the sorting and grain size, and its composition is strongly influenced by the nature of the rocks over which the ice moved.

In north-central Connecticut most of the ground moraine was probably deposited during the Wisconsin stage of ice advance and retreat. Flint (1953, p. 900) and R. E. Deane (oral communication, 1953) suggested that there may have been at least two substages of advance and retreat of Wisconsin ice in central Connecticut and that the latest may be equivalent to the Cary substage. For the purposes of this report, the ground moraine is discussed as a single unit, as the unstratified deposits of the Cary substage are thin and of limited areal extent. The ground moraine is the oldest of the unconsolidated deposits and generally directly overlies the bedrock. It is at the land surface almost everywhere in the Eastern Upland, and at altitudes above 150–200 feet on the trap ridges and the small hills in the lowland. In all, ground-moraine deposits cover about one-fourth of the report area, (pls. 1 and 2). Elsewhere, generally in areas below an altitude of 200 feet, they are buried beneath the younger unconsolidated deposits of Pleistocene and Recent age.

The ground-moraine deposits in north-central Connecticut are composed of rock fragments derived locally from red sandstone, shale, and conglomerate of Triassic age. They are therefore, predominantly red. In the vicinity of, and more especially to the south of the traprock ridges, fragments of dark basalt, some of them reaching the size of huge boulders, are mixed with fragments of red rocks in the morainal deposits. In contrast, the rock fragments composing the ground moraine in the easternmost part of the area are predominantly of crystalline material, and the till is buff, brown, or gray. Near the contact of the crystalline rocks and the sandstone, the till contains an increasing percentage of sandstone fragments and becomes progressively pinker. The color change takes place over a distance of several hundred feet. This change is particularly true where the contacts between adjacent contrasting rock types are oriented north and south; that is, parallel to the direction of ice movement.

In the occurrence of ground water, the difference in mineralogic composition is less important than the effect that the source rock has on size of the component particles of ground-moraine deposits. Deposits derived from sedimentary rocks of Triassic age normally are rich in clay and silt and have a low permeability. The clay is composed of microscopic particles of rock materials (rock flour) derived from the grinding action of glacial ice on the relatively soft sandstone and shale. Because there was little opportunity for the rock flour to be washed away during deposition, the material was compressed into a tough and compact till by the weight of the great thickness of ice. This tough clay-rich till is locally called "hardpan." A fine example of clay-rich till was exposed briefly in a 30-foot vertical cut on the west side of Laurel Park Hill in East Hartford. Here the dense, compact reddish-brown till showed almost no slumping during the few months that the pit was open. On the other hand in the upland area, where crystalline rocks crop out, ground-moraine deposits normally contain only a small amount of clay, have a sandy texture, and are more coarse and permeable.

Fine-grained thick bodies of till commonly show a blocky structure where joints have formed, probably due to slumping or to drying out. Similarly, many of these till bodies show closely spaced parting planes that split them into thin chips when excavated. The parting is parallel to the surface on which the till was deposited and may have been formed as a result of pressure exerted by the weight of overlying ice. The parting planes and joints serve as avenues for the movement of downward percolating water and thereby increase the permeability of the till.

A small part of the unstratified drift in north-central Connecticut locally forms numerous drumlins (pl. 1). A true drumlin is defined as a streamlined hill of glacial drift, whose long axis is oriented roughly parallel to direction of ice movement. Other streamlined hills of about the same size and appearance, such as at Bloomfield, Cromwell, and west of Manchester, have a core of bedrock covered by a veneer of drift and are called rock drumlins. Rock drumlins are not potentially water bearing and are not mapped on plate 1. Only the hills of glacial drift known or believed to be true drumlins are mapped separately and are further discussed simply as drumlins. Drumlins occur as isolated forms, such as the lone drumlin southeast of Broad Brook in East Windsor, but most of them occur in groups, or "fields." Prominent drumlin fields are in the lowland areas of Suffield, Windsor, and Bloomfield.

Where exposed, the material making up the core of the drumlins is till. It is generally unstratified, rich in clay, and massive and hard. A few drumlins show irregular bedding or stratification. For example, a borrow pit on the east side of a drumlin about 1½ miles west of the center of Windsor exposes reddish-brown till showing numerous thin contorted beds and lenses of laminated red clay that contains numerous pebbles. A number of drumlins also have south facing "tails" composed of well-stratified sand and gravel. The materials making up the so-called tails are probably younger and are probably derived from ice-contact or beach deposits. Excavations in some drumlins show beds or lenses of sorted material consisting predominantly of either clay, silt, sand, or gravel. Considering the mode of formation of till, the beds of sorted material are probably not continuous over wide areas; but where they consist of sand or gravel, they may facilitate movement of water through the formation.

The thickness of till is variable. Till is thinnest in upland areas where outcrops of bedrock are more numerous. Logs of wells in these areas show that the till is commonly less than 30 feet thick. It is likely to be thicker on the sides of bedrock hills than on the summits. The till is thickest where it underlies and forms drumlins. Well Su 25, near the summit of Taintor Hill, the easternmost of twin drumlins in the southwestern corner of the town of Suffield, penetrated 110 feet of till before reaching bedrock.

WATER-BEARING PROPERTIES

Water occurs in ground-moraine deposits mostly in pore spaces between constituent particles. Because till is composed of unsorted rock materials, predominantly clay, the pores are generally small and thus restrict the movement of water through the deposit. Although the small pore spaces may cause the movement of ground water to be rather slow, till holds appreciable quantities of water which it yields slowly to wells having a large infiltration surface. Some water may be stored in and move through openings along joints and parting planes. It is probable that many wells penetrating ground-moraine deposits obtain water from the more permeable gravel layers or lenses or from the contact zone between the till and the bedrock surface. Because of its wide distribution in hilly and upland areas of north-central Connecticut, till is the source of supply for many farms and rural homes. The wells tapping it are commonly dug wells about 30 feet deep and 3 feet in diameter. Old wells are lined with stone or brick, whereas modern dug wells commonly are constructed with tile or concrete pipe as a lining. Such large-diameter wells are especially effective in recovering water from till, inasmuch as they provide considerable infiltration area to receive slow seepage and a large storage capacity to meet short-term pumping demands.

Data on the maximum water-yielding capacity of wells in the ground moraine are lacking because most dug wells in till are equipped with pumps of small capacity. The average yield per well is about 1 or 2 gpm, but this yield does not necessarily represent the water-bearing capacities of the till. The sandy ground moraine of the eastern highlands is more permeable and thus yields water at a higher rate than the clayey and less permeable ground moraine of the lowlands.

No permeability tests of these soils were made by the Geological Survey during the investigation. A measure of the water-transmitting capacity of the ground moraine developed from these two contrasting rock types may be obtained from the results of percolation tests conducted by the town of Portland Zoning Commission (written communication, 1958) to determine the suitability of an area for domestic sewage-disposal systems. In these tests, the rate at which water percolates out of 1-foot-square pits at a depth of 2½ feet was measured for about 1 hour. Tests in the ground moraine formed from crystalline rocks in Portland show an average decline in water level of about 5 inches per hour, whereas the rate of decline in ground moraine formed from Triassic sedimentary rocks averages about 3 inches per hour. Laboratory permeability measurements were made by Bourbeau and Swanson (1954) on samples of the Wether-field silt loam from Windsor, Conn., a soil formed from ground moraine composed of Triassic material. The tests gave rates ranging from 17.14 inches per hour for soil a few inches below the surface to 0.16 inches per hour for subsoil at a depth of 25–27 inches.

When sanitary facilities and other automatic water-using devices were fewer, the average yield from wells tapping ground moraine was enough to supply the household needs of a rural family. When additional water was needed for farm purposes, another well was dug. The demand for water by modern rural homes, however, has increased beyond the capacities of most wells dug in till. This has resulted in a gradual shift from dug wells in ground moraine to drilled wells in bedrock. Nevertheless, the dug well in till has the advantage of being less expensive to construct and of providing water that is commonly of better chemical quality. At sites where the ground moraine is thick, such as in drumlin areas, the home owner should investigate the possibility of digging a well before going to the expense of drilling to bedrock.

ICE-CONTACT DEPOSITS

GENERAL CHARACTER AND EXTENT

Ice-contact deposits, together with the outwash-plain and valley-train deposits described in a following section, are materials of glaciofluvial origin formed probably during the stagnation and melting of the ice sheet in central Connecticut. The ice-contact deposits include kames, kame-terraces, and crevasse fillings. They consist of sand and some gravel and silt that was washed off the surface of the ice or from the adjacent slopes. The deposits were transported chiefly by glacial melt-water streams flowing through channels in ice or through spillway gaps between ice and the bedrock walls and were deposited upon or against residual ice. Ice usually formed the margin of one or more faces of the deposits.

Ice-contact deposits are usually the earliest of the stratified glacial deposits and where present immediately overlie the ground moraine or bedrock. They are at the surface in a considerable area and are overlain by outwash-plain, valley-train, or lacustrine and deltaic deposits. Locally, the ice-contact deposits may be overlain by veneers of eolian and swamp deposits. They are of Wisconsin age and possibly may have been deposited during the Cary substage of the Wisconsin (Flint, 1953, p. 900).

Deposits of ice-contact origin are exposed extensively in north-central Connecticut along the eastern margin of the Connecticut River Lowland from Glastonbury north to the Massachusetts border. (See pl. 1.) They are the surface deposits of many areas between altitudes of 100 and 250 feet. In fact, most of the stratified drift deposits above an altitude of 200 feet are of ice-contact origin. Three principal areas underlain extensively by ice-contact deposits are recognized. The largest of these extends from the southern part of Glastonbury northeastward through the central and eastern part of Manchester and into the western and central part of Vernon. A second area extends from the northwestern part of Manchester northward along the eastern margin of the Connecticut River Lowland in the towns of South Windsor and East Windsor to the vicinity of the village of Broad Brook. The third area occupies parts of the valleys of the Hockanum and Scantic Rivers in Ellington and Somers. These three areas are described in greater detail in the following section on water-bearing properties. Numerous other deposits of lesser extent are scattered throughout the area north of the latitude of Hartford. They flank many of the small hills that project above the general level of the valley floor in the area west of the Connecticut River and also underlie small high-level terraces in the Eastern Upland. A small but prominent terrace of this type flanks the western slope of the upland in Somers, immediately south of the Massachusetts border.

The exposed parts of the ice-contact deposits consist of materials ranging in size from cobbles to silt. The deposits were laid down by glacial melt waters whose velocity and direction of flow changed abruptly, and therefore vary considerably in sorting and grain size. The materials laid down first and those formed at the higher levels usually contain a higher percentage of coarse material. In general, the percentage of material of coarse sand size or larger is much smaller than the percentage of fine material. Characteristically, individual beds contain materials that are reasonably well sorted but there may be abrupt changes in grain size between beds. Cross-bedding, scour-and-fill, and slump features are common. The rock fragments making up the deposits are derived mostly from the local outcrops, and therefore consist mostly of sandstone and shale of Triassic age, which give the ice-contact deposits a characteristic red color. Small amounts of crystalline rock also are present. The shape of individual fragments making up the ice-contact deposits ranges from flat to round. The shale fragments are worn rather easily into flat pebbles with angular corners, whereas the harder sandstone and crystalline rock fragments are subangular to well rounded. The kame deposits, almost without exception, form terraces that have level or gently sloping surfaces. Many outer faces of the terraces show ice-contact features such as irregular indentations and steeply dipping faces not cut by streams. The inner faces abut against till-covered upland slopes, where the sediments change through a narrow zone from stratified drift into till. Many of the terrace surfaces are pitted with kettles, ranging from tiny to large depressions more than 0.5 mile in diameter. A spectacular area of kettles lies south of Broad Brook in East Windsor and includes one large kettle and many smaller kettles, which are separated by numerous crevasse fillings and kames.

Well logs show that the variable nature of ice-contact deposits continues at depth. Many wells are reported to pass through materials that vary in particle size from silt to gravel. For example, the driller's log of well Gl 126 penetrating ice-contact deposit shows:

Log of well Gl 126 about 2 miles east of Glastonbury

	Feet
Ice-contact deposits:	
Sand	10
Sand and some small stones	5
Silt and clay	10
Ice-contact deposits—Continued	
Medium dirty sand	9
Gravel and hardpan	8
Total	42

The locations of beds of gravel or coarse sand therefore are difficult to predict in advance of drilling because there is little continuity of beds between wells. In many places the materials decrease in size with depth.

The thickness of ice-contact deposits in north-central Connecticut is variable and depends largely on the location of the deposit with respect to the topography of the underlying bedrock. Commonly the thickness is greatest in buried valleys on the bedrock surface or at the outer edges of terraces that flank the valley walls. Kame terraces may be more than 100 feet thick at their outer edges and thin to a featheredge at their inner margins where they lie on the till-covered hillsides. A thickness of ice-contact deposits of more than 80 feet was recorded at the outer or western edge of the terrace in the vicinity of well SW 71 in South Windsor. The deposits south of Broad Brook are reportedly 110 feet thick in places.

WATER-BEARING PROPERTIES

Ice-contact deposits are one of the most important water-bearing units in north-central Connecticut because of their wide distribution and permeable character. They form sizeable catchment areas for the interception and storage of precipitation. Water occurs in these deposits in pore spaces between individual particles. Where the particles are well sorted, the pore spaces may be large and they may store and yield large quantitites of water. As the percentage of poorly sorted material contained within the deposit increases, the permeability decreases. For this reason, the highly variable nature of ice-contact deposits results in correspondingly variable water-bearing properties. Where the deposits consist of well-sorted material, sufficiently coarse and thick, they may yield sizeable supplies of water to properly constructed wells. For example, municipal wells in ice-contact deposits in the town of Manchester yield more than 450 gpm. An irrigation well in South Windsor, SW 71, reportedly yields 450 gpm from ice-contact deposits. On the other hand, in some areas wells were unsuccessful because coarse beds capable of transmitting water at high rates could not be located. A number of rural domestic wells have been cased through thick ice-contact deposits and have been completed in the underlying bedrock. The deposits may have contained a large percentage of fine materials and yielded little water or the wells may have been planned initially to obtain water from the bedrock and the water in the overlying deposits was overlooked.

For convenience, the water-bearing properties of ice-contact deposits are described according to the three principal areas in which the deposits are recognized. From south to north, the areas are: (a) Glastonbury, Manchester, and Vernon; (b) South Windsor and East Windsor; and (c) Ellington and Somers.

ICE-CONTACT DEPOSITS IN GLASTONBURY, MANCHESTER, AND VERNON

The main mass of ice-contact deposits in the southernmost area underlies most of northeastern and central Manchester (pl. 1). It is continuous with ice-contact deposits extending northeastward into the Hockanum River valley in Vernon and with deposits extending southward and underlying the eastern edge of the Connecticut River Lowland in Manchester and Glastonbury. It is also continuous with ice-contact deposits extending southward in the Salmon Brook valley in Glastonbury. The latter deposits divide to the south around a large area of ground moraine along State Route 2, about 3 miles southeast of the village of Glastonbury, where they form the valley fill of Roaring Brook and the narrow terraces flanking the Connecticut Lowland. Generally, the deposits in this area become progressively finer grained southward from Vernon and Manchester. The extensive deposits in Manchester are poorly sorted but contain considerable coarse sand and gravel. They underlie a variety of topographic forms which include crevasse fillings, kames, and kame terraces. The upper parts of most crevasse fillings and kames and the outer parts of the higher kame terraces usually are above the water table and are dry. Where coarse material is present and where the deposit is thick and saturated, it yields moderate to large ground-water supplies to properly constructed wells. A gravel-packed well of the Manchester Water Department (M

59) penetrates more than 50 feet of sand and gravel of ice-contact origin in the Hop Brook valley, and reportedly yielded 560 gpm at the end of a 48-hour pumping test. The specific capacity of the well was 20 gpm per ft. A well of similar construction (SW 112) penetrated beds of sand forming a small kame terrace in the southeast corner of South Windsor, and is reported to yield 350 gpm with a specific capacity of 13.5 gpm per ft.

Little is known of the water-yielding character of the ice-contact deposits in Vernon. Most drilled wells pass through them into bedrock, from which they yield small supplies. The surface exposures indicate that the deposits probably contain coarse materials, especially in areas adjacent to the sides of the valley. The deposits have a saturated thickness of about 80 feet in the area northeast of the intersection of State Routes 83 and 15 and west of Route 83. Thus conditions appear to be favorable in this area for the development of moderate to large ground-water supplies.

The ice-contact deposits in the valleys of Salmon and Roaring Brook in Glastonbury are coarse grained in the upper reaches of the valleys but become progressively finer grained downstream. The deposits in Roaring Brook valley underlie and form kame terraces that have been trenched and eroded so deeply that most of the permeable materials are above the water table and are dry. Because the present stream is flowing close to the surface of the bedrock, the only saturated materials of sufficient thickness for well construction are those located along inner edges of the kame terraces where the bedrock surface is closer to the terrace surface. No wells other than shallow dug wells are known to obtain water from the sand and gravel in Roaring Brook valley. The ice-contact deposits in Salmon Brook valley appear to be favorable for the development of moderate ground-water supplies. Exposures in cut banks show some coarse sand and gravel. Their thickness, which is variable, probably reaches a maximum near the center of the area underlain by the deposits. Well Gl 101 penetrates 112 feet of sand and gravel without reaching bedrock. Several wells for a housing development in the vicinity of well Gl 103 reportedly obtain small supplies of water from screened wells at depths generally less than 30 feet. Well Gl 126 reportedly yielded 50 gpm after being pumped continuously for 8 hours. The specific capacity was about 2 gpm per ft.

ICE-CONTACT DEPOSITS IN SOUTH WINDSOR AND EAST WINDSOR

The second large mass of ice-contact deposits in north-central Connecticut underlies a long narrow area along the eastern edge of the Connecticut River Lowland in South Windsor and East Windsor and in a broad area in the eastern part of East Windsor between Broad Brook and Windsorville. The outcrops of the deposits in all this area contain much coarse material. The outcrop consists generally of rather poorly sorted reddish-brown silt, sand, gravel, and boulders; in several places, the coarser facies are extracted for gravel. Numerous drilled wells penetrate the ice-contact deposits and obtain water from the underlying bedrock. The drillers and owners report sand and gravel above the bedrock. The data from drilled wells and the bedrock topography on plate 2 indicate that the deposits are 75–80 feet thick in places in the area north of Windsorville but are thicker along the eastern edge of the lowland where they overlie the buried bedrock valley. Numerous shallow dug wells and a few driven wells obtain satisfactory domestic supplies from these deposits. The only large-capacity well known to obtain water from them is well SW 71, which supplies water for irrigation of tobacco crops. The well was test pumped at 450 gpm for 48 hours, with a specific capacity of 15.5 gpm per ft. The ice-contact deposits are an important potential source of moderate to large ground-water supplies in much of this area because they are thick and permeable.

ICE-CONTACT DEPOSITS IN ELLINGTON AND SOMERS

The third large mass of ice-contact deposits occupies the east side of Broad Brook and Scantic River valleys from about 1 mile north of Ellington to the Massachusetts border. The part underlying the town of Ellington is of limited areal extent and is probably relatively thin. The deposits underlie and form narrow terraces flanking Broad Brook and are probably well drained and mostly above the water table. Consequently, only small water supplies can be obtained from the deposits in Ellington.

Little is known of the water-bearing character of the ice-contact deposits in Somers. They underlie a broad area between and south of the villages of Somers and Somersville. They also underlie a linear 1-mile-wide area extending north from the village of Somers along the east side of Scantic River. In outcrop, these deposits are coarse grained and poorly sorted and stratified along the eastern side of the area. They become finer grained and the sorting and stratification improves in a westward direction. They consist of reddish-brown sand and gravel generally, and the percentage of coarse gravel and boulders increases to the east. The log of well So 73 near Somers is as follows:

Log of drilled well So 73, 0.6 mile northeast of Somers

	Feet
Ice-contact deposits:	
Gray coarse sand	30
Gray medium sand	30
Gray fine sand with some ½-in. thick gravel	16
Sedimentary rocks of Triassic age:	
Red shale	32
Total	108

Little information is available on the thickness of the deposits in Somers, but generally they are thinnest in the area south of and in the vicinity of the village of Somers. They are thickest north of the village and in the area southeast of Somersville. Several exposures of till were noted in the vicinity of the village of Somers and well So 72 north of Somers is reported to have reached red hardpan at a depth of 38 feet. The deposits reach a maximum reported thickness of 76 feet at well So 73 northeast of Somers. Numerous dug wells, generally less than 30 feet deep, obtain satisfactory domestic supplies from ice-contact deposits in this area. No large-capacity drilled wells are known to obtain water from ice-contact deposits in the town of Somers. Ice-contact deposits however, are a potential source of moderate to large supplies, except in the extreme eastern part of the area.

OUTWASH-PLAIN, VALLEY-TRAIN, AND UNDIFFERENTIATED OUTWASH DEPOSITS

The deposits included under this heading are outwash in the sense that they consist of material that has been "washed out" by streams downstream from the main mass of the glacier. In contrast to the ice-contact deposits, outwash deposits were not laid down in contact with stagnant ice. As used in this report, valley-train deposits are long, narrow bodies of outwash confined during deposition within the walls of a valley. An outwash plain is a broader mass of outwash having the shape of a fan or broad plain. It may extend headward into bodies of ice-contact deposits or its headward end may have been in contact with the terminus of the retreating ice front.

Bodies of outwash deposits not readily assigned to either of the above groups and whose origins are not clearly understood are termed undifferentiated outwash in this report and are shown separately on plate 1. Included in this general category but not shown because they do not crop out are several disconnected bodies of buried outwash deposits in the former channel of the Connecticut River. The character and water-bearing properties of the buried outwash are discussed separately.

GENERAL CHARACTER AND EXTENT

All the outwash deposits named above except the buried outwash are similar in composition. They consist of well-sorted beds of sand and silt containing some pebble gravel. The proportion of sand to the other grain sizes is larger than in ice-contact and delta deposits but the sand is generally finer; fine sand predominates. The materials are coarsest in the direction of their source, and therefore individual deposits are coarsest along the valley sides and at their headward ends. Individual beds are continuous over larger areas than in most ice-contact deposits.

Outwash-plain and valley-train deposits are extensive at the surface in the eastern and southern parts of the report area. They may overlie ice-contact or older deposits and are overlain by scattered alluvial, eolian, and swamp deposits.

Outwash deposits in north-central Connecticut usually occur at lower altitudes than the deposits of ice-contact origin, but they may grade into ice-contact deposits at their headward ends. Outwash deposits occur extensively along the eastern margin of the Connecticut River Lowland from Glastonbury north to Hazardville and in the center of the upper Scantic and Hockanum River valleys in Somers and Ellington (pl. 1). They also underlie and form the broad plain in Cromwell and Rocky Hill and the flat-topped terraces east of the Connecticut River in Glastonbury and Portland. The deposits in the Scantic and Hockanum River valleys are considered to be mostly valley-train deposits. Those deposits along the eastern margin of the Connecticut River valley are mostly undifferentiated outwash. The broad areas of undifferentiated outwash in the towns of Glastonbury, East Hartford and Enfield may have been deposited originally as ice-contact deposits and later reworked in part by the waters of proglacial streams which flowed across their surfaces, or may have been originated as deltaic or shore deposits of glacial Lake Hitchcock. Other small areas of undifferentiated outwash surround or occur at the south end of numerous drumlins in the area north of Hartford. An example is the small body of undifferentiated outwash that surrounds a drumlin known as Buck Hill in the north-central part of the town of Suffield. These outwash areas are probably partly of ice-contact origin and partly derived from the reworking of till and ice-contact deposits by waves. The deposits forming the broad plain and terraces in southeastern Rocky Hill, southwestern Glastonbury, and in Cromwell are considered to be outwash-plain deposits. The southeasterly extension of these deposits in Portland, where they underlie and fill the narrow "Jobs Pond depression," are valley-train deposits. These were laid down by proglacial streams flowing from the terminus of the shrinking ice front when the latter stood in the vicinity of Rocky Hill. The deposits were laid down partly in the presence of small bodies and isolated blocks of ice which had become disassociated from the thin irregular terminal zone of the main body of ice in the valley to the north. The later melting of these buried ice blocks was responsible for the pitted surfaces of the terraces in Glastonbury and Portland.

In general, the surface materials of the outwash deposits consist of medium sand and a little gravel, but the beds may show a marked change in grain size from place to place. The materials become finer in a direction away from the source and in some cases may consist mostly of silt. An example is the area of undifferentiated outwash deposits in the town of Glastonbury, where the surface deposits grade from medium sand with a little gravel near the inner or eastern edge to silt in massive beds in bluffs overlooking the Connecticut River at the southwestern edge of the area. The exposed materials in the area of outwash-plain deposits south of Rocky Hill are finer in a southerly direction, grading generally from medium sand and some gravel at the north to fine sand and a little silt at the south. Considerable gravel however, is included along the eastern edge of the outwash plain area near the contact with the bedrock valley wall. In fact, some of the coarsest gravel in the north-central Connecticut area is exposed along U.S. Route 6A at the southern end of the valley train in Portland. Most outwash deposits are pink or red as they contain a large amount of material of Triassic age. Precipitation readily recharges the surface exposures of sand and gravel of the outwash deposits.

Well logs and test borings and exposures along the Connecticut River and other large streams show that the outwash-plain and valley-train deposits are generally finer grained at depth. The deposits grade downward through beds of fine sand to beds consisting almost wholly of silt. The upper beds of coarse material are usually less than 30 feet thick. Excellent exposures showing this downward change to finer grain sizes are found in sheer bluffs 150 feet high along the Connecticut River, on both sides of the narrows below the city of Rocky Hill, and in the southeastern part of Portland. In the latter area the materials grade from very coarse gravel and boulders at the surface downward to massive beds of fine sand and silt.

The outwash-plain and valley-train deposits are as much as 225 feet thick, but the thickness varies considerably depending chiefly on the irregular topography of the buried bedrock surface and to a lesser extent on occurrence of underlying older glacial deposits. The valley-train deposits in the southeastern part of Portland are known from several well logs to be about 190 feet thick. For example, the log of well P 68 shows:

Log of drilled well P 68, 2.9 miles east of Portland

	Feet
Valley-train deposits:	
Red sand and some gravel	60
Red coarse sand and gravel	40
Red fine sand and silt	93
Crystalline rocks of pre-Triassic age:	
Gneiss and schist	35
Total	228

Well M 64 west of the city of Manchester penetrated 223 feet of undifferentiated outwash before reaching bedrock.

WATER-BEARING PROPERTIES

The outwash-plain, valley-train, and undifferentiated outwash deposits constitute extensive aquifers, only parts of which are potential sources of even moderate supplies of water. Most of the surface area of these deposits is directly underlain by sandy materials, so that there is excellent opportunity for water to percolate into the ground from the surface and recharge the ground-water bodies. These upper sand beds, because of their permeability and widespread occurrence, are capable of yielding small supplies to shallow domestic wells in those areas where topographic conditions are favorable for the development of a shallow water table. The valley-train deposits in the upper Scantic and Hockanum River basins in the towns of Somers, Ellington, and Vernon, parts of the undifferentiated outwash in South Windsor, Manchester, and East Hartford, and most of the outwash-plain deposits in Cromwell supply water to a large number of shallow domestic wells. Adequate supplies are generally obtained from dug or driven wells. In other areas, however, such as the area of outwash-plain deposits in the town of Portland and the area of undifferentiated outwash in Enfield the water table is deep and the uppermost beds of sand and gravel are nonwater bearing above the saturation zone.

Inasmuch as most of the outwash deposits are composed of medium to fine sand and silt, they generally yield only small supplies to wells. Only where coarse sand and gravel is interbedded with the finer deposits are moderate yields obtained from outwash-plain and valley-train deposits. Several shallow wells supply municipal water to residents of Cromwell from beds of gravel and sand in the valley of Dividend Brook at the northern end of the outwash plain in Cromwell. One of these, well Cr 299, is gravel packed and reportedly wields 100 gpm. A Ranney water collector (well RH 78) supplies water to an industrial plant in Rocky Hill from gravel beds in outwash-plain deposits beneath the Connecticut River. Here the beds are at the headward end of outwash-plain deposits and are in hydraulic contact with the river. They reportedly yield water to the collector at a rate of 6 mgd (million gallons per day). Similar beds at the eastern side of this same outwash body in Portland yield water to a municipal supply well, P 69, at a rate of 400 gpm. The specific capacity of this well is 31 gpm per ft. Its log is as follows:

Log of drilled well P 69, 2.7 miles northeast of Portland

	Feet
Outwash-plain deposits:	
Fine sand, silt, and clay	25
Fine sand and fine gravel	6
Fine sand and medium gravel	10
Sand and fine gravel	7
Sand and medium gravel	5
Fine sand and coarse gravel	8
Sedimentary rocks of Triassic age:	
Dark-red coarse gravel	5
Total	66

In the area of undifferentiated outwash in Manchester, a gravel-packed irrigation well, M 57, yields 250 gpm from medium to fine sand and has a specific capacity of 10 gpm per ft. A municipal supply well, well V 2, of gravel-packed construction, yields 125 gpm from coarse-grained valley-train deposits in the town of Vernon. No large-capacity wells are known to obtain water from undifferentiated outwash and valley-train deposits in the northern part of the report area.

BURIED OUTWASH DEPOSITS IN THE PREGLACIAL CHANNEL OF THE CONNECTICUT RIVER

GENERAL CHARACTER AND EXTENT

Buried outwash deposits are discussed separately from the other outwash deposits because special problems arise from the development of their water supplies. These deposits are of uncertain origin and form because they do not crop out and because they have been penetrated by only a few wells. They are termed "outwash," in the absence of other evidence to the contrary, to denote a presumed mode of origin based on the large amount of fine-grained material present. However, the materials may be ice-contact deposits or, less probably, deposits of loose till.

The age of the buried outwash deposits is Pleistocene, but their relation to ice-contact and other outwash deposits is not known. They are older than the lacustrine deposits, which they underlie, and probably are younger than the ground-moraine deposits.

Although the location of the deposits is known only from wells or test borings, their general extent is suggested by the bedrock valleys shown on plate 2. The deposits occur in the center of the bedrock valleys in East Hartford, in East Windsor west of Windsorville and east of Warehouse Point, and in Enfield west of Hazardville. They are usually found at the base of lacustrine deposits, as shown in the following log of well EH 37 at East Hartford.

Driller's log of well EH 37, Oakland Avenue, East Hartford

	Feet
Glaciolacustrine deposits:	
Sand	25
Gray clay	125
Red clay	25
Fine sand and silt	45
Buried outwash deposits:	
Water-bearing sand	20
Gravel and broken stone	1
Total	241

At a few places, however, buried outwash is included within the lacustrine deposits, as shown in the following log of well EH 19.

Driller's log of well EH 19, South Main Street, East Hartford

	Feet
Glaciolacustrine deposits:	
Fine sand	25
Coarse sand and some gravel	5
Gray and red varved clay	225
Buried outwash deposits:	
Fine gravel and sand	10
Glaciolacustrine deposits:	
Red clay	22
Buried outwash deposits:	
Gravel, sand, and silt	8
Sedimentary rocks of Triassic age:	
Red sandstone	593
Total	888

Little is known of the character of the buried outwash deposits, because the records of most wells which have penetrated them lack sufficient detail to be of much assistance and few samples have been available for examination. These logs and other available records indicate considerable variation in grain size and degree of sorting. Generally they consist of reddish-brown sand and gravel intermixed with varying amounts of silt and occur in discontinuous masses or lenses of varying size and extent. Individual lenses range in thickness from 1 foot to a maximum of 20 feet. Most of the productive beds are at least 5 feet thick.

WATER-BEARING PROPERTIES

Little is known of the water-yielding capacity of the buried outwash deposits, but they may be a potential source of water and should not be overlooked when drilling. The total storage capacity of the deposits probably is limited because they are commonly less than 20 feet thick. The permeability is generally low, as many wells are reported to penetrate buried outwash consisting of a large proportion of fine sand and silt. A number of domestic wells penetrating deeply buried outwash materials reportedly range in yield from 7 to 30 gpm. Only two large-capacity wells (EH 19 and EH 37) are known to obtain water from these deposits. They yield 250 gpm and 500 gpm, respectively. Much more information is needed on the perennial yield of the large-yielding deposits. Problems in the development of large supplies concern the extent of the aquifer and the source of recharge to the ground-water body. If the area of outwash is limited, as the available data seem to indicate, or if the overlying clay of lacustrine origin limits recharge to the body, the included water may be "mined out" in a short period of time.

GLACIOLACUSTRINE AND ASSOCIATED DELTA DEPOSITS

The glaciolacustrine and deltaic deposits are widely distributed in north-central Connecticut. The glaciolacustrine deposits are the bottom and shore deposits of glacial Lake Hitchcock and the delta deposits were formed by tributary streams entering the lake.

GENERAL CHARACTER AND EXTENT OF THE GLACIOLACUSTRINE DEPOSITS

The bottom and shore deposits include the Hartford clay of Flint (1933), silt, and overlying sand (Flint, 1933, p. 970–975). In this report they are divided into a lower clay and silt unit and an upper sand unit. The lower unit consists uniformly of gray and red varved clay and silt deposited as rock flour in an extensive open lake believed by Loughlin (1905) and Flint (1933, 1953) to have been formed and controlled by a temporary dam of glacial debris and ice in the Rocky Hill area. The base of the clay unconformably overlies Pleistocene till or buried outwash, or, in their absence, it may lie directly upon the bedrock surface. Except where exposed locally by erosion, silt and clay are overlain by the upper sand unit or by deltaic deposits. The clay and silt may grade upward into the overlying sand unit; in a few places, it is unconformably overlain by the sand unit. In these places the upper clay beds are often truncated and eroded. Where the contact is gradational the sand unit probably is sediment from the delta and shore areas that was carried out into deeper water and settled out as lake-bottom deposits. Where the beds are unconformable, the sand unit probably is of fluvial origin, having been laid down as stream-terrace deposits by braiding streams that flowed across the lake bottom after the waters were drained. Because these stream-terrace sands usually are the original lake-bottom sediments that have been reworked and redistributed, and because their physical and water-bearing properties are not unlike those of the original lake-bottom sands, they are considered as lake-bottom or lacustrine deposits and are mapped as such on plate 1. They form the surface deposits over a large part of the lowland area of north-central Connecticut. The lacustrine deposits may rest against glaciofluvial deposits along the borders of the Connecticut River Lowland.

Lake Hitchcock deposits are confined within the shorelines of the former lake. Owing to crustal upwarping, the shoreline now appears to rise northward from an altitude of about 135 feet at Hartford to 220 feet at the Massachusetts border. Excellent exposures of the varved clays are present in several clay pits in South Windsor. The clays are also well exposed in bluffs facing the Connecticut River and along the deeply eroded sides of the Farmington and Scantic Rivers.

From their relation with adjacent formations, the lacustrine deposits are considered of late Pleistocene age. The deposits, however, are slightly younger than the ice-conact deposits, which Flint believes to be of Cary age, and they may belong to the Cary substage of the late Wisconsin. Based on evidence derived from radiocarbon dating, Flint (1956, p. 277–278) concluded that Lake Hitchcock was still in existence about 10,700 years ago, a time in reasonable agreement with Cary events in the Great Lakes region. A tentative age of 18,000 years (pre-Cary), however, was obtained by Urry (1948) from the radium content of a clay-silt varve taken from a pit in South Windsor.

Well logs and other borings show that the lower part of the lacustrine deposits at many localities consists of varved clay and silt having a distinct red color, not unlike the color of the varved clay and silt exposed in the vicinity of Berlin, Conn., 2 miles southwest of the area. The red clay occurs mostly in the deeper parts of the buried valley but is exposed locally in north-central Connecticut in an area in the central part of the town of Wethersfield and along the Mattabesett River in Cromwell. Logs of some wells and test holes indicate that the gray clay grades downward into red clay, and that the color change takes place at a much lower elevation in the deeper part than near the sides of the valley. This relation suggests a gradual change in the source of sediments from local red Triassic rocks to more distant crystalline rocks. In contrast, however, some records indicate that the color change is abrupt, and at one place a layer of gravel was penetrated between the gray and red clay. This contrast indicates that the upper surface of the red clay is an erosion surface and that the red clay is older than the gray clay.

The upper sand unit of the glaciolacustrine deposits consists largely of fine to medium sand and silt, and includes subordinate amounts of coarse sand and, rarely, layers of pebble gravel. The lower part is mostly silt but the constituents become coarser in the upper part of the zone. A thin layer of gravel, about an inch or two in thickness, occurs locally at the base of the deposit where it lies on an eroded surface cut on varved clay. The sand is usually well sorted and shows well-defined crossbedding. It is pale yellowish brown because the mineral grains were derived mostly from crystalline rocks. Flakes of mica were conspicuous in most of the samples. Generally the unit is uniform in lithology.

The lacustrine deposits in north-central Connecticut range from zero to more than 250 feet thick. The thickness varies considerably from place to place, depending upon the elevation of the underlying bedrock surface. The lacustine deposits are thinnest where they lie on the side of buried ridges of bedrock and are thickest where they lie in buried channels or depressions in the rock surface (pl. 3). Well EH 55 in East Hartford, penetrated about 255 feet of lacustrine deposits before entering bedrock. This well is near the center of the deepest part of the buried channel and is in an area where 50 feet of the clay may already have been eroded (Flint, 1933, p. 972). The thickness of the upper sand unit rarely exceeds 30 feet, although in places it may be thicker where it grades into the foreset beds of a delta.

WATER-BEARING PROPERTIES OF THE GLACIOLACUSTRINE DEPOSITS

The glaciolacustrine deposits contain a large proportion of fine-grained material which does not yield water readily. No wells are known to obtain water from the clay. In the shoreline areas of the former lake, however, beds or lenses of sand or gravel interbedded with the clay may yield as much as 100 gpm. Over most of the lowland area, the clay and silt is a nearly impermeable layer that restricts the vertical movement of water. Where the clay underlies the upper sand unit or deltaic deposits, it retards the downward movement of water and a shallow body of ground water occurs in the overlying deposit. The clay unit separates ground water in the upper sand unit and deltaic deposits from the aquifers in the buried outwash deposit. Small springs occur where the contact of the clay with the overlying sand is exposed in a gully, stream channel, or clay pit. The clay also confines the water in the underlying buried outwash, till, and bedrock under artesian or semiartesian conditions, but only few wells are known to flow.

Because of its wide extent and generally permeable nature, the upper sand unit of the glaciolacustrine deposits absorbs and transmits large quantities of water from precipitation. The total storage capacity of the sand is limited because the saturated part is commonly not more than 20 feet thick but the sand supplies water to a number of industrial wells in the area. These wells, such as those at the Pratt & Whitney Aircraft plant in East Hartford, are usually gravel-packed, and yield on the average from 80 to 100 gpm. Pumpage at the wells is often restricted by the drawdown because the saturated thickness of the deposit rarely exceeds 20 feet. Extreme care is necessary in the construction and development of these wells to insure that fine sand and silt will not enter the screen.

GENERAL CHARACTER AND EXTENT OF THE DELTAIC DEPOSITS

The deltaic deposits were deposited at the mouths of large streams emptying into Lake Hitchcock. They consist of sand, some gravel, and silt and represent material from valley-train, ice-contact, and ground-moraine deposits that were washed out into the quiet waters of the lake. The deltaic deposits overlie bedrock, ground-moraine, or ice-contact deposits at the inner edge of the delta near its apex, and usually overlie or interfinger with glaciolacustrine deposits at the outer edge of the delta. They are overlain locally only by veneers of alluvium or eolian deposits.

Deltaic deposits in north-central Connecticut are contemporaneous with the glaciolacustrine deposits, and therefore are probably of late Wisconsin and possibly Cary age. Together with the glaciolacustrine deposits, they are the youngest of the Pleistocene deposits.

The largest delta in the area is the broad sand plain in the towns of Bloomfield, Windsor, and Windsor Locks which was formed by deposition from the waters of the glacial Farmington River (pl. 1). Other smaller deltas not shown on plate 1 occur near Hazardville, where the glacial Scantic River entered Lake Hitchcock, and near Manchester where glacial Hockanum River entered the lake. The latter delta may consist in part of outwash-plain or valley-train deposits.

The deltaic sediments are generally composed of well sorted sand and some gravel and silt. Typical foreset beds of sand with beds and lenses of pebbly gravel are capped with topset beds of coarser material. The bottomset beds are generally medium to fine sand and silt which grade outward into the typical lake-bottom sediments. The materials are coarser toward the apex of the delta or in the direction of the source of the material. In general, fine to medium sand predominates, whereas gravel is less common. The degree of sorting is generally more uniform than in ice-contact deposits, and there are fewer abrupt changes in grain size. As exposed, the deltaic deposits consist uniformly of medium to coarse sand and some gravel. Log of well W 121 is typical of wells penetrating deltaic deposits.

Log of drilled well W 121, about 4.5 miles northwest of Windsor

	Feet
Deltaic deposits:	
Coarse sand	24
Fine sand	26
Clay	10
Deltaic deposits—Continued	
Coarse sand and clay	25
Total	85

The deltas of the Farmington and Scantic Rivers are composed predominantly of materials eroded from crystalline rocks and therefore are pale yellowish brown. The materials of the Hockanum delta have a high percentage of Triassic material and are pink or red.

The thickness of the deltaic deposits depends upon their position relative to the apex of the delta and the topography of the buried bedrock surface. The deposits may range from several feet thick where the inner edges of the deltas flank till-covered bedrock slopes or the outer faces of ice-contact terraces to more than 100 feet where the deposits lie in deep valleys in the bedrock. Well W 122 in Windsor penetrated 60 feet of deltaic deposits before reaching clay.

WATER-BEARING PROPERTIES OF DELTAIC DEPOSITS

Deltaic deposits form one of the most important water-bearing units of north-central Connecticut. Because of their permeable nature and their wide distribution at the surface, these deposits afford excellent opportunities for water to percolate into the ground and recharge the ground-water bodies. Deltaic materials are generally better sorted than those of ice-contact deposits, but because they contain a smaller amount of coarse material, the average yield of wells is about the same in both types of deposits. The coarse material of deltaic deposits will yield moderately large water supplies for all types of use, and some gravel-packed wells in deltaic deposits in north-central Connecticut, well WL 4 in Windsor Locks and well W 122 in Windsor, reportedly yield as much as 400 gpm. Both these wells penetrate thin gravel beds within the deltaic deposits. A third well (WL 16, now abandoned), in the area of deltaic deposits of the Farmington River in Windsor Locks, penetrated only sand on the outer edge of the delta, but was reportedly test-pumped at a rate of 300 gpm. Wells tapping one bed would eventually draw water from all the adjoining beds because the permeable materials of the main part of a delta are interconnected.

FLOOD-PLAIN DEPOSITS

Since the end of the Pleistocene epoch, streams in north-central Connecticut have deposited a thin blanket of alluvium along parts of their reaches during floods. This material is chiefly fine sand and silt. It is the surface material within the flood plain of the Connecticut River and for a distance of 5–10 miles back from the Connecticut River along its major tributaries. It is most widely distributed along the Connecticut River, where the flood plain ranges from ¼ to 2 miles in width. The surface of the deposit ranges from about 1 foot to 25 feet above river level. The flood-plain deposits are relatively thin, ranging from nearly 0 to 15 feet in thickness. They usually overlie sand, silt, and clay of Pleistocene age. Owing to their occurrence in bottom-land areas where there are few homes, they are not utilized as a source of water. Because the flood-plain deposits are fine-grained and relatively thin, it is doubtful that they will yield more than a few gallons per minute to a well.

DUNE DEPOSITS

Sand and silt of eolian origin occur as a discontinuous veneer overlying older deposits and are probably of postglacial age. The materials were deposited by wind as dunes and as thin beds of loess. Eolian deposits are commonly present on both sides of the Connecticut River, but are more extensive on the east side. The dune deposits are shown on plate 1, but the loess is so thin and discontinuous that it is not shown on the map.

The dune deposits are composed primarily of uniform coarse to fine-yellowish-brown crossbedded quartz sand averaging 10 feet in thickness. The laminae are nearly always horizontal instead of being inclined in the direction of dune advance. The dunes curve in form and usually are elongated in a north-south direction at right angles to the westerly direction of the prevailing wind. A number of large dunes in the town of Enfield, however, are elongated in an east-west direction. The larger dunes reach elevations of 25–30 feet above the surrounding terrace, but most dunes are less than 10 feet high.

A veneer of yellowish-brown loess covers many of the earlier deposits in the Connecticut River Lowland but is not mapped. The loess consists of silt and fine sand which was deposited from dust whipped up by the wind from the terrace surfaces. It ranges in thickness from 0 to about 2 feet. It is characteristically unstratified, and the contact with the underlying deposits is sharp and well defined.

The dune deposits are extremely porous and thus receive and readily transmit water from precipitation. For the most part, however, they lie above the water table and are unsaturated. They are unimportant as a source of water supply in north-central Connecticut but they assist in rapid recharge of the underlying glaciolacustrine deposits.

SWAMP DEPOSITS

Numerous swamps occur in north-central Connecticut. They are formed chiefly in low areas along the flood plains of the major streams or on level or nearly level surfaces where the water table is close to land surface. The large swamps are generally formed in flat lands along the major streams such as the Connecticut River between Cromwell and Portland, but also are numerous in areas of high water table such as the area of glaciolacustrine deposits in the Connecticut River Lowland. The latter area is favorable to the formation of swamps because it is nearly level and the underlying clay restricts the downward movement of water.

The swamp deposits consist of partly decayed plant materials, or peat, and dark-brown to black muck rich in thoroughly decomposed vegetable matter and iron oxide. The muck consists chiefly of the fine material from local deposits that has been washed or blown into the swamp. For example, the swamps on the flood plains contain much clay, silt, and fine sand washed in by the river during floods. The deposits are usually from 1 to 10 feet thick.

Swamp deposits have low permeability and are relatively unimportant as sources of water. Because of their high organic content and the presence of iron oxide, they may be responsible for the high iron content of the ground water in underlying deposits.

GROUND WATER

GENERAL PRINCIPLES

In north-central Connecticut ground water is derived entirely from precipitation (rain and melted snow and ice) that falls on the immediate area. An inch of rain per square mile is equivalent to about 17 million gallons of water. Thus, each inch of precipitation on north-central Connecticut is equivalent to about 11 billion gallons of water, or on the basis of an average annual rainfall of 40 inches, about 440 billion gallons falls on the area per year. Only a small part of the precipitation replenishes the ground-water reservoir, however. Some of the precipitation flows directly from the land surface into streams as surface runoff, some is returned to the atmosphere by evaporation or is transpired by plants, and some percolates downward through the soil zone and recharges the ground-water body. Although the potential supply of ground water generally varies directly with the precipitation, there are other factors that control the rate of recharge. For example, if the temperature is high, as it is in summer, the rate of evaporation materially decreases the recharge. On the other hand, if the temperature is low, as it is in winter, and the soil is frozen, the downward movement of water is prevented and much of the water flows off directly into the streams. During the growing season, vegetation may take potential ground water from the soil zone or may even take water directly from the zone of saturation. The determination of the average or total annual replenishment to the ground-water reservoirs was beyond the scope of this investigation. In the Pomperaug basin, Connecticut, about 32 miles southwest from Hartford, Meinzer and Stearns (1929) estimated that about 15 inches, or 35 percent, of the annual precipitation was added to the ground-water reservoirs. Randall (1961) estimated that 31 percent of the annual precipitation in the Farmington-Granby area was added to the ground-water reservoirs.

Below a certain depth the rocks of north-central Connecticut are generally saturated with water and are said to be in the zone of saturation. The upper surface of the zone of saturation is called the water table. In general, the water table is a subdued replica of the configuration of the land surface. The water table does not remain in a stationary position but fluctuates seasonally with variations in the gain or loss of water. Because the voids in the several types of bedrock and unconsolidated deposits are interconnected in varying degrees, the bodies of included ground water are probably interconnected to some degree throughout the project area. This concept is important where there is danger of overdevelopment of ground-water supplies.

Where the material penetrated by a well is uniformly permeable, water is first found at the level of the water table, and the body of ground water is said to be under water-table conditions. Most ground water in north-central Connecticut is probably under water-table conditions. At a few places, however, the saturated zone is confined by an impermeable rock or deposit, and the water is contained under artesian pressure. The pressure causes the water to rise in the well above the level at which it was first found. Where there is a slow leakage of water through the less permeable confining materials, the water is said to be under semiartesian conditions. The imaginary surface to which artesian or semiartesian water will rise in wells is referred to as the piezometric surface. The piezometric surface may be higher or lower or may coincide with the water table in a given locality.

In north-central Connecticut artesian or semiartesian conditions probably also exist in some ground-water bodies in the consolidated bedrock. The water in many joints is confined under artesian pressure by the mass of the otherwise relatively impermeable rock. The pressure in a given joint or joint set depends upon the difference in altitude between the joint and the water table in the intake area, and upon the head loss by friction as the water moves through the joint. When a well penetrates the joint, the confining pressure is released and the water rises in the well. If the land-surface elevation at the well is lower than the elevation to which the hydrostatic pressure forces the water (piezometric level), a flowing well results. Generally, most joints are interconnected so that the water level or piezometric surface in adjacent wells is the same. This surface generally coincides with the local unconfined water table. There are places, however, where the water level in the bedrock stands lower than the water level of the saturated zone in the overlying drift, particularly where the drift consists of clay-rich till. At other places where the connection between joint sets is probably poor, the water level in adjacent wells rises to different heights.

GROUND WATER IN UPLAND AREAS

TILL-MANTLED BEDROCK

The till-mantled bedrock uplands, as discussed in the following paragraphs, include all the upland areas that extend above the level of stratified unconsolidated deposits. They refer especially to the upland underlain by crystalline rocks, but include also the ranges of traprock and the low hills underlain by sedimentary rocks in the lowland. These areas are generally overlain by ground-moraine and drumlin deposits (pls. 1 and 2).

SHAPE AND SLOPE OF THE WATER TABLE

The shape and slope of the water table are controlled by the topography, local differences in the permeability and thickness of the aquifer, and local differences in recharge and discharge. In the bedrock uplands the water table follows the topography closely because of the great relief and the low permeability of the till and bedrock which causes a greater difference in head between points of recharge and discharge. No attempt was made to prepare maps of the water table in these areas as the water-level data are inadequate to show the detailed shape of the water surface. The available data suggest that in most places the water table follows the topography approximately but lies as much as 30 feet below the surface. The angle of slope is greatest where the slope of the land surface is steepest. In general, maximum slopes are in the areas underlain by crystalline bedrock as the slope of the ground surface in these areas is generally greater than in areas underlain by beds of sandstone and shale.

DEPTH TO WATER

Ground water in the uplands is contained in both the till and the underlying bedrock. In general, the two rocks are in hydraulic continuity and, at least under static conditions, the included ground waters appear to form a single water body. The upper surface of the water body is generally at shallow depths and is under water-table conditions in most areas. The depth to water measured in dug wells penetrating till and in drilled wells penetrating bedrock ranges from a foot or two to a little more than 40 feet below the land surface, and averages about 20 feet. The water table intersects or is close to the land surface in and near numerous swamps on the eastern upland.

In a few areas, notably where the bedrock has a thick cover of till, thin discontinuous zones of saturation occur in the till above the main water table in the underlying bedrock. The low permeability of some parts of the till retards the downward percolation of water to the bedrock, and a body of perched water is thus formed in the till.

RECHARGE, MOVEMENT, AND DISCHARGE

Recharge in the uplands is governed chiefly by the amount and intensity of precipitation, the permeability of the soil and water-bearing deposits, the soil-moisture content, the topography, and the seasonal changes in evaporation and transpiration. The precipitation and the permeability of the soil and underlying rocks are probably the most important factors governing recharge.

The water-transmitting capacity of the surface deposits determines the maximum rate at which water from precipitation may be transmitted down to the water table. The water table lies within the ground moraine in most upland areas so that recharge is governed primarily by water percolating through the soils and subsoils. The permeability of the material is highly variable because the composition of the till is highly variable. In the clayey and silty material, which are most prevalent in the ground moraine derived from sedimentary rocks, the interstitial openings are minute and considerable water is retained by molecular attraction. In the ground moraine derived from the crystalline rocks, the percentage of coarse material through which water may move relatively easily is larger, as the deposits are more permeable, and larger amounts of water are therefore transmitted to the zone of saturation.

Water in the uplands moves from points of recharge in inter-stream areas to points of discharge in the valleys and streams. The pattern of flow, however, is much less uniform than in most other areas because the movement is in many directions and at different but generally slow rates in the ground-moraine deposits and at slow rates along fractures and openings along bedding planes in the bedrock. Most of the circulation of ground water in the bedrock is in the upper few hundred feet, where fractures and other openings are common.

Discharge from the upland areas takes place mostly through springs and seeps into streams and swamps, by evaporation and transpiration, and by pumping from wells. The amount of discharge from springs and seeps varies seasonally with changes in slope of the water table, which fluctuates in response to changes in recharge and discharge. The discharge probably reaches a maximum in the early spring before the vegetation begins to use water and is at a minimum in the late fall.

Ground water may move into the roots of plants directly from the zone of saturation or from the capillary fringe directly above. It is discharged from the plants by transpiration. Some water may be brought to the land surface by capillary action and discharged by evaporation. Most of the discharge of ground water by transpiration in the uplands occurs where the depth to water is less than 10 feet, and most of the discharge by evaporation occurs where the depth to water is less than 5 feet.

The total amount of water that is discharged by wells is relatively small in the upland area. Because the till and the bedrock are low-yielding aquifers, most wells are of small capacity and furnish water for domestic and stock use. It is estimated that the withdrawal for domestic use may average about 14 million gallons per square mile per year in this area.

GROUND WATER IN LOWLAND AND VALLEY AREAS

TRACTS OF OUTWASH DEPOSITS

The tracts of outwash deposits referred to in this section of the report include the ice-contact deposits, outwash-plain and valley-train deposits, and the undifferentiated outwash deposits. They occur mostly along the eastern part of the lowland area, have a relatively level surface expression, and consist mostly of sand, silt, and gravel. Their distribution is shown on plate 1.

SHAPE AND SLOPE OF THE WATER TABLE

The ground water in tracts of outwash deposits is probably a single water body that occurs more or less continuously throughout the outwash. Except for several small scattered areas, these tracts are interconnected either in surface exposures or at depth. This ground-water body also is continuous with that in the adjacent till-mantled bedrock uplands.

The shape of the water table in most outwash tracts has not been determined accurately owing to a lack of a sufficient number of observation points. Under natural conditions the water table is assumed to have a gentle uniform slope toward points of discharge such as springs and stream beds. Thus the ground-water body contributes water to the stream and maintains its dry-weather flow. The slope is steepest in the vicinity of points of discharge.

DEPTH TO WATER

The water body in tracts of outwash deposits is generally shallow and is unconfined in most places. The depth to water is related to the relief, which controls the occurrence of ground-water runoff. The depth ranges from less than a foot below land surface near swampy areas or stream banks to more than 100 feet in outwash that is deeply dissected by stream erosion or is close to steep ice-contact faces. For example, the outwash underlying the upper valleys of Broad Brook and the Hockanum and Scantic Rivers in Somers and Ellington has a low relief and is very poorly drained. The deposits are almost completely saturated, as indicated by the large number of sizeable swamps in the area, and also by the shallow depth to water in most wells. For example, the water level in well So 43 was reportedly 7½ feet below the surface and that in well El 52 averaged about 17 feet below the land surface for the period of measurement. In contrast to this area, the valley-train deposits in the Jobs Pond area of eastern Portland are pitted with numerous ice-block depressions and flanked on the south by a steep erosional face. Ground-water underflow to the south is relatively easy, and as a result the water table is generally deep; in some places it is about 100 feet below the land surface. The water levels in wells P 53 and P 66 were reportedly 97 and 58 feet below land surface in 1948 and 1952, respectively. The altitude of the water surface in the large undrained depression that encloses Jobs Pond and in a smaller depression about half a mile to the southeast of Jobs Pond indicates that the water table slopes southeastward about 10 feet in half a mile.

RECHARGE, MOVEMENT, AND DISCHARGE

Recharge to the ground-water reservoirs in tracts of outwash deposits is governed by the same principles as described in the section dealing with the till-mantled bedrock uplands. Owing to the relatively high permeability of the deposits and the low relief, however, the rate of recharge from precipitation is probably much higher than in upland areas. A measure of the permeability of the outwash may be obtained from the previously mentioned percolation tests in Portland (p. 54), which indicate an average decline in water level in test pits to be about 25 inches per hour, a rate that is about six times faster than in ground moraine. Streams draining outwash tracts are much less flashy than those draining till-covered areas. This fact indicates that the outwash absorbs a greater amount of precipitation and thus permits less overland runoff. Generally, recharge is largest in the early winter and early spring when evapotranspiration losses are low. It is at a minimum during the growing season when evapotranspiration losses are large.

Ground water moves in the general direction of the slope of the water table from areas of recharge to areas of discharge. Thus, in tracts of outwash deposits, the water moves generally toward the nearest stream or spring. It also moves down the valley beneath areas of thick valley fill, discharging at some lower point. For example, underflow moves southeastward through the valley fill in the Jobs Pond area in eastern Portland, as indicated by the slope of the water table in this area and the absence of any streams draining the outwash deposits. It discharges to the Connecticut River.

Ground water is discharged from the outwash deposits by evapotranspiration, by seepage into streams and springs, and by pumpage from wells. The discharge into streams takes place more uniformly than in the till-covered uplands, as shown by relatively constant base flow of most streams draining areas of outwash. Discharge of water from the outwash deposits via springs probably accounts for a larger percentage of the total discharge than do any of the other aquifers owing to the prevalence of abrupt slopes—a condition favorable to the establishment of springs. Numerous springs were noted along the base of the outer slopes of kames, kame terraces, and kame plains, the slopes of the undrained depressions, and trenched outwash deposits.

The pumpage from wells tapping tracts of outwash deposits is several million gallons per day. Wells of the Manchester Water Co. and the Manchester, Cromwell, and Portland Water Departments as well as several industrial and irrigation wells are screened in the deposits of outwash. Most of this water, after use, is piped into surface streams as sewerage.

BURIED OUTWASH DEPOSITS IN THE PREGLACIAL CHANNEL OF THE CONNECTICUT RIVER

HYDROSTATIC HEAD

Ground water contained in the buried outwash deposits probably occurs in one or more water bodies separated from the ground water contained in the upper sand unit of the overlying lacustrine deposits. Scanty evidence suggests that the water in the buried outwash is confined and, at least locally, has a hydrostatic head that is lower than the head of the unconfined water above. For example, in East Hartford the water level in well EH 1 screened in the upper sand unit was reported to be about 4 feet below land surface, whereas the measured water level in well EH 37, which taps the buried sand and gravel beneath the same area, was 35 feet below the surface on the same day. In East Windsor the water level in three wells, penetrating the buried sand and gravel, ranged from 49 to 58 feet lower than the water level in the overlying lacustrine sand. No information is available on the seasonal or long-term fluctuations of the water level in the buried outwash.

RECHARGE, MOVEMENT, AND DISCHARGE

Recharge to the aquifers in the buried outwash may come from two possible sources: (1) water derived from precipitation on distant areas of outcrop which may move downward along the surface of the buried bedrock through interconnected lenses of sand and gravel; and (2) water which may move directly downward, but at a very slow rate, through the overlying thick clay. The clay has a low permeability, as indicated by the large difference in head of water above and below the clay, but some water probably passes slowly through the clay under the influence of the downward gradient. A small amount of data on the shape of the piezometric surface of the water body in the buried outwash in East Windsor suggests that some recharge takes place downward through the clay. The reported static water levels at wells EW 6, EW 7, and EW 10 show that the water surface slopes to the south. This evidence indicates that recharge is from the north and that movement is to the south rather than from the sides of the valley toward the center. The fact that the altitude of the water surface is above the level of water in the nearby Scantic River indicates that the river is not the source of recharge. Furthermore, the chemical analyses of water from wells EW 6 and EW 10 (see table 4) show a high concentration of dissolved constituents, and particularly significant is the higher concentration of sodium than calcium. These data suggest slow downward percolation accompanied by base exchange. The outwash deposits probably recharge the underlying bedrock because water levels recorded in a few drilled wells penetrating bedrock are lower than the levels recorded in the buried outwash.

Natural discharge is known to occur only through downward percolation into the underlying bedrock.

GLACIOLACUSTRINE AND ASSOCIATED DELTA DEPOSITS

Ground water in the glaciolacustrine and associated delta deposits in north-central Connecticut occurs largely in water bodies. These bodies have been separated from one another by streams which have eroded through the water-bearing sand beds into the underlying clay, thus isolating one ground-water body from another. Ground water is contained in most of the delta deposits and in the upper sand unit of the glaciolacustrine deposits. Some water is contained in the underlying clay unit, but due to the low permeability of the clay, it is not available to wells. The clay acts as a relatively impermeable barrier to retard vertical movement of the water and forms a base for the shallow ground-water body in the overlying sand unit.

SHAPE AND SLOPE OF THE WATER TABLE

Because of the flatness of the lowland, the water table in areas of glaciolacustrine and delta deposits is more nearly a plane surface than in other areas in north-central Connecticut. Water from precipitation is able to move freely through the deposits owing to their high permeability. Thus, the upper surface of the water-table body probably is nearly level in most of the lowlands. Locally, the water table slopes gently toward points of discharge, such as perennial streams. Local irregularities in the water table may be caused by irregularities in the land surface or, in the area of lacustrine deposits, by irregularities in the surface of the clay, but the shape of the water table in these areas has not been determined accurately.

DEPTH TO WATER

The bodies of ground water are shallow and are everywhere unconfined. The depth to water ranges from zero in swamps or along stream banks to about 30 feet below the land surface in areas underlain by delta deposits. Owing to the low relief and the generally impermeable nature of the underlying clay unit, the deposits are poorly drained and are saturated for most of their thickness.

RECHARGE, MOVEMENT, AND DISCHARGE

Recharge to the ground-water bodies in the glaciolacustrine and associated delta deposits is mostly from precipitation; a very small amount may be from downward percolation of irrigation water pumped from ponds and streams. Owing to the very high permeability of the deposits and the flatness of the land surface, the rate of infiltration of water from precipitation is very high. Probably much more than half the rainfall infiltrates to recharge the ground-water body. Most of the irrigated tobacco acreage is in areas underlain by glaciolacustrine and delta deposits. The recharge from this irrigation is probably very small or negligible, however, because most of the irrigation water is applied during dry periods by sprinklers. The amount applied, therefore, is probably sufficient only for soil moisture needs, and little or no excess is available for percolation below the root zone.

Ground water is discharged from these deposits by evapotranspiration, by seepage into streams and springs, by slow downward percolation into the clay unit, and by pumpage from wells. The conditions controlling discharge are similar to those in tracts of outwash deposits except that the rate of discharge may be slower owing to the low slope of the water table. Discharge by springs is probably higher than in most other areas in north-central Connecticut. For example, the headwaters of most streams in the area of the Farmington River delta originate in a well-defined spring, and as previously mentioned, numerous contact springs can be noted along the slopes of entrenched streambeds. The amount of water discharged through downward percolation to the clay and underlying aquifers in the buried outwash is small and depends upon the difference in the head between the water levels in the sand and the underlying water-bearing units.

FLUCTUATIONS AND TRENDS OF WATER LEVELS

Changes in water levels reflect changes in recharge, discharge, and storage in an aquifer. When the inflow or recharge to the ground-water reservoir exceeds the outflow or discharge, the water table rises; conversely, when the outflow exceeds the inflow, the water table declines. The principal factors that influence the fluctuation of water levels in north-central Connecticut are variations in the amount and rate of precipitation and evapotranspiration, the permeability of the water-bearing formation, and the withdrawal of ground water by pumping.

Fluctuations of water levels in four observation wells are shown in figure 3. Wells EH 21 and SW 64 are dug wells completed in the upper sand unit of the lacustrine deposits in the lowland area of the valley. Periodic water-level measurements were made during the period 1935–39, and also since the late 1940's. Well M 84 penetrates ice-contact deposits in Manchester. It has been measured periodically since 1948. Well RH 44 in Rocky Hill is a drilled well penetrating sandstone and shale of Triassic age. Periodic measurements of water level at this well have been made since 1954. The water levels in all observation wells show natural fluctuations; they are not influenced by pumping. The graphs show that in general the fluctuations are seasonal. During the period of record there has been little overall net change in water levels. This is true for the period 1946–56 and for the period from 1935–56. In general, the levels rise during the nongrowing season, when losses by evaporation and transpiration are low, and decline during the growing season, when such losses are high. As precipitation is more or less uniform throughout the year and most depths to water are relatively small, the variation in rate of evapotranspiration probably is the most important factor influencing the normal seasonal pattern of fluctuation of water levels. Peak levels are usually reached in April or May, but occasionally occur as late as June or July; the yearly low levels occur typically in No-

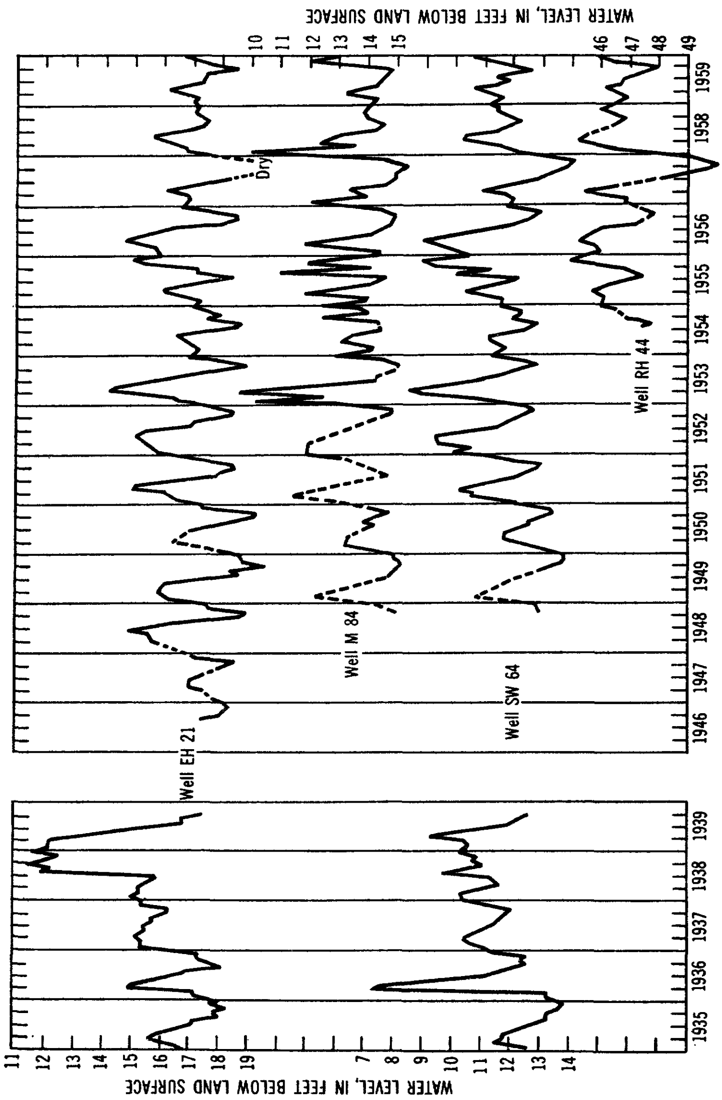


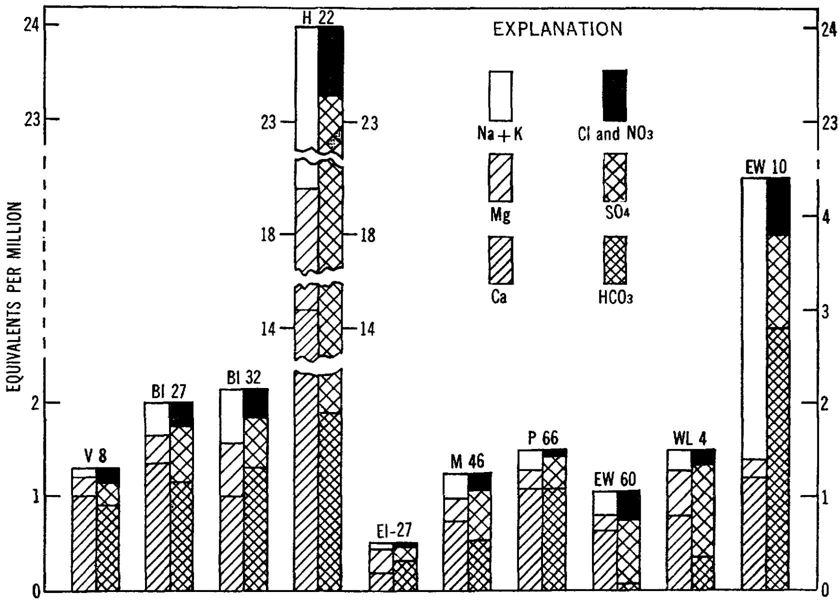
FIGURE 3.—Hydrographs of water levels in wells EH 21, M 84, RH 44, and SW 64.

vember. The typical or normal trend is clearly illustrated by the graph of the water level in well SW 64 for the period of 1950–53. Abnormal changes in the pattern of fluctuations are usually due to unusual changes in the rate and amount of precipitation. This type of fluctuation is illustrated in the graph of the water level in well SW 64 for 1954 and 1955. In 1954, the normal seasonal rise early in the year did not occur because of a marked deficiency in precipitation during January and February. Furthermore, the normal decline during the summer and early fall was halted and even reversed much earlier than usual by recharge from heavy rains accompanying the passage of two tropical hurricanes. Similarly, in 1955 there was an even more dramatic reversal of the normal seasonal trend, when heavy rains from two hurricanes caused severe flooding and marked rises in water level in August, October, and November.

The observation wells in north-central Connecticut are so few in number that it is not known if they are representative. The hydrographs in figure 3 show that the average range in fluctuation from the high in late spring to the low in late fall is similar for wells in bedrock and for those in stratified drift in valley areas. The range depends in large part on the permeability of the aquifer and the topographic location of the well. Records at observation wells in nearby areas show that the average range of water levels in wells completed in till is generally much greater than those completed either in bedrock or in stratified glacial drift. This difference seems to be largely due to the difference in permeability and partly due to the topographic situation, as wells in till are commonly in areas of high relief whereas wells in stratified drift are in the relatively flat valley areas.

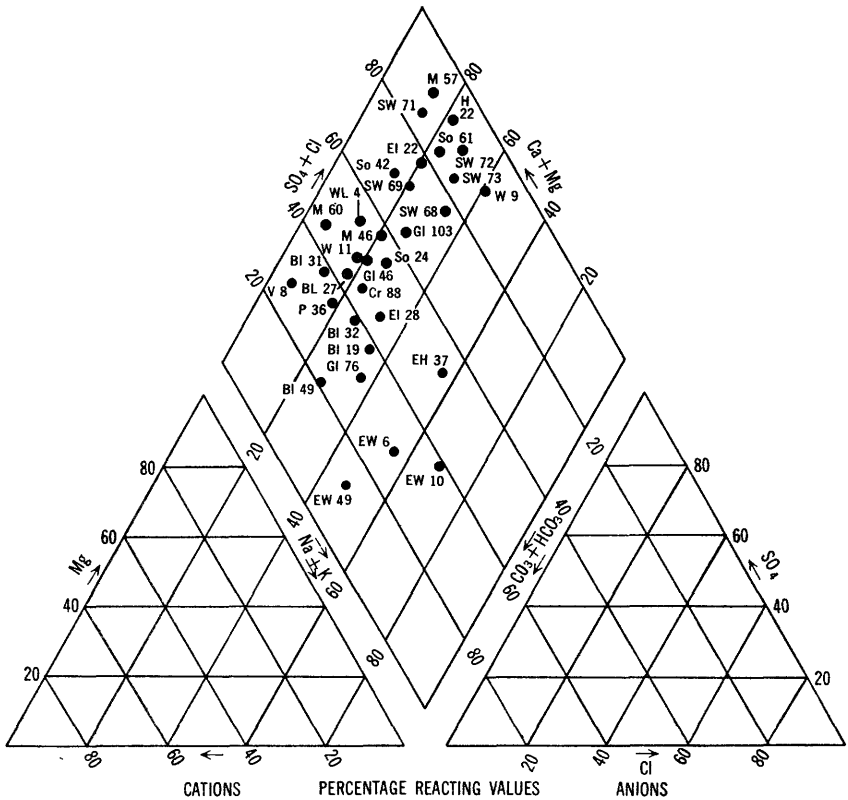
QUALITY OF WATER

The chemical character of the ground water in north-central Connecticut is indicated by the data in table 4 and is shown graphically in figures 4 and 5. Forty-three samples of water were collected from representative wells to obtain general information on the quality of ground water from the principal water-bearing formations and were analyzed by the U.S. Geological Survey. In addition, a few partial analyses of ground water in the area were obtained from the files of the Connecticut State Department of Health, Bureau of Sanitary Engineering, and from several private laboratories.



Well	*Water-bearing unit*
Bl 27	Triassic basalt.
Bl 32	Triassic sandstone and shale.
El 27	Pleistocene till (ground-moraine deposits).
EW 10	Pleistocene gravel (buried outwash deposits).
EW 60	Pleistocene sand and gravel (glacio-lacustrine deposits).
H 22	Triassic sandstone.
M 46	Pleistocene sand and gravel (ice-contact deposits).
P 66	Pleistocene sand and gravel (valley-train deposits).
V 8	Pre-Triassic crystalline rocks.
WL 4	Pleistocene sand (delta deposits).

FIGURE 4.—Typical chemical character of water from the principal water-bearing units.



Well	Water-bearing unit	Well	Water-bearing unit
Bl 19	Pleistocene sand (delta deposits).	M 57	Pleistocene sand and gravel (ice-contact deposits).
Bl 27	Triassic basalt.	M 60	Triassic sandstone.
Bl 31	Do.	P 36	Pre-Triassic crystalline rocks.
Bl 32	Triassic sandstone and shale.	So 24	Do.
Bl 49	Pleistocene sand and gravel (delta deposits).	So 42	Pleistocene sand (ice-contact deposits).
Cr 88	Triassic basalt.	So 61	Pleistocene sand (valley-train deposits).
EH 37	Pleistocene sand and gravel (buried outwash deposits).	SW 68	Pleistocene sand (glaciolacustrine deposits).
El 22	Pleistocene till (ground-moraine deposits).	SW 69	Do.
El 28	Pre-Triassic crystalline rocks.	SW 71	Pleistocene sand and gravel (ice-contact deposits).
EW 6	Pleistocene gravel (buried outwash deposits).	SW 72	Pleistocene sand (glaciolacustrine deposits).
EW 10	Do.	SW 73	Pleistocene till (ground-moraine deposits).
EW 49	Do.	V 8	Pre-Triassic crystalline rocks.
Gl 46	Pre-Triassic crystalline rocks.	W 9	Pleistocene sand (delta deposits).
Gl 76	Do.	W 11	Do.
Gl 103	Pleistocene sand and gravel (outwash deposits).	WL 4	Do.
H 22	Triassic sandstone.		
M 46	Pleistocene sand and gravel (ice-contact deposits).		

FIGURE 5.—Water-analysis diagram showing chemical character of water from the principal water-bearing units.

TABLE 4.—*Chemical analyses of water, in parts per million, from typical wells in north-central Connecticut*

[Analyses by U.S. Geol. Survey, Quality of Water Branch, except as indicated. Well numbers correspond to those shown on pl. 1.]

Well	Depth (feet)	Water-bearing unit	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Zinc (Zn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH
Bl 19	47	Pleistocene sand	May 21, 1953	----	9.4	0.11	0.06	0.00	12	1.3	8.6		----	40	14	2.1	0.1	3.5	0.5	71	35	2	97.3	7.4
Bl 23	63	Triassic sandstone	June 17, 1915	----	10	1.5	----	----	95	26	----	----	----	75	19	245	----	----	----	722	387	----	----	----
Bl 27	210	Triassic basalt	May 21, 1953	53	19	.13	.03	1.3	27	3.5	8.0		----	69	30	6.6	.3	4.0	.0	154	82	25	202	7.2
Bl 31	96	do	May 27, 1953	49	11	.40	.03	.00	28	15	7.8		----	112	27	6.8	.0	24	.0	184	132	40	312	7.4
Bl 32	609	Triassic sandstone and shale	Mar. 26, 1954	52	17	.24	.00	----	20	6.8	12	1.1	.2	80	26	3.9	.0	12	.0	145	77	14	201	7.8
Bl 49	66	Pleistocene sand and gravel	Mar. 30, 1954	55	16	.10	.01	----	20	13	16	1.0	.3	135	27	1.9	.3	.4	.0	156	104	0	250	7.9
Cr 88	60	Triassic basalt	Apr. 3, 1954	----	19	.16	.00	----	21	5.4	7.8	3.0	.5	64	26	7.1	.1	7.9	.0	140	75	22	197	7.1
EH 37	241	Pleistocene sand and gravel	May 18, 1953	57	9.3	.06	.13	.01	30	5.6	56		----	125	87	18	.3	.2	.0	285	98	0	442	8.1
EH 41[1]	386	Triassic sandstone	Oct. 25, 1951	----	----	4.0	----	----	----	----	----	----	----	----	----	3,000	----	.0	----	----	----	----	----	----
EH 42	26	Pleistocene sand	Mar. 26, 1954	47	9.4	.25	.02	----	25	6.6	9.4	8.2	.8	15	50	7.9	.1	63	.0	201	92	80	268	6.2
EW 6	198	Pleistocene gravel	May 27, 1953	50	16	.20	.10	.00	30	5.7	55		----	187	57	3.9	.2	.3	.1	262	98	0	404	7.8
EW 10	160	do	do	52	12	.09	.04	.00	22	2.6	65		----	180	53	2.8	.2	.1	.1	249	66	0	385	7.9
EW 49	83	do	do	50	9.9	.08	.00	.00	21	4.3	29		----	142	12	2.4	.3	.9	.1	163	70	0	261	7.7
EW 57	6	Pleistocene sand and gravel	Apr. 4, 1954	48	12	.42	.97	----	28	6.8	5.9	.8	.0	41	43	5.9	.0	33	.0	167	98	64	237	7.0
EW 58	12.5	do	Mar. 30, 1954	43	6.5	.09	.05	----	18	2.4	13	11	1.0	12	46	9.9	.0	43	.0	138	55	45	210	6.5
EW 59	8.9	do	do	49	7.8	.28	.02	----	7.4	2.5	2.1	4.8	.3	3.8	32	1.9	.1	1.8	.0	67	29	26	96.7	5.4
EW 60	9	do	do	43	3.5	.15	.01	----	13	2.0	3.6	2.0	.1	5.0	31	4.7	.1	9.5	.0	79	41	37	118	6.0
El 22	21	Pleistocene till	May 20, 1953	52	6.8	.84	.08	1.0	5.5	3.0	3.2		----	9.0	21	3.5	.1	.5	.0	58	26	18	80.6	6.1
El 27	28	do	do	47	8.7	2.0	.02	.53	4.2	2.8	1.5		----	20	7.2	1.5	.1	.5	.1	44	22	6	53.5	6.5
El 28	92	Pre-Triassic crystalline rocks	do	52	14	.09	.03	.26	8.6	2.8	6.9		----	32	18	2.0	.1	.5	.0	69	33	7	90.0	6.9
Gl 46	210	do	May 18, 1953	56	13	.06	.03	.26	30	4.0	11		----	69	34	10	.0	12	.0	157	91	35	248	6.9
Gl 76	353	do	Mar. 30, 1954	55	15	.39	.01	----	6.3	1.3	3.6	1.7	.0	26	8.0	.9	.1	.8	.2	58	23	2	64.0	6.9
Gl 103	52	Pleistocene sand and gravel	May 26, 1954	----	9.4	.06	.00	----	7.6	1.6	2.8	1.5	.2	17	18	2.2	.0	3.2	.0	52	29	16	70.7	6.6
Gl 104	23	do	do	50	14	.41	.01	----	10	2.3	11	3.4	.5	15	20	18	.0	9.0	.0	101	35	23	144	6.1
H 11[2]	640	Triassic sandstone	June 10, 1942	59	----	.40	----	----	----	----	----	----	----	----	----	14	----	.2	----	1,890	415	----	----	7.3
H 1[illegible]	398	do	Mar. 3, 1938	----	----	----	----	----	233	43	121		----	86	836	40	----	.15	----	----	734	----	----	----
H 22	502	do	do	----	----	----	----	----	285	53	129		----	121	1,029	28	----	.0	----	----	930	----	----	----
M 46	60	Pleistocene sand and gravel	Apr. 5, 1954	49	13	.14	.00	----	15	3.0	5.0	1.0	.2	33	27	3.8	.0	3.5	.0	98	50	23	137	6.6
M 57	65	do	July 20, 1954	57	15	.02	.03	----	35	9.1	8.7	.6	.6	16	57	4.0	.0	86	.0	258	125	112	317	6.3
M 58	64	do	Apr. 5, 1954	48	17	.21	.01	----	33	2.7	6.3	.7	.1	90	21	5.0	.1	12	7.9	144	95	21	212	7.9
M 60	600	Triassic sandstone	Nov. 4, 1954	55	14	.08	.10	.00	27	10	2.3	.8	.1	80	31	5.6	.1	18	.1	155	109	44	233	7.8
P 36	283	Pre-Triassic crystalline rocks	June 2, 1953	52	12	.06	.02	.00	33	5.3	11		----	100	17	10	.0	16	.3	167	104	22	262	7.7
P 66	146	Pleistocene sand and gravel	May 18, 1953	50	11	.06	.00	.00	22	2.0	3.8	.7	.1	68	16	1.8	.0	1.4	.0	119	63	7	147	8.0

RH 77 [1]	94	Pleistocene sand and gravel	Apr. 19, 1949	----	----	----	----	----	----	----	----	----	----	93	------	4.2	----	.1	----	------	100	----	-----	8.0
So 24	135	Pre-Triassic crystalline rocks	May 26, 1953	52	3.6	.34	.09	1.1	20	2.6	9.6		----	46	39	3.2	.1	.3	.0	110	61	23	175	7.2
So 42	13	Pleistocene sand	do	50	16	.01	.02	.04	25	5.3	7.1		----	37	46	10	.1	8.8	.1	143	84	54	225	7.1
So 61	28	do	do	48	12	.55	.03	.00	21	3.4	9.5		----	17	18	19	.1	34	.0	133	66	52	233	6.0
SW 68	9	do	May 20, 1953	49	9.6	.13	.08	.76	16	5.1	14		----	26	50	9.0	.3	9.0	.0	140	61	40	192	5.6
SW 69	30	do	do	51	12	.24	.06	.36	8.2	3.0	4.1		----	15	19	5.0	.0	4.0	.0	77	33	20	104	6.1
SW 71	56	Pleistocene sand and gravel	July 20, 1954	51	15	.02	.00	----	42	6.6	9.1	.6	.5	28	74	3.5	.0	62	.0	259	132	109	324	6.7
SW 72	30	Pleistocene sand	Mar. 27, 1954	49	8.6	.01	.00	----	15	4.3	6.7	4.0	.6	9.0	46	8.2	.0	11	.0	114	56	48	165	6.4
SW 73	30	Pleistocene till	do	45	12	.18	.02	----	5.6	2.0	3.3	1.3	.0	6.0	18	.7	.1	7.5	.0	63	22	17	71.7	6.1
V 8	150	Pre-Triassic crystalline rocks	May 20, 1953	52	23	.02	.12	1.1	20	2.6	1.7		----	56	10	4.5	.3	2.2	.0	107	61	15	161	7.4
V 47	57	do	do	54	11	1.1	.16	.17	7.0	3.1	4.2		----	22	18	6.0	.1	2.4	.0	63	30	12	106	6.3
WH 26	118	Triassic sandstone	June 24, 1915	----	----	1.1	----	----	54	25	----	----	----	156	220	3.8	----	-----	----	500	208	----	-----	----
Wf 87 [1]	404	do	July 13, 1936	----	----	----	----	----	-----	----	----	----	----	-----	-------	17	----	.5	----	300	160	----	-----	----
W 9	9	Pleistocene sand	Mar. 30, 1954	43	4.0	.09	.02	----	4.6	1.1	3.8	1.3	.1	3.4	18	3.2	.1	2.5	.0	48	17	14	60.6	5.5
W 11	20	do	May 27, 1953	50	8.7	.03	.01	.07	26	3.8	8.3		----	63	27	4.1	.1	16	.1	147	80	29	212	7.0
WL 3	80	Pleistocene sand and gravel	Apr. 15, 1954	49	9.2	.13	.00	----	25	6.4	8.0	1.5	.2	60	47	3.4	.0	6.0	.0	137	89	40	213	7.8
WL 4	32	Pleistocene sand	do	50	9.2	.12	.00	----	16	5.8	3.4	1.3	.2	42	31	3.2	.0	5.5	.0	104	64	29	147	7.3
WL 16	68	do	July 20, 1954	52	9.5	.01	.03	----	15	6.8	2.0	.5	.2	61	13	2.8	.0	5.0	.0	88	65	15	138	7.5

[1] Analysis by the Connecticut State Department of Health.
[2] Analysis by the Bridgeport Connecticut Testing Laboratory.

The minerals in ground water in north-central Connecticut are dissolved primarily from the soils and rocks through which the water percolates and to a much lesser extent from the atmosphere. The chemical character of the water is therefore not uniform throughout the area, but varies with the chemical composition of the soils and rocks and with the rate and pattern of circulation of the ground water. Water from precipitation immediately begins to dissolve mineral matter upon entering the soil, and the longer the circulating ground water is in contact with the soil and rocks, the greater is the opportunity to dissolve mineral matter. For example, the period of time that water travels through the ground-moraine deposits in the upland areas of north-central Connecticut is probably only a few days and thus the total content of mineral matter in the ground water is correspondingly low. This low content is illustrated in figure 4 by the analysis of water from well El 27. In contrast, water from buried outwash deposits, which has traveled a greater distance than water in ground-moraine deposits and which has probably been held in the deposits longer, has a much higher mineral content. (See analysis of water from well EW 10, fig. 4.) The relation of chemical character to rock type is discussed in a later section.

CHEMICAL CONSTITUENTS IN RELATION TO USE

The chemical character of ground water governs its suitability for certain uses. The users of ground water for ordinary domestic purposes are chiefly concerned with the hardness, iron content, and pH of the water, as well as sanitary quality. Industrial users are concerned with all these characteristics and also with the content of total solids and chloride and with the temperature of the water. Users of water for irrigation are concerned with the content of total solids and the percentage of sodium. The following general discussion of these constituents has been adapted from publications of the U.S. Geological Survey.

DISSOLVED SOLIDS

The dissolved solids are the residue on evaporation of a water sample at 180° C. They consist of the mineral constituents given in table 4, usually a small quantity of organic material, and a small amount of water of hydration. Water containing less than 500 ppm (parts per million) of dissolved solids is within the permissible limit for drinking water recommended by the U.S. Public Health Service (1962). It is generally satisfactory for domestic use, except for excessive hardness or iron. Water having a dissolved-solids content of 1,000 ppm may be permissible but is likely to contain enough of certain constituents to produce a noticeable taste or to make the water unsuitable in other respects.

The dissolved solids in samples of water from north-central Connecticut ranged from 44 to 1,890 ppm. Only one sample contained more than 1,000 ppm of dissolved solids and only two samples contained more than 500 ppm. The dissolved solids in the water averaged less than 200 ppm in 80 percent of the samples, which is within the recommended limits for ordinary use.

HARDNESS

The hardness of water, which is the characteristic that is noticed by most users of ground water, is commonly recognized by the amount of soap required to form a lather. When the mineral constituents causing hardness are present in large quantities, the addition of soap to water results in the formation of a sticky, insoluble curd which is difficult to remove from containers and fabrics. Calcium and magnesium cause almost all the hardness in water and are the active agents in the formation of the scale in steam boilers and in other vessels in which water is heated or evaporated. Hardness between 50 and 150 ppm does not seriously interfere with the use of water for most purposes; however, it does slightly increase the consumption of soap, and softening is profitable for laundries or other industries using large quantities of soap. Water having a hardness in the upper part of this range will cause scale on steam boilers. Hardness of more than 150 ppm can be noticed by anyone, and if the hardness is 200 or 300 ppm, it is common practice to soften the water.

Analyses of water samples obtained from north-central Connecticut show total hardness ranging from 17 to 930 ppm. About 90 percent of the samples had a hardness of less than 150 ppm; and of these, 35 percent had a hardness of less than 50 ppm. Thus most ground water in the area does not require softening.

Table 4 shows the carbonate hardness and the noncarbonate hardness. The carbonate hardness is caused by calcium and magnesium bicarbonates and can be almost entirely removed by boiling. This type of hardness is called temporary hardness. The noncarbonate hardness is caused by calcium magnesium sulfate and chloride salts. It cannot be removed by boiling and is called permanent hardness. Most ground water in north-central Connecticut has both carbonate and noncarbonate hardness in varying amounts. Only water from buried outwash in the Connecticut River channel has no noncarbonate hardness. Carbonate hardness exceeds 50 percent of the hardness in about half of the samples analyzed, and therefore resistant scale will probably be formed on boilers and cooking utensils by the water from many wells.

IRON

Iron is another constituent that causes trouble for many users of ground water. The quantity of iron in the water varies greatly from place to place, even in the same formation. Iron in excess of 0.3 ppm commonly forms a reddish-brown precipitate when exposed to air. It sometimes stains cooking utensils, bathroom fixtures, and fabrics and is troublesome to such industries as laundering, tanning, and paper making. Occasionally when water contains excessive iron, trouble may be experienced with the growth of iron bacteria (Crenothrix) in pipes, in the casing of wells, and on other plumbing fixtures.

The iron content of 46 samples of ground water from north-central Connecticut ranges from 0.01 ppm to 2.0 ppm and averages 0.29 ppm. The iron content in 12 samples is 0.3 ppm or higher.

CHLORIDE

Chloride is dissolved in small quantities from many rock materials and is one of the principal constituents of sea water. Sewage also may contain appreciable quantities of chloride and a chloride content higher than normal for the region may be an indication of pollution. The U.S. Public Health Service drinking water standards recommend 250 ppm as the limit for chloride in drinking water. Only one of the analyses for north-central Connecticut, that for well EH 41 (table 4), exceeds this limit, although water from well Bl 23 penetrating Triassic sandstone closely approaches it. Well EH 41 was never used because of the high chloride content of the water. A number of other wells penetrating the sandstone were reported to have water of high chloride content. Most ground waters of the area are low in chloride, the average being about 7.0 ppm if the chloride content of the water in wells EH 41 and Bl 23, containing 3,000 ppm and 245 ppm respectively, is excluded. The natural chloride content of ground water is probably about 2–3 ppm, and with the few exceptions noted for Triassic sedimentary rocks, chloride contents of more than 10 ppm are probably due to contamination from an outside source such as sewage.

HYDROGEN-ION CONCENTRATION (pH)

The hydrogen-ion concentration of water, expressed as pH, is an indication of the corrosiveness of the water. The pH of a water sample is the negative logarithm of the hydrogen-ion concentration in moles per liter. Water with a pH of 7 is said to be neutral. A water having a pH of 6 has 10 times the concentration of hydrogen ions as water having a pH of 7 and is acidic. Water having a pH generally less than 7 may corrode well casings, pumping equipment, and distribution systems and may dissolve iron, zinc, copper, or lead from this equipment. The ground waters analyzed from north-central Connecticut range in pH from 5.4 to 8.1 and average 7.1. Many of the dissolved constituents in ground water in the area are those that cause a water to be alkaline. In contrast, most acid waters have a low mineral content. (See analyses data for wells EW 59 and EW 60.)

MINOR CONSTITUENTS

Minor-constituent determinations are shown in table 4. Generally, minor constituents are present in small amounts and are not significant. The fluoride content ranges from 0.0 to 0.3 ppm. Fluoride as much as 1 ppm inhibits tooth decay. Waters containing more than 1.5 ppm of fluoride are likely to produce mottled enamel on the teeth of children (Dean, 1936).

WATER FOR IRRIGATION

The suitability of water for irrigation depends mainly on the quantity of soluable salts and the ratio of the quantity of sodium to the total quantity of sodium, calcium, and magnesium. As discussed by Wilcox (1955), if the dissolved-solids content is less than 700 ppm, the water will probably not be harmful to crops; but if the concentration exceeds 2,100 ppm, there is a strong probability of damage to crops. Water containing less than 50 percent sodium is not likely to be injurious; but if it contains more than 60 percent sodium, some danger of soil impairment might limit its use for irrigation. Similarly, less than about 150 ppm of chloride is not objectionable, but more than about 350 ppm chloride is undesirable. It is difficult to adopt definite limits of water quality because the degree to which water for irrigation may be harmful is dependent upon the type of soil and crops, on the manner of use, and on the drainage.

According to the aforementioned limits, most of the ground water in north-central Connecticut can be used safely for irrigation. It should be noted, however, that water from the buried outwash deposits has a high percent of sodium normally. Also, some water from the sandstone and shale of Triassic age may be objectionable because of a high concentration of dissolved salts or a high chloride content. Two wells in the sandstone at East Hartford reportedly yielded water that had a chloride content; one of them (EH 41) yielded water whose chloride content was as high as 3,000 ppm.

TYPES OF WATER

As shown in the analyses in table 4 and the diagram in figure 5, the content of calcium and magnesium exceeds that of the alkalies in most ground water in north-central Connecticut. Only in the water samples from the buried outwash deposits does the content of sodium and potassium exceed the content of calcium and magnesium. The water ranges from the calcium bicarbonate type to the calcium sulfate type and is about equally divided between the two. The water from the buried outwash deposits is of the sodium bicarbonate type.

QUALITY IN RELATION TO WATER-BEARING FORMATIONS

The chemical character of the water from the principal water-bearing formations is summarized in figure 5 and is discussed in the following sections.

PRE-TRIASSIC CRYSTALLINE ROCKS

On the basis of the analyses of seven water samples, ground water from the preTriassic crystalline rocks is somewhat variable in composition. It is generally of the calcium bicarbonate type, and the dissolved solids content is about normal for most ground water in north-central Connecticut, ranging from 58 to 167 ppm and averaging about 60 ppm. Carbonate hardness dominates but some noncarbonate, or permanent hardness, has been noticed. The iron content was more than 0.3 ppm in three of the samples of water analyzed from pre-Triassic crystalline rocks. In addition to the possible problem of high iron content and the occasional problem of excessive hardness (calcium and magnesium content), ground water from crystalline rocks is suitable for most purposes.

TRIASSIC SEDIMENTARY ROCKS

The chemical quality of ground water from Triassic sedimentary rocks is more variable than that of any other unit. This is due mostly to the variable lithology of the rocks, which ranges from fine-grained black shale to coarse conglomerate and fanglomerate. The black shale contains pyrite, calcite layers, and calcareous concretions. The red sandstone and shale contain layers and lenses of impure limestone, and have been reported to contain cavities lined with casts of crystals of sodium chloride and gypsum. Thus, local variations in the quality of ground water probably are related to local variations in the composition of the rocks.

Figure 4 shows chemical data from two samples of water from the Triassic sandstone and shale. Water from well Bl 32 is perhaps typical of water from these rocks, whereas water from well H 22 is of local significance only, but is found in enough places to be worthy of mention. The "typical" water from Triassic sandstone and shale is based on nine analyses; it is of the calcium bicarbonate type and has a hardness generally between 50 and 150 ppm as $CaCO_3$. Carbonate hardness usually exceeds noncarbonate hardness by 50 percent. Although the rocks contain considerable iron, only rarely do problems arise concerning excess iron in the water.

Some of the local variations in the quality of water in Triassic sandstone and shale are illustrated by the analytical data for well H 22 in figure 4 and for wells H 14 and H 22 in table 4. The water is of the calcium sulfate type; it contains a high content of dissolved solids and has a hardness of 734 and 930 ppm. The content of calcium and sulfate is high in comparison to most natural ground water in north-central Connecticut. The sulfate content exceeds 85 percent of all the anions in terms of reacting values (equivalents per million). The chloride content of the two samples is also higher than the normal concentration of 2–3 ppm for ground water in northern Connecticut. Ground water having a high concentration of chloride was found in two deep wells penetrating the Triassic sandstone and shale in East Hartford, and similar occurrences have been reported elsewhere in the area. A partial analysis of the water from one of the wells in East Hartford (EH 41) showed a chloride content of 3,000 ppm. The wells either penetrated a cavity or opening in the rock which contained salt crystals or struck connate water of a former inland sea. In any case, the high chloride content is not caused by salt-water contamination from the Atlantic Ocean.

Another fairly common local problem is the hydrogen sulfide odor and taste in water from several places in the western parts of the towns of Cromwell, Rocky Hill, and Bloomfield. The rocks in these areas, which belong to the Meriden formation of Krynine (1950), consist of beds of black shale. Water of poor quality is commonly found in black shale immediately below the upper trap sheet of the Meriden formation. The sulfurous gases probably originate from the carbonaceous material and iron sulfide minerals included in the beds. The concentration of gases is low in many waters, as the odor and taste cease within a short time after the waters stand in the open, but in some waters a whitish precipitate remains on the sides of containers.

TRIASSIC BASALT

Ground water from the basalt is uniform in composition according to the samples analyzed. It is of the calcium bicarbonate type, and carbonate hardness predominates. The hardness averages about 100 ppm and the total solids 160 ppm, which is slightly higher than average for all the ground waters sampled. The iron content was more than 0.3 ppm in one of the samples.

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GROUND-MORAINE DEPOSITS

Water in ground moraine has a lower dissolved solids content than that in any other type of rock. The samples, however, are from one area in north-central Connecticut and may not be representative of all ground water from till. In fact, it is probable that the water in the ground moraine derived principally from Triassic rock contains a higher dissolved solids content, contains more calcium and magnesium and is harder. The available analyses indicate that the dissolved-solids content averages 51 ppm and the hardness 24 ppm. The iron content of both analyses is high, but it may be due partly to rusting of piping and pumping equipment. The waters are acidic and corrosive, however, and thus may liberate iron from the surrounding rock.

ICE-CONTACT, VALLEY-TRAIN, AND OUTWASH-PLAIN DEPOSITS

The samples of ground water from ice-contact, valley-train and outwash-plain deposits are similar in composition. The composition of the water ranges from calcium bicarbonate to calcium sulfate type, the dissolved-solids content ranges from 52 to 259 ppm, and hardness ranges from 22 to 132 ppm. The iron content is usually low, and the water is suitable for most purposes. The relatively high content of nitrate and sulfate in water from wells M 57 and SW 71 may be due to the location of the wells in tobacco fields which are heavily fertilized and dusted with sulfurous compounds during the growing season.

LACUSTRINE AND ASSOCIATED DELTA DEPOSITS

Ground water from lacustrine and associated delta deposits is fairly uniform in composition and entirely suitable for most purposes. It ranges in dissolved-solids content from 67 to 156 ppm and in hardness from 29 to 104 ppm. The iron content usually is low. The water differs slightly from most other ground waters of the area in the higher ratio of sulfate to bicarbonate, and most of the water is the calcuim sulfate type. The noncarbonate hardness is therefore fairly high, ranging from 20 to 80 ppm.

BURIED OUTWASH DEPOSITS

Water from buried outwash deposits is perhaps the most unusual of any of the waters sampled in north-central Connecticut because the water is of the sodium bicarbonate type and has a relatively high content of sodium. In three of the four samples analyzed, sodium constituted more than 50 percent of the cations. The dissolved solids are relatively high, averaging 240 ppm; the hardness of the water is relatively low, averaging 66 ppm as $CaCO_3$. The sulfate content is high in comparison to most ground water in north-central Connecticut, ranging from 12 to 87 ppm. Although the percentage of sodium is more than 50, the dissolved solids are well within the acceptable limit, and therefore the water is suitable for most purposes, including irrigation. The sodium bicarbonate waters may once have been calcium bicarbonate water, but the calcium and magnesium may have been replaced by sodium owing to the ion-exchange capacity as the water percolated through clay deposits. The water was pumped from sand and gravel buried beneath a considerable thickness of clay. It may have percolated very slowly through the clay and required a long period of time to reach the buried sand and gravel. Silicates contained in the thick clay deposits and the long period of time that the water was in contact with the clay may have aided ion exchange and elimination of calcium and magnesium.

UTILIZATION OF GROUND WATER

The amount of ground water pumped from wells in the report area is estimated to be 64,600 million gallons in 1958 or an average of about 17.7 mgd. This amount represents about 22 percent of the annual pumpage of ground water in Connecticut in 1958 estimated by the Connecticut Department of Health. Estimated withdrawals according to principal use are listed below. Figures of estimated use for municipal supply were obtained from the Bureau of Sanitary Engineering, State Department of Health. The quantity of water used by industry was calculated from information supplied by industrial well owners and from a survey by the Connecticut Manufacturers Association. The pumpage for domestic and stock use was estimated on the basis of a rural population of about 32,000 using an average of 50 gpd (gallons per day) per capita for household and stock purposes. The pumpage of water from irrigation wells was obtained from the well owners.

Use	*Annual pumpage (million gallons)*
Municipal (includes water supplied to industry or to commercial establishments)	1,430
Industrial (from private sources only)	4,380
Domestic and stock (estimated)	590
Irrigation (from private sources only)	60
Total	6,460

PUBLIC WATER SUPPLIES

A total of 17 of the 19 public and semipublic water systems in north-central Connecticut supply ground water to an estimated 43,000 people. In 15 of the systems, ground water is the sole source of supply, whereas in the remaining 2 systems (Portland and Manchester Water Departments) wells serve as auxiliary sources to a much larger supply obtained from surface sources. Water is supplied from 32 wells and 3 springs; 17 of the wells obtain their supply from sand and gravel of Pleistocene age and the remaining 15 from the bedrock. Most of the wells tapping sand and gravel are gravel packed. These wells yield between 100 and 650 gpm and commonly yield more 250 gpm. One caisson well is reported to yield 1,500 gpm. Peak demands are reached in July and August.

All the municipal supply wells in bedrock obtain their water from the sandstone and shale of Triassic age. The wells yield from 25 to 175 gpm and thus are adequate for small communities. No municipal supplies are obtained from wells in pre-Triassic crystalline rocks in north-central Connecticut.

INDUSTRIAL SUPPLIES

"Industrial users" of water are restricted in this report to those that utilize water in the production of a product. Not included under this classification, therefore, are general commercial businesses such as theaters, retail stores, office buildings, restaurants, and garages, which use water for air-conditioning, cooling, and sanitary purposes. Water is probably used in greater abundance than any other raw material by industry and, because a large number of large and small industries are centered about the Hartford area, more ground water is pumped for industrial use than for any other use in north-central Connecticut. Industry uses about 12 mgd, or about 70 percent of the total estimated ground-water used in the area. More than 80 percent of the industrial use, or about 10 million gallons, is pumped daily by four large industries; the remaining 2 million gallons are utilized by many small industries. The largest single user of ground water in the area is the Hartford Rayon Co. at Rocky Hill which reportedly pumps about 6 mgd from a Ranney water collector (well RH 78) installed just offshore in the Connecticut River near its west bank. The water pumped from this well probably is partly ground water and partly Connecticut River water obtained by induced infiltration.

All the large supplies are obtained from wells penetrating sand and gravel beds of the several Pleistocene units, and most of the large users obtain water from more than one well. Excluding the Ranney collector, most of these wells yield less than 200 gpm. Many industries purchase additional water from the nearest municipal supply system. A number of smaller supplies in the Hartford-West Hartford area are obtained from drilled wells in the sedimentary rocks of pre-Triassic age.

DOMESTIC AND STOCK SUPPLIES

Ground water utilized for domestic and stock use includes water pumped by small restaurants, schools, motels, and dairies, in addition to the ordinary household and livestock use of water. Much of the water used for livestock is probably obtained from small streams and ponds. Most rural and suburban homes not supplied by a public water system probably utilize ground water as a source of supply. The population in north-central Connecticut was estimated by the State Department of Health to be about 468,000 in 1958. About 436,000 persons are supplied by municipal water systems, and about 32,000 people obtain their water supply from wells and springs. If the per capita use of water is assumed to be 50 gpd, including stock use and lawn sprinkling, the total ground water used for domestic and stock purposes in north-central Connecticut in 1958 was about 590 million gallons. At least a part of this water returns to the ground locally through dry wells and leaching fields from private sewage disposal systems.

IRRIGATION SUPPLIES

Development of water for irrigation in north-central Connecticut has increased steadily since 1945. Most irrigation has been primarily on tobacco and to a lesser extent on vegetable farms. Most irrigation supplies are obtained from surface sources by means of small ponds or by pumping directly from a stream. In a few places, where conditions are favorable, ground water is used as a source of irrigation supply. Only five such wells have been installed to date solely for irrigation, and one of these wells, WL 16, has since been abandoned. The five wells ranged in yield from 200 to 500 gpm and in specific capacity from 9 to 14 gpm per ft. The water from a number of wells of smaller yield is also used for irrigation, but these wells are used mainly for the wetting of seed beds and small vegetable plots. Based on the reported yields of the wells and period of operation, it is estimated that the annual pumpage of ground water in north-central Connecticut for irrigation is about 60 million gallons.

FUTURE DEVELOPMENT OF GROUND WATER

The ground-water resources of north-central Connecticut are not as yet fully developed. About 440 billion gallons of water per year falls on the area from precipitation. If only 20 percent of the annual precipitation is added to the ground water (35 percent was estimated by Meinzer in the Pomperaug Basin), then the recharge to all aquifers is about 90 billion gallons annually. Thus the estimated average annual use is only about 7 percent of the total recharge. The extent to which the draft on ground water can be increased and sustained will depend largely on whether a proper balance can be achieved locally between the rate of withdrawal from wells and the rate of replenishment of ground water by natural and artificial means.

Small supplies of ground water, where yields of a few gallons per minute will suffice, can be obtained anywhere in the area of this report from wells tapping most bedrock and sand and gravel aquifers and aquifers in some ground-moraine deposits. In areas of concentrated housing in which each dwelling is served by a bedrock well, future development of ground water should be concerned with the perennial yield or amount of ground water available locally and with the effect of increasing quantities of waste water from domestic sewage-disposal systems on the quality of the available supply. No accurate estimates are available on the percentage of the precipitation that reaches the zone of saturation in the bedrock or of the direction and rate of movement of the ground water. Investigations to provide such information would include an expanded network of water-level observation wells to record any long-term downward trends in water levels, aquifer tests to determine the hydraulic constants of the aquifers, and periodic sampling of water to determine chemical and bacteriological changes.

Moderate to large supplies of ground water—sufficient for industrial, commercial, and municipal uses—can be obtained from most sand and gravel deposits and from the Newark group. Sand and gravel deposits capable of yielding moderate supplies to wells (yields of 100–200 gpm per well) are the ice-contact deposits, the outwash-plain and valley-train deposits, the buried outwash, the upper sand unit of the glaciolacustrine deposits, and the associated delta deposits shown on plate 1. Each of these aquifers has been developed by one or more wells, but there are many undeveloped areas where additional withdrawals are feasible. The more favorable of these areas are summarized below. Such areas of potential ground-water development could be acquired and set aside in anticipation of future demands.

Additional supplies could be developed from the glaciolacustrine deposits in north-central Enfield, especially where these deposits overlie ice-contact deposits in the vicinity of the oval-shaped area of ice-contact deposits shown on plate 1. The deposits in this area are more than 100 feet thick and in most places are composed of sand and gravel. Some water is pumped for public supply from these deposits but additional withdrawals can probably be made from the area immediately east and south of the oval hill. Where the thickness of the glaciolacustrine deposits has been increased by especially large accumulations of dune sand, as in the area north of Shaker Pond in north-central Enfield, some potential supplies may be available.

The ice-contact deposits in the Scantic River valley upstream from Somersville are a potential source of moderate supplies of ground water where they are composed of sand and gravel. Test drilling would be required to determine the thickness and permeability of these deposits. The most favorable areas to test drill are where the deposits are thickest, such as southeast of Somersville and north of Somers. Some large supplies could be developed if wells were situated so as to induce infiltration from the Scantic River.

In a small area in the southeastern part of Enfield south of the Scantic River and the center of Hazardville a potential source of additional ground water is the undifferentiated outwash deposits. The stratified deposits in this area are largely undeveloped. They probably consist in part of deltaic material from the Scantic River and are composed largely of sand and some gravel. The deposits are more than 100 feet thick in some places. Test drilling would be required to find the thickest and most permeable zones in the stratified material.

A potential source of large amounts of ground water is ice-contact deposits that underlie the area along the eastern side of the Connecticut River Lowland between Wapping and Windsorville. The deposits in this area are as much as 100 feet thick and in some places are composed almost entirely of sand and gravel. Only one large-capacity well, SW 71, is known to withdraw water from the sand and gravel, and this supply is for irrigation use only. Additional supplies could be developed from the deposits north of the location of well SW 71, especially in the area north and northeast of Windsorville.

Some additional supplies could be developed from the deposits making up the delta of the Farmington River, especially from the part of the delta south of the Farmington River and from ice-contact deposits in the same area. Wells W 122 and W 127 yield about 400 gpm from these deposits. Moderate withdrawals are being made in the area of W 127, but additional quantities of water could be developed in the area with little interference between wells. The deposits are as much as 150 feet thick and are known to contain considerable sand and gravel locally, especially the ice-contact deposits. Test drilling would be required to determine the permeability of the delta deposits and the subsurface distribution of the ice-contact deposits. The most favorable area is southeast of Great Pond in Windsor.

The delta deposits north of the Farmington River have been developed or explored thoroughly in the vicinity of Bradley Field and additional supplies could be developed only after an extensive program of test well drilling. Some additional supplies could probably be developed from the delta sand east and southeast of Bradley Field, but considerable test drilling would be required to locate the more permeable zones in the deposits. This area is not as favorable for development of additional water supplies as formerly because a large part of the delta surface is already developed for household use.

Moderate to large supplies could be developed from parts of the large mass of ice-contact deposits in Manchester and Vernon. The deposits are composed largely of sand and gravel and are as much as 100 feet thick where they overlie bedrock valleys. The areas where they are thickest are in the valleys of the Hockanum and Tankerhoosen Rivers and Hop Brook. Wells of the Manchester Water Department (M 46 and M 59) in the Hop Brook valley and of the Manchester Water Co. (M 78) in the Hockanum River valley yield from 560 to 750 gpm from these deposits. A considerable amount of water is withdrawn locally from this aquifer in the valley of Hop Brook and from the Hockanum River valley in western Manchester. Additional withdrawals can be made in adjacent areas in these same valleys without danger of mutual interference between pumped wells. The most favorable areas for the development of additional supplies are adjacent to the Hockanum River in western and central Manchester, along the valley of Hop Brook for about 1 mile above its junction with the Hockanum River, the Hockanum River valley in southwestern Vernon, and along the Tankerhoosen River in Vernon.

A small amount of water is pumped from sand and gravel deposits in the Salmon Brook valley in north-central Glastonbury. These deposits are as much as 100 feet thick and probably would yield moderate supplies of ground water. Exploratory holes, however, would be required to locate suitable sites for large-capacity wells.

The Triassic sedimentary rocks are a potential source of moderate supplies of ground water in most of north-central Connecticut. The productivity of wells tapping these rocks depends on the number and size of openings in the rock and their interconnection with a good source of recharge. There are numerous large-yielding wells that obtain water from the sedimentary bedrock in north-central Connecticut, but only in three local areas are these wells concentrated so closely as to interfere with each other. Additional quantities of water could be developed from the sedimentary bedrock, especially in areas where new wells will produce little or no drawdown in existing wells. Yields of as much as 350 gpm have been obtained from wells as much as 500 feet deep in most of the sedimentary rocks of the Newark group in the area; however, these yields cannot always be obtained. Favorable locations for larger yields are in the area of coarse-grained sedimentary rocks east of the Connecticut River and in an area including Bloomfield, Hartford, and West Hartford.

REFERENCES CITED

Aitken, Janet M., 1955, The bedrock geology of the Rockville quadrangle: Connecticut Geol. Nat. History Survey Quad. Rept. 6.

Antevs, Ernst, 1922, The recession of the last ice sheet in New England: Am. Geog. Soc. Research ser. 11.

——— 1928, The last glaciation, with special reference to the ice retreat in northeastern North America: Am. Geog. Soc. Research ser. 17.

Bourbeau, G. A., and Swanson, C. L. W., 1954, The morphology, mineralogy and genesis of two southern New England soils: Connecticut Agr. Expt. Sta. Bull. 584, p. 22.

Collins, G. E., 1954, The bedrock geology of the Ellington quadrangle: Connecticut Geol. Nat. History Survey Quad. Rept. 4.

Colton, Roger B., 1960, Surficial geology of the Windsor Locks quadrangle, Connecticut: U.S. Geol. Survey Geol. Quad. Map GQ–137.

Cushman, R. V., Allen, W. B., and Pree, H. L. Jr., 1953, Geologic factors affecting the yield of rock wells in southern New England: New England Water Works Jour. v. 67, no. 2.

Daly, R. A., 1920, Oscillations of level in the belts peripheral to the Pleistocene ice-caps: Geol. Soc. America Bull., v. 31, p. 303–318.

Davis, W. M., 1898, The Triassic formations of Connecticut: U.S. Geol. Survey 18th Ann. Rept., pt. 2, p. 1–192.

Dean, H. T., 1936, Chronic endemic dental fluorosis: Am. Med. Assoc. Jour., v. 107, p. 1269–1272.

Flint, R. F., 1930, The glacial geology of Connecticut: Connecticut Geol. Nat. History Survey Bull. 47.

———1932, Deglaciation of the Connecticut valley: Am. Jour. Sci., v. 224, no. 140, p. 152–156.

———1933, Late-Pleistocene sequences in the Connecticut valley: Geol. Soc. America Bull., v. 44, p. 965–988.

———1947, Glacial geology and the Pleistocene epoch: New York, John Wiley and Sons, 589 p.

———1953, Probable Wisconsin substages and late-Wisconsin events in northeastern United States and southeastern Canada: Geol. Soc. America Bull., v. 64, p. 897–919.

———1956, New radiocarbon dates and late-Pleistocene stratigraphy: Am. Jour. Sci., v. 254, no. 5, p. 265–287.

Foye, W. G., 1949, The geology of eastern Connecticut: Connecticut Geol. Nat. History Survey Bull. 74.

Fuller, M. L., and Pynchon, W. H. C., 1905, Triassic rocks of the Connecticut Valley as a source of water supply: U.S. Geol. Survey Water-Supply Paper 110, p. 65–112.

Gregory, H. E., 1904, Notes on the wells, springs and general water resources of Connecticut: U.S. Geol. Survey Water-Supply Paper 102, p. 127–168.

———1909, Underground water resources of Connecticut: U.S. Geol. Survey Water-Supply Paper 232.

Gregory, H. E., and Ellis, A. J., 1916, Ground water in the Hartford, Stamford, Salisbury, Willimantic, and Saybrook areas, Connecticut: U.S. Geol. Survey Water-Supply Paper 374.

Gregory, H. E., and Robinson, H. H., 1907, Preliminary geological map of Connecticut: Connecticut Geol., Nat. History Survey Bull. 7.

Heald, M. T., 1956, Cementation of Triassic arkoses in Connecticut and Massachusetts: Geol. Soc. America Bull. v. 67, p. 1133–1154.

Herz, Norman, 1955, The bedrock geology of the Glastonbury quadrangle, Connecticut: Connecticut Geol. Nat. History Survey Quad. Rept. 5.

Jahns, R. H., and Willard, M. E., 1942, Late Pleistocene and Recent deposits in the Connecticut Valley, Massachusetts: Am. Jour. Sci., v. 240, no. 3, p. 161–191, 265–287.

Krynine, P. D., 1950, Petrology, stratigraphy, and origin of the Triassic sedimentary rocks of Connecticut: Connecticut Geol. Nat. History Survey Bull. 73.

LaSala, A. M., Jr., 1960, Ground-water levels in Connecticut 1956–1959: Connecticut Water Resources Bull. 2, 33 p.

Lehmann, E. P., 1959, The bedrock geology of the Middletown quadrangle, Connecticut: Connecticut Geol. Nat. History Survey Quad. Rept. 8.

Longwell, C. R., 1922, Notes on the structure of the Triassic rocks in southern Connecticut: Am. Jour. Sci., v. 204, no. 21, p. 223–236.

——— 1928, The Triassic of Connecticut. Am. Jour. Sci., v. 216, no. 93, p. 259–263.

——— 1933, The Triassic belt of Massachusetts and Connecticut: Internat. Geol. Cong., 16th Guidebook 1, p. 93–118.

Longee, R. J., 1939, Geology of the Connecticut Watershed: New Hampshire Fish and Game Dept., Biol. Survey of Connecticut Watershed, Rept. 4, p. 131–149.

Loughlin, G. F., 1905, The clays and clay industries of Connecticut: Connecticut Geol. Nat. History Survey Bull. 4.

Meinzer, O. E., 1923, The occurrence of ground water in the United States: U.S. Geol. Survey Water-Supply Paper 489.

Meinzer, O. E., and Stearns, N. D., 1929, A study of ground water in the Pomperaug Basin, Connecticut, with special reference to intake and discharge: U.S. Geol. Survey Water-Supply Paper 597–B, p. 73–146.

Palmer, H. S., 1920, Ground water in the Norwalk, Suffield, and Glastonbury areas, Connecticut: U.S. Geol. Survey Water-Supply Paper 470.

Percival, J. G., 1842, Report on the geology of the State of Connecticut: New Haven, Conn. General Assembly of the State, 495 p.

Randall, A. D., 1961, Geology and ground water in the Farmington-Granby area, Connecticut: U.S. Geol. Survey open-file report.

Redfield, W. C., 1856, On the relations of the fossil fishes of the sandstone of Connecticut and other Atlantic states to the Liassic and Oolitic periods: Am. Jour. Sci., v. 72, no. 46, p. 357–363.

Rice, W. N., and Gregory, H. E., 1906, Manual of the geology of Connecticut: Connecticut Geol. Nat. History Survey Bull. 6.

Rodgers, John, 1952, Absolute ages of radioactive minerals from the Appalachian region: Am. Jour. Sci., v. 250, no. 6, p. 411–427.

Rodgers, John, Gates, R. M., and Rosenfeld, J. L., 1959, Explanatory text for the preliminary geological map of Connecticut: Connecticut Geol. Nat. History Survey Bull. 84.

Schnabel, Robert W., 1962, Surficial geology of the Avon quadrangle, Connecticut: U.S. Geol. Survey Geol. Quad. Map GQ–147.

Simpson, Howard E., 1959, Surficial geology of the New Britain quadrangle, Connecticut: U.S. Geol. Survey Geol. Quad. Map GQ–119.

Stugard, Frederick, Jr., 1958, Pegmatites of the Middletown area, Connecticut: U.S. Geol. Survey Bull. 1042–Q, p. 613–683.

Thorpe, M. R., 1929, A new Triassic fossil field. Am. Jour. Sci., v. 218, no. 106, p. 277–300.

Urry, W. D., 1948, The radium content of varved clay and a possible age of the Hartford, Connecticut, deposits: Am. Jour. Sci., v. 246, no. 11, p. 689–700.

U.S. Geological Survey, 1946–57, Water levels and artesian pressures in observation wells in the United States, part 1, Northeastern States: U.S. Geol. Survey Water-Supply Papers 1071, 1096, 1126, 1156, 1165, 1191, 1221, 1265, 1321, 1404, 1537.

U.S. Public Health Service, 1962, Public Health Drinking Water Standards: Rept. 956, Public Health Repts., 61 p.

U.S. Weather Bureau, 1956, Local climatological data, Hartford, Connecticut.

Waring, G. A., 1920, Ground water in the Meriden area, Connecticut: U.S. Geol. Survey Water-Supply Paper 449.

Wilcox, L. V., 1955, Classification and use of irrigation waters: U.S. Dept. Agriculture Circ. 969, 19 p.

Works Progress Administration for Connecticut, 1938a, Records of wells, springs, and ground-water levels in the towns of Berlin, Cromwell, Durham, Meriden, Middlefield, Middletown, Portland, and Wallingford, Connecticut: Connecticut Ground Water Survey Bull. GW–4, 170 p.

——— 1938b, Ground-water levels in north-central Connecticut: Connecticut Ground Water Survey Bull. GW–6, 212 p.

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