GROUND-WATER AVAILABILITY AND WATER QUALITY AT SOUTHBURY AND WOODBURY, CONNECTICUT

By David L. Mazzaferro

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Inch-pound units	Multiplied by	Are converted to SI units
	Length	
inches (in.)	25.4	millimeters (mm)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
	Area	
square miles (mi^2)	2.59	square kilometers (km^2)
	Flow	
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
gallons per minute (gal/min)	0.0631	liters per second (L/s)
million gallons per day (Mgal/d)	0.04382	cubic meters per second (m^3/s)
	Hydraulic units	
hydraulic conductivity in feet per day (ft/d)	0.3048	hydraulic conductivity in meters per day (m/d)
hydraulic gradient in feet per mile (ft/mi)	0.1894	hydraulic gradient in meters per kilometer (m/km)
inches per year (in./yr)	25.4	millimeters per year (mm/yr)

Datum

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

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ABSTRACT

Increases in population and commercial and industrial development during the past 20 years have increased the demand for water in the Towns of Southbury and Woodbury, Connecticut. The stratified-drift aquifer, underlying much of the Pomperaug River valley, is the most practical source for additional large supplies. Quantitative estimates of the amounts of water available from this aquifer and an assessment of present water quality are needed for water resources planning and management.

The yield of the aquifer was evaluated with a two-dimensional, digital flow model. The model was constructed with hydrologic data from previous studies, and test boring logs, seismic profiles, water-level measurements and other information collected during the present study.

Simulations made with the calibrated model represent recharge conditions that range from least to most favorable. They indicate that, with no pumpage, ground-water levels in the aquifer will fall about 4.6 feet below average during low-recharge (least-favorable) periods, and rise about 0.6 feet above average during high-recharge (most-favorable) periods. Simulated withdrawals from 10 hypothetical wells tapping the aquifer indicated that from 5.0 to 8.8 million gallons per day are available as total recharge rates range from 21.4 to 36.1 inches per year. If these pumpages were consumed or exported from the basin, estimated average flow reductions of the Pomperaug River would range from 7.7 to 12.9 cubic feet per second.

The quality of the water from the stratified-drift aquifer is generally excellent in most areas and meets State drinking-water standards as established by the Connecticut General Assembly in 1975. Chemical analyses of ground water from 11 wells in the Middle Quarter area of Woodbury indicate that organohalide compounds are present. A maximum trichloroethane concentration of 260 micrograms per liter has been reported and ground water in the area is presently being monitored for organohalides by the Woodbury Water Company. Samples collected on October 13, 1981, indicate that the water meets standards established by the State. Surface-water samples collected at 7 sites in the study area meet the Connecticut drinking-water standards for all constituents except coliform bacteria.

Because of differences in sampling frequencies, the coliform-bacteria data collected during the study cannot be directly compared to State standards. However, the data indicate that in some instances, complete

conventional treatment of surface water would be required to meet State drinking-water standards relative to these organisms.

INTRODUCTION

Purpose and Scope

Since the mid 1960's, the demand for water in the Pomperaug River valley has increased in response to population growth, commercial expansion, and industrial development. The most promising source of large amounts of potable water in the area is the Pomperaug River aquifer, a body of saturated sand and gravel drained by the Pomperaug River. (See figure 1.) A previous study by the U.S. Geological Survey (Wilson and others, 1974) indicated that from 4 to 10 Mgal/d (million gallons per day) is available from this aquifer. The present report describes the results of a study to provide more accurate estimates of the amount of water available from the Pomperaug River aquifer under different recharge conditions and evaluates the effects of large-scale ground-water withdrawals on water levels in the aquifer and flow in the Pomperaug River. It also evaluates the present quality of the surface and ground water in the area with respect to drinking-water standards established by the State of Connecticut (Connecticut General Assembly, 1975) and enforced by the CTDOHS (Connecticut Department of Health Services); these are referred to as the Connecticut drinking-water standards. The report discusses essential features of the ground-water flow system to include the geologic framework and the circulation of water and describes the principal geologic and hydrologic features of the Pomperaug River aquifer that control ground-water availability. A digital flow model is used to evaluate the response of the aquifer to changes in annual recharge rates, estimate the amounts of ground water practically available, and predict the effects of large withdrawals on water-table altitudes and streamflow.

Location and Description

The Pomperaug River aquifer is located in west-central Connecticut and includes parts of the towns of Southbury and Woodbury. (See figure 1.) It is composed of stratified drift, principally sands and gravels, and extends over an area of about 18 mi^2 (square miles). The aquifer lies within the basin drained by the Pomperaug River, its principal tributaries, Nonewaug, and Weekeepeemee Rivers, and several smaller streams. The drainage area upstream from the points where the Nonewaug and Weekeepeemee Rivers enter the study area is about 49 mi^2, and is about 79 mi^2 where the Pomperaug River leaves the study area.

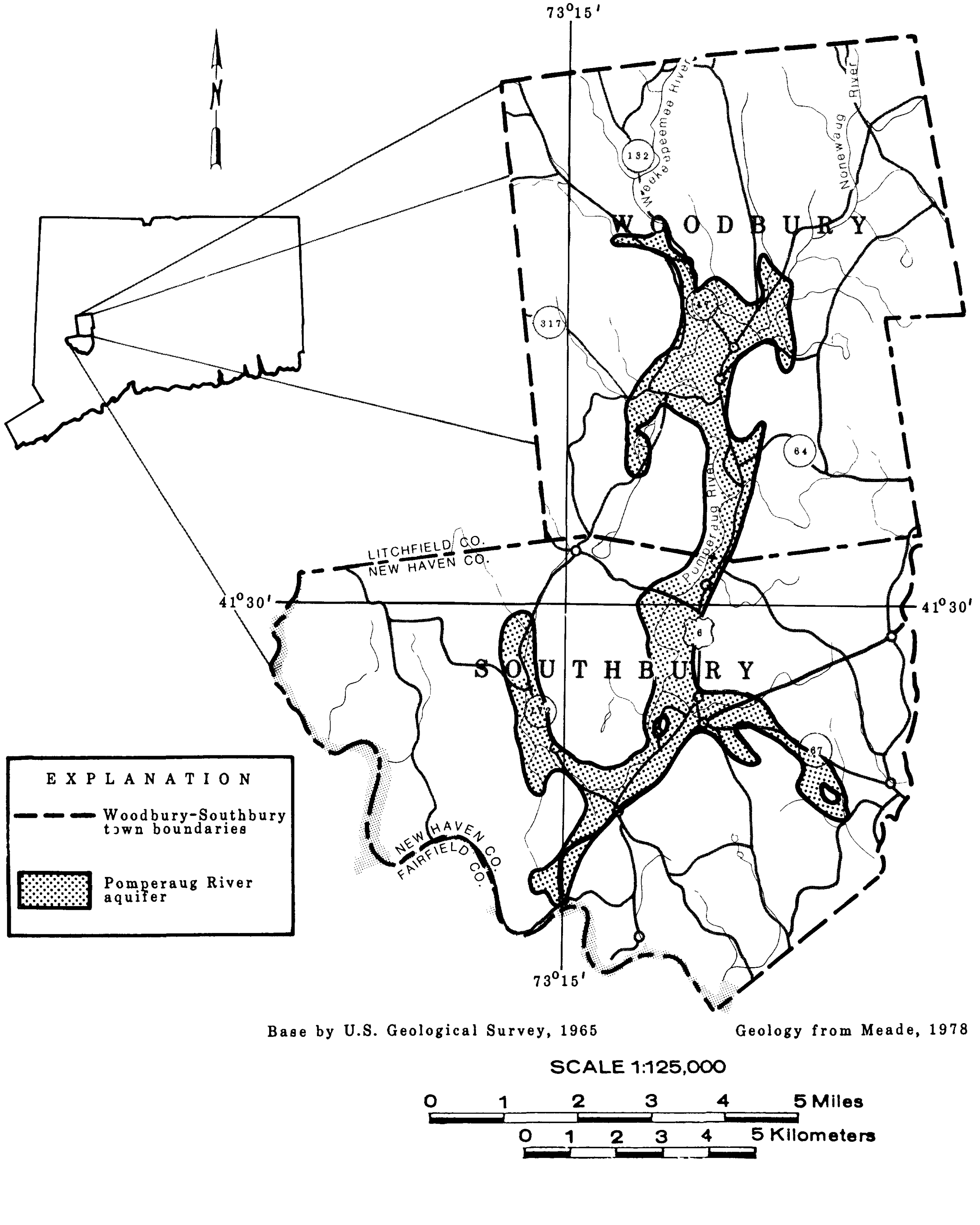


Figure 1.--Location and extent of the Pomperaug River aquifer and the principal streams in the Southbury-Woodbury area.

Previous Investigations

The ground-water resources of the Pomperaug River basin were investigated by Meinzer and Stearns (1929), and their report contained one of the first water budgets of a humid region. More recently, the area was included in a water resources inventory study of the lower Housatonic basin (Wilson and others, 1974); hydrologic data collected for that study is contained in Grossman and Wilson (1970). The surficial geology of the area was briefly discussed by Flint (1930), and mapped in detail by Pessl (1970, 1975).

Methods of Investigation

Data collected and analyzed in the course of this investigation were obtained from seismic-refraction profiles, test holes and observation wells, grain-size analyses of stratified drift, monthly ground-water levels, and chemical analyses of surface- and ground-water samples. The locations of the data collection sites are shown on plate A; the data are summarized in figure 22 and tables 22-27 in the back of the report.

Recharge from precipitation is estimated using two different techniques, one based on the relationships between total runoff, basin geology and ground-water outflow that have been used in other water investigations in Connecticut and the other based on an adjusted water budget originally prepared for the Pomperaug River basin by Meinzer and Stearns (1929). Both methods assume different recharge rates for till and stratified-drift areas and consider four different precipitation periods. The periods chosen represent dry conditions, wet conditions, long-term average conditions, and conditions during the wetter-than-average 10-year period that immediately preceded this investigation. The methods are discussed in more detail in the section of the report titled "Recharge".

A finite-difference, ground-water flow model developed by the U.S Geological Survey (Trescott and others, 1976) is used to estimate water availability and evaluate the response of the Pomperaug River aquifer to different stress conditions. After calibration, a series of simulations were made that evaluated the sensitivity of the model to small changes in recharge, aquifer hydraulic conductivity, and streambed leakage. The model, its related flow equations, and the results of the sensivity analysis are discussed, in detail, in later sections of this report. The major flow components considered by the model include recharge from precipitation, inflow and outflow across boundaries, leakage between the aquifer and the Pomperaug River, ground-water evapotranspiration, and withdrawals from wells. These items are illustrated in figure 2.

Water-quality samples were collected at a number of wells and stream locations in the study area and were analysed for biological, chemical, and physical characteristics. These data were used to evaluate present water-quality conditions in Southbury and Woodbury and are discussed in the water-quality section of this report.

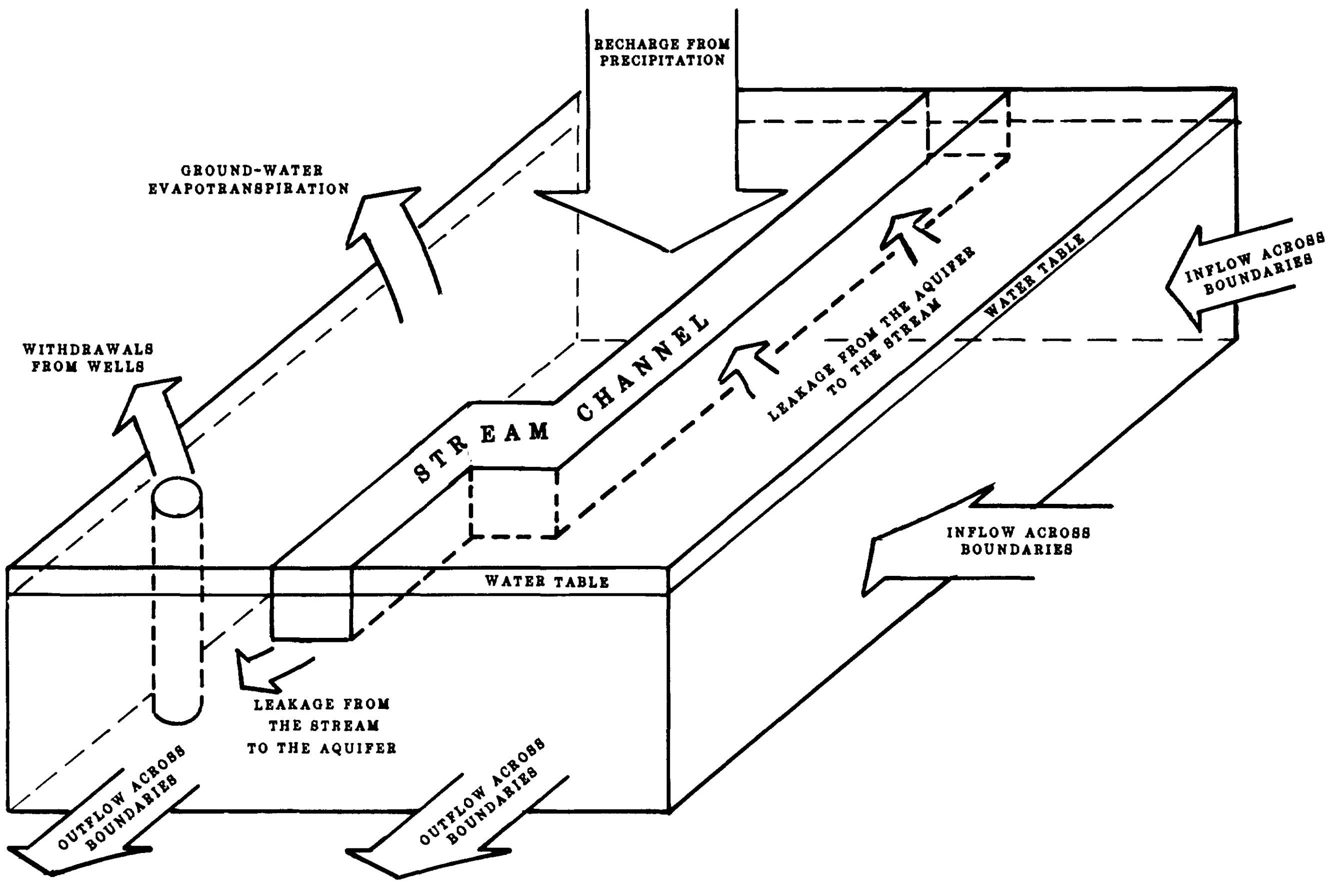


Figure 2.--Major flow components of the Pomperaug River aquifer model.

Acknowledgments

This investigation was conducted by the U.S. Geological Survey in cooperation with the towns of Southbury and Woodbury, Connecticut. The author is grateful for the assistance and information provided by officials and concerned citizens of Southbury and Woodbury, property owners, and officials of the Heritage Village and Woodbury Water Companies. The Connecticut Department of Environmental Protection and the Connecticut Department of Health Services also provided useful data and timely assistance; their contributions are sincerely appreciated.

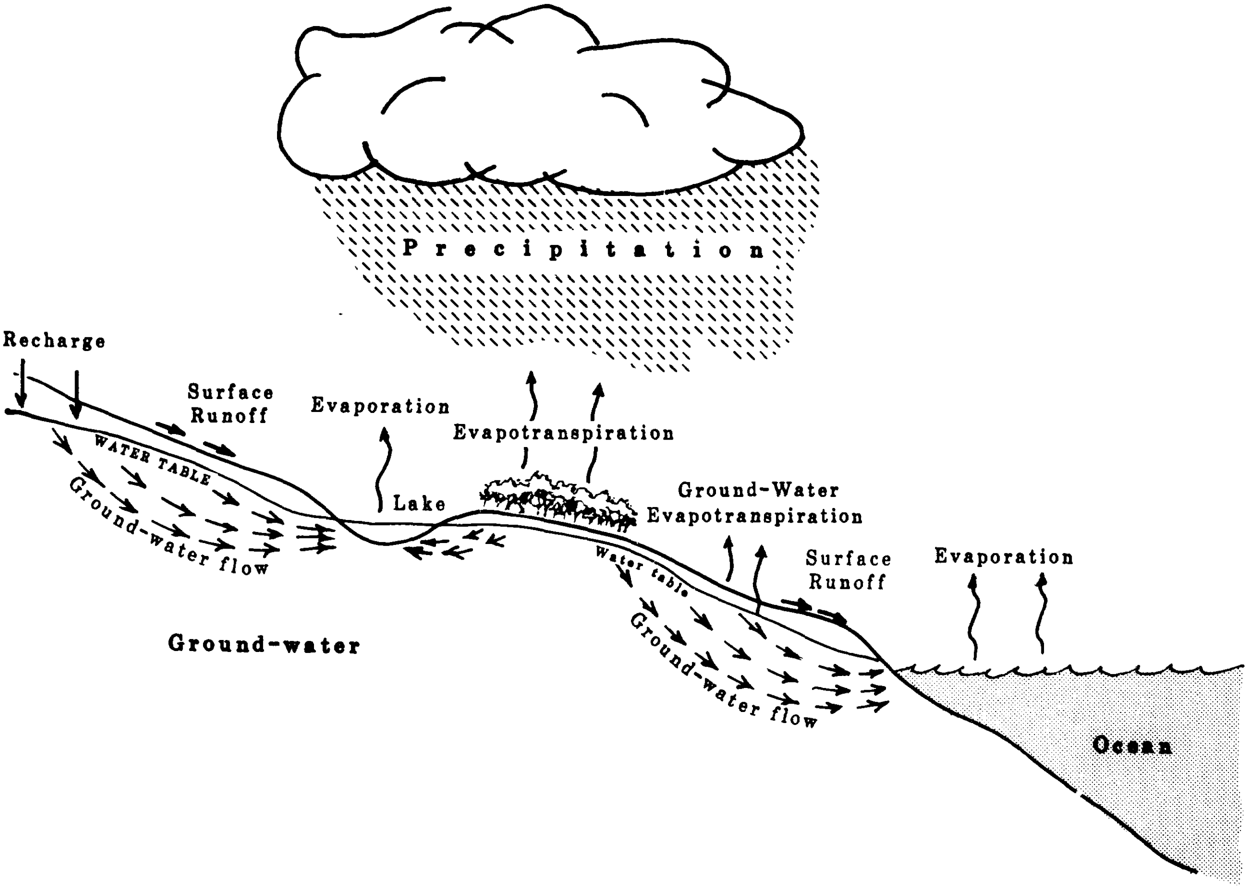


Figure 3.--The hydrologic cycle.

HYDROGEOLOGIC SYSTEM

Hydrologic Cycle

The hydrologic cycle is the continuous circulation of water between the oceans, the atmosphere, and the land. Figure 3 is an idealized representation of the hydrologic cycle that illustrates the three primary means of water movement in the Pomperaug River basin, precipitation, evapotranspiration, and runoff. In general terms, the amount of water entering the basin (precipitation) will equal the amount leaving the basin (evapotranspiration and runoff) if there is no change in storage. Figure 4 shows the average annual amounts of water entering and leaving the Pomperaug River basin during the 1969 - 1978 period. Adjustments were made to the evapotranspiration and runoff values to account for a modest increase in storage during the period.

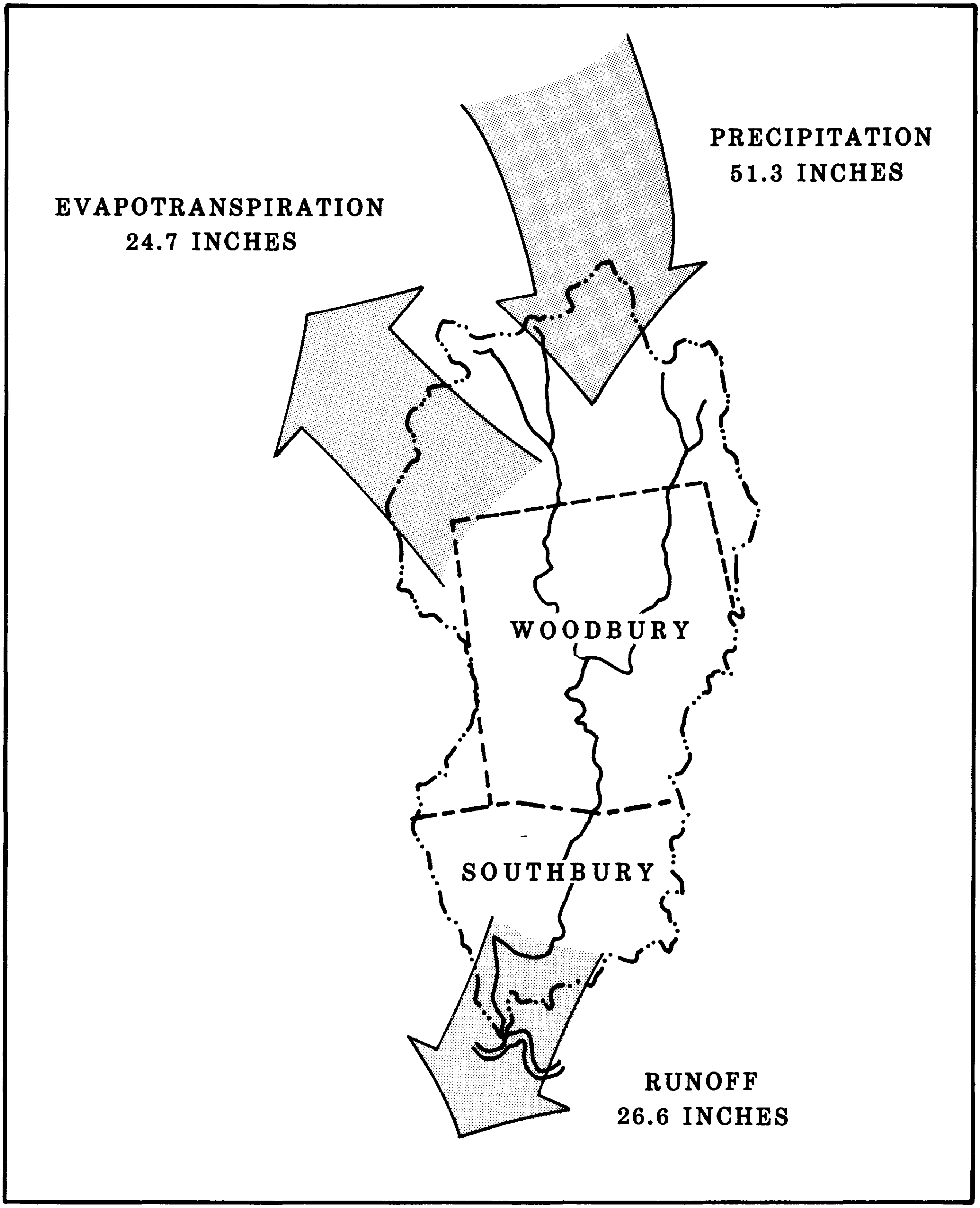


Figure 4.--Average rates of precipitation, evapotranspiration, and runoff in the Pomperaug River basin during 1969-78.

Geologic Framework

Stratified drift, till, and bedrock comprise the geologic framework that controls the movement and storage of ground water in the Pomperaug River basin; typical spatial relationships between these units are shown in figure 5.

Stratified drift comprises the most productive aquifer in the study area. In this report it is termed the Pomperaug River aquifer and consists of interbedded layers of gravel, sand, silt, and clay, that were transported, sorted, and deposited by glacial meltwaters. Stratified drift is present in valleys and lowland areas and typically shows abrupt horizontal and vertical changes in texture. The thickness of this material in the study area ranges from zero to over 150 feet. Stratified drift forms the only aquifer in the area capable of yielding large amounts of water to individual wells and is the subject of this report. The areal distribution of stratified drift is shown in figure 6.

Till, an unsorted or poorly sorted sediment deposited by glacial ice, is a minor aquifer in the area. It forms a continuous mantle over most of the bedrock and, in the central part of the valley, is commonly overlain by stratified drift. Individual wells in till generally yield less than 1 gal/min (gallon per minute) and the till aquifer can provide only small supplies of water (Wilson and others, 1974). The areal distribution of till is also shown in figure 6.

Bedrock units composed of arkose, basalt, gneiss, granite gneiss, and schist underlie the study area. Information on bedrock geology can be found in Gates, (1954), Rogers, (1982), and Scott (1974). Individual wells that tap bedrock generally yield low to moderate amounts of water, averaging from 5 to 10 gal/min (Wilson and others, 1974). The distribution of the principal bedrock units is shown in figure 7.

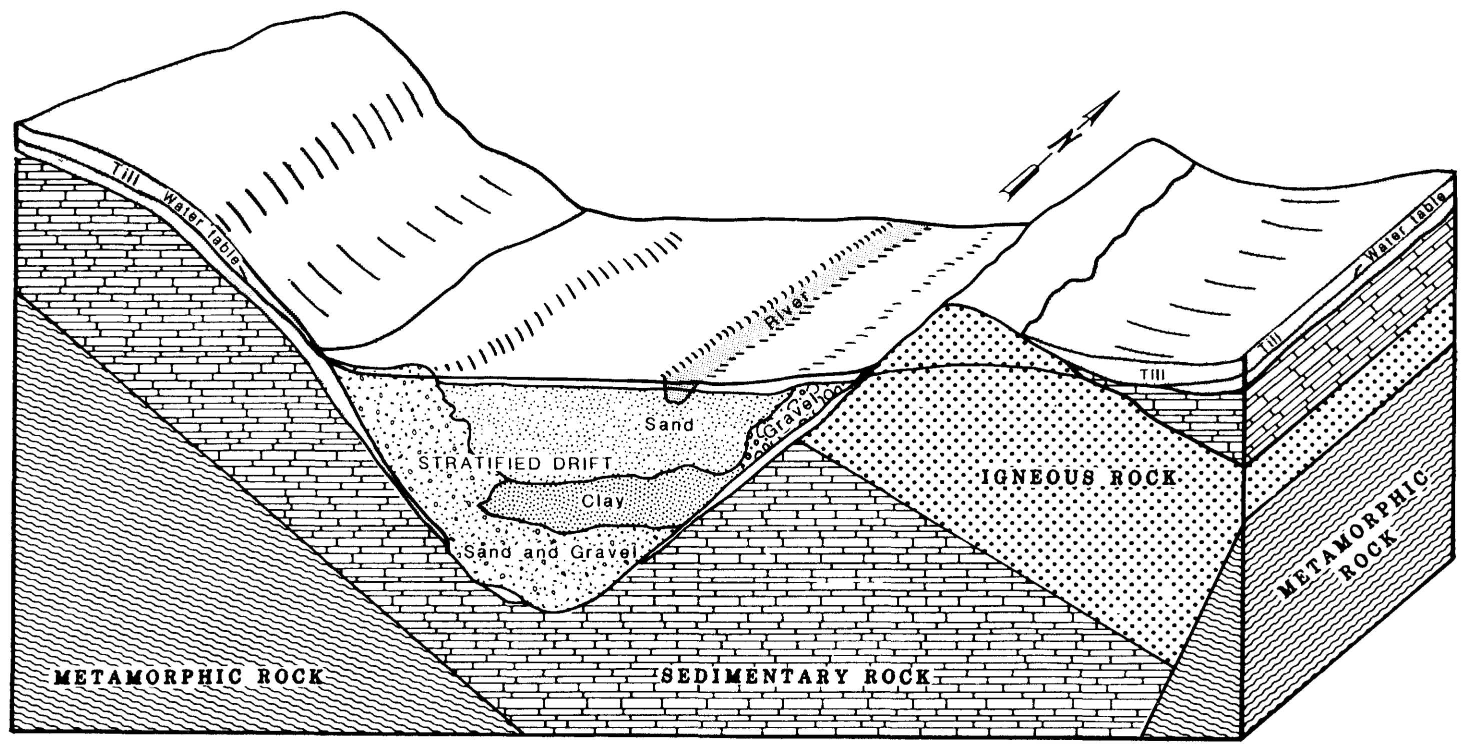


Figure 5.--Idealized block diagram showing the geology of the study area.

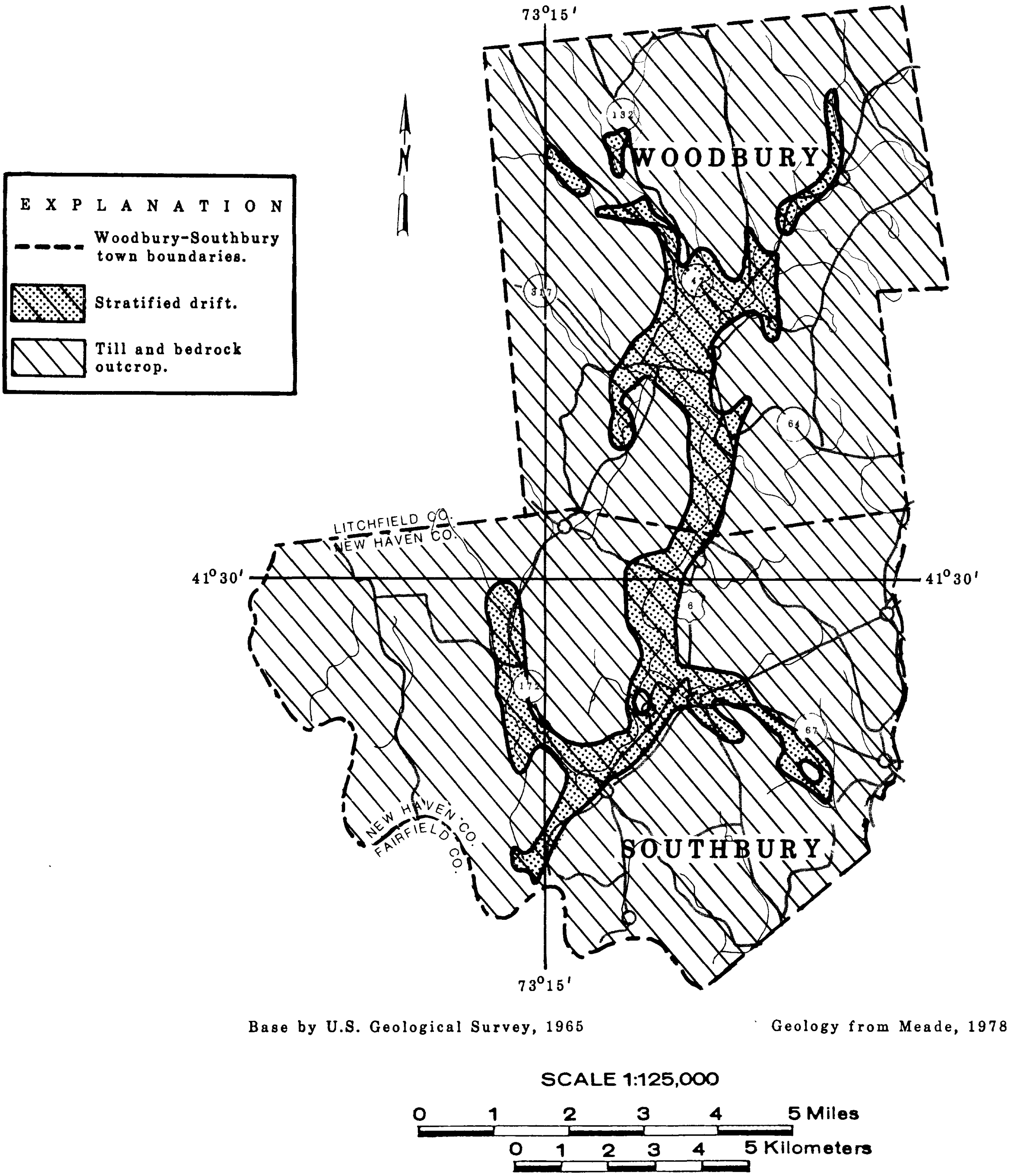


Figure 6.--Surficial geology of the Southbury-Woodbury area.

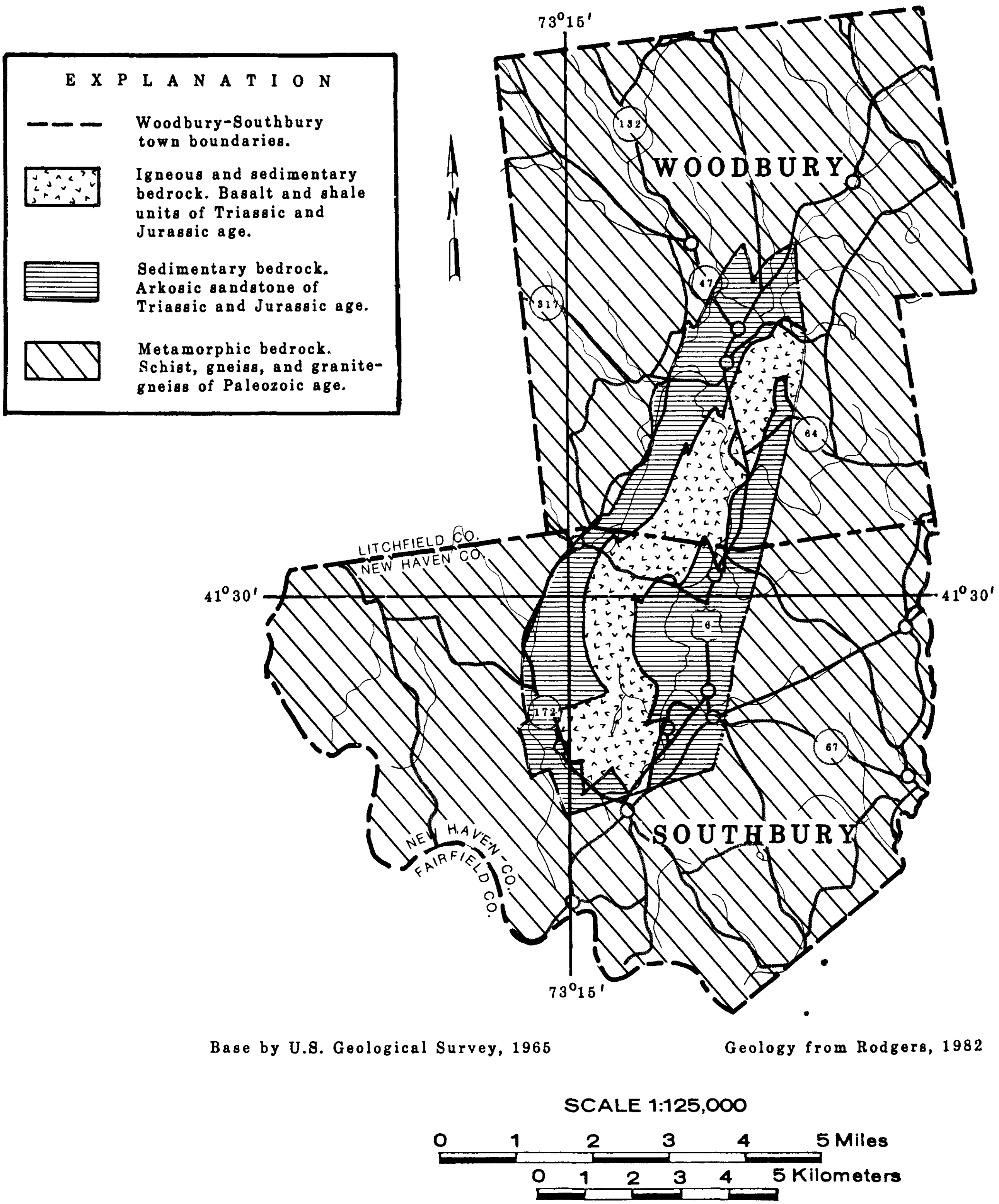


Figure 7.--Bedrock geology of the Southbury-Woodbury area.

Movement and Storage of Water

The movement and storage of water in the Pomperaug River basin is a reflection of the hydrologic cycle. The ultimate source of water is precipitation that falls on the land surface. After entering the basin, some water is returned to the atmosphere, some leaves as streamflow, or underflow, and some remains temporarily as storage. At any time, the system is in dynamic balance; the amount of water entering equals the amount leaving, plus or minus changes in storage.

In this report the emphasis is on ground water-- that part of the total water supply that reaches the saturated zone, moves through the subsurface, and supplies springs and wells. Ground-water movement is governed by the nature of the subsurface openings and the pressure or head distribution in the flow system. Subsurface openings include fractures in bedrock and pore spaces between the individual grains of stratified drift. The size, shape, and degree of interconnection of the pore spaces directly influence the rate at which water moves through stratified drift.

Water continually enters, flows through, and leaves the stratified-drift deposits that comprise the Pomperaug River aquifer. Changes in ground-water storage are indicated by fluctuations of the water table. (See figure 8.)

These water-level changes are the result of variations in recharge to, and discharge from, the saturated zone. Under equilibrium conditions, the ground-water system is in balance and the amounts of water entering and leaving are equal. Water entering is a single item-- ground-water recharge; water leaving, under natural conditions, includes three items-- ground-water runoff, ground-water evapotranspiration, and underflow. If there are differences between the amounts entering and leaving the system, changes in storage develop and equilibrium conditions no longer exist. The movement of ground water through the saturated zone is described by the equation:

$$GW(r) = GW(ro) + GW(et) + U \pm S$$

where:

GW(r) = Ground-water recharge

GW(ro) = Ground-water runoff

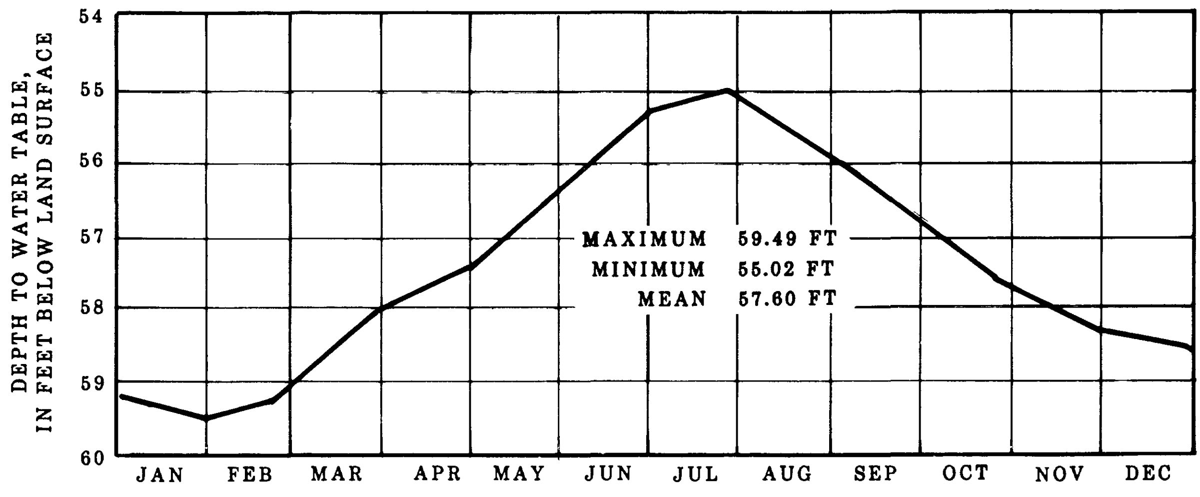
GW(et) = Ground-water evapotranspiration

U = Underflow

S = Change in ground-water storage

In the study area, ground-water recharge generally occurs during the nongrowing season (mid October to mid May) while ground-water discharge (GW(ro) + GW(et) + U) occurs throughout the year. The difference between recharge and discharge over a period of time is equal to the change in ground-water storage.

Observation well SB-26



Observation well WY-31

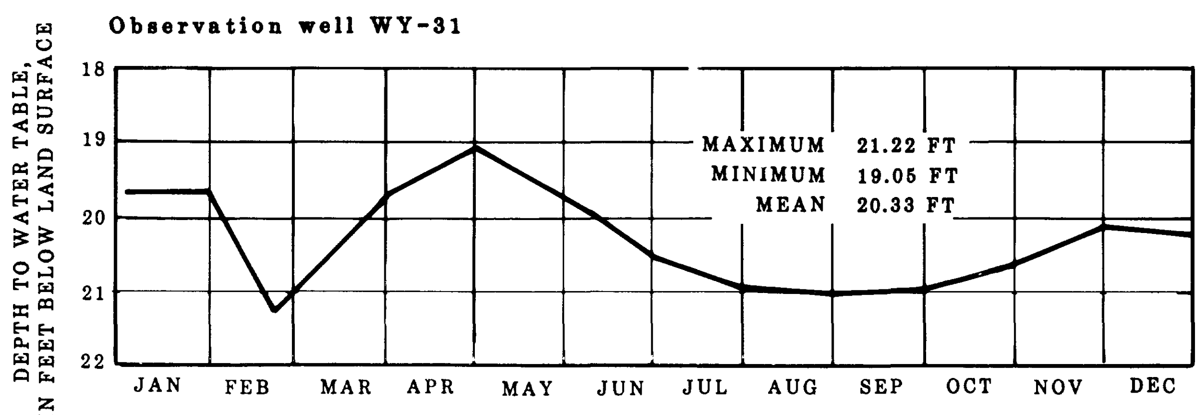


Figure 8.--Hydrographs of wells SB-26 and WY-31, in 1979.

[Changes in water levels indicate changes in ground-water storage. As water levels rise, storage is increased: as they fall, storage is reduced.]

Surface-water and ground-water flow systems are directly related in that ground-water runoff is an important component of streamflow. During periods of little or no rainfall, ground-water runoff makes up almost all of the flow of the Pomperaug River. If large amounts of ground water are withdrawn from the aquifer and exported from the basin, significant reductions in streamflow will result.

STRATIFIED-DRIFT AQUIFER

Description

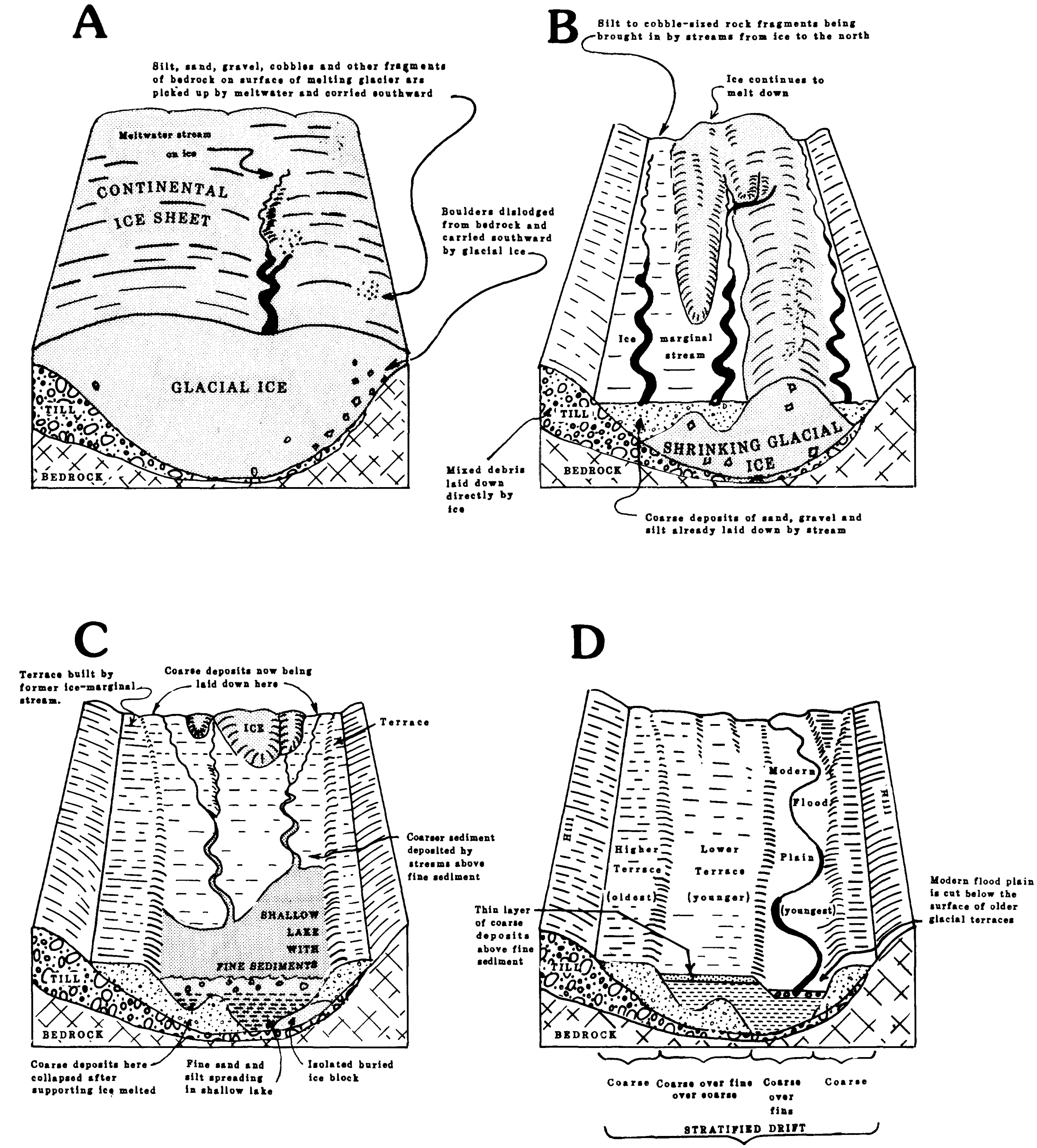
As glacial ice retreated from the Pomperaug River basin, sediments that had been carried by the ice were moved by meltwaters and deposited in lowland areas such as stream channels or lake bottoms. Materials in these deposits are termed stratified drift and include clay, silt, sand, and gravel. Figure 9 shows an idealized sequence of events similar to the one that resulted in deposition of the stratified drift that forms the present Pomperaug River aquifer. Fine-grained materials (fine sand, silt, and clay) are generally found in the center of the valley, whereas coarse-grained materials (sand and gravel) are generally found along the valley margins.

The variability in texture and thickness of stratified drift in the study area is shown by well and test-hole logs contained in Table 22. The locations of these borings are shown on plate A. Test hole WY 19TH, near the Pomperaug River and about 500 feet north of Good Hill Road, penetrated 155 feet of very fine sand, silt, and clay. This is the thickest deposit of fine-grained stratified drift found in the area.

In Southbury, deposits of fine-grained materials are thinner, but more extensive. Test hole SB 36TH, about 1,000 feet south of Roxbury Road, penetrated 80 feet of fine to very-fine sand while test hole SB 40TH, 500 feet south of Main Street and 1,000 feet south of South Britain Road penetrated about 70 feet of very fine sand and silt. Deposits of coarse-grained materials in the area are generally less extensive than deposits of fine-grained material but can also be quite thick. Maximum thickness of coarse-grained stratified drift is about 100 feet in both Southbury and Woodbury (see test boring SB 39TH and well WY 39).

Factors Controlling Ground-Water Availability

The amount of water that can be obtained from an aquifer, over the long term, depends upon three primary factors. These are (1) recharge rates (recharge from precipitation, flow across aquifer boundaries, and leakage from streams); (2) withdrawal rates (largely determined by hydrologic characteristics of the aquifer); and (3) storage (also determined by hydrologic characteristics of the aquifer). Secondary factors may also influence the yield potential



(from Thomas and others, 1968)

Figure 9.--Diagrams showing the origins of stratified drift in the Pomperaug River valley.

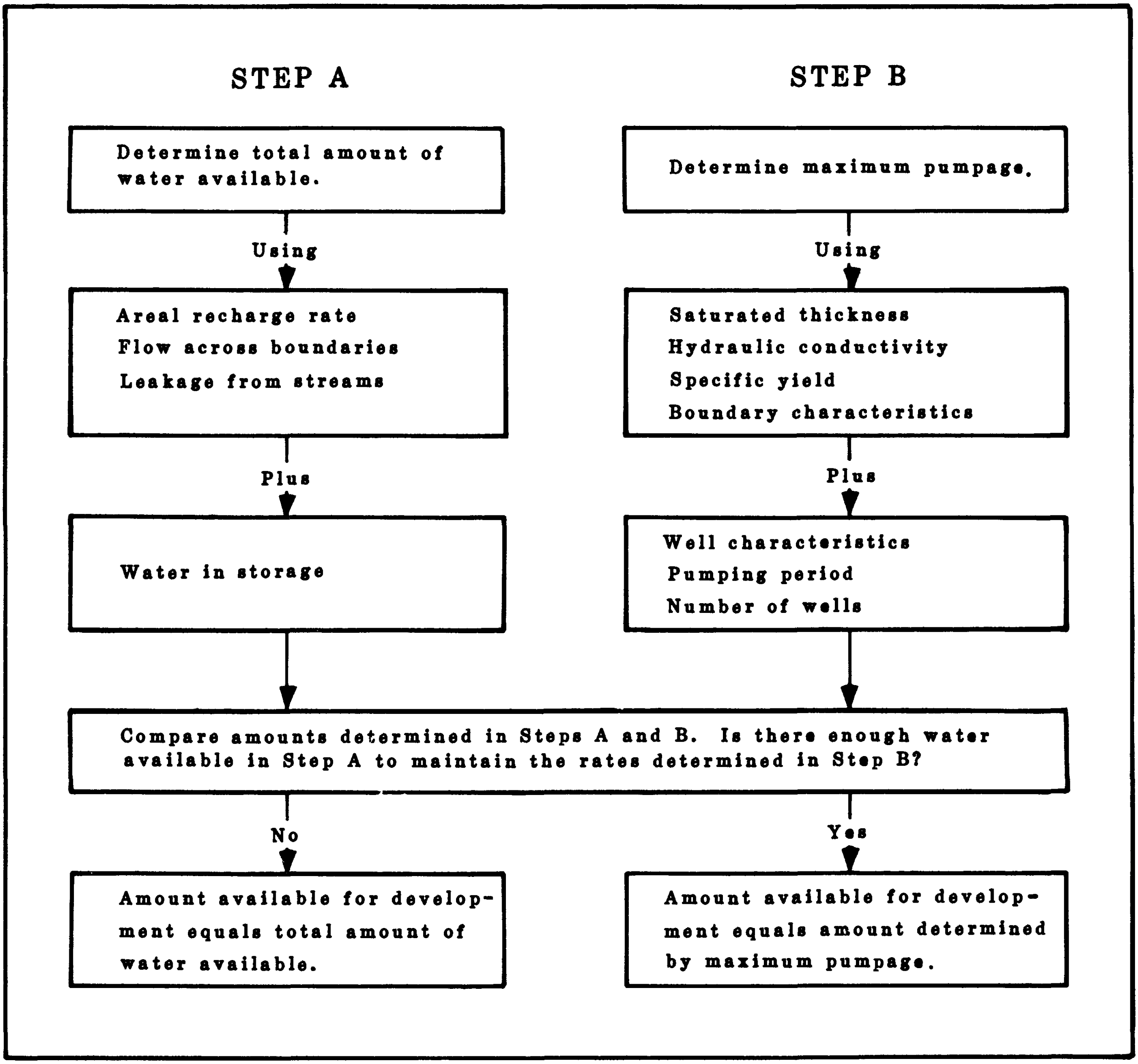


Figure 10.--Flow chart illustrating the procedure used to determine the amount of ground water available from the aquifer.

of an aquifer. These include the number, spacing, and construction characteristics of wells, their location relative to major streams or impermeable boundaries, and the duration of pumping. The distinction between primary and secondary factors is based on the degree of control a water manager might expect to exercise over the resource. Primary factors are generally beyond the control of the water manager but they ultimately determine the total amount of water available from the aquifer. Secondary factors can usually be controlled by the water manager; they determine how much of the total amount can practically be withdrawn.

Figure 10 shows the steps taken to estimate the total amount of water available to an aquifer, the maximum pumpage obtainable from wells tapping the aquifer, and the the amount of water practically available for development. Other factors such as variations in the annual recharge rate, seasonal fluctations in demand, and the economics of ground-water versus surface-water development also influence water availability. In addition, management options such as the decision to export water from the basin, the establishment of minimum streamflow standards, and streamflow augmentation will have an influence on the amount of water an aquifer can yield.

Hydrologic Characteristics

The most important hydrologic characteristics of materials comprising the Pomperaug River aquifer are saturated thickness, hydraulic conductivity, and specific yield. The saturated thickness of an unconfined aquifer is the depth from the water table to the bottom of the aquifer. (See figure 11 A.) Saturated thickness generally determines the amount of available drawdown at a well site and is a key element in the determination of ground-water yields. If materials are suitable, the parts of the aquifer with saturated thicknesses of 40 feet or more have the highest potential for large, sustained yields (200 gal/min or more from individual wells). The saturated thickness of stratified drift in the Pomperaug River valley ranges from less than 1 foot along the margins to as much as 150 feet in central areas (see test boring WY 19TH).

The saturated thickness of the coarse-grained, more productive parts of the aquifer, is about 70 to 85 feet in Southbury (see test borings SB 39TH and SB 40TH) and about 80 to 100 feet in Woodbury (see test boring WY 20TH and well WY 39).

Hydraulic conductivity is a measure of the rate at which water moves through a cross-section of the aquifer. It is defined as the volume of water at the prevailing viscosity that will flow through a given cross-sectional area of an aquifer, under a given hydraulic gradient, during a given time. In this report, hydraulic conductivity is expressed in ft/d (feet per day). The assumed cross-sectional area is 1 foot square and the assumed hydraulic gradient is 1 foot of head decline over 1 foot of horizontal flow. (See figure 11 B.) Hydraulic conductivity values assigned

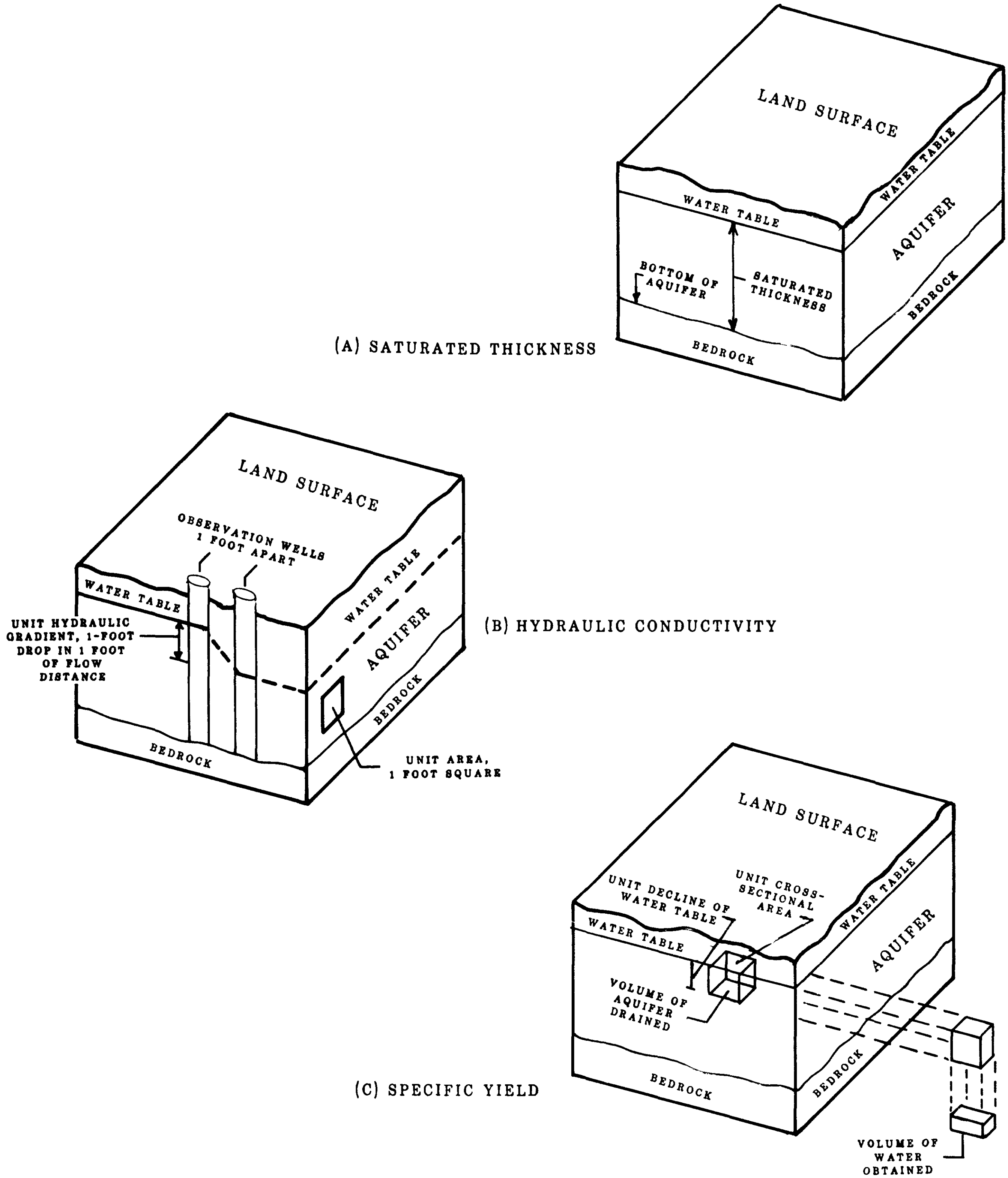


Figure 11.--Block diagram illustrating (A) saturated thickness, (B) hydraulic conductivity, and (C) specific yield in an unconfined aquifer.

to materials making up the Pomperaug River aquifer are based on data obtained from pumping tests and specific capacity determinations of wells, and grain-size characteristics of stratified-drift sediments.

Specific yield is a measure of the ability of an unconfined aquifer to store or yield water. It is analogous to the storage coefficient of an artesian aquifer. Specific yield is determined by gravity drainage of the available pore spaces of saturated materials and is influenced by the duration of the drainage period (Johnson, 1967; Lohman, 1972). Specific yield is the ratio of the volume of water yielded by gravity drainage to the volume of the material drained and is dimensionless. (See figure 11 C.) For example, if gravity drainage of 1 cubic foot of saturated sand yields 0.2 cubic foot of water the specific yield is 0.2 . The specific yield of unconfined aquifers generally ranges from 0.1 to 0.3 and averages about 0.2 (Lohman, 1972).

Recharge

Recharge to the Pomperaug River aquifer is derived principally from precipitation that falls directly on the stratified drift or on the adjacent till-mantled uplands. Records from the National Weather Service station in Woodbury (Index Number 9775) show that during the 1960-79 period, precipitation ranged from 28.2 in./yr (inches per year) in 1965 to 59.9 in./yr in 1975. At this station, the long-term average annual precipitation during the 1941-70 period was 43.1 inches and the average annual amount for the 10 years preceding this study (1969-78) was 51.4 inches. These variations in annual precipitation lead to variations in the rate at which water recharges the aquifer and must be considered in order to properly evaluate the response of the stream-quifer system to different types of hydrologic stress.

In this study, basin-wide recharge rates were estimated for four time periods selected to represent four specific precipitation conditions. The conditions and corresponding time periods are:

Precipitation condition	Time period
Long-term average	1941 - 1970
10-year average	1969 - 1978
3-year highest	1975 - 1977
3-year lowest	1964 - 1966

Two methods were used to estimate basinwide recharge rates; the first uses the National Weather Service precipitation data for each of the above time periods and adjusts these data to the water budget prepared for the Pomperaug River basin by Meinzer and Stearns (1929). The second method considers average annual runoff of the Pomperaug River for each of the four time periods and uses the relationships between total runoff, basin geology, and ground-water outflow that are discussed in several Connecticut water-resources reports (Randall and others, 1966; Thomas, M.P. and others, 1967; Ryder and others, 1970; Cervione and others, 1972; Mazzaferro and others, 1979). In the latter method, ground-water outflow is assumed to be a conservative estimate of recharge if changes in ground-water storage are small.

Average annual precipitation, runoff, and estimated recharge for the four reference periods are shown in table 1. Recharge values, as determined by the two methods, generally agree. For the first three periods (long-term average, 10-year average, and 3-year highest) differences ranged from between 3 and 8 percent. For the fourth period (3-year lowest), the difference was significantly greater. The estimate based on precipitation (6.9 in./yr) is about 30 percent greater than the estimate based on total runoff (5.3 in./yr) and is considered more representative of the annual recharge rate during this drought period (1964-66).

The values shown in table 1 assume that recharge is distributed uniformly over the basin. In the Pomperaug River valley, this is not the case. Average annual, effective recharge in areas underlain by stratified drift is estimated to be almost three times greater than in areas underlain by till (Mazzaferro and others, 1979). Table 2 shows the average annual, effective recharge rates, determined for the four reference periods, that apply to the two areas. The rates shown in the table are determined from:

(1) Basinwide recharge estimates as shown in table 1.

(2) The relative areas of stratified drift (14 percent) and till (86 percent) in the basin.

(3) The assumption, supported by an earlier study in Connecticut (Mazzaferro and others, 1979, p. 45) that areas underlain by stratified drift receive, on the average, 2.7 times more recharge than do areas underlain by till (see (K) below).

(4) The equations:

$$\text{RECH (s.d.)} = \frac{\text{RECH (b.w.)}}{((TL/K) + SD)}$$

$$\text{RECH (till)} = \frac{\text{RECH (b.w.)}}{(TL + (SD \times K))}$$

Where:

RECH (s.d.) = Recharge rate for stratified-drift areas (in./yr)

RECH (till) = Recharge rate for till areas (in./yr)

RECH (b.w.) = Recharge rate, basin wide (in./yr)

SD = Area of stratified drift (percent/100)

Table 1.--Average annual precipitation, runoff, and effective recharge in the Pomperaug River basin during four reference periods

Condition and time period	Average annual precipitation (inches)	Average annual runoff (inches)	Average annual, effective basinwide recharge	
			Estimated from precipitation (inches)	Estimated from runoff (inches)
Long-term average (1941-70)	43.1	21.3	8.6	9.2
10-year average (1969-78)	51.4	27.1	10.3	11.8
3-year highest (1975-77)	55.2	28.6	11.0	12.4
3-year lowest (1964-66)	34.5	12.2	6.9	5.3

Table 2.--Effective average annual recharge to stratified-drift and till areas of the Pomperaug River basin estimated from precipitation and ground-water runoff data

Condition and time period	Average annual, effective recharge			
	Stratified-drift areas		Till and bedrock areas	
	Estimated from precipitation (inches)	Estimated from runoff (inches)	Estimated from precipitation (inches)	Estimated from runoff (inches)
Long-term average (1941-70)	18.8	20.1	6.9	7.4
10-year average (1969-78)	22.5	25.8	8.3	9.5
3-year highest (1975-77)	24.1	27.1	8.9	10.0
3-year lowest (1964-66)	15.1	11.6	5.6	4.3

TL	= Area of till (percent/100)
K	= Ratio of annual, effective recharge rates in stratified-drift areas to those in till areas. The estimated value is 95/35 (Mazzaferro and others, 1979, p. 45) or about 2.7 (dimensionless).

For example, using the basinwide, long-term, average recharge rate of 8.6 in./yr and the appropriate equation, recharge rates for the stratified-drift and till areas of the basin can be estimated:

$$\text{RECH (s.d.)} = \frac{8.6}{((0.86\ /2.7) + 0.14)}$$

$$= 18.8 \text{ in./yr}$$

$$\text{RECH (till)} = \frac{8.6}{(0.86 + (0.14 \times 2.7))}$$

$$= 6.9 \text{ in./yr}$$

The values shown in tables 1 and 2 are average annual, "effective" recharge rates and do not include water that recharges the aquifer and then is returned to the atmosphere by the process of ground-water evapotranspiration. In the stratified-drift parts of the basin, ground-water evapotranspiration is assumed to occur only when the water table is within 8 feet of land surface and is greatest in the lowlands near the Pomperaug River. In the stratified-drift areas, ground-water evapotranspiration is estimated to range from 5 to 10 in./yr during the four reference periods. Consequently, under natural conditions, on an average-annual basis, effective recharge to the Pomperaug River aquifer is estimated to be 20 to 30 percent less than total recharge. Table 3 shows average annual, "total" recharge rates for these areas. This is the sum of the average annual effective recharge rate (see table 2), plus the average annual ground-water evapotranspiration rate for stratified-drift areas, estimated for each of the reference periods.

The ground-water flow model of the Pomperaug River aquifer considers total recharge and ground-water evapotranspiration for areas within the boundaries of the model, and effective recharge for areas that contribute water to the aquifer but are outside the boundaries of the model. In the contributing areas, the ground-water evapotranspiration component of total recharge is returned to the atmosphere before it reaches the model area and only the effective recharge component flows across the model boundaries. The effective recharge rates for adjacent contributing areas, located outside of the model boundaries, are shown in table 2 under the "Till and bedrock areas" heading. A more detailed discussion of recharge from adjacent contributing areas is found in the section of this report titled "Boundary Conditions." Of the two estimates shown for each reference period, the estimate based on precipitation is considered more accurate.

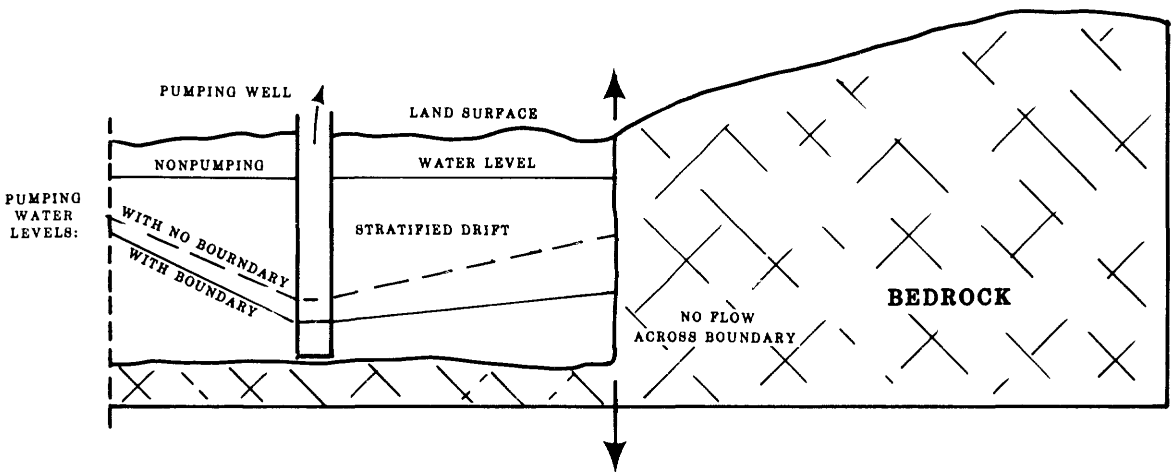
Table 3.--Summary of recharge and ground-water evapotranspiration rates in the stratified-drift areas of the Pomperaug River basin during four reference periods

Condition and time period	Estimated, average annual recharge and ground-water evapotranspiration rates for stratified-drift areas					
	Estimated from precipitation			Estimated from runoff		
	Effective recharge (inches)	+ Ground-water evapotranspiration (inches)	= Total recharge (inches)	Effective recharge (inches)	+ Ground-water evapotranspiration (inches)	= Total recharge (inches)
Long-term average (1941-70)	18.8	8.1	26.9	20.1	8.1	28.2
10-year average (1969-78)	22.5	9.7	32.2	25.8	9.7	35.5
3-year highest (1975-77)	24.1	10.3	34.4	27.1	10.3	37.4
3-year lowest (1964-66)	15.1	5.3	20.4	11.6	5.3	16.9

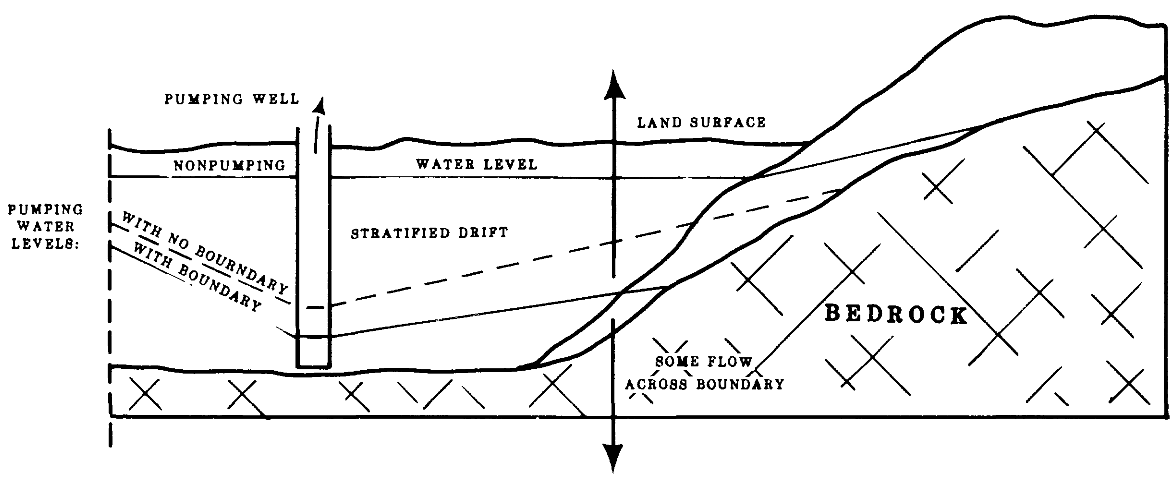
Boundaries

Till, bedrock, and thin stratified drift along the margins of the Pomperaug River aquifer define the aquifer's limits. If these materials were impermeable, no ground-water flow would occur and the contacts between such features and the aquifer would be termed "impermeable-barrier" or "no-flow" boundaries. In the study area, the materials are not impermeable and some ground-water flow does occur. The hydrologic conditions that operate along the margins of the model and the assumptions and calculations that provide estimates of the amounts of water flowing to, or from, the aquifer, are discussed in the section of this report titled "Boundary Conditions." Figure 12 illustrates an idealized impermeable-barrier boundary (A) and compares it to field conditions typical of the study area (B). As the figure shows, under field conditions, there is some flow across the boundary.

The Pomperaug River can also be considered a type of boundary that defines the limits of the aquifer. The river does not fully penetrate the aquifer and there is some flow or "leakage" from the river to the aquifer or from the aquifer to the river. The hydrologic considerations relative to this type of "leaky" boundary are also discussed, in more detail, in the "Boundary Conditions" section of this report. Figure 13 illustrates an idealized line-source boundary (A) and compares it to field conditions typical of the study area (B). The figure shows that, under field conditions, the river does not fully penetrate the aquifer and the influence of a pumping well will extend to the other side of the river channel.



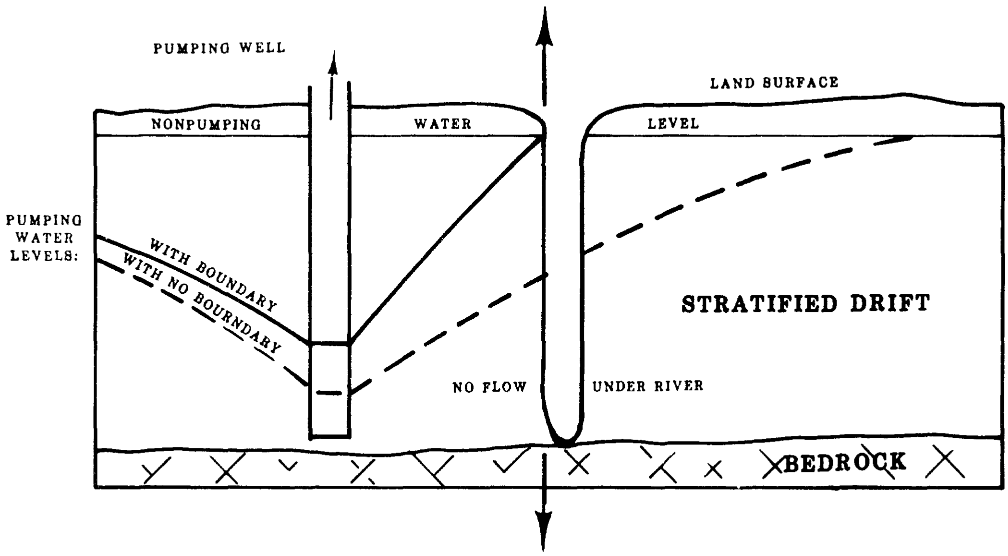
(A) POSITION OF IMPERMEABLE-BARRIER BOUNDARY-THEORETICAL



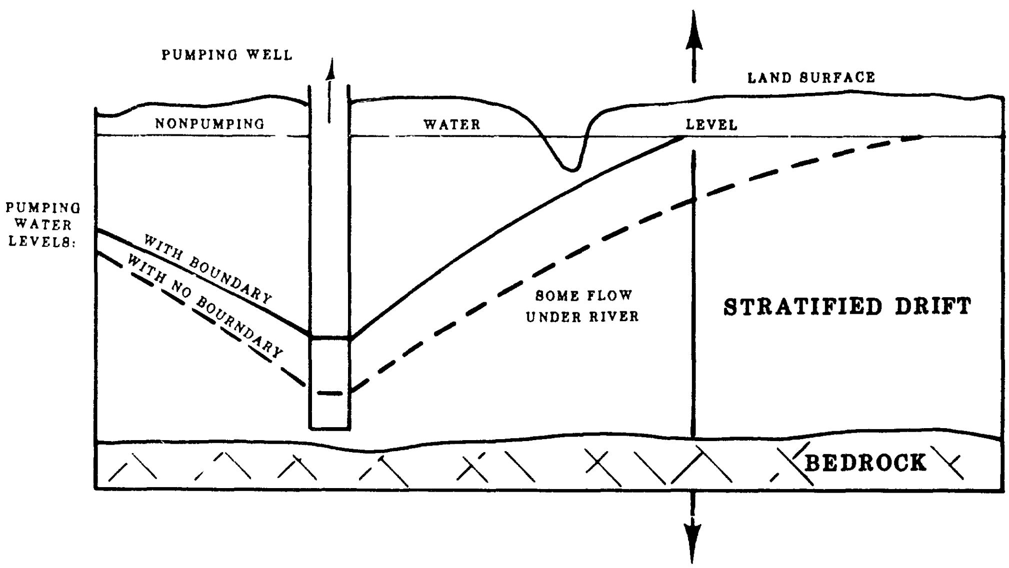
(B) EFFECTIVE POSITION OF IMPERMEABLE-BARRIER BOUNDARY-ACTUAL

(modified from Ferris and others, 1962)

Figure 12.--Hydrogeologic sections of a stratified-drift aquifer showing (A) theoretical and (B) actual conditions that may result if an impermeable-barrier boundary is present.



(A) POSITION OF LINE-SOURCE BOUNDARY - THEORETICAL



(B) EFFECTIVE POSITION OF LINE-SOURCE BOUNDARY - ACTUAL

(modified from Ferris and others, 1962)

Figure 13.--Hydrogeologic sections of a stratified-drift aquifer showing (A) theoretical and (B) actual conditions that may result if a line-source boundary is present.

Both figures illustrate how hydraulic boundaries influence the drawdown of nearby wells. The general effect of an impermeable-barrier boundary is to increase drawdown, whereas that of a line-source boundary is to reduce it. Both types of boundaries alter the shape of the cone of depression.

Stream-aquifer Relationships

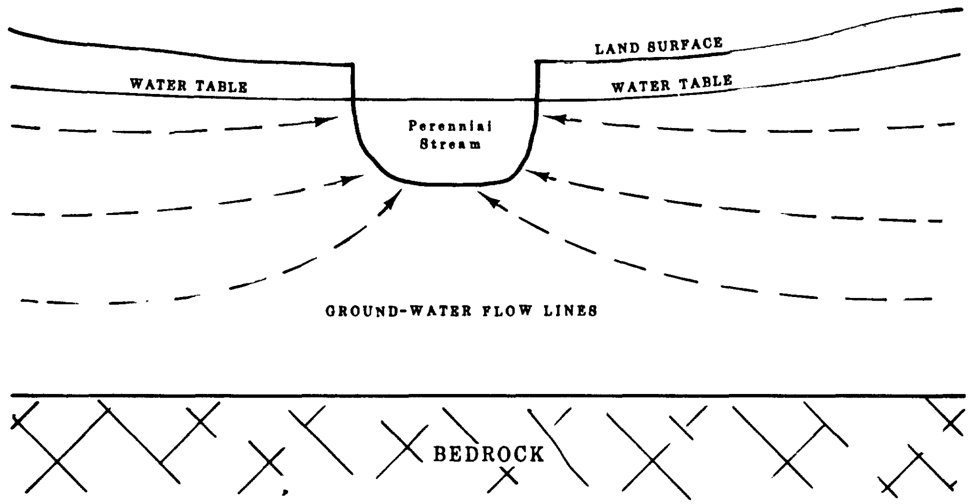
In the study area, the relationship between the stratified-drift aquifer and the Pomperaug River is an important factor that influences both the availability and quality of ground water. If pumpage is small, most of the water that recharges the aquifer moves through it to the stream channel and leaves the basin as streamflow.

In southern New England, this component of streamflow, termed ground-water runoff, is a significant part of total streamflow and is influenced by the percentage of the surface area of the basin that is covered by stratified drift (Randall and others, 1966; Thomas, M.P., and others, 1967; Ryder and others, 1970; Cervione and others, 1972; Mazzaferro and others, 1979). Ground-water outflow (ground-water runoff plus underflow) from undeveloped drainage basins in Connecticut varies from 35 to 95 percent of total runoff as the area covered by stratified drift varies from 0 to 100 percent.

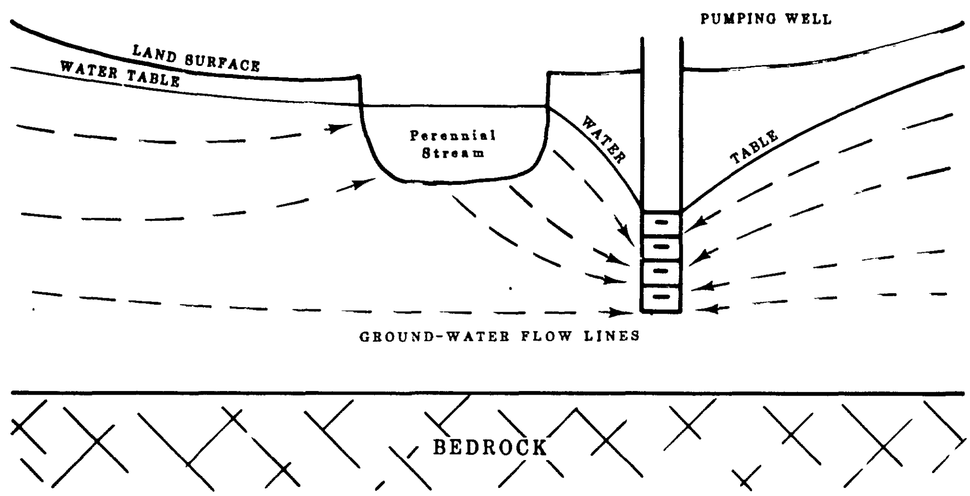
In the Pomperaug River basin, about 14 percent of the drainage area, upstream from Connecticut Route 172, is covered by stratified drift. An equation presented in an earlier report, (Mazzaferro and others, 1979, p. 45) expresses the relationship between ground-water outflow and the percentage of stratified drift in a basin, and estimates that 43 percent of total runoff in the Pomperaug River basin is ground-water outflow.

If large amounts of water are pumped from a well near a stream that is hydraulically connected to the aquifer, ground-water levels will be lowered to the point where water flows from the stream to the aquifer. This process is called induced infiltration. The quantity of water that enters the aquifer depends upon (1) the location, pumping rate, and pumping duration of the well; (2) the hydraulic conductivity and thickness of streambed materials and the difference in head between water in the stream and water in the aquifer; (3) the area of the streambed over which infiltration takes place, and (4) the viscosity of water in the stream channel.

The amount of water that can enter the aquifer by means of this process can be considerable. For example, a recent investigation of a stream-aquifer system in Farmington, Connecticut indicated that, after 180 days of pumping, about 80 percent of the water from a hypothetical well would have infiltrated from the nearby Farmington River (Mazzaferro, 1980). Figure 14 illustrates the general direction of ground-water movement between a stream and a hydraulically connected aquifer under nonpumping (A) and pumping (B) conditions.



(A) NON-PUMPING CONDITIONS



(B) PUMPING CONDITIONS

(from Mazzaferro and others, 1979)

Figure 14.--Hydrogeologic sections of a stratified-drift aquifer showing direction of ground-water movement under (A) non-pumping and (B) pumping conditions.

The quality of water in an aquifer subject to induced infiltration will also be affected as stream water infiltrates. The withdrawn water will be a mixture of surface and ground water, and its quality will reflect the relative contributions of the two sources. In the study area, water from the Pomperaug River generally is less mineralized than ground water, and induced infiltration can improve the chemical quality of water withdrawn from the aquifer. However, if the river became contaminated, the induced infiltration of poor quality surface water might lead to a degradation of water in the aquifer. Surface waters are most likely to be degraded during periods of low flow when dilution effects are minimal. If waste water is discharged to the stream during periods of low flow, the dissolved-solids concentrations of surface waters can be significantly increased. Induced infiltration of this water can lead to serious ground-water quality problems even if surface-water quality deterioration is of short duration.

AQUIFER EVALUATION BY DIGITAL MODEL

Model Description

The Pomperaug River aquifer in Southbury and Woodbury was evaluated using a finite-difference modeling technique developed by Pinder and Bredehoeft (1968) and modified by Trescott and others (1976). The model simulates ground-water flow in two directions and accomodates water-table aquifers that have irregular boundaries and variable hydrologic characteristics. Model input includes initial water-table altitudes, recharge rates, boundary conditions, and aquifer characteristics. Model output includes total sources and discharges of water, head distribution, and drawdowns at specific locations.

Sources of water supplying the aquifer that are considered by the model include recharge from precipitation, inflow across boundaries, and leakage from streams. Discharges include ground-water evapotranspiration, outflow across boundaries, withdrawals from wells, and leakage to streams. (See figure 2.) Water that is temporarily added to, or removed from the aquifer is treated as a change in storage.

The partial-differential equation that describes ground-water flow in an unconfined aquifer is given in two-dimensional form by Bredehoeft and Pinder (1970):

$$\frac{\partial}{\partial X}\left(K_{xx}\, \frac{b\,\partial h}{\partial X}\right) + \frac{\partial}{\partial Y}\left(K_{yy}\, \frac{b\,\partial h}{\partial Y}\right)$$

$$= S_y \frac{\partial h}{\partial t} \pm W(x,y,t) \qquad (1)$$

where;

K_{xx} and K_{yy} are the principal components of hydraulic conductivity operating in the x and y directions (L/t);

h is hydraulic head (L);

S_y is specific yield (dimensionless);

b is saturated thickness (L);

x and y are rectangular coordinates assumed to be co-linear with the principal major and minor flow axes (L);

t is time (t);

W(x,y,t) is the volumetric flux to, or from the aquifer (recharge or withdrawal), per unit surface area (L/t);

In differential form, equation (1) cannot be solved directly. An approximate solution can be obtained by subdividing the region over which the equation operates into a number of rectangular subregions in which aquifer properties are assumed to be uniform. In this manner, the continuous derivatives of the partial-differential equation are replaced by finite approximations at points that correspond to the "nodes" or centers of the sub-regions. This technique produces an equation (a finite-difference approximation) and an unknown (hydraulic head or water-table altitude) at each node used to represent the aquifer. The equation at each node considers conditions at adjacent nodes and, because the number of equations and the number of unknowns are equal, a solution is possible. In this manner, the hydraulic head at each node can be determined.

In the model used to evaluate the Pomperaug River aquifer, a square grid with uniform dimensions (500 by 500 feet) defines the sub-regions and a system based on the convention i = rows and j = columns identifies the nodes. A part of the grid, its dimensions, and an example of the node identification system are shown in figure 15. The adoption of these conventions allows the partial-differential flow equation to be approximated by a finite-difference form at any node. In finite-difference form, the equation (or, more precisely, the approximation) operating at node i,j is:

$$\frac{1}{\Delta x_j}\left\{\left[K_{xx}(i,j+1/2)\;b(i,j+1/2,k)\;\frac{(h_{i,j+1,k}-h_{i,j,k})}{\Delta x_{j+1/2}}\right]\right.$$
$$\left.\left[K_{xx}(i,j-1/2)\;b(i,j-1/2,k)\;\frac{(h_{i,j,k}-h_{i,j-1,k})}{\Delta x_{j-1/2}}\right]\right\}$$

$$+ \frac{1}{\Delta y_i} \left\{ \left[K_{yy}(i + 1/2, j) \; b(i + 1/2, j, k) \; \frac{(h_{i + 1, j, k} - h_{i, j, k})}{\Delta y_{i + 1/2}} \right] - \left[K_{yy}(i - 1/2, j) \; b(i - 1/2, j, k) \; \frac{(h_{i, j, k} - h_{i - 1, j, k})}{\Delta y_{i - 1/2}} \right] \right\}$$

$$= \frac{S_{i,j}}{\Delta t} (h_{i,j,k} - h_{I,J,K - 1}) + W_{i,j,k} \qquad (2)$$

Where;

$K_{xx}(i, j + 1/2)$ is the hydraulic conductivity value operating between nodes (i,j,) and (i,j + 1) in the x-direction (L/t);

$K_{yy}(i + 1/2, j)$ is the hydraulic conductivity value operating between nodes (i,j) and i + 1,j) in the y-direction (L/t);

$h_{i,j,k}$ is the hydraulic head at node (i,j) at time k (L);

$S_{i,j}$ is specific yield at node (i,j) (dimensionless);

$b_{i,j,k}$ is saturated thickness at node (i,j) at time k, calculated as a function of head and determined from either initial conditions or conditions during the preceding iteration (L);

$\Delta xj, \Delta yj$ are the space increments in the x-direction and y-direction (L);

Δt is the time increment (t);

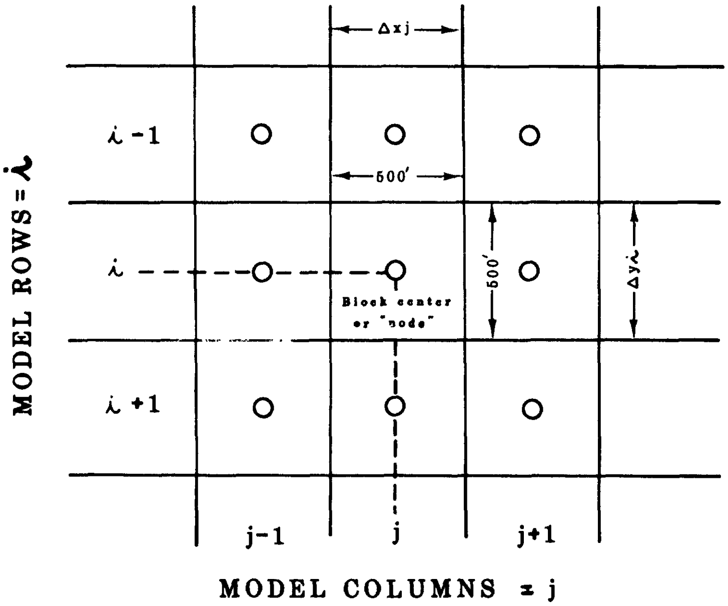
$\Delta x_{j + 1/2}$ is the distance between nodes (i,j) and (i, j + 1) in the x-direction (L);

$\Delta y_{i + 1/2}$ is the distance between nodes (i,j) and (i + 1, j) in the y-direction (L);

i and j are the indices in the y-direction and x-direction, (dimensionless)

k is the time index (dimensionless).

The equations in the form of equation (2) operating over a region of n nodes (n being equal to the number of rows times the number of columns in the model) can be solved by several numerical techniques. In this report the SIP (Strongly Implicit Procedure) solution is used. In this procedure, the series of equations is solved by a matrix algebra technique that replaces the initial coefficient matrix with a modified matrix created to be numerically similiar to the initial matrix and capable of direct solution. Thus, the modified matrix forms the basis for an iterative technique, and a solution to the original set of equations is possible. Detailed discussions of the development of the finite-difference form of the two-dimensional flow equation that is the basis of the model and the SIP solution are found in Remson and others, (1971), and Trescott and others, (1976).



(modified from Trescott and others, 1976)

Figure 15.--Node-designation system, block dimensions, and coordinate notations used in the Southbury-Woodbury aquifer model.

The use of a two-dimensional model to approximate flow conditions in the Pomperaug River aquifer requires the adoption of a series of assumptions that enable the model to simulate the natural system:

(1) Flow in the aquifer is horizontal. Available data indicate that, on an areal basis, vertical flow is not significant and the assumption that flow is essentially horizontal is valid.

(2) Recharge from precipitation is assumed to be distributed uniformly over the aquifer and is maintained at a constant rate during each simulation.

(3) Ground-water evapotranspiration decreases linearly as a function of the depth of the water table below land surface and stops at 8 feet.

(4) The surface of the aquifer is divided into a number of subregions in which hydrologic properties are uniform.

(5) Ground water withdrawn by wells is removed from the area. The consequences of this assumption are lower water-table altitudes and less ground-water runoff than might actually occur. For modest pumping rates, this is not considered significant.

(6) Stream stage is constant for each simulation. In nature, stream stage rises and falls in response to variations in runoff. In the model, the assumption of a constant stream stage that approximates average stream altitude for a given period, is considered reasonable.

(7) Flow across aquifer boundaries is represented by a series of recharging and discharging wells. This assumption may cause some distortion of the water table in the vicinity of the boundaries. In the central part of the model, these differences are not thought to be significant.

(8) Drawdowns at pumping wells are not corrected for the effects of finite well radius, partial penetration or well loss. As a result, water-table altitudes as indicated on plates E and F are averaged over the sub-regions of the model in which the wells are located. Actual drawdowns at these wells, which are optionally computed by the model, are considerably greater.

The conditions discussed above depart to some degree from those existing in the natural system. The discrepencies are not considered great enough to produce significant errors in the simulation process.

Boundary Conditions

The Pomperaug River aquifer model is part of a more extensive natural flow system and the margins of the model are represented by hydraulic boundaries. These boundaries are located so they simulate actual flow conditions as closely as possible. Ideally, boundaries would coincide with natural features such as impermeable bedrock (a no-flow boundary) or a large body of water with a constant water level (a constant head boundary). In the study area, extending the margins of the model to points where no-flow boundaries naturally exist is impractical because of the lack of data and the distances involved. Instead, a line of demarcation between the stratified-drift aquifer and adjacent areas of till, bedrock or thin stratified drift was designated as the model boundary. The areas beyond this boundary are relatively extensive, are generally mantled by thin deposits of till or stratified drift, and contribute some flow to the model area. The method used to estimate the amount of this flow consists of the following steps:

(1) Determine the area of each adjacent area of till and thin stratified drift not drained by a major stream.

(2) Determine the recharge rate for these areas. The recharge rates for till areas, based on precipitation, are used. (See table 2.)

(3) Apportion the rate uniformly among the boundary nodes that share the common border between the adjacent area and the model proper.

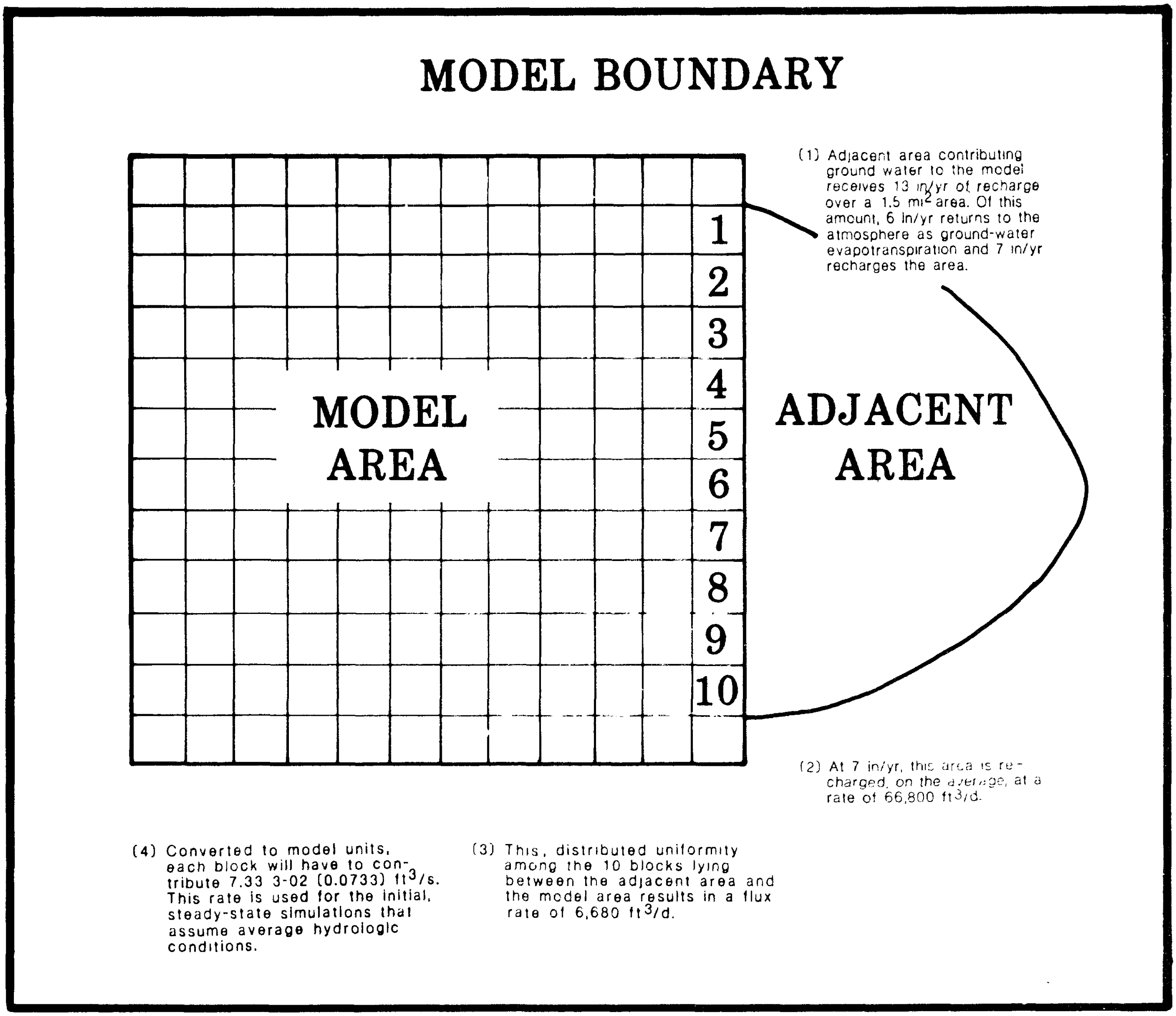


Figure 16.--An idealized model boundary showing the method used to apportion flow from an adjacent area.

Constant flux conditions are assumed along the boundary and a hypothetical well, recharging at a rate equal to the uniform rate previously determined, is placed at each affected boundary node. Figure 16 illustrates the method.

At a few points along the margins of the model, the above technique is not used because: (1) direction of flow is from the model to the adjacent area or (2) the material is saturated, stratified drift, at least 10 feet thick. In these areas, constant flux conditions are again assumed but flow rates under average conditions are estimated from Darcy's Law expressed as the the relationship:

$$Q = KIA \tag{3}$$

where;

Q = rate of flow (L^3/t)

K = hydraulic conductivity (L/t)

I = hydraulic gradient (L/L)

A = cross-sectional area along the boundary through which flow occurs (L^2)

Units assigned to the variables in equation (3) were such that the resultant flux (Q) calculated at each node was in cubic feet per second as required by the model.

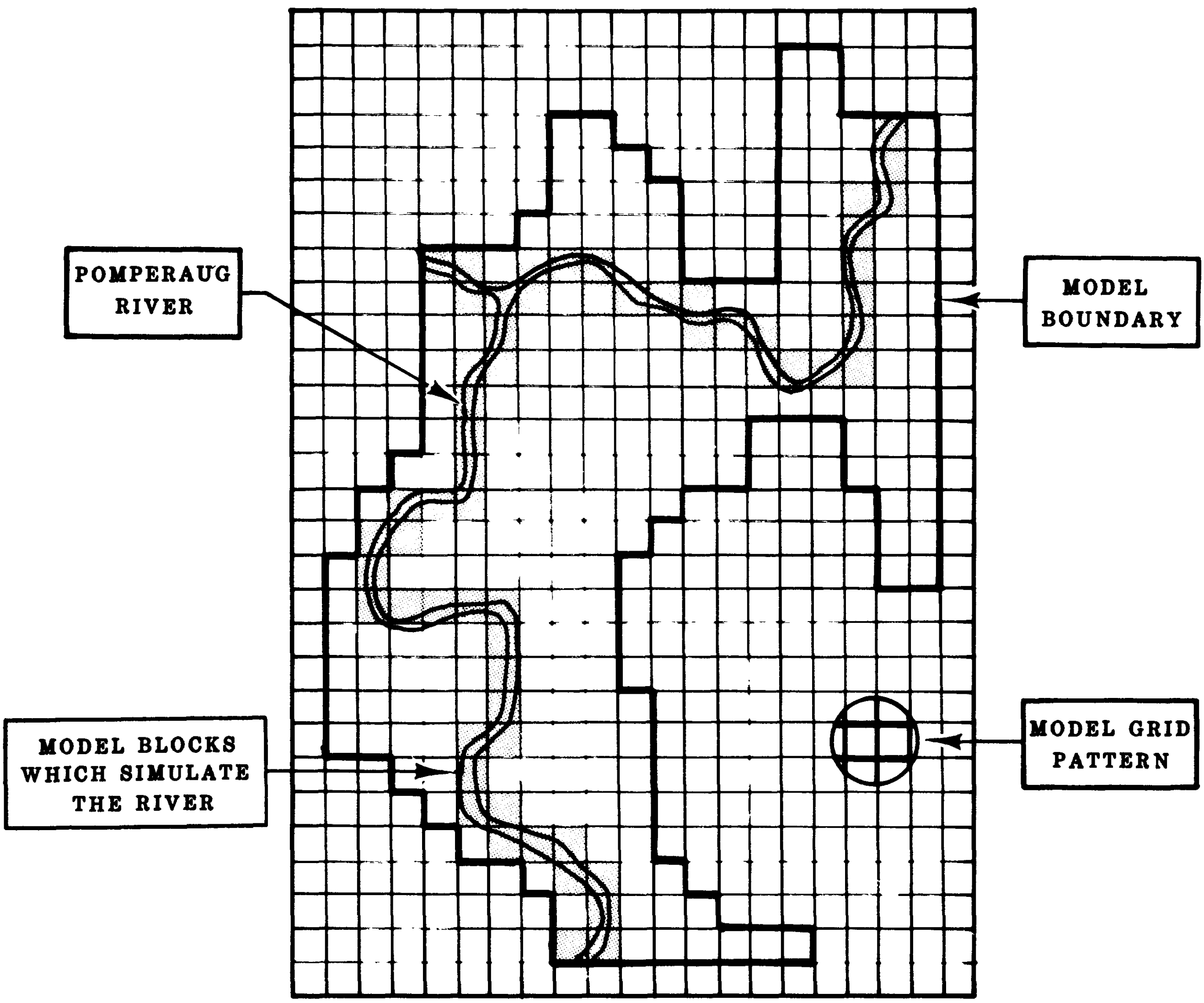


Figure 17.--Part of the Pomperaug River aquifer model showing how certain blocks represent the location of the river.

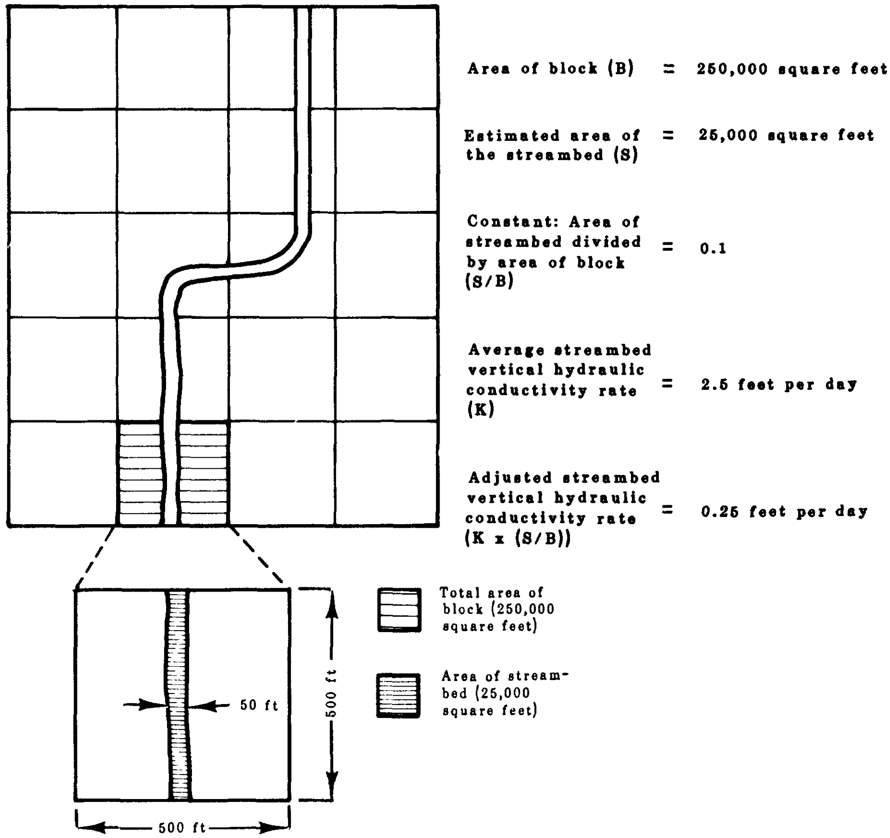


Figure 18.--Idealized sketch of an aquifer model showing how streambed hydraulic conductivity rate is adjusted to compensate for the difference between block area and streambed area.

The Pomperaug River forms a type of boundary that, as water-table altitudes vary, either contributes water to the aquifer or receives water from it. To approximate this condition, the streambed is simulated as a thin, leaky confining bed of limited areal extent. The subregions or blocks of the model that represent the the stream are selected so their position in the model grid generally coincides with the actual location of the stream. (See figure 17.) Exact positioning is not possible because the configuration of the stream channel is not everywhere compatable with the straight lines that form the model grid and, in some areas, the stream flows from one model block to another over a relatively short distance.

Data needed to simulate the stream as a leaky confining bed include vertical hydraulic conductivity and thickness of streambed materials, altitude of the water in the stream channel, and width of the stream. These data were obtained from field observations (stream altitudes, streambed thickness, and stream-channel widths) and from an earlier investigation by Wilson and others, (1974) (average streambed hydraulic conductivity, and streambed thickness). In the model, the actual area of the streambed is smaller than the area of the model block that represents it. Because of this, the vertical hydraulic conductivity of the streambed is reduced to account for the fact that leakage to, or from the streambed, occurs over only part of the block representing the stream. (See figure 18.)

Model Calibration

Calibration is a process during which a series of simulations, adjustments, and evaluations of the model are made to determine if it is capable of accurately reproducing the response of the flow system to specific conditions. For the Pomperaug River aquifer model, calibration consisted of the steps shown below:

(1) Select a reference period during which accurate estimates of recharge, ground-water runoff, and water-table altitudes are available.

(2) Run an initial simulation of the model using recharge rates and water-table altitudes determined for the reference period.

(3) Evaluate the results of the simulation, especially the observed versus calculated values for water-table altitudes and ground-water runoff.

(4) Adjust parameters in areas of the model where evaluation of initial data elements and a comparison of observed versus calculated water-table altitudes indicate that adjustments are needed.

(5) Run another simulation using adjusted parameters determined in step (4).

(6) Repeat steps (3) through (5) until the calculated water-table altitudes and ground-water runoff rates are reasonably close to the observed values.

The reference period that provided the water-table altitude data used to calibrate the model extended from January, 1979 through February, 1980. During this period, and during the ten years preceding it (1969-78), average annual precipitation was similar, and significantly greater than during the long-term (1941-70) period:

TIME PERIOD	AVERAGE PRECIPITATION (in./yr)
Jan. 1979 - Feb. 1980	50.6
Jan. 1969 - Dec. 1978	51.4
Jan. 1941 - Dec. 1970	43.1

This increased precipitation resulted in more recharge and higher ground-water levels for the calibration period than would have occured if precipitation rates had been equal to the 1941-70 average value. Therefore, a recharge rate based on precipitation experienced during 1969-78 was initially used to account for the higher ground-water levels. Also, in observation well WY 1, average ground-water levels during 1969-78 and during January 1979 - February 1980 were nearly equal (24.20 versus 24.17 feet below land surface), a further indication that recharge and other hydrologic conditions for the two periods were similar. This initial recharge rate was subsequently increased by 5 percent on the basis of a sensitivity analysis discussed in a later section of this report, and the adjusted rate (initial rate plus 5-percent adjustment) is used as the final calibration value.

Water-table altitude data were obtained from a network of 25 observation wells located in the study area and measured monthly. Average monthly water-table altitudes from the January 1979 - February 1980 period, determined for each of the 25 observation wells, were used to calibrate the model. Other data used in the initial construction and calibration of the model are summarized in table 4.

Changes in the values of different combinations of model parameters can result in similar model responses; thus, the selection of the parameter and the degree of adjustment is critical. In the calibration of the model, the following criteria are used:

(1) Adjustments to parameters are kept within a range that is considered reasonable for the region.

(2) Adjustments are made only if they conform to known hydrologic and geologic conditions in the study area.

(3) The proximity of reliable data points governs the magnitude of parameter adjustment permitted for an area.

Most of the adjustments to model parameters involved average hydraulic conductivity, aquifer thickness, and conditions along the boundaries. The largest change was a significant reduction in average hydraulic conductivity over much of the model area. This change was acceptable because data used to construct the initial model input arrays were biased toward the more favorable parts of the aquifer. Extrapolation of these relatively high values to other areas of the model produced lower than expected ground-water levels during early calibration runs. The reduction of average hydraulic conductivity values in such areas by about 25 percent improved the correlation between model-simulated and observed water levels.

Adjustments to initial parameter values were also made along parts of the model boundaries. In these areas, the initial estimates of saturated thickness were too low and water levels, computed by the model, rose above land surface. In some areas, the saturated thickness was increased as much as 20 feet in order to allow a specific amount of water to enter the model area while maintaining reasonable water-table altitudes. Data in these areas are sparse but increasing saturated thicknesses from an initial estimated value of 10 feet to a final value of 30 feet is not thought to be unreasonable. In any event, these adjustments along the margins of the model do not greatly alter its response, especially in the central areas where data are more complete and information needs are more critical.

During calibration, the model was allowed to operate over a sufficient number of iterations to insure that flow was essentially steady and water levels had ceased to decline. This condition,

Table 4.--Summary of data used in the initial construction and calibration of the Pomperaug River aquifer model

Parameter	Value or remarks
Model rows and columns - (total number of blocks in model)	34 X 88 - (2,992 blocks)
Model grid dimensions - (spacing convention)	500 X 500 feet - (uniform spacing)
Model blocks with data - (total area)	840 - (7.53 mi^2)
Calibration period	Ten years (1969-1978). Chosen because average water levels at long-term observation well (WY-1) during this time were similar to average water levels during the January, 1979 - February, 1980 period.
Recharge rate	33.8 inches (32.2 inches total recharge plus a five percent adjustment)
Maximum ground-water evapotranspiration rate	28.8 inches
Maximum depth to which ground-water evapotranspiration is assumed to operate	8.0 feet below land surface
Average hydraulic conductivity of the aquifer	Ranges from 5 to 150 ft/d over most of the modeled area.
Average streambed width	50 feet
Average streambed thickness	3.0 feet
Average vertical hydraulic conductivity of the streambed	2.5 ft/d

termed steady-state, was used for all model simulations. After a series of simulations, parameter adjustments, and evaluations of response, the water levels determined by the model were considered acceptable when they met the following criteria:

(1) The average difference between observed and calculated water levels at the 25 observation well sites was less than 2 feet.

(2) The maximum difference between the observed and calculated water level for any of the wells was less than 10 feet.

For these evaluations, the "observed" water level was the average water-table altitude for the 14-month reference period (January, 1979 - February, 1980) determined for each of the observation wells. The observed and model-calculated water levels for the 25 observation wells, determined at this stage of the calibration procedure, are summarized in table 5.

One additional simulation was made during which minor changes of 5 percent were made to average hydraulic conductivity and recharge. These adjustments were made after data were obtained from a sensitivity analysis of the model, discussed in the following section. The 5-percent adjustments made a modest improvement in the correlation between observed and calculated water-table altitudes, (compare tables 5 and 6), and at this point, the model was considered to be calibrated.

A map of the water-table configuration, under steady-state conditions, was prepared from model-generated data and is shown on plate C. The recharge rate is based on the 10-year reference period (1969-78) and is estimated to be 33.8 in./yr (22.5 in./yr effective recharge plus 9.7 in./yr ground-water evapotranspiration plus a 5-percent increase). Contributions of flow from adjacent areas of till and bedrock are based on a recharge rate of 8.7 in./yr (8.3 in./yr effective recharge plus a 5-percent increase). (See Table 2.) A map of average water-table altitudes of the aquifer for the January, 1979 to February, 1980 period is shown on plate B. As noted earlier, average recharge rates and ground-water levels during the two periods are considered to be similar and water-table altitudes shown on the two maps, generally agree. The greater amount of detail on plate B is due to control on water-table altitudes provided by small streams. These data are not included in the model and, thus, are not reflected in the water-table contours shown on plate C.

The ground-water runoff rate, as calculated by the model for steady-state conditions, was also compared to values calculated independently from field data. Ground-water runoff, termed "leakage" by the model, is determined by the four items listed below with their average values:

(1) Vertical hydraulic conductivity of streambed materials (2.5 ft/d)

Table 5.--Comparison of observed and model-determined water levels at 25 locations in the Pomperaug River aquifer

Observation well number (Pl. A)	Location in model (column - row)	Observed water-table altitude (feet above NGVD, 1929)	Model-determined water-table altitude (feet above NGVD, 1929)	Difference (feet)
SB 24	8 - 9	162	162	0
SB 25	9 - 12	178	178	0
SB 27	22 - 25	237	231	+6
SB 28	14 - 26	196	192	+4
SB 29	20 - 30	202	197	+5
SB 30	22 - 35	234	233	+1
SB 32	22 - 38	217	218	-1
SB 33	23 - 40	225	221	+4
WY 1	24 - 62	246	239	+7
WY 25	30 - 81	281	287	-6
WY 26	25 - 73	271	277	-6
WY 27	24 - 80	264	259	+5
WY 28	19 - 79	251	253	-2
WY 29	23 - 73	264	256	+8
WY 30	20 - 75	238	245	-7
WY 32	15 - 70	260	255	+5
WY 33	29 - 57	261	257	+4
WY 34	28 - 53	265	263	+2
WY 35	22 - 53	218	213	+5
WY 36	23 - 50	203	199	+4
WY 37	33 - 80	296	295	+1
WY 38	32 - 77	275	279	-4
WY 39	23 - 62	226	226	0
WY 40	26 - 46	214	214	0
WY 41	32 - 75	287	287	0

Mean, all locations .... +1.4 feet

Number of sites with less than 5 feet difference between observed and model-determined water levels .... 15 (60 percent)

Numer of sites with less than 10 feet difference between observed and model-determined water levels .... 25 (100 percent)

Table 6.--Comparison of observed and model-determined water levels at 25 loctions in the Pomperaug River aquifer after sensitivity analysis

Observation well number (Pl. A)	Location in model (column - row)	Observed water-table altitude (feet above NGVD, 1929)	Model-determined water-table altitude (feet above NGVD 1929)	Difference (feet)
SB 24	8 - 9	162	163	-1
SB 25	9 - 12	178	180	-2
SB 27	22 - 25	237	234	+3
SB 28	14 - 26	196	194	+2
SB 29	20 - 30	202	198	+4
SB 30	22 - 35	234	236	-2
SB 32	22 - 38	217	219	-2
SB 33	23 - 40	225	223	+2
WY 1	24 - 62	246	240	+6
WY 25	30 - 81	281	288	-7
WY 26	25 - 73	271	279	-8
WY 27	24 - 80	264	260	+4
WY 28	19 - 79	251	253	-2
WY 29	23 - 73	264	257	+7
WY 30	20 - 75	238	245	-7
WY 32	15 - 70	260	257	+3
WY 33	29 - 57	261	260	+1
WY 34	28 - 53	265	266	-1
WY 35	22 - 53	218	213	+5
WY 36	23 - 50	203	199	+4
WY 37	33 - 80	296	297	-1
WY 38	32 - 77	275	279	-4
WY 39	23 - 62	226	226	0
WY 40	26 - 46	214	216	-2
WY 41	32 - 75	287	288	-1

Mean, all locations .... +0.2 feet

Number of sites with less than 5 feet difference between observed and model-determined water levels .... 19 (76 percent)

Numer of sites with less than 10 feet difference between observed and model-determined water levels .... 25 (100 percent)

(2) Thickness of streambed materials (3 feet)

(3) Estimated head difference between the stream and the aquifer under initial conditions (1 foot).

(4) Ratio between the actual area of the streambed in a model block and the total area of the block (1:10)

The values, with the exception of head difference, remained constant during the calibration simulations. Head difference is dependent on water-table altitudes in the vicinity of the stream and is calculated by the model during each simulation.

When the calibration process was completed, ground-water runoff, calculated by the model, averaged 35 ft^3/s (cubic feet per second). Using observed total runoff data for the same period, and a relationship that estimates ground-water runoff as a function of basin geology, (Mazzaferro and others, 1979) a comparative value of 35.8 ft^3/s was obtained. Considering the range of error possible in either calculation, the values are essentially the same. Head differences between the stream and the aquifer, as calculated by the model, averaged 0.96 foot at the nodes representing the Pomperaug River. This compares favorably with the initial head difference estimates of 1 foot at each node and is an additional indication that the calibrated model reasonably represents existing, average, conditions.

Model Sensitivity

Sensitivity is a model characteristic that determines the degree to which variations in input parameters influence model response. After initial calibration, the Pomperaug River aquifer model was evaluated for sensitivity to changes in three hydrologic variables: K(ave) (average aquifer hydraulic conductivity), RECH (recharge from precipitation), and LEAK (streambed leakage). The procedure was to run a series of steady-state simulations during which the parameter of interest was increased or decreased by 5 percent of its original or initial calibration value. This resulted in a set of nine steady-state simulations with 5-percent variations on either side of the original values (See table 7).

The nine simulations shown in table 7 represent only seven unique combinations of K(ave), RECH, and LEAK because simulations using the initial (100 percent) values for these parameters (2A, 2B, and 2C in table 7) are the same. After completion of the simulations, the arithmetic mean, standard deviation, and sum of differences squared were determined for the differences between observed (field values) and predicted (model values) water levels at the 25 observation well sites; they are summarized in table 7.

Table 7.--Statistical summary of the differences between observed and model-determined ground-water levels at 25 locations in the Pomperaug River aquifer

[Values of average aquifer hydraulic conductivity, recharge from precipitation, and streambed leakage used to initially calibrate the model are shown below as 100 percent.]

Simulation number	Hydrologic variable (as percentage of initial model calibration value)			Differences between observed and model-determined water levels at 25 locations (measurements are in feet)		
	Average aquifer hydraulic conductivity	Recharge from precipitation	Streambed leakage	Mean	Standard deviation	Sum of differences squared
1 A	95	100	100	0.82	4.05	410.58
2 A	100	100	100	1.40	4.13	457.98
3 A	105	100	100	1.90	4.21	516.31
1 B	100	95	100	2.00	4.21	525.74
2 B	100	100	100	1.40	4.13	457.98
3 B	100	105	100	0.79	4.06	411.26
1 C	100	100	95	1.37	4.13	456.07
2 C	100	100	100	1.40	4.13	457.98
3 C	100	100	105	1.43	4.11	457.06

Examination of these data indicated that, for K(ave) and RECH, optimum conditions had not been achieved. Under optimum conditions, small input-parameter variations, in either direction, will cause a deterioration in model response. This would be shown by an increase in the mean, standard deviation, and sum of the differences squared as parameters are either increased or decreased. As the data in table 7 indicate, this is not the case and some improvement might result if K(ave) and RECH values were modestly adjusted.

After evaluation of the data produced by the first series of sensitivity simulations, a second series was run. In this group, the 100 percent value for K(ave) is the initial calibration value reduced by five percent; for RECH it is the initial calibration value increased by five percent. Streambed leakage (LEAK) was not adjusted for the second series of simulations because the first series indicated that aquifer-wide water levels are relatively insensitive to small changes in this parameter (See table 7). Data from the second series of simulations are shown in table 8.

Table 8.--Statistical summary of the differences between observed and model-determined ground-water levels, after adjustments to hydraulic conductivity and recharge, at 25 locations in the Pomperaug River aquifer

[Adjusted initial calibration values for average aquifer hydraulic conductivity (reduced by 5 percent) and recharge from precipitation (increased by 5 percent) are shown below as 100 percent. Unchanged initial calibration value for streambed leakage also shown as 100 percent.]

	Hydrologic variable (as a percentage of adjusted initial calibration value)			Differences between observed and model-determined water levels at 25 locations (measurements are in feet)		
Simulation number	Average aquifer hydraulic conductivity	Recharge from precipitation	Streambed leakage	Mean	Standard deviation	Sum of differences squared
1 D	95	100	100	-0.39	4.01	388.88
2 D	100	100	100	0.21	4.00	385.85
3 D	105	100	100	0.79	4.06	411.26
1 E	100	95	100	0.82	4.05	410.58
2 E	100	100	100	0.21	4.00	385.85
3 E	100	105	100	-0.39	4.02	391.27
1 F	100	100	95	0.18	4.02	388.68
2 F	100	100	100	0.21	4.00	385.85
3 F	100	100	105	0.24	4.00	385.08

Evaluation of these data indicates a better model response as a result of the 5-percent adjustments. When compared to the first series of simulations, differences between observed and predicted water levels are smaller and departures from the adjusted initial values, in either direction, do not improve the response of the model. This indicates that adjusting the K(ave) and RECH values resulted in a local convergence and further adjustments will not lead to a significantly better relationship between observed and predicted water levels. For these reasons, the adjusted values have been incorporated in the final version of the model and are used in subsequent simulations.

An evaluation of the sensitivity of model-calculated ground-water runoff rates to changes in the three parameters was also made. Increases or decreases in K(ave) of 5 percent resulted in about a 0.5-percent change in average ground-water runoff. Similiar changes in RECH had more significant impacts, increasing or decreasing ground-water runoff rates by about 5 percent. Changes in streambed leakage had a minor effect on model-calculated ground-water runoff rates. Increases or decreases of this parameter by 5 percent changed model-calculated ground-water runoff rates, on the average, less than 0.1 percent from original values. The effects that the changes in K(ave), RECH, and LEAK have on average ground-water runoff rates are summarized in table 9.

Table 9.--Changes in ground-water runoff rates that result from 5 percent increases or decreases in average hydraulic conductivity, recharge, and streambed leakage

[Values of average aquifer hydraulic conductivity, recharge from precipitation, and streambed leakage used to initially calibrate the model are shown as 100 percent.]

Simulation number	Hydrologic variable (as a percentage of initial model calibration value): Average aquifer hydraulic conductivity	Recharge from precipitation	Streambed leakage	Ground-water runoff (ft^3/d)	Ground-water runoff (ft^3/s)
1 G	95	100	100	3,009,162	34.83
2 G	100	100	100	3,025,785	35.02
3 G	105	100	100	3,038,817	35.17
1 H	100	95	100	2,883,617	33.88
2 H	100	100	100	3,025,785	35.02
3 H	100	105	100	3,166,720	36.65
1 I	100	100	95	3,022,188	34.98
2 I	100	100	100	3,025,785	35.02
3 I	100	100	105	3,026,710	35.03

Model Simulations

Several simulations of the calibrated model were made to evaluate the response of the aquifer to specific hydrologic stresses. Three generalized pumpage conditions were assumed and a group of simulations that represented specific combinations of recharge rates and pumpages were run. The pumpage and recharge conditions selected and the number of simulations are shown below; all simulations assume steady-state flow conditions:

(1) No pumpage; recharge ranges from least-favorable (3-year lowest) to most-favorable (3-year highest) conditions; four simulations.

(2) Maximum practical pumpage, 10 wells; recharge ranges from least-favorable to most-favorable conditions; four simulations.

(3) Excess pumpage, 15 wells; average recharge condition (10-year average); three simulations.

Each simulation was evaluated with regard to changes in ground-water levels and ground-water runoff. Simulations with pumpage assume that all water withdrawn from the aquifer is exported. The model is capable of simulating conditions where a part of the withdrawn water is recharged locally but this was not done for this study. The consequences of assuming 100-percent exportation are greater model-calculated water-level declines and less ground-water runoff. Details and results of the simulations are discussed in the sections that follow.

Variations in Recharge

Four simulations of the model were made with no pumpage and with recharge rates varied to represent 10-year average, long-term average, 3-year highest, and 3-year lowest conditions. The recharge rates used in these simulations are based on average precipitation and the method used to estimate them is discussed in the section of the report titled "Recharge." The 10-year average period (1969-78), is the calibration period for the model. The long-term average period (1941-70) is a reference period used by the National Weather Service and includes the drought years of the mid-1960's. The 3-year highest period (1975-77) spans the three consecutive years since 1941, with the highest average annual precipitation and estimated recharge. The 3-year lowest period (1964-1966), spans the three consecutive years since 1941, with the lowest average annual precipitation and estimated recharge. The latter two periods are assumed to represent "most-favorable" and "least-favorable" recharge conditions.

After the four simulations were run, model calculated water levels and ground-water runoff rates were compared. Data from the simulations representing the 10-year average (calibration) period are used as a reference. The greatest departures from reference values, for both water levels and ground-water runoff rates, are seen in the simulation representing the 3-year lowest (least-favorable) period. Declines in water-table altitudes range from less than a foot in some areas near the Pomperaug River to as much as 20 feet in the southeastern part of the study area.

The average ground-water runoff rate calculated by the model for this period was 21.6 ft^3/s about a 40-percent decline from the 35.0 ft^3/s rate calculated for the 10-year reference period. Changes for the other two simulation periods are not as great. Compared to the reference period, ground-water levels for the long-term average period were about 2 to 3 feet lower with a maximum decline of 6 feet. Ground-water runoff averaged 29.5 ft^3/s, about 15 percent less than the reference period. For the 3-year highest (most-favorable) period, water levels were generally 1 to 2 feet higher over the model area with a maximum rise of about 3 feet. Ground-water runoff rates also increased about five percent, from 35.0 to 36.9 ft^3/s.

The relatively small differences in model-calculated water levels and ground-water runoff rates for simulations representing the 10-year average and 3-year highest recharge periods are as expected. The 10-year average period had above-average precipitation (51.4 in./yr), only about 3.8 in./yr less than the 3-year highest period. (See table 1.) The response of the Pomperaug River aquifer to variations in recharge, as calculated by the model, is summarized in table 10. Water-table configurations prepared from model-generated data and representing 10-year average and 3-year lowest recharge conditions, and no pumpage, are shown on plates C and D.

Table 10.--Summary of changes in ground-water levels and ground-water runoff that result from variations in recharge to the aquifer

[Average changes in ground-water levels for each recharge condition are based on the the mean water-table altitudes of the 840 nodes that form the model. Maximum changes in ground-water levels are based on the mean water-table altitudes of the model blocks (500 x 500 feet) with the greatest departure from 10-year average water levels. Total recharge values shown below are the values estimated from precipitation (see table 3) increased by 5 percent.]

Recharge condition	Total recharge (in./yr)	Changes in ground-water levels (departures from 10-year average values)		Ground-water runoff (ft^3/s)
		Average (feet)	Maximum (feet)	
10-year average	33.8	N/A	N/A	35.0
Long-term average	28.2	-1.3	-6.0	29.5
3-year highest	36.1	0.6	3.0	36.9
3-year lowest	21.4	-4.6	-20.0	21.6

Pumping Conditions

Simulations of the calibrated model were also made to establish practical pumping rates for the aquifer under varying conditions of recharge and to evaluate the response of the aquifer to these hypothetical withdrawals. Recharge rates representative of the four recharge conditions (10-year average, long-term average, 3-year highest, 3-year lowest), were again used. Ten hypothetical wells--five in Southbury, and five in Woodbury-- were added to the model and pumped at rates ranging from 125 to 950 gal/min. The sites chosen for these hypothetical wells have a favorable combination of aquifer hydraulic conductivity, saturated thickness, and proximity to the Pomperaug River and thus represent areas most likely to be developed for large water supplies. The locations of the 10 hypothetical wells are shown on plates E and F.

Pumping rates of the hypothetical wells were adjusted during this series of simulations to insure that drawdowns came close to the top of the screen in each hypothetical well, thus approximating practical, long-term pumping rates. The adjustment process consisted of assigning initial pumping rates to each well, running a simulation, examining the resulting drawdowns, corrected for the effects of partial penetration and dewatering of the aquifer (Walton, 1962, p 7-8) and increasing or decreasing the pumping rate in order to bring drawdowns to the desired levels. This process was repeated until drawdowns in all the hypothetical wells were near the top of the well screens. Combined pumping rates of the 10 wells determined in this manner ranged from 5.0 to 8.8 Mgal/d as recharge conditions ranged from least to most favorable.

Table 11.--Summary of the effects of withdrawals from the Pomperaug River aquifer, at maximum practical rates, on ground-water levels and ground-water runoff, for four recharge conditions

[Average changes in ground-water levels for each recharge condition are based on the mean water-table altitudes of the 840 nodes that form the model. Maximum changes in ground-water levels are based on the mean water-table altitudes of the model blocks (500 x 500 feet) with the greatest drawdown. These values are not corrected for the effects of real well radius, dewatering of the aquifer, or partial penetration.]

Recharge condition	Pumpage		Changes in ground-water levels that result from pumping. (Departures from average, non-pumping, ground-water levels, under 10-year, average recharge conditions.)		Ground-water runoff		
			Average	Maximum	Non-pumping conditions	Pumping conditions	Reductions due to pumping
	(Mgal/d)	(ft^3/s)	(feet)	(feet)	(ft^3/s)	(ft^3/s)	(ft^3/s)
10-year average	8.3	12.8	-0.5	-7.0	35.0	26.9	8.1
Long-term average	6.2	9.6	-1.3	-10.0	29.5	23.2	6.3
3-year highest	8.8	13.7	+0.06	-7.0	36.9	28.6	8.3
3 year lowest	5.0	7.8	-4.6	-25.0	21.6	16.6	5.0

As a consequence of the hypothetical withdrawals from the aquifer, ground-water levels, ground-water runoff rates, and total streamflow declined. Impacts were greatest for the simulation representing least-favorable recharge conditions but the data cannot be directly compared because different pumping rates were used for simulations representing each recharge condition. For example, table 14 shows that a pumping rate of 5.0 Mgal/d, under 3-year lowest recharge conditions, results in an average water-level decline of 4.6 feet over the model area, whereas a pumping rate of 8.3 Mgal/d, under 10-year average conditions, results in an average water-level decline of 0.5 feet-- a difference of 4.1 feet. If the 8.3-Mgal/d pumping rate had been used for both simulations, the difference in average water-level declines for the two periods would be significantly greater. Ground-water runoff rates and total streamflow are similarly affected; a uniform pumping rate, held constant during all recharge conditions, would show increasingly lower ground-water levels, less ground-water runoff, and greater reductions in total streamflow as recharge conditions ranged from most to least favorable.

Streamflow in the Pomperaug River is influenced by aquifer withdrawals in two ways: (1) reductions in ground-water runoff that occur when ground water that normally discharges to the stream is intercepted and withdrawn by pumping wells, and (2) reductions in streamflow that occur when water in the stream channel moves through the streambed and recharges the aquifer. If this water is exported from the basin, permanent reductions in streamflow will result.

Ground-water runoff rates, determined by the model under pumping conditions, ranged from 28.6 ft^3/s under 3-year highest recharge conditions to 16.6 ft^3/s under 3-year lowest recharge conditions. Under nonpumping conditions, the rates ranged from 36.9 ft^3/s to 21.6 ft^3/s respectively. The difference in ground-water runoff rates part of the streamflow reduction that can occur when an aquifer is developed. These reductions ranged from 8.3 ft^3/s for most-favorable conditions when the withdrawal rate was 8.8 Mgal/d to 5.0 ft^3/s for least-favorable conditions when the withdrawal rate was 5.0 Mgal/d. The data are summarized in table 11.

Reductions in streamflow resulting from induced infiltration of surface water to the aquifer are termed leakage. Under nonpumping conditions, there is essentially no leakage to the aquifer under any recharge condition. With pumpage, reductions in streamflow due to leakage range from 4.6 ft^3/s (3-year highest recharge conditions, 8.8 Mgal/d pumping rate) to 2.7 ft^3/s (3-year lowest recharge conditions, 5.0 Mgal/d pumping rate). Total reductions in streamflow (ground-water runoff loss plus streambed leakage loss) for the four reference periods ranged from 12.9 to 7.7 ft^3/s. (See table 12.)

As in the case of average ground-water levels, reductions in total streamflow estimated for different recharge conditions cannot be directly compared because pumping rates are not the same. The adjusted pumping rates, however, are practical estimates of sustainable, long-term rates at Ohich water might be withdrawn from the aquifer under different recharge

Table 12.--Summary of the effects on streamflow of withdrawals from the Pomperaug River aquifer

[Four recharge conditions and their corresponding maximum practical pumpages are shown. All water withdrawn from the aquifer is assumed to be consumed or exported from the area.]

Recharge condition	Pumpage (Mgal/d)	Pumpage (ft^3/s)	Reduction in ground-water runoff (ft^3/s)	Leakage from the stream to the aquifer (ft^3/s)	Total streamflow reduction (ft^3/s)
10-year average	8.3	12.8	8.1	4.3	12.4
Long-term average	6.2	9.6	6.3	2.9	9.2
3-year lowest	5.0	7.8	5.0	2.7	7.7
3-year highest	8.8	13.7	8.3	4.6	12.9

Table 13.--Summary of the effects on streamflow, of increased withdrawals from two areas of the Pomperaug River aquifer, under 10-year average recharge conditions

[Total pumpages shown below are the sum of the additional pumpages and 8.3 Mgal/d, the maximum practical rate determined for 10-year average recharge conditions. All water withdrawn from the aquifer is assumed to be consumed or exported from the area.]

Area of increased pumpage	Withdrawals		Reduction in ground-water runoff (ft^3/s)	Reduction due to leakage from the stream (ft^3/s)	Total reduction in streamflow (ft^3/s)
	Additional pumpage (Mgal/d)	Total pumpage (Mgal/d			
Woodbury	2.9	11.2	9.7	7.1	16.8
Southbury	3.2	11.5	8.2	8.9	17.1
Both areas	6.0	14.3	10.0	11.6	21.6

conditions. It should be noted that the pumping rate estimated for 10-year average recharge conditions (8.3 Mgal/d), could not be maintained during extended drought periods without a significant impact on streamflow. Water withdrawn from the aquifer in the simulations described above is assumed to be either totally consumed or exported from the basin and the reductions in ground-water runoff and leakage that result represent permanent reductions in streamflow. If management practices enable a part of this water to remain in the area, ground-water levels and streamflow rates would be increased.

Increases in Pumpage

A third series of simulations was made to evaluate the response of the aquifer to withdrawals considerably in excess of the rates discussed in the preceding section. Only the 10-year average recharge condition was evaluated and steady-state conditions were assumed. The procedure followed in the evaluation is shown below:

(1) Add two wells to the original group of 10 and assign them pumping rates so that total withdrawal is increased by 2.9 Mgal/d (from 8.3 to 11.2 Mgal/d). The new wells are located in the Woodbury part of the aquifer and they increase pumpage about 35 percent over the yield originally estimated for this recharge condition.

(2) Replace the two wells added in step 1 with three wells located in Southbury and assign them pumping rates so that total withdrawal is increased by 3.2 Mgal/d (from 8.3 to 11.5 Mgal/d).

(3) Combine steps 1 and 2 so that five wells are added to the original group. Assign these wells the same pumping rates used in steps 1 and 2 in order to increase the combined yield by about 6 Mgal/d (from 8.3 to 14.3 Mgal/d).

(4) Evaluate the effects of these three conditions of increased pumpage on ground-water runoff and total streamflow.

This procedure shows how the model can be used to assess the impact of specific ground-water development plans on ground-water runoff and total streamflow. One of the assumptions made is that all of the withdrawn water is consumed or exported. Return of some of this water to the aquifer or the stream will result in smaller streamflow losses.

The results of the three simulations are summarized in table 13 and indicate that withdrawals from the aquifer at the rates shown have a significant impact on streamflow. A pumpage increase of about 6.0 Mgal/d (a total withdrawal of 14.3 Mgal/d) reduces streamflow by 21.6 ft^3/s. This is significantly greater than the 90-percent duration flow of the Pomperaug River at Southbury (station number 01204000), which is estimated to be about 15 ft3/s.

A comparison of the data in tables 12 and 13 shows how the increased withdrawals affect streamflow by reducing ground-water runoff and increasing leakage to the aquifer. The data also show that, as pumpage increases, streambed leakage rates become relatively greater than reductions in ground-water runoff. For example, with 10-year average recharge conditions and a withdrawal rate of 8.3 Mgal/d, the reduction in ground-water runoff is about 63 percent of pumpage (8.1 ft^3/s) and streambed leakage is about 34 percent of pumpage (4.3 ft^3/s). (See table 12.) Under the same recharge conditions, but at the higher withdrawal rate of 14.3 Mgal/d, the reductions in ground-water runoff decrease to about 45 percent of pumpage (10.0 ft^3/s), whereas streambed leakage increases to about 52 percent of pumpage (11.6 ft^3/s). (See table 13.) In both instances, the remaining water (about 3 percent of pumpage) is derived from reductions in ground-water evapotranspiration or is model error. The data are summarized in table 14.

Table 14.--Reductions in streamflow due to leakage to the aquifer and reduced ground-water runoff for four pumping rates and 10-year average recharge conditions

Pumpage		Reduction in ground-water runoff		Reduction due to leakage from the stream		Total reduction in streamflow
(Mgal/d)	(ft^3/s)	(ft^3/s)	(Percent of pumpage)	(ft^3/s)	(Percent of pumpage)	(ft^3/s)
8.3	12.8	8.1	63.3	4.3	33.6	12.4
11.2	17.3	9.7	56.1	7.1	41.0	16.8
11.5	17.7	8.2	46.3	8.9	50.3	17.1
14.3	22.2	10.0	45.0	11.6	52.3	21.6

Role of Aquifer Model in Water-Resources Management

The ground-water flow model of the Pomperaug River aquifer developed during this investigation is a tool that can continue to be used in the formulation and implementation of water-management plans in Southbury and Woodbury. The model considers aquifer characteristics and boundary conditions, recharges to, and discharges from the aquifer, and stresses on the system. In operation, the model is provided appropriate data and mathematically determines the altitude of the water table and the related inflow-outflow water balance. In this manner, it provides information that can be used to evaluate the response of the aquifer to specific stress conditions.

A two-way relationship should develop between the users of the information provided by the model and the model itself. In one direction, the model provides an insight on how the stream-aquifer system operates and responds to man-imposed stress. It demonstrates how specific ground-water development plans can influence ground-water levels, streamflow and well yields. The model also shows the effects that a natural stress, such as an extended drought period, would have on the stream-aquifer system. In the other direction, planners, water-resources managers, and town officials who use information provided by the model should take steps to insure that hydrologic data, pertinent to the model area, are catalogued as they become available and are eventually incorporated in the model. In this way, the model becomes a more refined and better water-management tool.

Model output consists of hydrologic data such as head distribution (water-table altitudes), leakage, (ground-water runoff) and discharge (pumpage from wells). By themselves, these data provide only limited answers to specific water-management questions. However, interpretation of these data by competent investigators can provide insights, solutions, and guidance to a wide variety of water-resources processes, problems, and management activities. For example, the water-table configuration around a hypothetical pumping center, determined by a model of the stratified-drift aquifer in Farmington, Connecticut, was used to delineate the size and shape of the area contributing flow to the pumping center under various hydrologic conditions. This information was then used to aid in the development of an aquifer protection plan for that town (Capitol Region Council of Governments, 1982).

Evaluating the consequences of the disposal of water to the ground is another case where the model could be used to assist planners and town officials. If large volumes of water such as storm runoff or treated sewage effluent are to be disposed of to the ground in an area, the water table may rise to unacceptable levels. Simulations of the model, using a recharge rate that reflects this increased contribution of water to a part of the aquifer, would provide valuable information on how water-table altitudes might be affected. Information of this nature can then be used to judge the feasibility of a specific proposal.

Data provided by simulations of the aquifer model can be used in the investigation of a wide variety of hydrologic phenomena. The two key considerations in proper use of the model are (1) a knowledge of the interrelationships that operate between the various model parameters, and (2) an understanding of the capabilities and limitations of the model relative to specific tasks.

Locations and Types of Sampling Sites

Water samples collected at 26 sites in the study area were used to evaluate existing water quality and identify areas with possible water-quality problems. Six ground-water sampling sites are located in Southbury and 13 are in Woodbury. Two surface-water sites are each located in the towns of Bethlehem and Southbury and three are in Woodbury; these sites are shown on plate A. Specific-conductance measurements were made at 14 sites along the Pomperaug River and its tributaries during a low-flow period, and surface-water samples were analyzed for bacteria at 4 of these sites; their locations are also shown on plate A. The results of the analyses of the ground-water and surface-water samples collected during the course of this investigation are shown in tables 15, 16, 26 and 27.

Conditions Affecting Water Quality

Water moving through the hydrologic cycle is subject to changes in physical and chemical characteristics, and these changes determine water quality. In the atmosphere, water in vapor form comes in contact with aerosols, gases, and dust particles. As the water vapor condenses and falls to earth, it dissolves and combines with these substances and, upon reaching the land surface, already contains a significant amount of

Table 15.--Summary of the dissolved-metals reconnaissance of ground water from the Woodbury part of the Pomperaug River aquifer

[Except for germanium only concentrations that equaled or exceeded limiting values are shown.]

Well Number	Copper (ug/L as Cu)	Germanium (ug/L as Ge)	Iron (ug/L as Fe)	Manganese (ug/L as Mn)	Zinc (ug/L as Zn)
(Concentrations determined by ICP emission spectroscopy)					
WY 20	1,000				
WY 26		100	1,000	3,000	
WY 27				300	
WY 35			7,000	1,000	
WY 42					5,000
Limiting values	1,000	No established limit	300	50	5,000
Basis for limit	State 1/	None	EPA 2/	EPA 2/	State 1/

1/ Connecticut General Assembly, 1975

2/ U.S. Environmental Protection Agency, 1976 dissolved and suspended materials. The nature of these materials is determined by the agricultural, industrial, and urban activity in the area, the prevailing wind direction, the proximity of the ocean, and other factors. for example, rain from storms that have recently passed over industrialized areas may have high concentrations of hydrocarbon and sulfur compounds; rain from storms that have passed over the ocean may have high concentrations of sodium and chloride ions.

In the Pomperaug River basin, water quality is typically determined by the quality of precipitation, the composition of earth materials, and local land-use practices. Water in streams is composed of direct and ground-water runoff and, as a consequence, its quality reflects the relative contributions of these components. During periods of high flow, direct runoff is the major component of streamflow and the chemical quality of surface waters may resemble that of precipitation (low dissolved-solids concentrations, generally little or no iron and manganese, pH well below 7.0). During periods of low flow, ground-water runoff is the major component of streamflow, and the chemical quality of surface water under these conditions resembles that of ground water (high dissolved-solids concentrations, increased levels of iron and manganese, pH generally around 7.0). Surface-water quality can be greatly influenced by effluent discharges to streams; dilution effects are at a minimum during low-flow periods, and as a consequence, the impacts of effluent discharges are greatest during these times.

In aquifers, water quality is also determined by the quality of precipitation, the composition of earth materials, and land-use practices. In the basin, under natural conditions, ground water is generally more mineralized than precipitation or surface water. Man's activities can have a significant influence on the quality of ground water in an area. Discharges of waste water directly to the ground, for example, increase the mineralization of ground water and introduce substances that may render the water unfit for many uses. Once contaminated, ground water may remain impaired in quality for an extended period of time.

The infiltration of large quantities of surface water to an aquifer, as sometimes occurs under pumping conditions, can also influence water quality. If the infiltrating surface water is less mineralized than the water in the aquifer, it can dilute the ground water and significantly decrease its dissolved-solids concentration. If, on the other hand, the infiltrating water is more mineralized than the ground water, it could alter ground-water quality and limit its use.

Ground-water Quality

Water quality in the Pomperaug River aquifer was evaluated using chemical data from water samples collected from 19 wells located in Southbury and Woodbury. The samples were first analyzed for dissolved metals by the ICP (Inductively Coupled Plasma) emission spectroscopy procedure. This semiquantitative analytical technique gives the approximate concentrations of 29 dissolved metals that may occur in ground water. It allows a rapid assessment of the quality of the water in the aquifer relative to dissolved metals and can be used to identify areas with potential water-quality problems. Water samples from 5 of the 13 wells in Woodbury analyzed by the ICP procedure had concentrations of one or more metals that indicated a possible water-quality problem. The wells and associated metals are WY 20 (copper and zinc), WY 26 (germanium, iron, and manganese), WY 27 (manganese), WY 35 (iron and manganese), and WY 42 (zinc). The concentrations of these metals and their limiting values are summarized in table 15.

At the levels determined by the ICP reconnaissance, concentrations of the five metals are not high enough to definitely establish a ground-water quality problem. The concentrations of copper and zinc, from wells WY 20 and WY 42, just equal the maximum permissible levels for drinking water established by the State of Connecticut (Connecticut General Assembly, 1975). Concentrations of iron and manganese from wells WY 26, Wy 27, and WY 35 exceed standards set by the USEPA (U.S. Environmental Protection Agency, 1976) but, for these metals, the recommended limits are based on aesthetic rather than toxic considerations. The germanium concentration for well WY 26 is shown in table 15 only because it was detected during the ICP reconnaissance. Germanium is a relatively rare element in the earth's crust; concentrations ranging from 0 to 7 grams per ton have been reported for sedimentary rocks (Rankama and Sahama, 1950). Recommended limits have not been established for germanium. Although the concentrations of the other metals discussed above do not exceed Connecticut drinking-water standards, they point to a potential water-quality problem in the Woodbury part of the aquifer. Because of limitations inherent to the ICP procedure, water from these wells should be analysed by more precise, quantitative techniques and the new data used to establish a baseline for future water-quality evaluations.

Water samples from six wells that tap the Southbury part of the aquifer were also analyzed by the ICP procedure. None of the water samples from these wells had dissolved metals concentrations in excess of the limiting values established by the State of Connecticut or recommended by the USEPA. The results of the chemical analyses of water samples from the 19 wells, collected during the reconnaissance phase, are published in Water Resources Data for Connecticut (1980), a water-data report prepared by the U.S. Geological Survey in cooperation with the State of Connecticut and other agencies. The locations of the sampled wells are shown on plate A.

After evaluating the ICP reconnaissance data, water samples from the same 19 wells were analyzed for additional consituents using atomic absorption spectroscopy and other quantitative techniques. The chemical analyses of these water samples are shown in table 26 and are also published in Water Resources Data for Connecticut (1980). Data from this phase of water-quality testing indicated that concentrations of all the constituents analyzed, with the exception of sodium from wells WY 28 and SB 25, and nitrate from WY 31, were below the maximum permissible levels of the Connecticut drinking-water standards. Table 16 lists 13 ions and the maximum permissible levels for drinking water as established by the State and sum-water in the Pomperaug River aquifer. The table includes the range of concentration for iron and manganese in water from the aquifer. As previously noted, maximum permissible levels for iron and manganese in

Table 16.--Summary of ground-water quality in the Pomperaug River aquifer

[Concentrations in micrograms per liter (ug/L) unless otherwise noted. Method of analysis: Q = atomic absorption (AA) or other quantitative analysis; S = Inductively coupled plazma (ICP) semi-quantitative analysis.]

Chemical constituent	Number of samples	Maximum	Minimum	Limiting value 3/	Method of analysis
Arsenic	19	4.0	0	50	Q
Barium	19	70	10	1,000	S
Cadmium	19	3.0	2/	10	S
Chloride 1/	19	120	4.1	250	Q
Chromium	19	2/	2/	50	S
Copper	19	1,000	2/	1,000	S
Flouride 1/	19	0.2	0	2.0	Q
Iron	19	7,000	2/	300	S
Lead	19	2/	2/	50	S
Manganese	19	3,000	2/	50	S
Mercury	19	0.2	2/	2.0	Q
Nitrate (plus nitrite) as N 1/	19	16	0	10	Q
Selenium	19	0	0	10	Q
Silver	19	2/	2/	50	S
Sodium 1/	19	61	4.1	20	Q

1/ Maximum, minimum, and limiting value shown in milligrams per liter (mg/L).

2/ Below detection limit of analytical method.

3/ Maximum permissible level for Connecticut drinking-water standards (Connecticut General Assembly, 1975) except for iron and manganese where limiting values are those recommended by the U.S Environmental Agency (1976).

drinking water have not been established by the State of Connecticut but limiting values have been recommended by the USEPA (1976).

A ground-water sampling program conducted by the CTDOHS in 1979 indicated a possible organohalide contamination problem in the Middle Quarter area of Woodbury. (See plate A.) A water sample collected from Woodbury Water Company's well no. 2 (U.S. Geological Survey well WY 23) on May 15, 1979, had 83 ug/L (micrograms per liter) of 1,1,1-trichloroethane. At the time, the limiting value for concentrations of this chemical in drinking water, recommended by the CTDOHS was 35 ug/L. This value was based on a SNARL (Suggested No Adverse Response Level) of 33 ug/L suggested by the USEPA (1979). A short time later, (July 13, 1979), the well was resampled and the trichloroethane concentration had risen to 62 ug/L. Analyses of water samples from three nearby wells showed concentrations of this chemical ranging from 1.1 to 140 ug/L.

Because of the high levels of trichloroethane detected in the ground water from this part of the aquifer, water samples were collected from nine wells (four in Southbury and five in Woodbury) and analyzed for organohalide compounds to determine if the problem was widespread. The nine wells are listed in table 17; their locations are shown on plate A. The water samples were collected on August 27, and August 29, 1979 by the U.S. Geological Survey and analyzed by the CTDOHS Laboratory. The procedure used to collect these samples followed guidelines established by the CTDOHS for volatile organic compounds. Each of the wells sampled was pumped to waste for a period of time to insure that formation water was being withdrawn. The water was then directed to a stainless steel container and allowed to overflow for several minutes. A special, glass "volatile organics vial" supplied by the CTDOHS Laboratory was then completely immersed and sealed, while still under water. An evaluation of the results of the chemical analyses indicated:

(1) Organohalide compounds were absent in water from the four wells tapping the Southbury part of the aquifer.

(2) Organohalide compounds were present, in varying concentrations, in water from all five wells tapping the Woodbury part of the aquifer.

(3) Concentrations of organohalide compounds were highest in that part of the aquifer where they were originally identified. (In the vicinity of WY 23, the Woodbury Water Company's production well no. 2.)

Results of the chemical analyses of water samples from the wells sampled during this phase of the investigation are summarized in table 17.

The three Woodbury wells with the highest concentrations of organohalide compounds (WY 25, WY 35, and WY 42) were resampled on November 14, 1979 to determine if the concentrations of these chemicals remained constant or showed a seasonal variation. In addition, the water samples collected from each of these wells were split and sent to two laboratories; the CTDOHS Laboratory, Hartford, Connecticut, and U.S. Geological Survey Laboratory, Atlanta, Georgia,

Table 17.--Summary of organohalide concentrations and construction details for nine observation wells in Southbury and Woodbury, sampled on August 27-28 1979

[All nine wells have 2-inch diameter PVC plastic casings and slotted-casing or plastic, wire-wound screens. Analyses are by the Connecticut Department of Health Services Laboratory, Hartford Connecticut. Dashes indicate constituent not detected.]

	Constituent								
Well number	Chloro-form (ug/L)	Trichloro-ethane (ug/L)	Trichloro-ethylene (ug/L)	Total organo-halides (ug/L)	Number of compounds reported	Well depth in feet be-low land surface	Casing length in feet	Screened interval in feet below land surface	Depth to water in feet be-low land surface
SB 27	--	--	--	0.0	0	22.5	17.5	17.5-22.5	9.8 1/
SB 28	--	--	--	0.0	0	32.9	29.9	32.9-29.9	20.2 1/
SB 29	--	--	--	0.0	0	32.7	27.7	27.7-32.7	20.3 1/
SB 30	--	--	>1.0	>1.0	1	27.5	22.5	22.5-27.5	21.9 1/
WY 25	4.6	4.2	10	21	5	22.4	17.4	22.4-17.4	5.6 2/
WY 27	2.5	3.0	3.3	11	5	23.0	18.0	18.0-23.0	3.8 2/
WY 35	25	5.8	27	77	8	22.7	17.7	17.7-22.7	6.3 1/
WY 39	--	7.3	--	7.3	1	22.2	19.2	19.2-22.2	6.4 1/
WY 42	--	260	1.1	262	3 4/	26.0	23.0	23.0-26.0	16.0 3/

1/ Water level measured August 28, 1979.

2/ Water level measured August 27, 1979.

3/ Water level measured July 13, 1979.

4/ Two compounds identified, one unidentified.

for a comparison of analytical results. This was done to insure that interpretations of the results reported by the laboratories reflected changes in field concentrations, not differences in analytical techniques.

The results of these analyses indicated that determinations from the two laboratories are generally the same. (See table 18.) The data from the November samples also show that there was a significant decrease in organohalide concentrations when compared to the August samples. Water from well WY 25 had a total organohalide concentration of 20 ug/L in August and none in November. Water from well WY 42, which is located about 300 feet northeast of the Woodbury Water Company well no. 2, showed a decrease in total organohalide concentrations from 262 ug/L in August to 126 ug/L in November. These reductions may be the result of dilution by precipitation, the movement of contaminated ground-water downward during the fall recharge period or subsurface biodegradation (Simon, 1983). The results of the chemical analyses of this group of samples are summarized in table 18.

On December 11, 1979, another group of water samples was collected from Woodbury Water Company well no. 2 and from eight nearby wells. These samples were analysed for organohalide compounds by the Newlands Sanitary Laboratory, Bloomfield, Connecticut. Data from this series of analyses confirmed earlier findings: (1) trichloroethane was the most prevalent organohalide compound, and (2) the highest concentrations of organohalide compounds appeared to extend from the vicinity of Woodbury Water Company well no. 2 to the northeast toward an area of commercial and industrial development. The data also showed a further reduction in organohalide concentrations in water from well WY 42. Total organohalide concentrations of the sample collected from this well on December 11, 1979 was 92 ug/L. This is about a 65 percent decrease from the 262 ug/L determined for the water sample collected on August 29, 1979.

A map showing the locations of the nine sampled wells is shown in figure 19. The results of the chemical analyses of the water samples collected from these wells on December 11, 1979 are summarized in table 19.

Because of the organohalide compounds, especially trichloroethane, detected in the water from their production well, the Woodbury Water Company decided to pass all the water from this well through activated carbon filters. This practice is being continued at the present time. In addition, water samples from the production well are periodically analyzed for organohalide compounds and the raw (untreated) water is showing a reduction in the amount of trichloroethane present. A sample collected from this well on October 13, 1981 and analysed by the Newlands Sanitary Laboratory had a trichloroethane concentration of about 32 ug/L (Kevin Moran, Woodbury Water Company, oral communication, 1982). This value was significantly less than those from samples collected in 1979 which showed trichloroethane concentrations ranging from 62 to 104 ug/L. It is also below the SNARL used by the CTDOHS in 1979, and well below the revised SNARL of 300 ug/L (U.S. Environmental Protection Agency, 1980) presently in use.

Table 18.--Summary of organohalide concentrations detected in water from three wells in Woodbury sampled in August and November, 1979

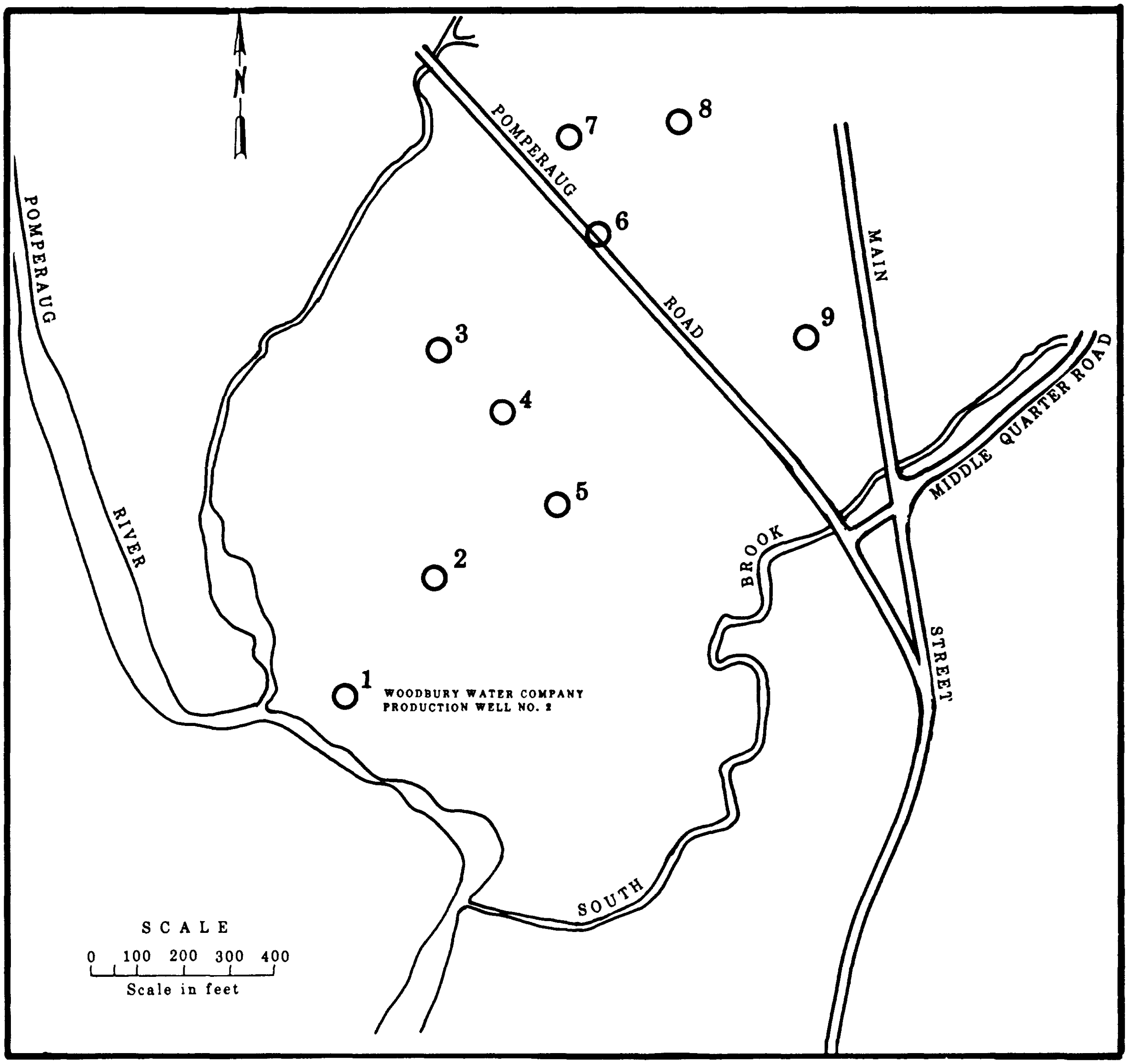
[Analytical laboratories noted below are Connecticut Department of Health Services Laboratory, Hartford, Connecticut (CTDOHS) and U.S. Geological Survey Laboratory, Atlanta, Georgia (USGS).]

Well number	Date sampled	Number of compounds reported	Trichloro-ethane (ug/L)	Total organo-halides (ug/L)	Analytical laboratory
WY 25	08-29-79	5	4.2	21	CTDOHS
WY 25	11-14-79	0	0.0	0.0	CTDOHS
WY 25	11-14-79	0	0.0	0.0	USGS
WY 35	08-29-79	8	5.8	77	CTDOHS
WY 35	11-14-79	2	1.7	4.3	CTDOHS
WY 35	11-14-79	1/ 1	0.0	0.0	USGS
WY 42	08-29-79	3	260	262	CTDOHS
WY 42	11-14-79	1	126	126	CTDOHS
WY 42	11-14-79	1	137	137	USGS

1/ No organohalide compounds detected; 4.0 ug/L of toluene reported.

The source of the trichloroethane detected in ground-water samples from the Middle Quarter area has not been identified. This chemical compound, also known as methyl chloroform, is commonly used as a metal cleaner and degreaser. Trichloroethane has been found in water samples from other areas in the United States and its presence in ground water is often due to the improper or accidental disposal of solvents.

Trichloroethane is not considered to be a carcinogen according to the USEPA and is relatively low in toxicity compared to some of the other alkyl halocarbon compounds to which it is related. Presently (1980), there is insufficient data to fully evaluate the uptake, distribution, and metabolism of this compound in human beings (U.S. Environmental Protection Agency, written commun., 1980).



Base by U.S. Geological Survey

Woodbury Quadrangle, 1955,
Photorevised 1970

Figure 19.--Sketch map showing locations of nine wells in Woodbury sampled for organohlide compounds on December 11, 1979.

Table 19.--Summmary of organohalide concentrations in water from the Woodbury Water Company production well and eight observation wells sampled on December 11, 1979

[Analyses by the Newlands Sanitary Laboratory, Bloomfield, Connecticut. results reported in ppb (parts per billion), values shown in table converted to ug/L (micrograms per liter) and assume a water density of 1.00 grams per cubic centimeter.]

Well location number shown on figure 19	Other identification	Chloroform (ug/L)	Trichloroethane (ug/L)	Trichloroethylene (ug/L)	Total organohalides (ug/L)	Number of compounds reported
1	Woodbury Water Co. production well Number 2. 1/	0.6	104	0.7	108	7
2	U.S. Geol. Survey observation well. 2/	0.9	84.7	2.0	92	7
3	Woodbury Water Co. observation well.	0.9	2.6	0.2	3.7	3
4	do.	0.9	147	0.8	157	7
5	do.	3.2	2.1	3/	7.5	4
6	Other nearby observation well.	12.8	28.5	2.6	71	7
7	do.	0.6	0.3	3/	6.1	4
8	do.	0.3	3/	3/	0.3	1
9	do.	0.3	148	0.5	152	6

1/ U.S. Geological Survey well WY 23. 2/ U.S. Geological Survey Well WY 42.

3/ None detected at the 0.1 ug/L level.

Table 20.--Summary of the concentrations of five constituents or properties of surface-water samples in the Pomperaug River basin collected during low and high flows

[Data are compared to Connecticut drinking-water standards for raw or untreated water.]

Constituent or property	Connecticut drinking-water standards (Specifications shown below refer to untreated water and determine level of treatment required.)		Low-flow range			High-flow range		
	Disinfection and chemical treatment	Complete conventional treatment	Number of sites sampled	Minimum	Maximum	Number of sites sampled	Minimum	Maximum
Coliform organisms (colonies per 100 milliliters of water)	Not to exceed 100 colonies per 100 ml as measured by an average based on the running arithmrtic mean for the most recent 12-month period. No individual sample is to exceed 500 colonies per 100 ml.	Not to exceed 20,000 colonies per 100 ml as measured by a monthly geometric mean.	5	85	750	7	600	2,800
Turbidity (NTU)	Not to exceed 1 NTU except as allowed under EPA regulations for finished water. 1/	Not to exceed 250 NTU as measured by a monthly geometric mean.	5	1.0	2.0	7	1.0	1.0
Copper (mg/L)	0.05 mg/L	1.0 mg/L	5	0	.008	7	.002	.003
Cyanide (mg/L)	.01 mg/L	.2 mg/L	4	0	0	0	----	----
Mercury (mg/L)	.002 mg/L	.005 mg/L	5	2/	2/	7	2/	.0005

1/ Nephelometric Turbidity Units (NTU) are considered comparable to Jackson Turbidity Units (JTU) by the U.S. Environmental Protection Agency, (1974.)

2/ Less than 0.0005 mg/L.

Surface-Water Quality

Surface-water quality in the Pomperaug River basin was evaluated using chemical and physical data from 12 surface-water samples collected at seven sites in Bethlehem, Southbury, and Woodbury. The streams, number of sites, and number of samples are; Pomperaug River (three sites, six samples), Nonewaug River (two sites, three samples), Weekeepeemee River (one site, two samples) and East Spring Brook, (one site, one sample). Water samples were collected during both low-flow (November 6, 1978) and high-flow (May 14, 1979) periods at five of the sites to see what effects large variations in stream discharge may have on water quality. The results of the chemical analyses of the samples collected during this phase of the study, together with physical characteristics determined in the field, are summarized in table 27.

Five of the chemical constituents or physical properties determined for the surface waters of the Pomperaug River basin are among those used by the CTDOHS to judge the suitability of untreated water for human consumption and the level of treatment needed. These items include turbidity, the number of coliform bacteria colonies present in a known volume of water, and the concentrations of dissolved copper, cyanide, and mercury. The Connecticut drinking-water standards for these five constituents, relative to untreated water at a treatment plant intake, are shown in table 20 and compared with data obtained from waters of the Pomperaug River basin during high and low flow.

In addition to the five items shown in table 20, the concentrations of 11 other constituents were evaluated. These constituents have limiting values for drinking water, established by the State of Connecticut, that are independent of the level of treatment. They include seven metals (arsenic, barium, cadmium, chromium, lead, selenium, and silver), three non-metals (chloride, flouride, and nitrate), and one detergent indicator (MBAS-- methylene-blue active substance). The results of these analyses are also summarized in table 27. These data are also compared against the Connecticut drinking-water standards. The results of the comparison are shown in table 21.

Of the 16 water-quality characteristics investigated, all except turbidity and coliform bacteria concentrations appear to be well below the Connecticut drinking-water standards during both low and high-flow conditions. Turbidity ranged from 1.0 to 2.0 NTU (Nephelometric Turbidity Units) for the five samples collected during low flow and was 1.0 NTU for all seven samples collected during high flow. At these levels, turbidity of the surface waters for the Pomperaug River basin is well below the Connecticut drinking-water standards for water requiring complete conventional treatment that specify a limit of 250 NTU, measured as a monthly geometric mean. The much more restrictive standards requiring disinfection and chemical treatment only specify that untreated water samples should not exceed 1.0 NTU. Of the 12 samples analyzed, only the sample collected from this limit. The turbidity of this sample was 2.0 NTU. This indicates that turbidity should not be a major water-quality problem in the Pomperaug River basin under most flow conditions.

Table 21.--Summary of the concentrations of 11 constituents detected in surface-water samples in the Pomperaug River basin, collected during low and high flows

[Data are compared to the Connecticut drinking-water standards for finished or treated water except for MBAS. Low flow samples collected Nov. 6, 1978; high flow samples collected May 14, 1979.]

Chemical constituent	Maximum permitted level allowed by Connecticut drink-water standards (mg/L)	Low-flow range			High-flow range		
		Number of sites sampled	Minimum (mg/L)	Maximum (mg/L)	Number of sites sampled	Minimum (mg/L)	Maximum (mg/L)
Arsenic	0.05	5	0	0	7	0	0.002
Barium	1.00	5	0	0	7	0	0
Cadmium	.01	5	0.001	0.002	7	0	.002
Chromium	.05	5	0	0	7	0.001	.002
Lead	.05	0	N/A	N/A	4	0	.002
Selenium	.01	5	0	0	7	0	0
Silver	.05	5	0	0	7	0	0
Chloride	250	5	12	21	7	7.6	16
Flouride	2.0	5	.1	.1	7	.1	.2
Nitrate (plus nitrite) as N	10	5	.21	.99	7	.24	.64
MBAS 1/	.5	4	0	0	1	0	0

1/ MBAS (methylene-blue active substance) is an indicator of chemical detergent compounds. Maximum permitted level shown is for untreated water.

The number of coliform bacteria colonies per 100 mL (milliliters) of water that was determined for the water samples analyzed during this phase of the investigation cannot be compared directly to the Connecticut drinking-water standards for untreated water. These standards are based on either a 12-month running average (disinfection and chemical treatment) or a 12-month geometric mean (complete conventional treatment), whereas the data shown in tables 20 and 27 represent only one or two samples per site. Nonetheless, some general interpretations can be made. The standards requiring complete conventional treatment specify that water samples do not exceed 20,000 coliform bacteria colonies per 100 mL of water, measured as a monthly geometric mean. Although only a limited number of samples were collected, the ranges determined for both low flow (85 - 750 colonies per 100 mL of water) and high flow (680-2,800 colonies per 100 mL of water) indicate that, under normal conditions, the surface waters in the basin easily meet the standard. The standards requiring disinfection and chemical treatment only, are much more restrictive; they specify that water samples do not exceed 100 colonies of coliform bacteria per 100 mL of water based on a 12-month running average and no individual sample exceeds 500 colonies per 100 mL of water. As the data in table 20 indicate, coliform bacteria levels exceed these standards. The fact that the number of coliform bacteria colonies generally increases as flows increase indicates that soil bacteria are being washed to the stream during storms. It does not indicate a specific source of contamination.

Impact of Development

Data collected during this study indicate that water quality is generally good relative to Connecticut drinking-water standards with the exception of the previously discussed organohalide contamination in the Middle Quarter section of Woodbury. As an area develops, however, the chances of adverse impacts on the quality of both surface and ground water increase. For example, agricultural activities, waste disposal, accidental spills, and leaks in liquid storage facilities that may accompany commercial, industrial and residential growth can significantly degrade water quality.

Ground water may become more mineralized in places where aquifers are recharged with the effluent from septic systems or industrial and municipal waste treatment facilities or where they are recharged with precipitation infiltrating through landfills, salt piles, and other materials associated with development. In areas where water used for coolant purposes is discharged to the ground, water temperatures in the aquifer may rise to unacceptable levels. The improper or accidental discharge of industrial wastes such as solvents, plating chemicals or spent process waters may also degrade ground water. The high levels of trichloroethane, a common industrial solvent, detected in ground-water samples from the Middle Quarter area of Woodbury, are probably the result of an accidental discharge. Pesticides, used in both residential and agricultural areas, can be troublesome because of widespread application and the the low maximum permissible levels established for some compounds. For example, the

Connecticut drinking-water standards specify a concentration of 0.0002 mg/L for endrin, a widely used pesticide. At this level, one kilogram (2.2 pounds) of endrin would make five billion liters (1.32 billion gallons) of water unfit for human consumption.

Surface waters may also be adversely affected by many types of development. Water in streams becomes more mineralized and less oxygenated as the ratio of treated sewage effluent to total stream discharge increases. Activities such as clearing forested areas for agriculture, road building, and housing construction cause increased soil erosion and larger sediment loads in streams. Runoff from developed areas contributes a wide variety of dissolved and suspended materials to the surface waters of a basin. The result of these and other activities on the surface water of an area is a general deterioration in water quality.

Surface water and ground water are closely related in the Pomperaug River valley and the deterioration of water quality in one of these resources can significantly affect the other. For example, leachate from a landfill could contaminate ground water. This degraded water, discharging to a nearby stream, could cause serious surface-water quality problems especially during low-flow periods. Another example would be the infiltration of contaminated surface water to an aquifer. As was noted earlier in the report, the induced infiltration of poor quality surface water could lead to a deterioration of water in the aquifer. A problem of this nature is a possible consequence of ground-water development because it is common practice to locate large production wells close to perennial streams in order to increase yields.

The adverse effects on the quality of the surface-water and ground-water resources of an area that often are the consequences of development may be short- or long-term. For example, when an area is excavated and natural vegatation is removed, high sediment concentrations in streams and lakes can result despite precautions. This condition is usually temporary and, in a relatively short time, when drainage systems have been installed and permanent ground cover has been reestablished, the problem can be eliminated.

On the other hand, some examples of degraded water quality that have resulted from man's activities have persisited for decades. This is especially true when ground-water is involved because the rate at which ground water moves through the subsurface is slow. Once contaminated, an aquifer can continue to supply degraded water even though the source of contamination has been identified and removed or other remedial steps have been taken. This is because the natural flushing action of uncontaminated recharge flowing through an aquifer is often the only practical means of improving ground-water quality and the process can take many years. In the New Haven, Connecticut area, for example, large withdrawals of ground-water in the 1940's caused saline water to intrude the stratified-drift aquifer and chloride concentrations as high as 3,000 mg/l were reported. Since the late 1940's, ground-water withdrawals from this area have been substantially reduced and ground-water quality has improved because of the flushing action of the natural recharge that supplies the aquifer. Nearly 30 years later however, as a consequence of slow, ground-water movement, chloride concentrations in the area were still higher than they were prior to the intrusion of saline water (Mazzaferro and others, 1979).

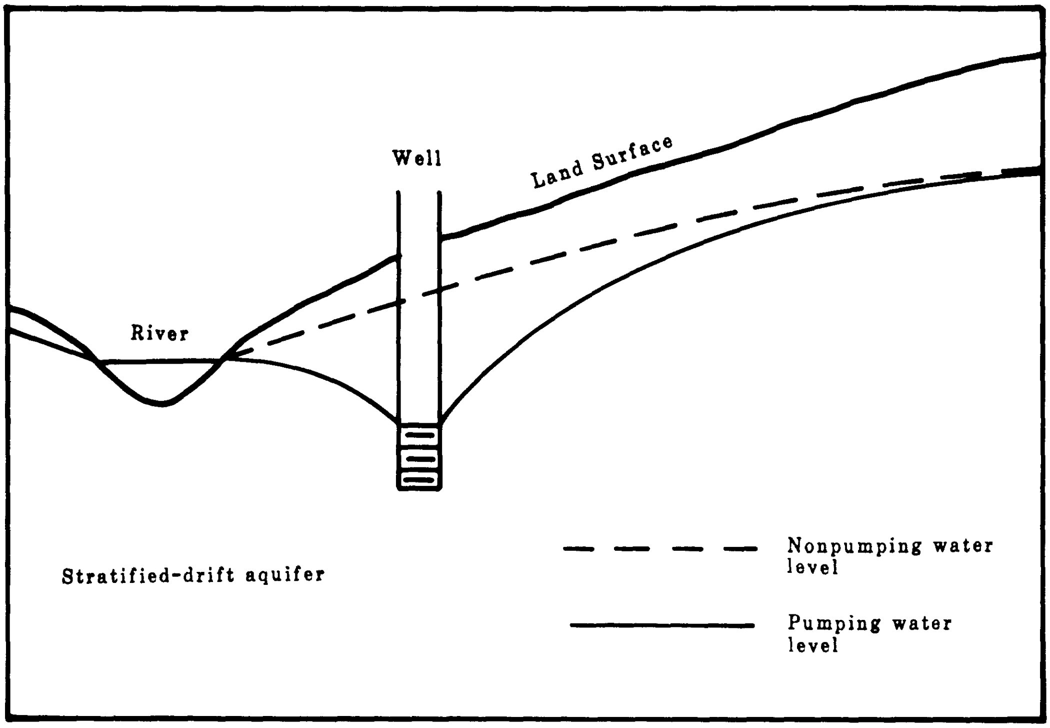


Figure 20.--Idealized hydrologic section of part of a stratified-drift aquifer showing how pumping a well steepens the water table and increases the hydraulic gradient.

Relationship Between Ground-Water Movement and Water Quality

The quality of water pumped from an aquifer is determined by the natural quality of the ground water and the nature and proximity of possible sources of contamination. Ground water flows in the direction of decreasing head; thus, contaminated water entering the aquifer at a point of higher head (higher water-table altitude) flows toward areas of lower head (lower water-table altitude) and eventually discharges to a stream, lake, swamp, or spring. If a discharging well is located down-gradient from a source of contamination, the rate of flow of ground water (and its associated contaminants) may be increased because pumping lowers the water table near a well thereby increasing the hydraulic gradient. (See figure 20.)

The relative locations of contamination sites and pumping centers and the direction of ground-water flow are key factors in evaluating how contamination might affect a ground-water supply. In an unconfined aquifer, maps showing water-table altitudes can be used to determine the horizontal direction of ground-water flow and from this, the general horizontal direction of a contaminant moving through the aquifer. Water-table maps have contour lines that show equal water-gradient or slope of the water table, the increase or decrease of the water-table altitude over a

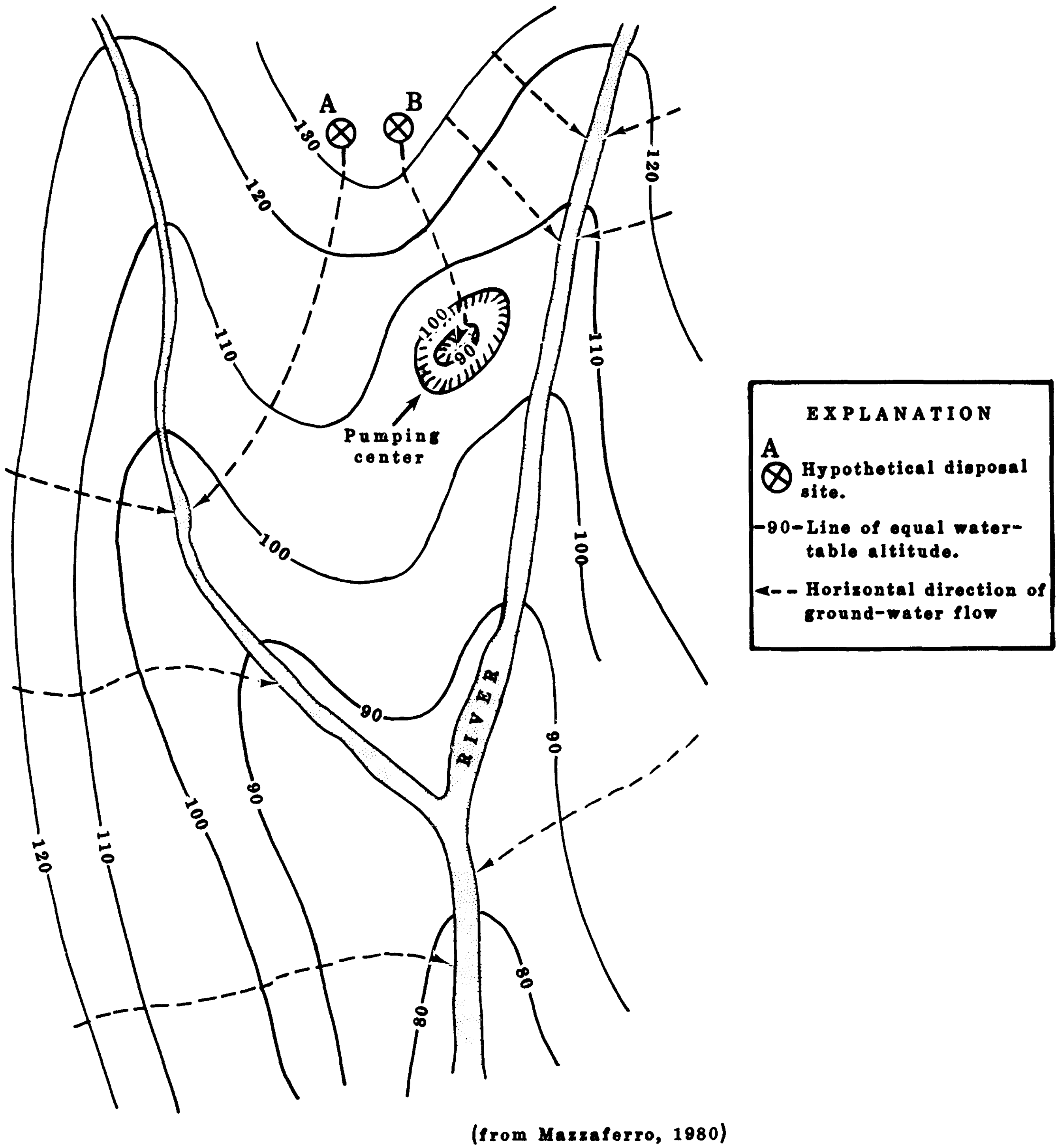


Figure 21.--Generalized map of a hypothetical aquifer showing ground-water flow directions near two sites and their relationship to a pumping center.

[A substance introduced to the aquifer at site A would eventually discharge to the tributary stream. A substance introduced at site B would flow toward the center of pumping, eventually reach it, and affect the quality of the water withdrawn there] known distance. The horizontal direction of ground-water flow in an area will be perpendicular to the water-table contours and in the direction of decreasing hydraulic gradient.

Figure 21, a map with water-table contours, a center of pumping, and two ground-water contamination sites, illustrates the relationship between water-table altitude and the direction of ground-water flow. The figure also shows that if a source of contamination is known, the general horizontal direction of flow of the degraded water can be determined.

In addition to flow direction, average flow velocity provides some insight on the movement of contaminated water through the aquifer. The average linear velocity ($\bar{v}$) of ground water can be estimated by the equation (Freeze and Cherry, 1979, p.71):

$$\bar{v} = \frac{K}{n} \quad \frac{\partial h}{\partial l} \qquad (4)$$

where;

$\bar{v}$ is average linear ground-water velocity (L/t)

K is hydraulic conductivity (L/t)

n is volumetric porosity of the aquifer materials (dimensionless)

$\frac{\partial h}{\partial l}$ is the partial differential of hydraulic head (h) with respect to length of flow path (l) or the hydraulic gradient (L/L)

If only approximate velocities are needed, the field hydraulic gradient, $(h_1 - h_2)/l$, can replace the partial differential form ($\partial h / \partial l$) in equation (4) and the resulting expression becomes:

$$\bar{v} = \frac{K}{n} \cdot \frac{h_1 - h_2}{l} \qquad (5)$$

where; $\bar{v}$, K, and n are as previously defined

h_1 and h_2 are the water-table altitudes at points p_1 and p_2 respectively

l is the horizontal distance between points p_1 and p_2

Using field values for average hydraulic conductivity, water-table altitude and distance that are representative of parts of the Pomperaug River aquifer and assuming an effective porosity of 0.30:

K = 75 ft/d

$$n = 0.30$$

$$h_1 = 175 \text{ feet}$$

$$h_2 = 165 \text{ feet}$$

$$l = 1{,}000 \text{ feet}$$

equation (5) can be solved for average linear velocity.

$$\bar{v} = \frac{75}{0.30} \cdot \frac{(175 - 165)}{1{,}000}$$

$$\bar{v} = 2.5 \text{ ft/d}$$

At this rate, the average time of travel for ground water over the 1,000 feet between hypothetical points p_1, and p_2 would be about 400 days. It is important to note that the values determined by equation 5 are approximate. Hydraulic conductivity and porosity used in the equation represent average values (Heath and Trainer, 1968) and the use of the arithmetic expression for hydraulic gradient [$(h_1-h_2)/l$] assumes this factor remains constant. In addition, average linear ground-water velocities as determined by equation 5, should not be used to predict velocities or times of travel of contaminants. Nevertheless, data provided by the equation indicates the slow rate of movement of ground water through an aquifer. Contamination problems that become apparent at some point in time may have originated months or years earlier.

Variations in Streamflow and Water Quality

Surface-water quality is affected by variations in stream discharge in a variety of ways. Under natural conditions, when the consequences of man's activities on streamflow and water quality are at a minimum, low flows tend to be more mineralized than high flows but have lower concentrations of coliform bacteria. This is because (1) under low-flow conditions, streamflow consists principally of ground-water runoff, and (2) under natural conditions, the principal source of coliform organisms in surface water is the soil; low-flow conditions reflect the absence of recent storm events and relatively few coliform bacteria are washed to the stream from the soil.

When man's activities in an area increase, streamflow patterns and surface- water quality change. The degree of change is determined by the waste-disposal, water-development, and land-use practices that become established. If, for example, large parts of the basin are served by sanitary sewers, and the treated effluent is discharged to the stream, the reach of stream below the treatment plant outfall will experience an increase in both the volume and degree of mineralization of low flows due to the volume and increased dissolved solids concentration of the discharged effluent. If the area is also served by storm sewers, peak streamflows, especially during the early part of a storm event, may substantially increase. This can cause erosion and lead to an increased sediment load in the water. In addition, the initial runoff from storm events often dissolves and flushes away debris that has accumulated on the land surface. In developed areas, this can significantly increase the amount of dissolved and suspended material carried by the stream.

Surface-water quality problems that might occur as a basin is developed and related remedial actions depend on a number of factors; detailed discussion of which is beyond the scope of this report. At the most elementary level, the volume and nature of the waste material discharged, and the streamflow characteristics must be known. These data, when used in conjunction with water-quality standards that are based on the most beneficial uses of the water, will enable water managers to properly utilize the resource. This information is also needed to develop regulations that will improve water quality in areas where improvement is needed and maintain water quality in areas where it is presently satisfactory.

SUMMARY AND CONCLUSIONS

Ground-Water Avialibility

Data obtained from the Pomperaug River aquifer model indicate that the stratified-drift aquifer, under present conditions, has a potential long-term yield of 5.0 to 8.8 Mgal/d. This range considers the aquifer's hydraulic characteristics, variations in natural recharge rates, and reductions in streamflow that might result as a consequence of the withdrawals. Four recharge conditions are evaluated; they range from 3-year lowest (least-favorable) with an average total recharge rate of 21.4 in./yr, to 3-year highest (most-favorable), with an average total recharge rate of 36.6 in./yr. All evaluations assume that none of the withdrawn water would be returned to the Pomperaug River or the aquifer within the boundaries of the study area. With this assumption, average streamflow is reduced by 7.7 ft^3/s under least-favorable conditions, and 12.9 ft^3/s under most-favorable conditions. The larger reduction under most-favorable recharge conditions reflects the fact that an additional 3.8 Mgal/d is assumed to be withdrawn from the aquifer and exported from the basin.

Long-term yield estimates assume 10 hypothetical pumping wells, five in Southbury, and five in Woodbury. They are located in the most-favorable parts of the aquifer. The combined withdrawal rate estimated for this hypothetical plan of development under 10-year average total recharge conditions (33.8 in./yr), is 8.3 Mgal/d. At present, the principal withdrawals from the aquifer are in Southbury. During the period 1979 - 1981, the Heritage Village Water Company pumped six wells, all in Southbury, and reported an average pumpage of about 1.0 Mgal/d. In 1981, about 68 percent of the water withdrawn by the Heritage Village Water Company was distributed within the basin and about 32 percent was exported. The other major water utility in the area, the Woodbury Water Company, reported an average withdrawal of 0.15 Mgal/d during the same period. This pumpage was from two wells located in Woodbury and was distributed entirely within that town.

The potential long-term yield determined for the aquifer (5.0 - 8.8 Mgal/d) is significantly greater than the present average withdrawal rate (about 1.5 Mgal/d) and the development of additional ground-water supplies is likely. The locations of future withdrawal sites and projected pumping rates depend upon factors such as exportation versus in-basin use, the desireability and consequences of reductions in streamflow and the feasibility of reusing water. These factors are beyond the scope of the present report.

Effect of Ground-Water Development on Streamflow

Because of the relationship between ground water and surface water in the Pomperaug River basin, the withdrawal of large amounts of water from the aquifer, if not returned to the system, will result in a reduction in streamflow. If all pumpage were exported from the basin, reductions in flow of the Pomperaug River (in the vicinity of South Britain) would range from 7.7 to 12.9 ft^3/s. These reductions are the result of two processes; declines in the amount of ground water entering the stream channel (ground-water runoff loss) and increases in the amount of water infiltrating from the stream to the aquifer (induced recharge). Simulations of the model using the adjusted 10-year average total recharge rate (33.8 in./yr) and the long-term withdrawal rate (8.3 Mgal/d) show that the streamflow reductions due to decreased ground-water runoff are about 63 percent of total pumpage, and those due to increased induced recharge are about 34 percent of pumpage. With the same recharge but a significantly higher withdrawal rate (14.3 Mgal/d), the streamflow reduction due to decreased ground-water runoff falls to about 45 percent of total pumpage while induced recharge increases to about 52 percent. This means that, under the conditions stated, the equivalent of 11.6 ft^3/s would have to infiltrate from the stream to the aquifer to maintain the 14.3 Mgal/d pumping rate.

Estimates of the reductions in streamflow assume that all the water withdrawn from the aquifer is exported from the basin. If typical patterns of ground-water development evolve, this would not be the case, and part of the withdrawn water would be used within the basin and returned either to the aquifer or to the Pomperaug River. These actions would mitigate the effect that ground-water withdrawals have on streamflow. Nonetheless, even if all the water pumped from the aquifer were used within the basin, some consumptive losses will result. These losses would cause an undetermined reduction in streamflow that should be considered in future ground-water development plans.

Water Quality

The quality of ground water and surface water in the study area, with one exception, is generally excellent and meets Connecticut drinking-water standards. Chemical analyses of ground-water samples, collected at sites in Woodbury, show that organohalide compounds, principally trichloroethane, are present in ground water from the Middle Quarter area. This problem was first identified by the CTDOHS. The Woodbury Water Company, which has a production well in the area, has taken a series of steps including monitoring and filtration through activated carbon, to insure the quality of the water withdrawn from this part of the aquifer. The concentrations of two metals, iron and manganese, were found to exceed USEPA (1976) recommended standards in some ground-water samples. These standards are for aesthetic and economic reasons and elevated iron and manganese concentrations in drinking water are not considered to constitute a health problem.

Surface-water samples collected at seven sites in the study area meet the Connecticut drinking-water standards except for the number of coliform bacteria colonies present. The data show that concentrations as high as 750 colonies per 100 mL of water during low-flow periods and as high as 2,800 colonies per 100 mL of water during high-flow periods are present. At these levels, complete conventional treatment is required if the water is to be used for public supply. The chemical analyses of surface-water samples in the study area, evaluated for concentrations of ten dissolved metals, three nonmetals, and MBAS (a synthetic-detergent indicator) showed that the water met the Connecticut drinking-water standards.

The quality of a water resource can change significantly in a short period of time, especially if improper waste disposal activities or accidental waste spills occur. In addition, the temporary degradation of surface water can lead to the long-term degradation of ground-water especially, if significant amounts of surface water recharge the aquifer through the process of induced infiltration. For these reasons, the quality of both the surface water and ground water, as discussed in this report, reflect conditions that existed at the time the samples were collected. If the generally good quality of the water in the area is to be maintained, ground-water and surface-water quality should monitored and waste-disposal activities carefully controlled.

(Figure 22 and Tables 22-27 follow)

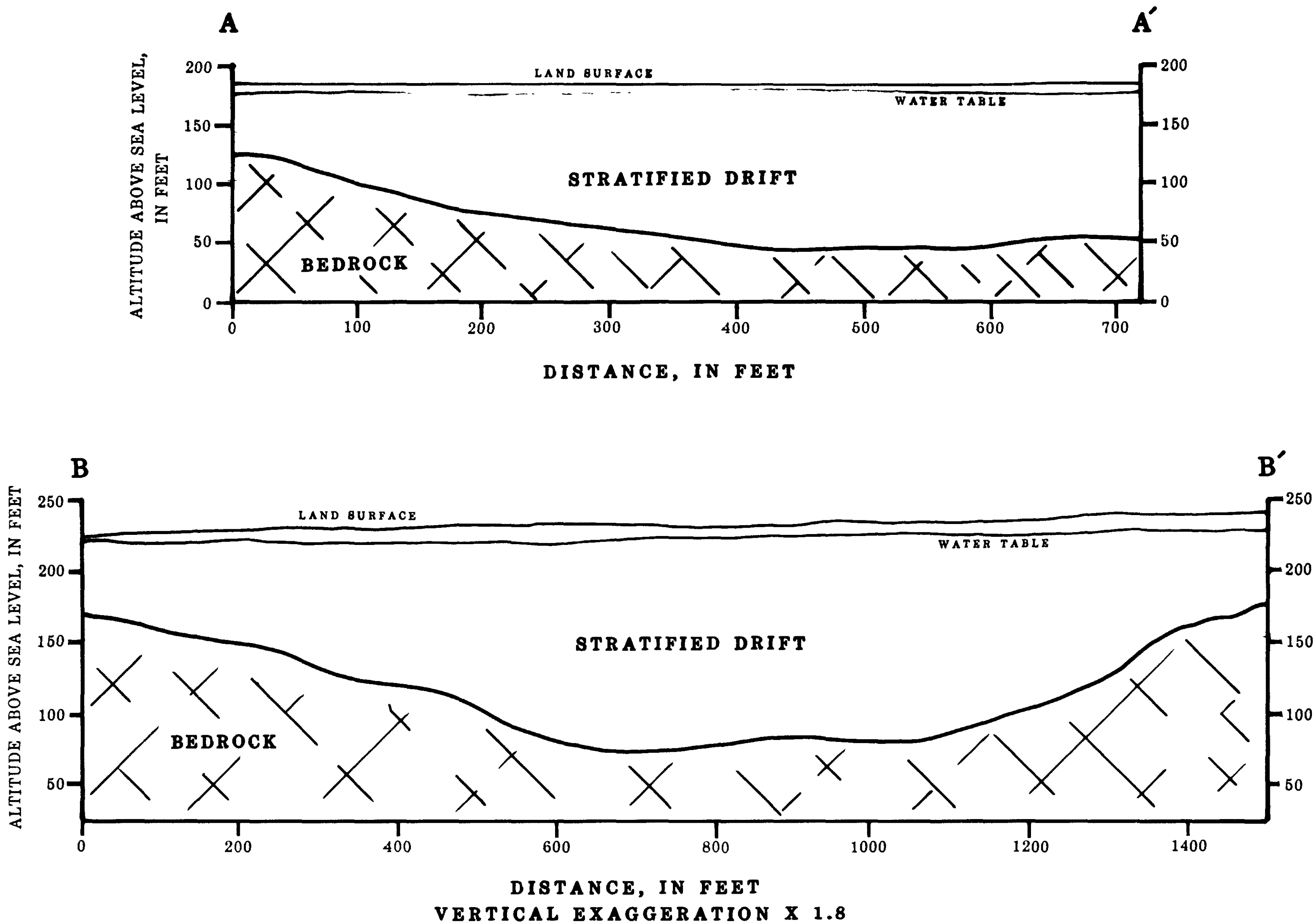
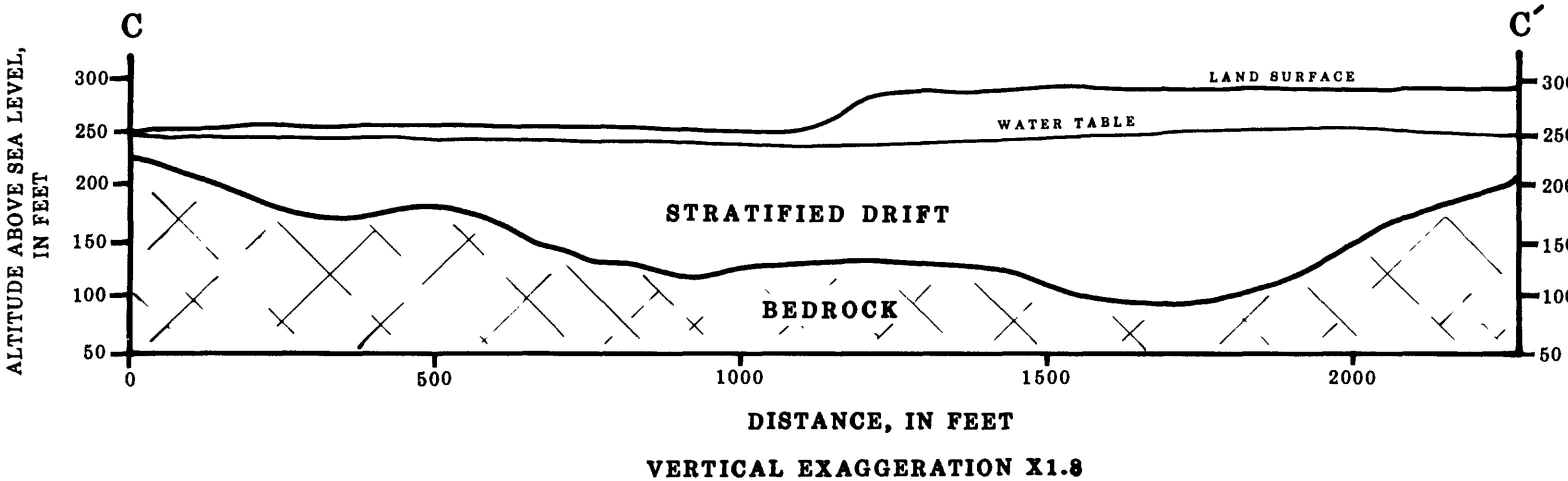


Figure 22.--Seismic refraction profiles showing depth to the water table and depth to bedrock.

[Hydrogeologic sections from seismic refraction surveys conducted by U.S. Geological Survey in April, 1979. Locations of profiles are shown on Plate A. Interpretation of field data based on a computer modling technique described by Scott and others (1972).]



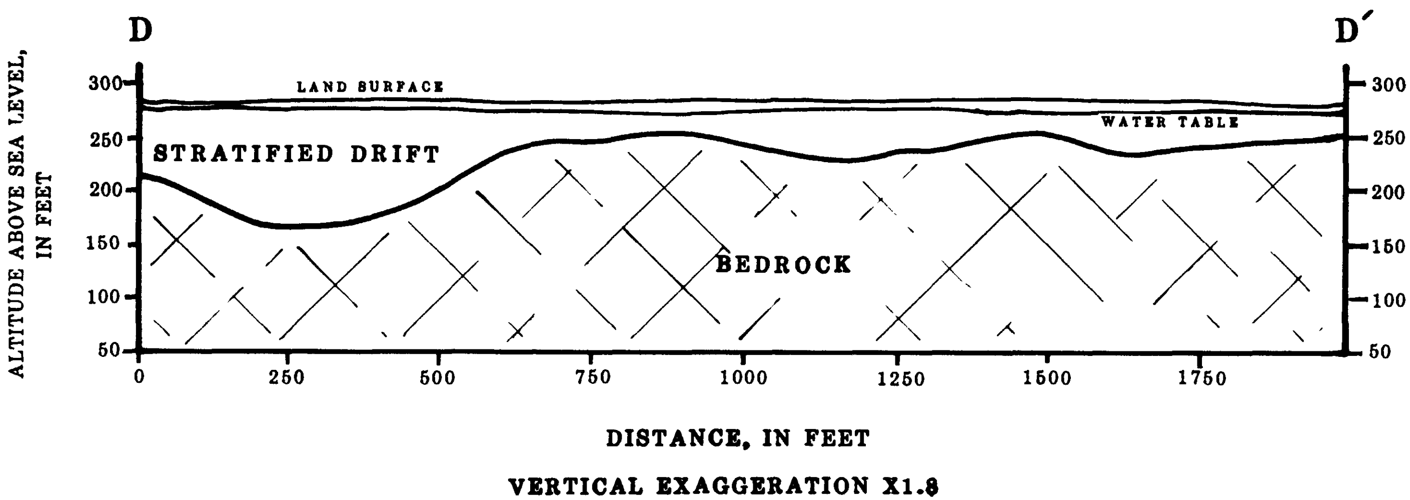
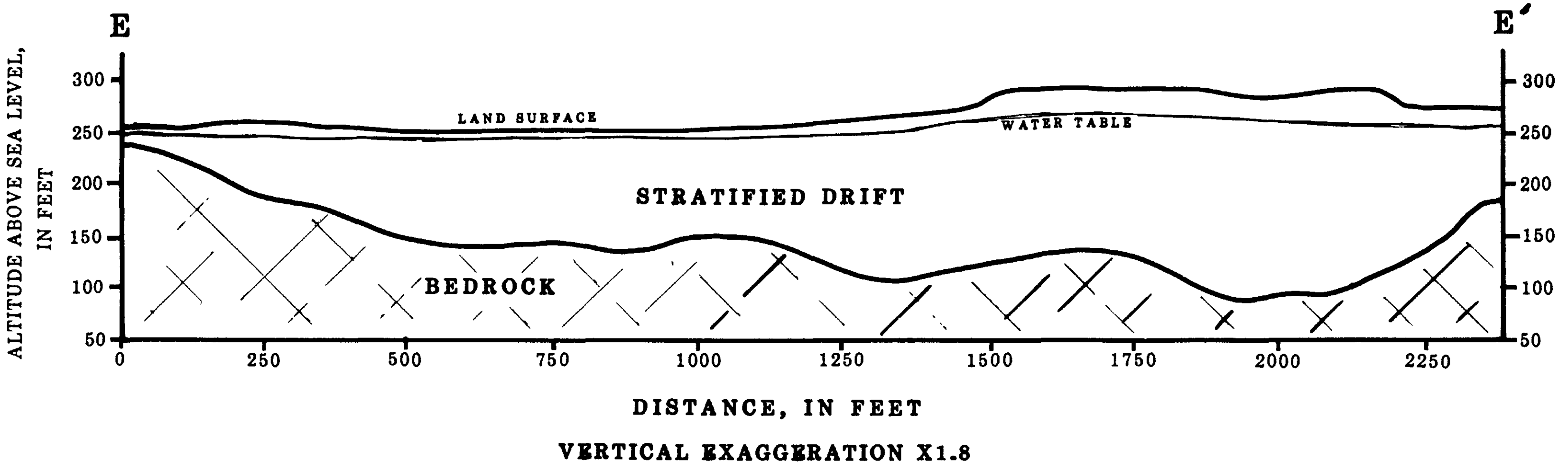


Figure 22.--Continued--Seismic refraction profiles showing depth to the water table and depth to bedrock.



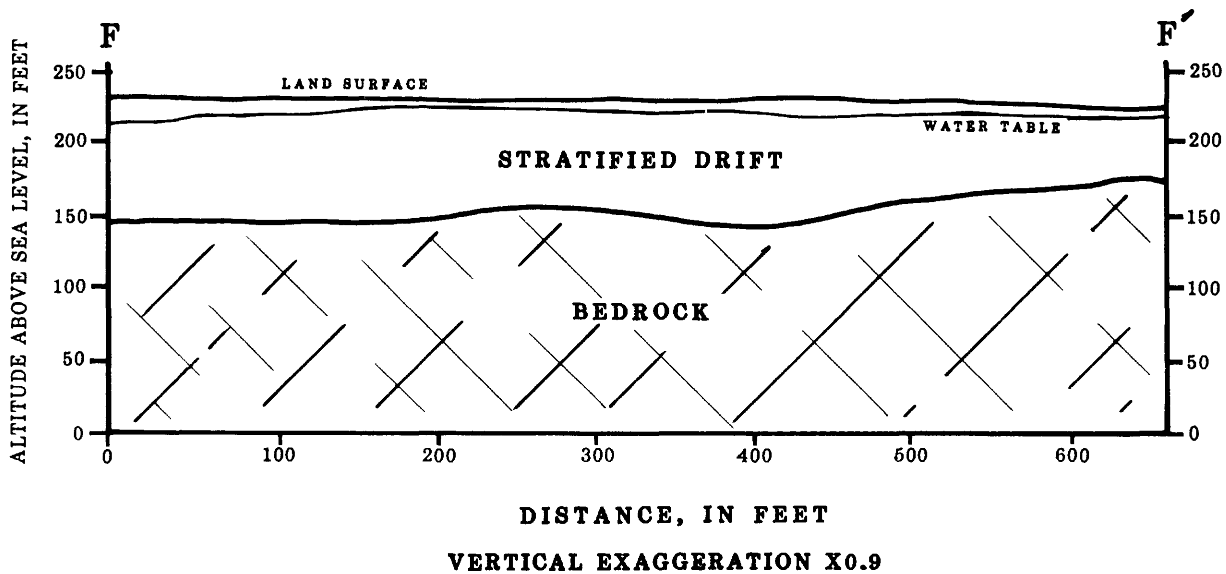
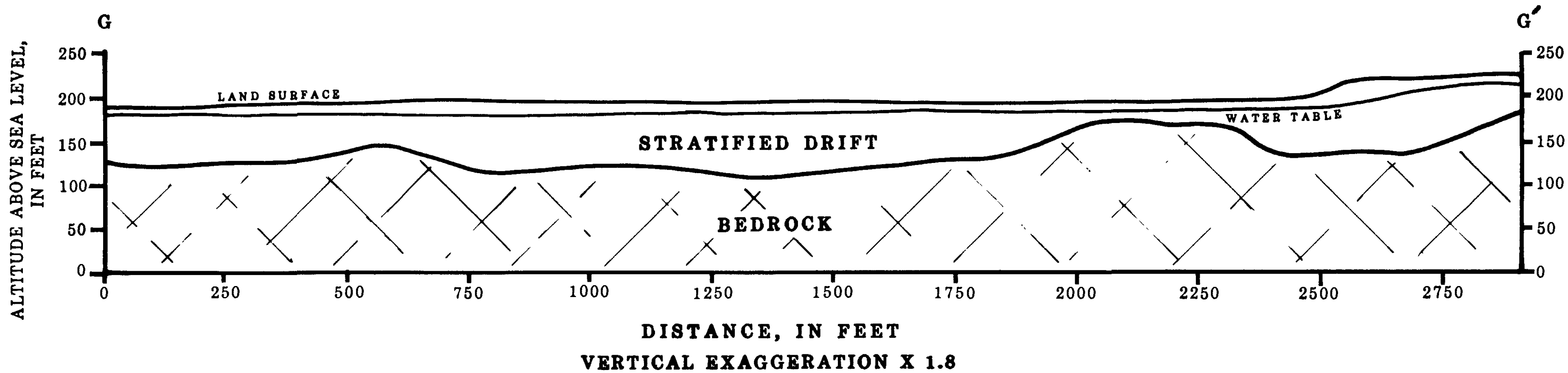


Figure 22.--Continued--Seismic refraction profiles showing depth to the water table and depth to bedrock.



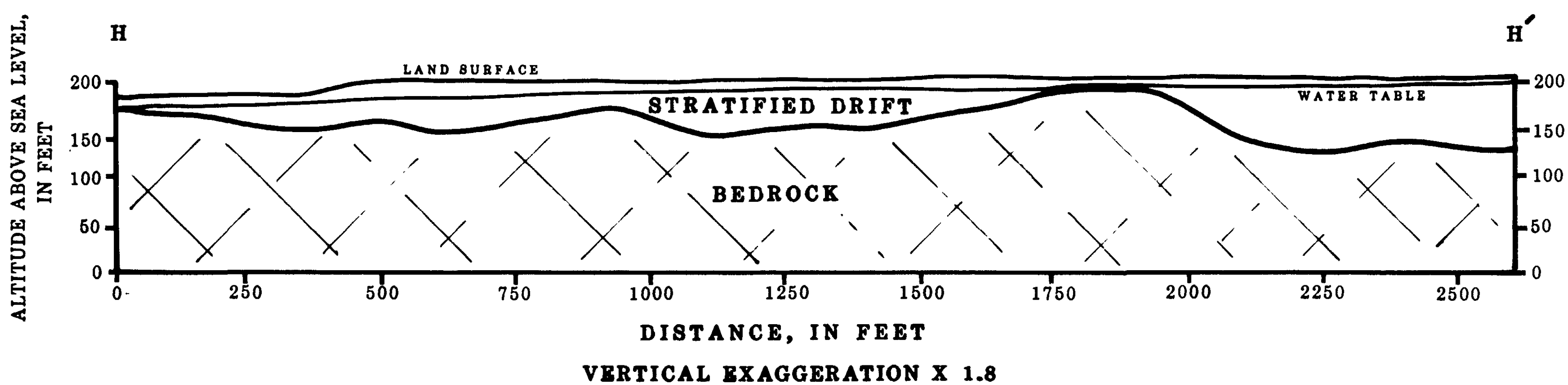


Figure 22.--Continued--Seismic refraction profiles showing depth to the water table and depth to bedrock.

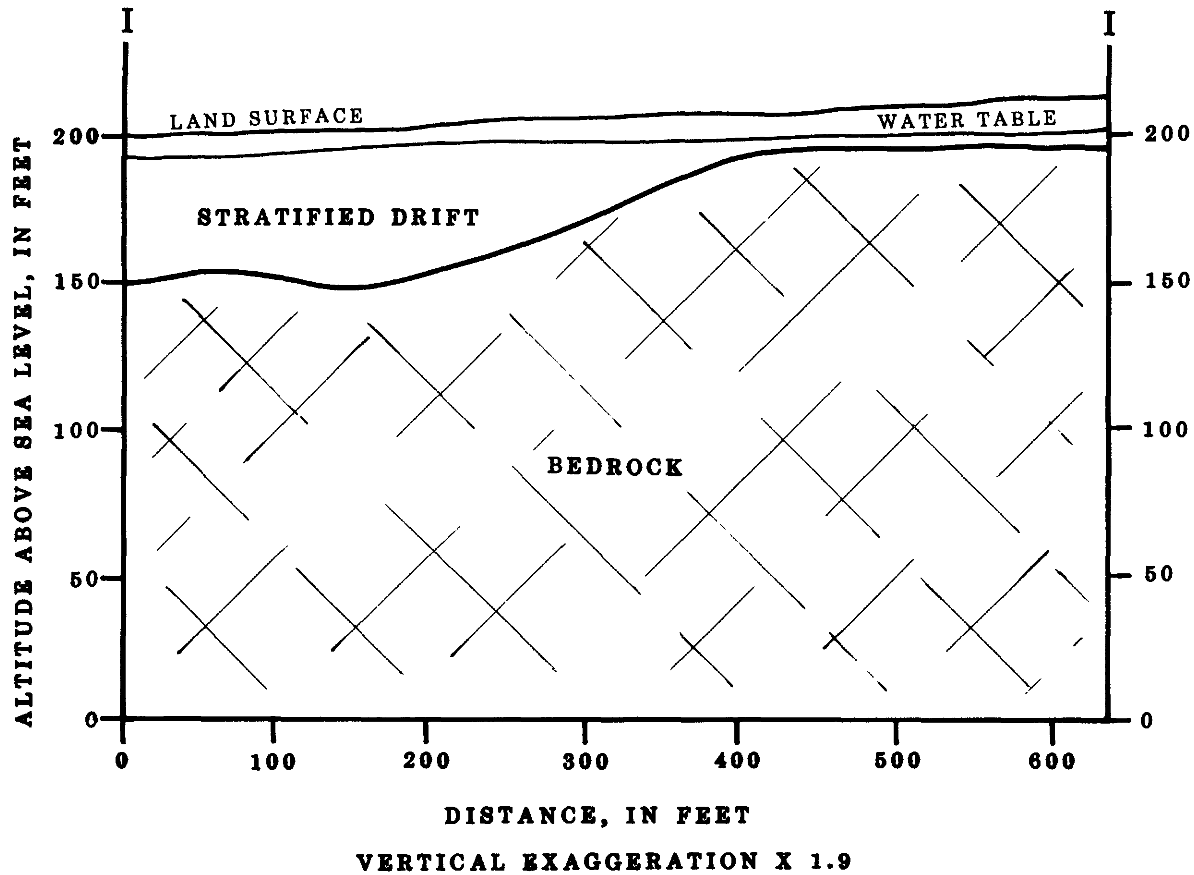


Figure 22.--Continued--Seismic refraction profiles showing depth to the water table and depth to bedrock.

[Entries include identification number, location, owner, year drilled, altitude, depth to water (if applicable), and description of earth materials penetrated.]

Identification number: U.S. Geological Survey number assigned to each site. The "SB" and "WY" prefixes denote the towns of Southbury and Woodbury, rspectively. Test holes are identified by the "th" suffix. Sites are shown on Plate A.

Location number: Latitude and longitude of testhole or well site. Number after decimal point is a sequential number used to identify closely spaced wells and test holes.

Altitude: Land-surface datum in feet above NGVD (National Geodetic Vertical Datum) of 1929, which is approximately equal to mean sea level, at each site. Test-hole altitudes are estimated from topographic maps with 10-ft contour intervals. Well altitudes are determined by differential leveling.

Depth to water: Measurement generally made shortly after completion of test hole or well and may not represent static conditions. Expressed in feet below land surfaces.

Depth: Depths shown in table are measured from land surface.

Description of earth materials: Logs of test holes and wells are based on the appropriate grain-size classifications shown in the table to the right.

Terms used in logs of test holes and wells.

Poorly sorted.--Indicates approximately equal amounts, by weight, of all grain sizes present in sample.

Till.--A predominately nonsorted, nonstratified sediment deposited directly by a glacier and composed of boulders, gravel, sand, silt, and clay.

End of hole.--Depth of bottom of boring in which bedrock or refusal was not reached.

Refusal.--Depth at which the drill equipment could not penetrate farther.

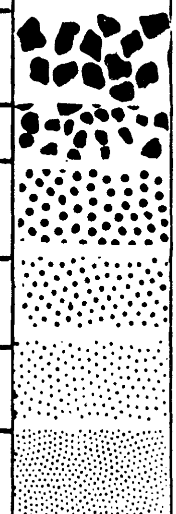
Modifier.--Percentage, by weight, of individual components in the sample.

Trace............. less than 2
Little............ 2 - 5
Some.............. 5 - 15
No modifier....... greater than 15

Terms in parentheses are interpretations by D.L. Mazzaferro

Grain size chart

Grain size (millimeters)	Wentworth grade scale U.S. Geological Survey logs		Grain size (inches)	Actual grain size
	Boulders (gravel)			
256			10.08	
	Cobbles (gravel)			
64			2.52	
	Pebbles (gravel)	Very coarse gravel		
32			1.260	
		Coarse gravel		
16			0.630	
		Medium gravel		
8			0.315	
		Fine gravel		
4			0.157	
	Granules - very fine gravel			
2			0.079	
	Very coarse sand			
1			0.039	
	Coarse sand			
0.5			0.019	
	Medium sand			
0.25			0.0098	
	Fine sand			
0.125			0.0049	
	Very fine sand			
0.063			0.0025	
	Silt			
0.004			0.0002	
	Clay			



SB 24. 412740N0731425.01. State of Connecticut - Department of Transportation. Drilled 1978. Altitude 202 ft. Depth to water 30 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Gravel, very fine to very coarse, and medium to very coarse sand	0 - 5	5
Sand, medium to very coarse, and very fine gravel; little fine sand	5 - 8	3
Sand, very fine to medium	8 - 16	8
Sand, very fine, and silt	16 - 17	1
Sand, very fine to medium, with layers of silt	17 - 27	10
Sand, very fine, and silt	27 - 30	3
Silt and very fine sand; some fine to medium sand, little coarse to very coarse sand little clay	30 - 40	10
Sand, medium, and silt; some fine to very fine sand, little clay	40 - 48	8
Sand, very fine to fine, and silt; little clay, little medium to very coarse sand	48 - 50	2
Silt and very fine sand, some clay, some fine sand, trace medium to coarse sand	50 - 65	15
Silt and very fine sand; some fine sand, some clay	65 - 103	38
Till	103 - 107	4
End of hole	at 107	

SB 25. 412748N0731355.01. State of Connecticut - Department of Transportation. Drilled 1978. Altitude 204 ft. Depth to water 30 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Gravel; granules, pebbles, and very fine to very coarse sand and silt	0 - 10	10
Gravel fine to coarse; some very fine gravel, some coarse to very coarse sand, some fine to medium sand, little silt and clay	10 - 20	10
Sand fine to very fine, and silt; some medium to very coarse sand, trace clay	20 - 40	20
Silt and fine to very fine sand; little clay, trace medium to coarse sand	40 - 60	20
Till	60 - 64	4
Refusal	at 64	

SB 26. 412807N0731325.01. Town of Southbury. Drilled 1978. Altitude 251 ft. Depth to water 50 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Gravel; granules to cobbles and very fine to very coarse sand, some silt	0 - 7	7
Sand, fine to coarse; little very fine sand, little very coarse sand	7 - 14	7
Silt, clay, and very fine sand, in layers	14 - 24	10
Sand, very fine to medium; some silt, little coarse sand, trace clay	24 - 48	24
Silt and very fine sand, in layers	48 - 52	4
Sand, fine to very fine; some medium sand, some silt trace clay; trace coarse sand	52 - 62	10
Sand, medium to fine, some coarse sand, some very fine sand, some silt, trace very coarse sand	62 - 82	20
Sand, fine to very fine; some medium sand, some silt, little coarse to very coarse sand	82 - 94	12
Sand, very fine, and silt in layers	94 - 95	1
Sand and poorly sorted gravel	95 - 102	7
Till	102 - 107	5
End of hole	at 107	

SB 27. 412901N0731249.01. State of Connecticut - Department of Transportation. Drilled 1978. Altitude 245 ft. Depth to water 9 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (silty loam)	0 - 2	2
Sand, fine to medium; little silt	2 - 7	5
Gravel; granules, pebbles and fine to coarse sand, some very fine sand and silt	7 - 12	5
Sand, fine to coarse; little silt, layers of pebble gravel	12 - 18	6
Sand very fine to very coarse, and granule to pebble gravel; some silt	18 - 22	4
Boulder, basalt (till?)	22 - 22.5	0.5
End of hole	at 22.5	

SB 28. 412906N0731333.01. Heritage Village Golf Course. Drilled 1978. Altitude 215 ft. Depth to water 20 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, very fine to medium, and silt	0 - 4	4
Gravel; granules, pebbles, and very fine to coarse sand, some very coarse sand and silt	4 - 8	4
Sand, very fine to fine; little silt	8 - 14	6
Silt and very fine sand; some fine sand, some medium to very coarse sand, little gravel, little clay	14 - 25	11
Gravel, fine to coarse; some very fine gravel, some fine to coarse sand, some silt, little clay	25 - 32	7
Sand, very fine to medium, little coarse to very coarse sand, varves of silt	32 - 34	2
Bedrock (basalt)	34 - 37	3
End of hole	at 37	

SB 29. 412929N0731259.01. Town of Southbury. Drilled 1978. Altitude 220 ft. Depth to water 19 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Gravel; granules to pebbles and coarse to very coarse sand	0 - 3	3
Sand, medium to very coarse, and granule to pebble gravel	3 - 17	14
Sand, medium to very coarse; some granule to pebble gravel	17 - 24	7
Sand, mdeium to very coarse; some fine sand, some very fine sand and silt, little very fine gravel	24 - 28	4
Gravel, fine to medium, and coarse sand; some fine to medium sand, some silt	28 - 37	9
Gravel, fine to coarse, and fine to very coarse sand; some silt, some very fine sand	37 - 43	6
Till	43 - 45	2
End of hole	at 45	

SB 30. 412954N0731252.01. State of Connecticut - Department of Transportation. Drilled 1978. Altitude 252 ft. Depth to water 20 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (sandy loam)	0 - 2	2
Gravel, fine to coarse, and fine to very coarse sand; some very fine sand, some silt	2 - 15	13
Sand, fine to coarse, and fine to medium gravel, some very coarse sand to very fine gravel, some very fine sand, some silt	15 - 33	18
Till	33 - 38	5
End of hole	at 38	

SB 31. 413019N0731311.01. O. & G. Industries. Drilled 1978. Altitude 200 ft. Depth to water 25 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Silt, sand, and gravel (fill)	0 - 7	7
Sand, very fine to medium, and silt; some very fine gravel	7 - 10	3
Sand, very fine to coarse, and granule to pebble gravel; little silt	10 - 18	8
Sand, medium; some fine to very fine sand, some gravel, some silt	18 - 32	14
Silt and very fine sand, some fine sand, some medium to very coarse sand, trace gravel, trace clay	32 - 39	7
Sand, fine to very coarse, and very fine to medium gravel; some medium to coarse gravel, some silt and very fine sand	39 - 50	11
Sand, medium, and fine to medium gravel; some coarse sand to very fine gravel, some silt to fine sand	50 - 65	15
Sand, very fine to very coarse, some silt, some gravel, little clay	65 - 68	3
Till	68 - 69	1
End of hole	at 69	

SB 32. 413007N0731246.01. State of Connecticut - Department of Transportation. Drilled 1978. Altitude 230 ft. Depth to water 13 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Gravel; granules, pebbles, cobbles, and very fine to very coarse sand; some silt..........	0 - 14	14
Sand, very fine to very coarse and granule to pebble gravel, some silt............	14 - 27	13
Till..	27 - 29	2
End of hole..................................	at 29	

SB 33. 413020N0731235.01. State of Connecticut - Department of Transportation. Drilled 1978. Altitude 253 ft. Depth to water 30 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (sandy loam)............................	0 - 2	2
Gravel; granules, pebbles, cobbles, and very fine to very coarse sand, some silt..........	2 - 20	18
Sand, very fine to very coarse, and granule to pebble gravel; trace silt....................	20 - 36	16
Sand, very fine to very coarse; some silt......	36 - 47	11
Bedrock (shale)...............................	47 - 51	4
End of hole..................................	at 51	

Woodbury Wells

WY 25. 413339N0731143.01. State of Connecticut - Department of Trasnportation. Drilled 1978. Altitude 285 ft. Depth to water 3 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (sandy loam)............................	0 - 3	3
Gravel; pebbles to cobbles and very fine to very coarse sand; some silt..................	3 - 8	5
Sand, very fine to very coarse, and granule gravel; little silt..........................	8 - 10	2
Sand, fine to coarse; some very coarse sand, little silt to very fine sand, little very fine gravel..................................	10 - 18	8
Sand, medium to coarse; some very coarse sand, some gravel, some silt to fine sand.........	18 - 22	4
Silt and very fine sand; little fine sand, little clay, trace medium sand..............	22 - 29	7
Sand, very fine to very coarse; little gravel, little silt.................................	29 - 37	8
Sandstone (boulder)...........................	37 - 39	2
Sand, fine to very coarse; little gravel.......	39 - 47	8
Till..	47 - 55	8
Bedrock (sandstone)...........................	at 55	

WY 26. 413300N0731219.01. Town of Woodbury. Drilled 1978. Altitude 280 ft. Depth to water 11 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (sandy loam)............................	0 - 3	3
Gravel; cobbles and pebbles...................	3 - 5	2
Sand, very fine to coarse, little granule gravel..	5 - 6	1
Sand, very fine to medium, and silt; little granule gravel..............................	6 - 8	2
Gravel (cobbles)..............................	8 - 9	1
Sand, medium to very fine, and silt; some coarse sand, little clay, little very coarse sand, little gravel..........................	9 - 30	21
Sand, fine to coarse; some very fine sand, some very coarse sand, some gravel, little clay and silt................................	30 - 35	5
Sand, very fine to coarse, and silt; some very coarse sand, some gravel, little clay........	35 - 50	15
Sand, very fine to medium, and silt; some granule and pebble gravel (till?)............	50 - 58	8
Till..	58 - 62	4
Bedrock (shale)...............................	62 - 63	1
End of hole..................................	at 63	

WY 27. 41333N0731227.01. Frank Shepard. Drilled 1978. Altitude 267 ft. Depth to water 2 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (silty loam)............................	0 - 3	3
Sand, very coarse to medium, and gravel; some fine sand, some very fine sand and silt, trace clay..................................	3 - 13	10
Sand, very fine to medium, and silt; some coarse to very coarse sand and gravel, trace clay..	13 - 17	4
Sand, fine to very coarse, and gravel; some very fine sand, some silt..................	17 - 20	3
Sand, coarse to very coarse and very fine to medium gravel; some medium sand, some fine sand, some very fine sand and silt..........	20 - 30	10
Gravel, very fine to coarse, and fine to very coarse sand; some very fine sand and silt...	30 - 35	5
Gravel, very fine to medium, and fine to very coarse sand; some very coarse sand, some silt	35 - 39	4
Gravel, very fine to medium, and very coarse sand, some medium to coarse sand, some very fine to fine sand, some silt................	39 - 46	7
Gravel, very fine to fine, and very fine to very coarse sand, some silt.................	46 - 57	11
Sand, fine to very coarse, and gravel; some very fine sand and silt.....................	57 - 58	1
Gravel, very fine to coarse, and fine to very coarse sand; some silt, some very fine sand, trace clay..................................	58 - 59	1
Sand, very coarse to fine, and very fine to medium gravel; some very fine sand, some silt, little clay................................	59 - 75	16
Till..	75 - 77	2
End of Hole..................................	at 77	

WY 28. 41330N0731254.01. David Shepard. Drilled 1978. Altitude 258 ft. Depth to water 7 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil	0 - 1	1
Gravel, very fine to coarse, and fine to very coarse sand; some silt, some very fine sand.	1 - 18	17
Sand, very fine to very coarse, and very fine to coarse gravel; some silt and clay	18 - 40	22
Bedrock	40 - 42	2
End of hole	at 42	

WY 29. 413258N0731236.01. Town of Woodbury. Drilled 1978. Altitude 292 ft. Depth to water 29 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Gravel; granules to pebbles and fine to very coarse sand	0 - 5	5
Sand, fine to very fine, and silt; some medium-sand, trace coarse to very coarse sand, trace gravel, trace clay	5 - 50	45
Silt and very fine sand; some fine sand, little medium to coarse sand, little clay	50 - 60	10
Silt; some very fine sand, some clay, little fine sand, little medium to coarse sand	60 - 85	100
Silt; some very fine sand, little clay, trace fine to medium sand	85 - 100	15
Silt and very fine sand; some fine sand, little clay, trace medium to coarse sand	100 - 110	10
Sand, very fine to fine, and silt; trace medium to very coarse sand, trace clay	110 - 114	4
End of hole	at 114	

WY 30. 413307N0731250.01. Woodbury Cemetery Association. Drilled 1978. Altitude 275 ft. Depth to water 36 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil, sand, and silt	0 - 2	2
Gravel; granules to cobbles and very fine to very coarse sand	2 - 9	7
Gravel; granules and pebbles and fine to very coarse sand	9 - 16	7
Sand, very fine to medium, and silt; some coarse to very coarse sand, some gravel; trace clay	16 - 28	12
Silt and very fine to fine sand; some medium sand, little coarse to very coarse sand and gravel, little clay	28 - 35	7
Sand, very fine to coarse, some very coarse sand, some silt; some gravel, trace clay	35 - 45	10
Sand, fine to coarse; some very coarse sand, some gravel, some silt to very fine sand	45 - 60	15
Gravel, very fine to medium, and coarse to very coarse sand; some fine to medium sand, some very fine sand and silt, trace clay	60 - 80	20
Sand, very fine to medium, and silt	80 - 102	22
End of hole	at 102	

WY 31. 413247N0731259.01. James Ravenscroft. Drilled 1978. Altitude 270 ft. Depth to water 20 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, very fine to medium	0 - 6	6
Sand, very fine to medium with occasional pebble	6 - 7	1
Sand fine to medium	7 - 10	3
Silt and very fine sand	10 - 13	3
Sand, very fine to fine, and silt, in layers	13 - 18	5
Silt and very fine to fine sand; some clay, little medium sand, trace coarse sand	18 - 25	7
Silt; some very fine sand, little clay, trace medium sand	25 - 45	20
Silt and very fine sand, little clay little fine sand, trace medium sand	45 - 60	15
Sand, very fine, and silt; some fine sand, little medium sand, trace clay	60 - 70	10
Silt and very fine sand, some medium sand, little clay	70 - 110	40
End of hole	at 110	

WY 32. 413238N0731326.01. William Moody. Drilled 1978. Altitude 282 ft. Depth to water 25 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Gravel; granules to pebbles and fine to very coarse sand	0 - 6	6
Sand, fine to very coarse	6 - 8	2
Sand, fine to very fine, and silt; some medium sand, little coarse to very coarse sand, trace clay	8 - 30	22
Silt and very fine sand; some fine to coarse sand, some very coarse sand and gravel, little clay	30 - 35	5
Sand, very fine to fine, and silt; some gravel, little medium to very coarse sand, little clay	35 - 40	5
Sand, fine to medium; some very fine sand, some silt, some coarse to very coarse sand, some gravel, trace clay	40 - 45	5
Gravel, very fine to coarse, and fine to very coarse sand; some silt	45 - 51	6
Refusal	at 51	

WY 33. 413141N0731157.01. Charles Nininger. Drilled 1978. Altitude 268 ft. Depth to water 6 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (sandy loam)	0 - 1	1
Gravel, granules to cobbles and very fine to very coarse sand; little silt	1 - 10	9
Sand, very fine to very coarse; some gravel, some silt	10 - 15	5
Gravel, medium to coarse, and fine to very coarse sand; some very fine to fine gravel, some very fine sand and silt	15 - 20	5
Sand, fine to very coarse, and very fine gravel; some fine to medium gravel, some very fine sand and silt	20 - 22	2
Silt and very fine to fine sand; little medium to very coarse sand, little clay, trace gravel	22 - 25	3
Sand, fine to very coarse, and very fine to coarse gravel; some very fine sand, some silt, little clay (poorly sorted gravel)	25 - 33	8
End of hole	at 33	

WY 34. 413117N0731209.01. Steadman Hitchcock. Drilled 1978. Altitude 282 ft. Depth to water 23 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, fine to very coarse, and pebble to cobble gravel	0 - 14	14
Sand, very fine to very coarse; some pebble gravel	14 - 17	3
Gravel, granules to cobbles and very fine to very coarse sand; some silt (poorly sorted gravel)	17 - 25	8
Sand, very fine to coarse; some gravel, some silt, little clay (poorly sorted gravel)	25 - 35	10
Gravel, fine to medium, and very fine to medium sand; some coarse to very coarse sand, some silt and clay	35 - 45	10
Sand, very fine to very coarse, and very fine to medium gravel; some silt, little clay (till?)	45 - 56	11
Bedrock	56 - 57	1
End of hole	at 57	

WY 35. 413119N0731235.01. O & G Industries. Drilled 1978. Altitude 223 ft. Depth to water 5 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (sandy loam)	0 - 3	3
Gravel; pebbles to cobbles, and fine to coarse sand	3 - 7	4
Sand, fine to coarse, and gravel; some very coarse sand, some very fine sand and silt	7 - 10	3
Sand, fine to medium; some very fine sand, some coarse to very coarse sand and gravel, little silt	10 - 21	11
Sand, fine to coarse, and gravel; some very fine sand, some silt	21 - 51	30
Till	51 - 52	1
End of hole	at 52	

WY 36. 413104N0731235.01. O & G Industries. Drilled 1978. Altitude 212 ft. Depth to water 7 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, very fine to medium; some silt	0 - 13	13
Sand, coarse to medium; some fine sand, some very coarse sand, little gravel, little very fine sand and silt	13 - 20	7
Sand, fine to very fine, and silt; some medium to very coarse sand, trace gravel, trace clay	20 - 30	10
Sand, fine to very fine; some silt, some medium sand, trace coarse to very coarse sand	30 - 40	10
Gravel, fine to coarse, and fine to coarse sand; some very coarse sand to very fine gravel, some very fine sand and silt	40 - 52	12
End of hole	at 52	

WY 37. 413336N0731126.01. Regional School District No. 14. Drilled 1978. Altitude 299 ft. Depth to water 2 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (sandy loam)	0 - 2	2
Gravel; pebbles to cobbles and very fine to very coarse sand; some silt	2 - 8	6
Sand, medium to very coarse; some gravel, little fine to very fine sand and silt	8 - 15	7
Sand, medium to very coarse, and gravel; some fine sand, little very fine sand and silt	15 - 25	10
Gravel, very fine to coarse, and fine to very coarse sand; some silt, some very fine sand	25 - 35	10
Sand, fine to very coarse, and gravel; some very fine sand and silt	35 - 38	5
End of hole	at 38	

WY 38. 413318N0731126.01. Frederick Strong. Drilled 1978. Altitude 319 ft. Depth to water 45 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (sandy loam)	0 - 1	1
Gravel, pebbles to cobbles and fine to very coarse sand	1 - 9	8
Sand, fine to coarse	9 - 17	8
Sand, medium to very coarse, and very fine to very coarse gravel; some fine sand, little very fine sand and silt	17 - 32	15
Sand, medium to very coarse; some fine sand, little very fine sand and silt, little gravel	32 - 43	11
Sand, fine to very coarse; some gravel	43 - 48	5
Gravel, medium to coarse, and fine to coarse sand	48 - 54	6
Gravel; pebbles and cobbles	54 - 57	3
Refusal	at 57	

WY 39. 413206N0731235.01. Town of Woodbury. Drilled 1978. Altitude 232 ft. Depth to water 4 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, fine to very coarse, and very fine to coarse gravel	0 - 8	8
Sand, medium to very coarse, and very fine gravel	8 - 13	5
Sand, medium to very coarse; some fine sand, some very fine to fine gravel, little very fine sand and silt	13 - 22	9
Sand, fine to medium; some coarse to very coarse sand, some very fine sand, little gravel, little silt	22 - 30	8
Sand, medium to very fine; some coarse to very coarse sand, little gravel, trace silt	30 - 40	10
Sand, coarse to fine; some very coarse sand, some very fine sand and silt, little gravel	40 - 50	10
Sand, fine to very fine and silt; some medium sand, little coarse to very coarse sand, little gravel, little clay	50 - 65	15
Sand, very coarse to fine, and very fine gravel, some very fine sand, little silt, little fine gravel	65 - 73	8
Sand, very fine to fine and silt; some medium sand, some clay, trace very coarse sand	73 - 77	4
Sand, medium to very coarse, and very fine to coarse gravel; some fine to very fine sand, some silt	77 - 87	10
Sand, fine to very fine, and silt; little medium to very coarse sand, trace clay	87 - 103	16
Gravel	103 - 104	1
Sand, fine to very fine, and silt	104 - 115	11
End of hole	at 115	

WY 42. 413124N0731224.01. George Hardesty. Drilled 1979. Altitude 230 ft. Depth to water 16 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Gravel; pebbles and cobbles	0 - 1.5	1.5
Sand, fine to very fine; some silt	1.5 - 7.5	6
Sand, fine to coarse, with occasional gravel lens	7.5 - 12	4.5
Sand, very fine to very coarse, and silt, and very fine to medium gravel	12 - 22	10
Gravel, very fine to coarse, and very fine to very coarse sand; some silt	22 - 26	4
End of hole	at 26	

Southbury Test Holes

SB 28 th. 412815N0731259.01. Roger E. Kelley. Drilled 1978. Altitude 391 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, very fine to medium; occasional layer of gravel	0 - 12	12
Sand, medium to very coarse; some fine sand, some very fine to fine gravel, little medium gravel, little silt to very fine sand	12 - 18	6
Sand, fine to very coarse, and medium to coarse gravel; some very fine to fine gravel, some silt to very fine sand	18 - 30	12
Gravel, granules to pebbles and very fine to very coarse sand; some silt	30 - 37	7
Till	37 - 42	5
End of hole	at 42	

SB 29 th. 412835N0731306.01. State of Connecticut - Department of Transportation. Drilled 1978. Altitude 270 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Silt, sand, pebbles, cobbles and clay (fill)	0 - 16	16
Bedrock (sandstone)	16 - 18	2
End of hole	at 18	

SB 30 th. 412840N0731325.01. Town of Southbury. Drilled 1978. Altitude 209 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (loam)	0 - 1	1
Gravel; granules, pebbles, and medium to very coarse sand	1 - 5	4
Sand, medium to very coarse, and very fine gravel; little fine gravel	5 - 21	16
Sand, medium to very coarse, and gravel	21 - 22	1
Sand, fine to coarse; little fine gravel	22 - 28	6
Till	28 - 38	10
Bedrock (basalt)	38 - 41	3

SB 31 th. 412852N0731347.01. Heritage Village Golf Course. Drilled 1978. Altitude 252 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (sandy, loam)	0 - 2	2
Gravel; granules, pebbles and fine to very coarse sand	2 - 9	7
Gravel; granules, pebbles, cobbles, and very fine to very coarse sand and silt	9 - 13	4
Till	13 - 32	19
End of hole	at 32	

SB 32 th. 412939N0731344.01. Henry J. Paparazzo. Drilled 1978. Altitude 240 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Gravel; granules, pebbles and very fine to medium sand, some silt	0 - 13	13
Bedrock (basalt)	13 - 17	4
End of hole	at 17	

SB 33 th. 413029N0731229.01. State of Connecticut - Department of Transportation. Drilled 1978. Altitude 252 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (sandy loam)	0 - 3	3
Gravel; granules, pebbles and very fine to very coarse sand; some silt	3 - 23	20
Sand, very fine to very coarse and very fine to fine gravel	23 - 33	10
Till	33 - 37	4
End of hole	at 37	

SB 34 th. 412844N0731337.01. Heritage Village Golf Course. Drilled 1979. Altitude 175 ft. Depth to water 6 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (loam)	0 - 1	1
Silt and very fine sand	1 - 7	6
Gravel, fine to coarse, and coarse to very coarse sand; some very fine gravel, some fine to medium sand, some very fine sand and silt (poorly sorted gravel)	7 - 12	5
Gravel, very fine to coarse, and very fine to very coarse sand; some silt and clay (poorly sorted gravel)	12 - 18.5	6.5
Gravel, very fine to medium, and very fine to very coarse sand; some silt and clay, some coarse gravel (poorly sorted gravel)	18.5 - 23.5	5
Till	23.5 - 27.5	4
Bedrock (gneiss)	27.5 - 28.5	1
End of hole	at 28.5	

SB 35 th. 412853N0731330.01. Town of Southbury. Drilled 1979. Altitude 10 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Gravel; pebbles, cobbles coarse sand	0 - 10	10
Sand, fine to coarse, and very fine to fine gravel, in layers		
Till	13 - 15	2
Bedrock (basalt)	15 - 16	1
End of hole	at 16	

SB 36 th. 413002N0731324.01. Melvin Wheeler. Drilled 1979. Altitude 240 ft. Depth to water 50 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (sandy loam)	0 - 1	1
Gravel; granules, pebbles and fine to coarse sand, in layers	1 - 14	13
Silt and very fine sand;		
Sand, fine to very fine, and silt	27 - 32	5
Sand, very fine and silt		
Sand, fine to very fine, and silt	45 - 57	12
Sand, fine to very fine; so some silt	57 - 63.5	6.5
Sand, fine to very fine; some silt, some very coarse sand	63.5 - 72	8.5
Sand, fine to very fine, some silt, some medium sand	72 - 78.5	6.5
Sand, medium to fine, some very fine sand, some silt, some coarse to very coarse sand	78.5 - 93.5	15
Till	93.5 - 96.5	3
Refusal	at 96.5	

SB 37 th. 412940N0731315.01. Ralph and Frank Matula. Drilled 1979. Altitude 185 ft. Depth to water 6 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (loam)	0 - 4	4
Gravel, coarse to medium, and fine to very coarse sand; some fine to very fine gravel; some very fine sand and silt	4 - 8.5	4.5
Sand, coarse to fine, sna very fine to coarse gravel; some very fine sand and silt, some very coarse sand	8.5 - 13.5	5
Gravel, coarse to very fine, and fine to very coarse sand; some very fine sand and silt	13.5 - 23.5	10
Gravel, coarse to fine, and fine to very coarse sand	23.5 - 28	4.5
Till	28 - 33.5	5.5
End of hole	at 33.5	

SB 38 th. 412911N0731315.01. Town of Southbury. Drilled 1979. Altitude 211 ft. Depth to water 46 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (sandy loam)	0 - 4	4
Gravel; pebbles, cobbles, and sand	4 - 11	7
Sand and gravel, in layers	11 - 15	4
Sand, fine to very fine, and silt	15 - 37	22
Gravel and fine to coarse sand	37 - 42	5
Gravel, poorly sorted	42 - 45	3
Gravel, poorly sorted, with rock fragments (till)	45 - 50	5
Bedrock (basalt)	50 - 52	2
End of hole	at 52	

SB 39 th. 412802N0731354.01. Dorthy Parsel. Drilled 1979. Altitude 168 ft. Depth to water 6 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand and gravel	0 - 6	6
Sand, medium to fine; some coarse to very coarse sand, trace silt	6 - 12	6
Sand, fine to very fine, and silt; some medium sand, some coarse to very coarse sand, trace clay	12 - 19	7
Sand, medium to coarse	19 - 21	2
Gravel, granules, pebbles, and fine to coarse sand, some silt and clay	21 - 27.5	6.5
Sand, coarse to very fine; some silt, trace gravel	27.5 - 30	2.5
Sand, coarse to fine; some silt and clay, some very coarse sand and gravel	30 - 38.5	8.5
Sand, coarse to very coarse, and gravel; occasional layers of fine to medium sand	38.5 - 43.5	5
Gravel, very fine to coarse, and medium to very coarse sand; some fine to very fine sand, some silt	43.5 - 52	8.5
Sand, fine to very fine, and silt; little gravel	52 - 56	4
Sand and gravel	56 - 61	5
Sand, very fine to medium, and gravel; some coarse to very coarse sand, some silt and clay	61 - 73.5	12.5
Sand, coarse to very fine; some very coarse sand, some silt, little gravel	73.5 - 78.5	5
Refusal	at 78.5	

SB 40 th. 412732N0731425.01. Edward Winship. Drilled 1979. Altitude 183 ft. Depth to water 12 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (loam)	0 - 2	2
Sand, fine to very fine	2 - 5	3
Sand, fine to very fine, and silt	5 - 13.5	8.5
Silt; some sand, some gravel, little clay	13.5 - 23.5	10
Silt and very fine to fine sand; some medium to very coarse sand, some gravel, little clay	23.5 - 38.5	15
Silt and very fine sand; some gravel, trace clay	38.5 - 53.5	15
Silt and very fine sand; some fine sand, trace very coarse sand, trace clay	53.5 - 73	19.5
Silt; some very fine sand, little clay	73 - 84	11
Gravel; granules, pebbles, and fine to coarse sand, some clay	84 - 88.5	4.5
Gravel, fine to coarse, and fine to very coarse sand; some very fine gravel, some silt (poorly sorted gravel)	88.5 - 97.5	9
Till	97.5 - 98.5	1
End of hole	at 98.5	

SB 41 th. 412814N0731338.01. Richard Huntley. Drilled 1979. Altitude 165 ft. Depth to water 1 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Gravel; granules, pebbles, and medium to very coarse sand	0 - 4	4
Gravel; pebbles, cobbles, and medium to very coarse sand	4 - 7	3
Gravel, very fine to medium, and fine to very coarse sand; some very coarse gravel, some silt and clay (poorly sorted gravel)	7 - 15	8
Sand, very fine to coarse, and fine to medium gravel; some very coarse sand to very fine gravel, some silt and clay (poorly sorted gravel)	15 - 30	15
Gravel, coarse to fine, and coarse to very fine sand; some very fine sand to very fine gravel, some silt and clay	30 - 33.5	3.5
Gravel; granules, pebbles, and medium to very coarse sand, and silt	33.5 - 36	2.5
Refusal	at 36	

Woodbury Test Holes

WY 16 th. 413228N0731228.01. Town of Woodbury. Drilled 1978. Altitude 282 ft. Depth to water 22 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Gravel; pebbles, cobbles and very fine to very coarse sand	0 - 13	13
Sand, very fine to medium, and silt; some pebbles	13 - 16	3
Silt and clay; some very fine to medium sand and pebbles	16 - 25	9
Bedrock (shale and sandstone)	25 - 32	7
End of hole	at 32	

WY 17 th. 413043N0731243.01. O & G Industries. Drilled 1978. Altitude 235 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Bedrock (basalt)	0 - 3	3
End of hole	at 3	

WY 18 th. 413318N0731146.01. Frederick Strong. Drilled 1979. Altitude 277 ft. Depth to water 6 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (loam)	0 - 3	3
Soil (sandy loam)	3 - 5	2
Gravel; fine to coarse sand and pebbles to 3 in. diameter	5 - 7	2
Sand, medium	7 - 8	1
Sand, fine to very coarse, and very fine to coarse gravel; some silt, some very fine sand, trace clay	8 - 14	6
Sand, medium to coarse	14 - 20	6
Sand, fine to very coarse, and very fine to coarse gravel; some very fine sand, some silt and clay	20 - 28	8
Sand, fine to coarse, and very fine to medium gravel; some very fine sand, some silt and clay	28 - 36	8
Sand, fine to coarse; some very fine sand, some silt, trace clay	36 - 41	5
Gravel, very fine to coarse, and medium to very coarse sand; some fine sand, little very fine sand, little silt	41 - 48.5	7.5
Sand, very fine to very coarse, and very fine to coarse gravel; some silt, trace clay (poorly sorted gravel(	48.5 - 63	14.5
Till, gray	63 - 67	4
Till, red or decomposed bedrock	67 - 67.5	0.5
Refusal	at 67.5	

WY 19 th. 413229N0731250.01. Woodbury Congregational Church. Drilled 1979. Altitude 235 ft. Depth to water 8 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (sandy alluvium)	0 - 6	6
Gravel, fine to coarse	6 - 10	4
Sand, fine to very fine, and silt; some medium sand	10 - 18.5	8.5
Silt and very fine sand; some fine sand, little clay	18.5 - 48.5	30
Silt; some very fine sand, some clay	48.5 - 58.5	10
Sand, very fine to fine, and silt; trace clay	58.5 - 68.5	10
Sand, fine to very fine, and silt; some medium sand, little clay	68.5 - 78.5	10
Sand, fine to very fine; some very coarse sand, some silt, trace clay	78.5 - 88.5	10
Sand, very fine to fine, and silt; some very fine gravel, trace clay	88.5 - 103.5	15
Sand, medium to very fine; some silt, trace clay	103.5 - 113.5	10
Sand, medium to very fine; some coarse sand, some silt, trace clay	113.5 - 133.5	20
Sand, fine to very fine; some medium sand, some silt, trace clay	133.5 - 155	21.5
Till	155 - 158	3
End of hole	at 158	

WY 20 th. 413243N0731305.01. James Ravenscroft. Drilled 1979. Altitude 242 ft. Depth to water 7 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Gravel (fill)	0 - 4	4
Alluvium (silt, clay, and organic material)	4 - 10	6
Gravel; sand and pebbles	10 - 11	1
Alluvium	11 - 13	2
Sand, very fine to fine, and silt	13 - 17	4
Sand, very fine; some silt and clay.		
Silt; some clay, some very fine sand	22 - 35	13
Gravel, medium to coarse, and sand,		
Gravel, very fine to coarse, and fine to coarse sand; some silt	47 - 57	10
Gravel, very fine to medium, and fine to very coarse sand; some very fine sand and silt	57 - 70	13
Sand, very coarse to very fine, and gravel; some silt	70 - 85	15
Sand, coarse to fine, and very fine gravel	85 - 90	5
Refusal	at 90	

WY 21 th. 413339N0731135.01. Regional School District No. 14. Drilled 1979. Altitude 295 ft. Depth to water 15 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (loam)	0 - 3	3
Gravel; pebbles, cobbles, and fine to coarse sand	3 - 10	7
Sand, coarse to very coarse	10 - 17	7
Sand, very coarse to medium; some fine to very fine sand, trace silt	17 - 23	6
Gravel; granules, pebbles, and very fine to coarse sand	23 - 24	1
Sand, coarse to fine; some fine sand, some very coarse sand, some very fine sand and silt	24 - 30	6
Gravel; granules, pebbles, and fine to coarse sand	30 - 37	7
Sand, fine to very coarse, and very fine to coarse gravel; some very fine sand and silt (decomposed bedrock)	37 - 43.5	6.5
End of hole	at 43.5	

WY 22 th. 413339N0731133.01. Regional School District No. 14. Drilled 1979. Altitude 276 ft. Depth to water 11 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (sandy alluvium)	0 - 3	3
Gravel; pebbles and cobbles	3 - 13	10
Gravel; fine to coarse, and sand; some silt, trace clay	13 - 20	7
Sand, fine to very fine; some silt; some coarse sand, some gravel, trace clay	20 - 24	4
Gravel; granules, pebbles, and fine to coarse sand, in layers	24 - 35	11
Sand, very fine to medium, and silt; some medium to coarse sand, some gravel, trace silt	35 - 40	5
Gravel, fine to medium, and fine to coarse sand, in layers	40 - 45	5
Sand, very fine to coarse, and gravel; some silt	45 - 50	5
Sand, fine to very coarse, and gravel; some very fine sand and silt	50 - 65	15
Sand, very fine to very coarse, and gravel; some silt, trace clay	65 - 75	10
Till	75 - 88	13
Refusal	at 88	

WY 23 th. 413040N0731230.01. Richard Vangoshe. Drilled 1979. Altitude 208 ft. Depth to water 15 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, fine to medium	0 - 6	6
Gravel, very fine to medium, and sand	6 - 15	9
Sand, fine to very fine; some medium some silt	15 - 22	7
Sand, fine to medium; some very fine sand, some silt	22 - 28	6
Till	28 - 37	9
End of hole	at 37	

WY 24 th. 413117N0731225.01. O & G Industries. Drilled 1979. Altitude 212 ft. Depth to water 15 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand and gravel	0 - 8	8
Gravel, fine to medium, and medium to coarse sand, in layers	8 - 17	9
Sand, fine to very fine, and silt; some medium to coarse sand, some very coarse sand and gravel	17 - 22	5
Sand, very fine to fine, and silt; some medium to very coarse sand, trace gravel, trace clay	22 - 27	5
Silt and clay, in layers	27 - 36	9
Sand, very coarse to fine, and gravel; some very fine sand, some silt	36 - 45	9
Gravel, coarse to fine, and fine to coarse sand; some very fine sand and silt (poorly sorted gravel)	45 - 60	15
Till	60 - 63.5	3.5
End of hole	at 63.5	

WY 25 th. 413300N0731252.01. Regional School District No. 14. Drilled 1979. Altitude 275 ft. Depth to water 13 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Sand, medium to fine; some gravel	0 - 3	3
Sand, fine to coarse; some very fine to medium gravel	3 - 12	9
Sand, fine to medium; some very fine sand, some coarse to very coarse sand and gravel, little silt	12 - 18.5	6.5
Sand, fine to medium; some very fine sand, some coarse to very coarse sand and gravel	18.5 - 22.5	4
Silt and very fine to fine sand; little clay, little medium sand	22.5 - 48.5	26
Silt; some very fine sand, some clay, little medium to coarse sand	48.5 - 58.5	10
Sand, very fine, and silt	58.5 - 63.5	5
Sand, very fine to fine, and silt	63.5 - 68	4.5
Silt and very fine to fine sand, little clay	68 - 74	6
Sand, medium to fine, some coarse sand, some very fine sand, some silt, little gravel	74 - 83.5	9.5
Sand, coarse to fine; some very coarse sand and gravel, some very fine sand and silt	83.5 - 98.5	15
Sand, very coarse to medium, and very fine to medium gravel	98.5 - 108	9.5
Sand, medium to very fine; some silt, some coarse sand, trace clay	108 - 118	10
Till	118 - 118.5	0.5
End of hole	at 118.5	

WY 26 th. 413208N0731247.01. Town of Woodbury. Drilled 1979. Altitude 232 ft. Depth to water 11 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Gravel; pebbles, cobbles, and fine to very coarse sand	0 - 8	8
Gravel; pebbles and fine to coarse sand	8 - 12	4
Sand, coarse to medium; some very coarse sand, some fine to very fine sand, little gravel, little silt	12 - 17	5
Sand, fine to very fine	17 - 20	3
Gravel, coarse to very fine, and very fine to very coarse sand; some silt and clay (dirty gravel)	20 - 28.5	8.5
Gravel, coarse to very fine, and fine to very coarse sand; some very fine sand and silt	28.5 - 48.5	20
Gravel, medium to very fine, and fine to very coarse sand; some very fine sand and silt	48.5 - 58.5	10
Sand, medium to very fine, and silt; little coarse sand and gravel, trace clay	58.5 - 68.5	10
Gravel, very fine to coarse, and very coarse to fine sand; some very fine sand and silt	68.5 - 78.5	10
Gravel, coarse to very fine, and very coarse to very fine sand; some silt and clay (dirty gravel)	78.5 - 88.5	10
Till	88.5 - 94	5.5
End of hole	at 94	

WY 27 th. 413201N0731232.01. Town of Woodbury. Drilled 1979. Altitude 225 ft. Depth to water 6 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (sandy loam)	0 - 3	3
Sand, medium to coarse; some fine to very fine sand	3 - 9	6
Gravel; pebbles and fine to coarse sand	9 - 12	3
Sand, medium to very coarse; some fine sand, some gravel, some very fine sand and silt	12 - 18	6
Sand, very fine to medium, and silt; some coarse to very coarse sand and gravel, trace clay	18 - 27	9
Sand, medium to very fine; some coarse to very coarse sand and gravel, trace silt	27 - 37	10
Sand, very fine to medium; some silt; some coarse to very coarse sand and gravel	37 - 43.5	6.5
Sand, very fine to fine, and silt; some medium to very coarse sand, some gravel, trace clay.	43.5 - 57	13.5
Sand, medium to fine; some very fine sand, some silt, some coarse to very coarse sand, little gravel	57 - 65	8
Gravel, very fine to coarse, sand and silt; little clay (poorly sorted gravel)	65 - 68.5	3.5
Gravel, very fine to coarse, and coarse to fine sand, in layers; some silt, little clay	68.5 - 78.5	10
Gravel, very fine to coarse, and fine to coarse sand; some very fine sand, some silt	78.5 - 98.5	20
Gravel, coarse to very fine and very coarse to fine sand; some silt, little very fine sand.	98.5 - 103.5	5
Sand, fine to very coarse, and very fine to coarse gravel; some silt, some very fine sand, little clay	103.5 - 113.5	10
Gravel, fine to coarse, and fine to coarse sand, in layers	113.5 - 128.5	15
End of hole	at 128.5	

WY 28 th. 413314N0731202.01. Edward Coles. Drilled 1979. Altitude 277 ft. Depth to water 18 ft. Log by U.S. Geological Survey.

	Depth (feet)	Thickness (feet)
Soil (loam)	0 - 4	4
Gravel; pebbles and fine to coarse sand	4 - 15	11
Gravel, fine to very fine, and medium to coarse sand; some fine sand, some very fine sand and silt	15 - 25	10
Sand, fine to very coarse, and very fine to medium gravel		
Sand, fine to very coarse; some very fine to fine gravel, some very fine sand and silt	33.5 - 43.5	10
Sand, medium to very coarse, and coarse gravel; some fine sand, some very fine sand and silt	43.5 - 48.5	5
Gravel, very fine to coarse, and very fine to very coarse sand; some silt and clay (poorly sorted gravel)	48.5 - 63	14.5
Till or poorly sorted gravel		
Till	64 - 68	4
End of hole	at 68	

All analyses by U.S. Geological Survey. Size class intervals are those of the Wentworth grade scale (see heading of Table 22) and are expressed in millimeters (mm).

Identification (well or test-hole) number: U.S. Geological Survey number assigned to each site. The SB and WY prefixes denote the towns of Southbury and Woodbury, respectively. Test holes are identified by the "th" suffix. Sites shown on plate A.

Location number: Latitude and longitude of test-hole or well site.

Median grain size. A measure of average particle size obtained by calculating the particle size associated with the midpoint of the cumulative particle-size distribution curve.

Samples were disturbed but uncontaminated and were collected by driving a split-spoon sampler or split core-barrel sampler vertically through the depth interval indicated.

Test-hole or well number	Location number	Depth interval sampled (ft below land surface)	Clay & silt (less than 0.0625 mm)	Very fine sand (0.0625-.125 mm)	Fine sand (0.125-.25 mm)	Medium sand (0.25-.5 mm)	Coarse sand (0.5-1.0 mm)	Very coarse sand (1.0-2.0 mm)	Gravel (greater than 2.0 mm)	Median grain size (mm)
SB 28 th	412815N0731259.01	15 - 17	2	2	10	25	29	14	18	0.65
		17 - 20	4	6	12	18	15	10	35	.79
SB 34 th	412844N0731337.01	7 - 8.5	6	5	7	7	9	10	56	3.36
		17 - 18.5	13	7	9	8	8	8	47	1.54
		22 - 23.5	13	14	13	8	7	8	37	.61
SB 35 th	412853N0731330.01	12 - 13	6	13	27	23	14	7	10	.28
SB 36 th	413002N0731324.01	57 - 58.5	7	24	60	7	0	1	1	.16
		67 - 68.5	13	25	55	0	0	7	0	.14
		77 - 78.5	12	28	47	10	0	3	0	.14
		87 - 88.5	5	10	35	43	4	1	1	.25
		95 - 96.5	6	3	4	5	8	11	14	3.81
SB 37 th	412940N0731315.01	7 - 8.5	7	6	11	9	8	7	52	2.52
		12 - 13.5	8	6	14	21	18	10	23	.52
		22 - 23.5	6	7	10	11	9	9	48	1.71
		33 - 33.5	7	4	6	7	9	11	56	2.75
SB 38 th	412111N0731315.01	47 - 48.5	18	11	13	10	8	8	32	.44
SB 39 th	412802N0731354.01	7 - 8.5	2	5	33	50	5	3	2	.29
		17 - 18.5	24	26	23	13	10	3	1	.12
		27.5 - 28.5	9	13	30	31	15	0	2	.24
		37 - 38.5	11	16	27	20	15	7	4	.23
		47 - 48.5	8	7	8	11	13	12	41	1.19
		52 - 53.5	17	36	42	0	0	0	5	.12
		67 - 68.5	12	13	17	12	8	9	29	.40
		77 - 78.5	8	12	20	33	14	9	4	.31
SB 40 th	412732N0731425.01	17 - 18.5	79	3	2	2	2	3	9	.022
		37 - 38.5	68	8	8	3	3	3	7	
		47 - 48.5	55	37	0	0	0	0	8	.048
		62 - 63.0	49	39	11	0	0	1	0	.064
		77 - 78.5	82	16	0	0	0	0	2	.021
		92 - 93.5	8	7	10	7	7	8	43	2.46
SB 41 th	412814N0731338.01	12 - 13.5	13	6	10	10	9	9	43	1.17
		22 - 33.5	13	11	12	16	11	6	29	.42
		32 - 33.5	10	5	8	13	11	9	44	1.26
SB 24	412774N0731425.01	32 - 35	50	31	12	3	1	2	1	0.063
		37 - 48	32	8	1	57	1	0	0	.28
		48 - 49	29	45	23	1	0	1	0	.086
		52 - 54	72	21	5	1	1	1	0	.026
		62 - 64	68	24	6	1		0	0	028
SB 25	412748N0731355.01	16 - 17	3	3	6	7	11	9	61	4.54
		21 - 22	11	32	45	4	2	2	4	.14
		37 - 39	22	29	38	8	1	1	1	.12
		42 - 44	63	9	25	2	1	0	0	.034
		52 - 54	77	20	3	0	0	0	0	.023
		62 - 64	70	4	5	5	7	4	5	.026
SB 26	412807N0731325.01	25 - 27	12	24	43	18	3	0	0	.16
		7 - 59	19	45	34	2	0	0	0	.10
		62 - 64	10	17	61	11	1	0	0	.16
		72 - 74	9	9	30	40	11	1	0	.26
		82 - 84	30	50	19	1	0	0	0	.082
		92 - 94	6	28	50	13	2	1	0	.16
SB 28	412906N0731333.01	22 - 24	47	26	10	5	5	4	3	.068
		27 - 29	11	5	8	6	6	7	57	3.43
SB 29	412929N0731259.01	27 - 28	3	3	11	26	32	21	4	.58
		28 - 29	6	3	6	7	40	9	29	.81
		32 - 33	9	5	10	9	8	9	50	2.00
		37 - 39	10	6	11	13	9	8	43	1.09
		42 - 44	12	10	14	15	16	13	20	.48

Test-hole or well number	Location number	Depth interval sampled (ft below land surface)	Clay & silt (less than 0.0625 mm)	Very fine sand (0.0625-.125 mm)	Fine sand (0.125-.25 mm)	Medium sand (0.25-.5 mm)	Coarse sand (0.5-1.0 mm)	Very coarse sand (1.0-2.0 mm)	Gravel (greater than 2.0 mm)	Median grain size (mm)
SB 30	412954N0731252.01	8 - 12	8	11	17	14	11	10	29	.50
		22 - 27	9	9	12	12	12	9	37	.79
SB 31	413019N0731311.01	27 - 29	6	6	9	64	6	4	5	.34
		37 - 39	49	28	12	6	2	2	1	.064
		42 - 44	9	6	13	18	16	11	27	.60
		47 - 49	11	8	12	15	12	10	32	.63
		57 - 59	7	4	9	44	7	6	23	.40
		67 - 68	14	10	13	15	14	12	22	.46
		68 - 69	14	5	3	4	6	10	58	3.18
WY 18 th	413318N0713346.01	12 - 13.5	12	8	12	12	12	12	32	0.71
		22 - 23.5	11	5	10	12	11	9	42	1.08
		32 - 33.5	6	4	14	18	10	9	39	.87
		37 - 38.5	10	8	18	33	27	0	4	.34
		42 - 43.5	3	3	7	9	8	11	59	3 73
		52 - 53.5	12	10	15	19	11	7	26	.40
		62 - 63.0	8	14	16	14	10	9	29	.45
WY 19 th	413229N0731250.01	12 - 13.5	29	38	25	7	0	0	1	.092
		22 - 23.5	60	34	5	0	1	0	0	.039
		42 - 43.5	58	32	8	0	2	0	0	.042
		52 - 53.5	85	13	0	0	0	0	2	.018
		62 - 63.5	27	50	22	0	0	0	1	.086
		72 - 73.5	23	28	38	10	0	0	1	.12
		82 - 83.5	14	30	44	0	0	12	0	.14
		92 - 93.5	29	43	22	0	0	0	6	.088
		107 - 108.5	11	23	45	19	0	0	2	.16
		122 - 123.5	14	19	28	26	12	0	1	.19
		137 - 138.5	13	28	43	11	2	2	1	.14
		156 - 157	8	7	11	8	6	7	53	2.59
WY 20 th	413243N0731305.01	22 - 23.5	84	5	1	1	1	1	7	.019
		27 - 28.5	75	12	2	1	2	2	6	.023
		37 - 38.5	11	6	4	5	9	7	58	5.28
		47 - 48.5	5	4	7	9	12	11	52	2.24
		57 - 58.5	4	5	10	16	16	13	36	.96
		67 - 68.5	5	4	6	6	8	18	53	2.14
		77 - 78.5	7	9	12	15	16	14	27	.68
		87 - 88.5	1	4	18	26	24	9	27	.52
WY 21 th	413339N0731135.01	17 - 18.5	1	2	7	17	32	31	10	.82
		27 - 28	4	5	10	20	27	20	14	.66
		37 - 38.5	6	7	17	20	16	13	21	.50
		42 - 43.5	0	6	6	13	12	11	52	2.33
WY 22 th	413321N0731133.01	12 - 13.5	10	9	11	10	7	7	46	1.35
		17 - 18 5	5	4	6	6	8	11	60	3.76
		22 - 23.5	12	25	37	10	5	4	7	.16
		37 - 38.5	15	20	22	14	7	7	15	.20
		47 - 48.5	9	15	10	11	10	9	36	.71
		62 - 63.5	6	6	10	16	19	16	27	.78
		72 - 73.5	10	14	17	11	8	7	33	.44
		82 - 83.5	10	10	22	13	13	10	32	.65
WY 23 th	413040N0731230.01	17 - 18.5	8	30	51	8	1	1	1	.15
		22 - 23.5	7	13	55	23	0	0	2	.18
		32 - 33.5	6	3	6	10	11	18	46	1.71
WY 24 th	413117N0731225.01	17 - 18.5	15	29	31	7	5	6	7	0.14
		22 - 23.5	22	45	25	2	2	3	1	.096
		38 - 38.5	9	8	11	12	13	13	34	.85
		42 - 43.5	6	6	11	12	13	12	40	1.12
		52 - 53.5	6	5	7	7	7	6	62	5.66
		62 - 63.5	6	7	9	9	8	9	52	2.33
WY 25 th	413300N0731252.01	17 - 18.5	4	11	40	33	7	3	2	.23
		27 - 28.5	47	29	17	3	0	1	3	.067
		37 - 38.5	49	31	16	2	0	0	2	.064
		47 - 48.5	58	31	10	2	0	1	0	.046
		57 - 58.5	86	6	3	2	2	0	1	.018
		72 - 73	48	34	14	0	0	0	4	.065
		87 - 88.5	6	10	30	38	14	0	2	.27
		97 - 98.5	3	5	19	35	19	8	1	.39
		107 - 108.5	0	7	9	18	23	20	23	.81
		117 - 118	11	19	39	25	5	0	1	.18
WY 26 th	413208N0731247.01	12 - 13.5	2	2	6	25	50	12	3	.62
		22 - 23.5	10	7	12	10	9	9	43	1.17
		32 - 33.5	8	6	11	12	10	9	44	1.26
		42 - 43.5	6	5	8	8	9	11	53	2.42
		52 - 53.5	8	6	11	11	9	11	44	1.37
		62 - 63.5	24	21	19	31	4	0	1	.15
		72 - 73.5	7	6	8	9	13	17	43	1.33
		82 - 83.5	13	6	9	9	10	14	39	1.16
		93 - 93.5	10	5	8	9	9	9	50	2.00

Table 23.--Grain-size analyses of samples of startified drift--Continued

Test-hole or well number	Location number	Depth interval sampled (ft below land surface)	Clay & silt (less than 0.0625 mm)	Very fine sand (0.0625-.125 mm)	Fine sand (0.125-.25 mm)	Medium sand (0.25-.5 mm)	Coarse sand (0.5-1.0 mm)	Very coarse sand (1.0-2.0 mm	Gravel (greater than 2.0 mm)	Median grain size (mm)
WY 27 th	413201N0731232.01	12 - 13.5	3	2	14	33	23	15	10	0.48
		18 - 18.5	16	19	39	18	3	2	3	.16
		27 - 28.5	1	26	29	34	5	2	3	.22
		37 - 38.5	13	19	35	18	7	4	4	.18
		47 - 48.5	23	36	22	9	2	1	7	.10
		57 - 58.5	9	10	31	37	7	3	3	.25
		67 - 68.5	17	12	17	12	7	5	30	.32
		77 - 78.5	17	9	17	20	12	7	18	.32
		87 - 88.5	8	5	9	9	9	11	49	1.88
		102 - 103.5	9	4	8	9	11	18	41	1.41
		112 - 113.5	13	8	12	15	14	10	28	.55
WY 28 th	413314N0731202.01	22 - 23.5	2	2	8	12	14	20	42	1.52
		27 - 28.5	6	6	18	22	18	12	18	.47
		37 - 38.5	4	4	12	21	23	22	14	.66
		47 - 48.5	5	4	11	16	15	13	37	.96
		57 - 58.5	13	7	9	8	8	9	46	1.47
WY 25	413339N0731143.01	12 - 14	3	5	18	38	25	9	2	.39
		17 - 19	3	3	5	24	45	9	11	.63
		22 - 24	54	39	5	1	0	1	0	.051
WY 26	413300N0731219.01	25 - 27	19	18	23	20	11	5	4	.19
		32 - 33	5	11	29	23	13	10	9	.29
		37 - 39	14	20	22	17	11	7	9	.21
		46 - 48	15	17	21	17	13	8	9	.23
		48 - 49	15	19	32	24	7	1	2	.18
WY 27	413331N0731227.01	12.5 - 13	10	7	11	12	18	24	18	.74
		13 - 13.5	20	20	28	18	7	3	4	.16
		17 - 18	10	9	13	13	11	11	33	.68
		22 - 24	6	5	7	9	12	15	46	1.66
		32 - 34	8	6	8	10	10	11	47	1.66
		37 - 39	10	7	12	13	13	14	31	.77
		47 - 49	8	4	7	7	8	19	47	1.79
		57 - 58	5	6	17	20	14	16	22	.55
		58 - 59	10	7	11	10	9	11	42	1.21
		67 - 68	12	7	10	12	11	13	35	.88
		75 - 76	10	7	9	10	9	9	46	1.47
WY 28	413330N0731254.01	15 - 17	8	5	7	8	8	9	55	3.08
		27 - 29	11	9	13	14	13	10	30	.59
		32 - 34	12	8	11	9	10	9	41	1.00
		37 - 39	12	8	10	10	11	9	40	.94
WY 29	413258N0731236.01	47 - 49	15	33	42	7	1	1	1	.13
		52 - 54	71	18	6	2	3	0	0	.027
		62 - 64	88	8	2	1	1	0	0	.017
		72 - 74	79	12	5	2	2	0	0	.021
		82 - 84	90	5	2	1	2	0	0	.017
		92 - 94	88	10	1	1	0	0	0	.018
		102 - 104	60	32	6	1	1	0	0	.039
		112 - 114	33	48	17	1	0	1	0	.080
WY 30	413307N0731250.01	16 - 18	18	19	29	14	4	4	12	.17
		28 - 30	72	10	10	5	1	1	1	.026
		38 - 39	12	14	19	15	13	9	18	.32
		42 - 44	9	18	40	24	5	2	2	.19
		47 - 49	8	8	18	26	16	7	17	.38
		52 - 54	7	8	17	19	12	9	28	.48
		57 - 59	9	10	21	24	12	9	15	.33
		67 - 69	10	7	9	8	11	15	40	1.26
WY 31	413247N0731259.01	18 - 22	78	10	9	2	1	0	0	.021
		32 - 34	86	12	1	1	0	0	0	.019
		42 - 44	87	8	2	1	0	1	1	.018
		52 - 54	88	28	2	1	0	1	0	.030
		62 - 64	33	51	14	2	0	0	0	.079
		72 - 74	62	26	8	3	0	1	0	.036
WY 32	413238N0731226.01	20 - 22	14	30	45	9	1	1	0	.14
		32 - 33	52	22	4	5	7	6	4	.056
		37 - 39	30	31	25	2	1	1	10	.098
		42 - 44	14	15	30	22	6	3	10	.20
		47 - 48	7	6	9	9	9	14	46	1.64

Table 23.--Grain-size analyses of samples of stratified drift--Continued

Test-hole or well number	Location number	Depth interval sampled (ft below land surface)	Clay & silt (less than 0.0625 mm)	Very fine sand (0.0625-.125 mm)	Fine sand (0.125-.25 mm)	Medium sand (0.25-.5 mm)	Coarse sand (0.5-1.0 mm)	Very coarse sand (1.0-2.0 mm)	Gravel (greater than 2.0 mm)	Median grain size (mm)
WY 33	413141N0731157.1	10 - 12	8	11	23	20	12	11	15	.33
		17 - 19	4	4	7	9	7	7	62	9.08
		20 - 22	4	5	14	17	17	15	22	.75
		22 - 24	41	33	21	2	1	1	1	.076
		27 - 28	11	9	14	14	12	8	32	.56
WY 34	413117N0731209.1	32 - 34	13	14	23	17	12	8	13	.25
		37 - 38	9	10	13	10	7	3	48	1.26
		47 - 49	11	12	19	15	13	9	21	.36
WY 35	413119N0731235.1	7 - 9	6	7	13	19	17	9	29	.61
		9 - 12	7	8	15	18	22	16	14	.53
		12 - 14	5	15	48	19	5	4	4	.19
		22 - 24	10	8	12	11	10	10	39	.93
		27 - 29	6	5	9	10	11	12	47	1.68
		32 - 34	8	7	11	11	11	12	40	1.12
		42 - 44	8	6	10	11	11	11	43	1.29
WY 36	413104N0731235.1	17 - 19	2	2	14	31	34	13	4	.51
		22 - 24	23	39	32	3	1	1	1	.10
		27 - 29	19	29	41	9	1	0	1	.13
		32 - 34	8	17	66	7	1	1	0	.16
		42 - 44	7	6	11	13	12	8	43	1.09
WY 37	413336N0731126.1	12 - 14	1	0	4	15	35	32	13	.91
		17 - 19	2	1	7	18	27	17	28	.88
		22 - 24	6	5	9	12	11	12	45	1.50
		32 - 34	10	6	9	8	8	9	50	2.00
		35 - 36	4	8	19	17	15	15	22	.55
WY 38	413318N0731126.1	27 - 32	2	3	8	15	17	13	42	1.31
		32 - 37	2	2	9	28	33	20	6	.60
WY 39	413206N0731235.1	17 - 19	1	2	14	28	27	20	8	.57
		22 - 24	8	21	55	12	2	1	1	.16
		27 - 29	2	8	38	32	10	6	4	.26
		37 - 39	1	16	30	37	11	2	3	.26
		47 - 49	3	4	17	43	22	8	3	.38
		62 - 64	23	29	28	15	2	1	2	.12
		72 - 73	3	7	18	15	12	30	15	.75
		73 - 74	26	37	11	5	0	1	0	.098
		77 - 79	7	6	7	15	19	10	36	.86
		87 - 89	15	42	40	2	0	1	0	.11
WY 42	413124N0731224.1	17 - 18.5	18	14	11	9	8	9	31	0.43
		22 - 23.5	9	8	11	11	9	10	42	1.15

Table 24.--Records of observation wells

Identification number: U.S. Geological Survey local number assigned to each well. Numbers are assigned sequentially; SB prefix denotes town of Southbury, WY prefix denotes town of Woodbury. Sites shown on plate A.

Location number: Latitude and longitude of each well site. Number after decimal point is in sequential number used to identify closely spaced wells.

Altitude: Land surface datum at well site in feet above NGVD of 1929, which is approximately equal to mean sea level. Determined from topographic map.

Well depth: Finished depth of well in feet below land surface.

Casing depth: Depth to bottom of unperforated casing in feet below land surface.

Water level: Static water level in feet below land surface. Measurements made by steel tape to 0.01 ft accuracy.

Remarks: CA, Chemical analysis published in table 26; F, Field determinations of specific conductance and temperature available; GS, Grain-size data published in table 23.

Note: All wells except WY 40 and WY 41 are 2 inches in diameter, have slotted casing finish, and were installed using a power auger. Monthly water-level measurements for each well are shown in table 25.

Identification number	Location number	Owner	Date drilled	Altitude (feet)	Well depth (feet)	Casing depth (feet)	Water level (feet)	Date of water-level measurement	Remarks
SB 24	412740N 0731425.01	State of Connecticut	11-03-78	202	44.4	41.4	41.07	01-02-79	GS
SB 25	412748N 0731355.01	State of Connecticut	11-02-78	204	41.4	38.4	29.58	01-02-79	CA,F,GS
SB 26	412807N 0731325.01	Town of Southbury	11-07-78	251	75.1	70.1	59.20	01-02-79	F,GS
SB 27	412901N 0731249.01	State of Connecticut	11-02-78	245	22.5	17.5	9.22	01-02-79	CA,F
SB 28	412906N 0731330.01	Heritage Village G. C.	11-01-78	215	32.9	29.9	19.88	01-02-79	CA,F,GS
SB 29	412929N 0731259.01	Middleground Cem. Assoc.	11-01-78	220	32.7	27.7	18.83	01-02-79	CA,F,GS
SB 30	412954N 0731252.01	State of Connecticut	11-06-78	252	27.5	22.5	19.72	01-02-79	CA,F,GS
SB 31	413019N 0731311.01	O & G Sand and Gravel Co.	11-13-78	200	41.6	36.6	29.18	01-03-79	F,GS
SB 32	413007N 0731346.01	State of Connecticut	10-31-78	230	26.3	21.3	13.14	01-02-79	F
SB 33	413020N 0731335.01	State of Connecticut	10-31-78	253	47.3	43.3	30.37	01-02-79	F
WY 25	413339N 0731143.01	State of Connecticut	10-25-78	285	22.4	17.4	3.13	01-02-79	CA GS
WY 26	413300N 0731219.01	Town of Woodbury	10-18-78	280	34.0	31.0	11.12	01-02-79	CA,F,GS
WY 27	413331N 0731227.01	Frank Shepard	10-16-78	267	23.0	18.0	2.17	01-03-79	CA,F,GS
WY 28	413330N 0731254.01	David Shepard	10-20-78	258	22.7	17.7	7.25	01-02-79	CA,F,GS
WY 29	413258N 0731236.01	Town of Woodbury	11-15-78	292	44.8	41.8	29.05	01-03-79	F,GS
WY 30	413307N 0731250.01	Woodbury Cem. Assoc.	10-19-78	275	49.1	44.1	36.22	01-02-79	F,GS
WY 31	413247N 0731259.01	James Ravenscroft	10-23-78	270	59.9	56.9	19.64	01-03-79	CA,F,GS
WY 32	413238N 0731326.01	Willam Moody	11-16-78	282	45.9	40.9	25.12	01-03-79	CA,F,GS
WY 33	413141N 0731157.01	Charles Nininger	10-24-78	268	22.4	17.4	5.84	01-03-79	CA,F,GS
WY 34	413117N 0731209.01	Steadman Hitchcock	10-24-78	282	31.8	28.8	22.66	01-03-79	F,GS
WY 35	413119N 0731235.01	O & G Sand and Gravel Co.	10-26-78	223	22.7	17.7	4.70	01-03-79	CA,F,GS
WY 36	413104N 0731235.01	O & G Sand and Gravel Co.	10-27-78	212	21.9	16.9	7.34	01-03-79	F,GS
WY 37	413336N 0731126.01	Town of Woodbury	10-27-78	299	25.5	22.5	1.67	01-03-79	F,GS
WY 38	413318N 0731126.01	Frederick Strong	10-17-78	319	57.0	52.0	44.85	01-02-79	F,GS
WY 39	413206N 0731235.01	Town of Woodbury	11-14-78	232	22.2	19.2	4.06	01-03-79	CA,F,GS
WY 40	413051N 0731219.01	Terrace Apartments	10-15-78	235	26.5	----	21.82	01-02-79	24 In. Diam.
WY 41	413259N 0731134.01	James Ravenscroft	10-04-78	295	14.0	14.0	7.90	01-02-79	36 In. Diam.
WY 42	413124N 0731224.01	George Hardesty	07-13-79	230	26.0	23.0	16.00	07-13-79	CA,GS

Table 25.--Monthly water levels, ranges and means, from 28 observation wells

[Well WY-1 has water-level measurements from 1944 to date.]

Month and year of measurement	Well Numbers and Water Levels									
	SB 24	SB 25	SB 26	SB 27	SB 28	SB 29	SB 30	SB 13	SB 32	SB 33
Jan - 1979	40.72	27.50	59.49	5.69	14.41	15.66	16.28	26.89	10.72	25.52
Feb - 1979	40.73	27.17	59.75	7.18	18.19	18.23	17.52	27.04	14.83	27.69
Mar - 1979	40.10	25.69	58.00	5.60	16.35	16.69	16.63	25.18	10.76	26.75
Apr - 1979	39.10	24.47	57.40	4.72	16.19	16.79	16.37	24.53	9.21	26.60
May - 1979	39.43	22.22	56.22	5.79	19.90	17.07	16.87	24.03	12.83	27.30
Jun - 1979	39.60	22.56	55.32	7.69	28.74	18.95	18.21	25.31	15.21	27.94
Jul - 1979	40.09	24.16	55.02	9.32	20.45	19.88	19.80	26.63	15.57	28.81
Aug - 1979	40.45	25.79	55.83	9.78	20.24	20.32	21.87	27.47	14.85	29.74
Sep - 1979	40.70	27.04	56.74	9.47	19.65	19.96	21.00	26.47	13.78	30.16
Oct - 1979	40.81	27.77	57.61	8.93	18.92	18.68	19.72	25.02	13.52	29.22
Nov - 1979	39.55	28.36	58.31	8.06	18.96	18.40	18.57	26.51	11.58	28.47
Dec - 1979	40.82	28.37	58.53	7.72	19.30	18.29	18.07	26.76	12.41	28.00
Jan - 1980	40.95	28.33	59.27	8.06	19.85	18.65	18.33	26.89	14.62	28.49
Feb - 1980	41.13	28.65	59.35	9.02	21.09	19.50	19.29	28.14	15.38	29.08
Maximum	41.13	28.65	59.49	9.78	21.09	20.32	21.87	28.14	15.57	30.16
Minimum	39.10	22.22	55.02	4.72	14.41	15.66	16.28	24.03	9.21	25.52
Mean	40.30	26.29	57.60	7.65	18.52	18.36	18.47	26.21	13.23	28.13

Month and year of measurement	Well Numbers and Water Levels								
	WY 1	WY 25	WY 26	WY 27	WY 28	WY 29	WY 30	WY 31	WY 32
Jan - 1979	20.28	2.62	7.17	2.81	5.34	28.41	36.06	19.65	20.59
Feb - 1979	21.06	3.96	7.99	3.74	7.37	27.99	37.43	21.22	21.72
Mar - 1979	20.68	3.16	6.19	3.33	6.29	27.48	36.81	19.74	20.77
Apr - 1979	21.20	2.33	4.62	2.28	5.42	26.96	35.50	19.05	20.39
May - 1979	20.96	3.29	6.50	3.02	6.67	26.12	36.95	19.79	20.91
Jun - 1979	21.94	4.13	8.25	3.49	8.04	25.92	37.72	20.50	21.95
Jul - 1979	23.55	4.67	9.80	3.64	8.44	26.35	37.93	20.89	22.88
Aug - 1979	27.03	5.55	10.77	3.82	8.36	26.83	37.89	21.00	23.47
Sep - 1979	28.92	4.20	10.93	1.83	8.02	27.41	37.69	20.94	23.44
Oct - 1979	28.71	3.97	10.80	2.88	7.75	27.75	37.40	20.67	23.37
Nov - 1979	27.84	3.25	10.27	2.87	6.97	28.20	36.60	20.13	22.96
Dec - 1979	25.84	3.25	9.87	2.56	7.08	28.52	36.69	20.16	22.83
Jan - 1980	24.52	4.03	9.64	3.73	7.75	28.75	37.59	20.06	23.27
Feb - 1980	25.84	4.19	10.58	3.43	8.19	28.86	37.66	20.83	23.61
Maximum	28.92	5.50	10.93	3.74	8.44	28.86	37.93	21.22	23.61
Minimum	20.28	2.33	4.62	1.83	5.34	25.92	55.50	19.05	20.39
Mean	24.17	3.76	8.81	3.10	7.26	27.54	37.12	20.33	22.30

Month and year of measurement	Well Numbers and Water Levels								
	WY 33	WY 34	WY 35	WY 36	WY 37	WY 38	WY 39	WY 40	WY 41
Jan - 1979	3.69	11.36	3.52	8.39	0.95	42.13	4.08	18.25	6.30
Feb 1979	6.26	15.54	5.52	9.54	2.43	43.09	5.92	21.64	7.69
Mar - 1979	5.15	12.99	5.02	8.97	1.93	42.45	5.11	20.37	7.65
Apr - 1979	4.19	11.38	3.83	8.12	1.20	42.22	3.75	19.22	6.48
May - 1979	5.20	14.34	5.13	9.14	----	42.71	5.24	20.33	7.29
Jun - 1979	8.05	17.37	6.08	9.51	3.37	43.84	6.28	21.89	7.98
Jul - 1979	9.29	19.52	6.29	10.00	3.48	44.84	6.49	23.10	8.49
Aug - 1979	8.33	21.18	6.25	9.86	4.35	45.03	6.46	23.02	8.33
Sep - 1979	8.48	21.23	5.89	9.67	3.10	44.89	6.15	21.78	8.22
Oct - 1979	7.48	20.64	5.75	9.43	2.98	44.55	6.04	20.74	8.06
Nov - 1979	7.32	19.64	4.98	8.76	2.20	44.14	5.14	20.86	7.64
Dec - 1979	6.37	17.39	5.01	8.76	2.68	44.00	5.20	21.24	7.65
Jan - 1980	7.22	17.57	6.04	9.52	2.99	44.13	6.12	21.67	6.09
Feb - 1980	8.51	18.68	6.27	9.74	3.09	44.17	6.27	22.16	6.32
Maximum	9.29	21.23	6.29	10.00	4.35	45.03	6.49	23.10	8.49
Minimum	3.69	11.36	3.52	8.12	.95	42.13	3.75	18.25	6.09
Mean	6.82	17 06	5.40	9.24	2.67	43.73	5.59	21.16	7.44

Table 26.--Analyses of water from the Pomperaug River aquifer, Southbury and Woodbury, Connecticut

[Well locations are shown on plate A. All analyses are by U.S. Geological Survey.]

Well number	Date of sample	Well depth (feet)	Dis-solved calcium (mg/L)	Dis-solved magne-sium (mg/L)	Dis-solved sodium (mg/L)	Dis-solved potas-sium (mg/L)	Dis-solved silica (mg/L)	Calcium, magnesium hardness (mg/L)	Noncar-bonate hardness (mg/L)
SB 4	8-08-79	64.	16	4.0	7.3	1.0	13	56	24
SB 25	8-15-79	41.4	40	13.	61.	3.7	17	150	78
SB 27	8-07-79	22.5	28	8.6	7.6	.3	22	110	33
SB 28	8-08-79	32.9	65	11.	5.7	.6	17	210	88
SB 29	8-07-79	32.7	22	5.1	9.2	1.0	13	76	37
SB 30	8-07-79	27.5	16	5.7	11.	1.4	21	63	36
WY 11	8-14-79	126.	30	6.0	6.7	1.7	18	100	52
WY 20	8-09-79	104.	34	8.6	18.	1.7	17	120	50
WY 23	8-14-79	54.	22	6.0	11.	1.1	15	80	44
WY 25	8-09-79	22.4	8.0	2.0	4.1	1.4	14	28	16
WY 26	8-09-79	34.0	66	22.	15.	5.7	15	260	130
WY 27	8-09-79	23.0	18	5.8	4.7	2.7	13	69	48
WY 28	8-08-79	22.7	15	3.6	29.	2.4	11	52	33
WY 31	8-10-79	59.9	22	7.5	6.0	2.2	14	86	66
WY 32	8-10-79	45.9	16	4.9	7.2	1.5	19	60	34
WY 33	8-14-79	22.4	19	5.6	18.	1.1	12	71	47
WY 35	8-15-79	22.7	8.5	1.7	5.1	.9	18	28	17
WY 39	8-08-79	22.2	21	5.7	6.0	3.3	11	76	29
WY 42	8-14-79	26.0	22	6.7	14.	1.7	11	83	40
Maximum			66	22	61	5.7	22	260	130
Minimum			8.0	1.7	4.1	.3	11	28	16
Median			22	11	7.6	1.5	15	76	40
Mean			26	7.0	13	1.9	15	94	47

Well number	Alka-linity (mg/L as CaCO3)	Dis-solved sulfate (mg/L)	Dis-solved chloride (mg/L)	Dis-solved nitrate plus nitrite (mg/L)	Dis-solved fluoride (mg/L)	Specific conduct-ance (umhos/cm)	Dis-solved solids, sum of consti-tuents (mg/L)	Field pH (units)	Temper-ature (deg C)
SB 4	32	14	13	0.92	0.1	165	92	7.2	12.5
SB 25	75	25	120	2.1	.0	600	334	6.4	11.5
SB 27	72	11	20	2.9	.1	260	154	6.6	13.0
SB 28	120	15	45	5.4	.2	425	256	7.0	10.0
SB 29	39	14	27	.85	.1	225	119	6.4	10.5
SB 30	27	11	28	.57	.1	215	113	6.2	12.5
WY 11	48	16	16	6.1	.0	234	150	6.1	12.0
WY 20	70	20	28	6.1	.1	202	197	7.1	15.5
WY 23	36	21	26	1.3	.1	230	130	6.4	12.5
WY 25	12	12	4.1	98	.1	90	57	5.8	12.0
WY 26	130	10	100	.01	.2	560	312	7.2	13.0
WY 27	21	23	12	3.5	.1	180	107	5.8	11.0
WY 28	19	17	43	4.6	.1	290	153	6.0	11.0
WY 31	20	7.6	5.6	16	.0	225	148	6.6	12.0
WY 32	26	15	11	3.5	.1	190	106	6.6	10.5
WY 33	24	13	42	.45	.1	235	127	6.4	11.0
WY 35	11	13	12	.00	.1	113	66	5.9	11.5
WY 39	47	9.6	19	1.1	.1	202	109	7.0	12.0
WY 42	43	13	36	2.7	.1	260	142	5.9	11.0
Maximum	130	25	120	6.1	.2	600	334	7.2	15.5
Minimum	11	7.6	4.1	.00	.0	90	57	5.8	10.0
Median	36	14	26	2.1	.1	225	130	6.4	12.0
Mean	46	15	32	3.1	.1	258	151	6.2	12.0

Table 27.--Analyses of water from streams in the Pomperaug River basin, Bethlehem, Southbury, and Woodbury, Connecticut

[Sampling sites are shown on plate A. All analyses are by U.S. Geological Survey.]

Station number	Stream name and location	Date of sample	Time of collection	Instantaneous discharge (ft3/s)	Dissolved calcium (mg/L)	Dissolved magnesium (mg/L)	Dissolved sodium (mg/L)	Dissolved potassium (mg/L)	Dissolved silica (mg/L)	Calcium magnesium hardness (mg/L)	Noncarbonate hardness (mg/L)
2035.20	Nonewaug River near Bethlehem	05-14-79	1200	4.4	7.7	2.8	5.2	1.3	6 2	31	10
2035.40	East Spring Brook near Bethlehem	05-14-79	1120	8.0	8.0	2.2	6.0	1.1	6.9	29	13
2036	Nonewaug River at Minortown	11-06-78	1500	3.8	10	2.5	9.0	2.1	5.6	39	18
do	do	05-14-79	1240	26	7.6	3.5	7.2	1.4	7.2	29	10
2038.05	Weekeepeemee River at Hotchkissville	11-06-78	1330	5.9	9.2	2.6	6.7	1.8	4.8	34	15
do	do	05-14-79	1330	47	6.6	1.8	5.0	1.0	6.9	24	8
2038.47	Pomperaug River at Pomperaug	11-06-78	1130	19	12	3.3	7.8	1.8	6.5	44	15
do	do	05-14-79	1420	112	7.8	2.8	9.2	1.8	7.1	31	13
2040	Pomperaug River at Southbury	11-06-78	1030	22	16	4.0	9.2	1.9	8.1	56	20
do	do	05-14-79	1515	135	9.4	2.5	6.7	1.2	7.3	34	13
2041.99	Pomperaug River at South Britain	11-06-78	0800	23	18	4.7	10	1.9	8.6	64	24
do	do	05-14-79	1605	143	11	2.7	6.8	1.2	7.6	39	15

Station number	Alkalinity (mg/L as CaCO3)	Dissolved sulfate (mg/L)	Dissolved chloride (mg/L)	Total nitrate plus nitrite (mg/L)	Dissolved fluoride (mg/L)	Specific conductance (umhos/cm)	Dissolved solids residue at 180 deg C (mg/L)	Turbidity (NTU)	Dissolved oxygen (mg/L)	Dissolved oxygen (percent saturation)	Total coliform (colonies per 100 mL)	Fecal coliform (colonies per 100 mL)	Fecal streptococci (colonies per 100 mL)
2035.20	21	13	7.8	0.41	0.1	93	64	1.0	10.2	100	2800	100	50
2035.40	16	11	9.6	45	.1	116	68	1.0	10.4	100	680	110	51
2036	21	16	17	.44	.1	160	80	1.0	15.6	144	620	500	37
do	19	14	12	.64	.1	103	70	1.0	10.4	102	1200	620	100
2038.05	19	14	12	.21	.1	130	65	1.0	16.2	144	160	19	26
do	16	13	7.6	.24	.0	87	52	1.0	11.0	108	1100	180	100
2038.47	29	14	14	.67	.1	160	78	1.0	10.0	88	750	90	29
do	18	13	16	.45	.1	95	82	1.0	11.0	108	1100	120	80
2040	36	15	16	.98	.1	190	103	1.0	15.0	133	85	4	4
do	21	12	11	.49	.1	106	74	1.0	11.0	108	2400	440	260
2041.99	40	16	21	.99	.1	222	115	2.0	9.8	84	120	100	32
do	24	13	13	.46	.1	118	77	1.0	10.8	108	2000	240	120

Station number	Dissolved arsenic (ug/L)	Dissolved barium (ug/L)	Dissolved cadmium (ug/L)	Dissolved chromium (ug/L)	Dissolved copper (ug/L)	Total cyanide (mg/L)	Dissolved lead (ug/L)	MBAS (ug/L)	Dissolved mercury (ug/L)	Dissolved selenium (ug/L)	Silver (ug/L)	Field pH (units)	Field temperature (deg C)
2035.20	0	0	1	10	2	--	2	--	0.5	0	0	7.2	15.0
2035.40	1	0	2	10	2	--	2	--	0.5	0	0	7.1	14.0
2036	0	0	1	0	8	.00	--	.00	<.5	0	0	6.5	12.0
do	0	0	1	10	3	--	1	--	<.5	0	0	7.5	15.0
2038.05	0	0	1	0	0	.00	--	.00	<.5	0	0	7.2	10.5
do	0	0	1	10	2	--	0	--	<.5	0	0	7.4	15.0
2038.47	0	0	2	0	1	.00	--	.00	<.5	0	0	6.3	10.0
do	2	0	1	10	3	--	2	--	.5	0	0	7.2	15.0
2040	0	0	2	0	2	.00	--	.00	<.5	0	0	7.1	10.5
do	0	0	0	20	2	--	0	--	.5	0	0	7.2	15.0
2041.99	0	0	2	0	1	.00	--	.00	<.5	0	0	6.2	9.0
do	0	0	1	10	2	--	2	--	.5	0	0	7.5	15.5

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GLOSSARY

Aquifer: A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable materials to yield significant quantities of water to wells and springs.

Arkose: A sandstone containing 25 percent or more feldspar.

Bedrock: Solid rock, locally called "ledge," that forms the earth's crust. It is locally exposed at the surface but more commonly is buried beneath a few inches to more than 150 feet of unconsolidated deposits.

Coliform organisms: Any of a group of bacteria, some of which inhabit the intestinal tracts of vertebrates. Their presence in water is regarded as evidence of possible sewage pollution and fecal contamination, although they are generally considered to be nonpathogenic.

Cone of depression: A depression produced in a water table or other potentiometric surface by the withdrawal of water from an aquifer; in cross section, shaped like an inverted cone with its apex at the pumping well.

Cubic feet per second (ft^3/s): A unit expressing rate of discharge. One cubic foot per second is equal to the discharge of a stream 1 foot wide and 1 foot deep flowing at an average velocity of 1 foot per second.

Cyanide: In waters, refers to all of the CN groups in the cyanide compounds present that can be determined as the cyanide ion, CN , by the methods used. A toxic compound present in industrial wastes from metal plating operations and chemical industries.

Dissolved solids: The residue from a clear sample of water after evaporation and drying for one hour at 180°C; consist primarily of dissolved mineral constituents, but may also contain organic matter and water of crystallization.

Drainage area: The area or tract of land, measured in a horizontal plane, that gathers water and contributes it ultimately to some point on a stream channel, lake, reservoir, or other water body.

Drainage basin: The whole area or entire tract of country that gathers water and contributes it ultimately to a particular stream channel, lake, reservoir, or other body of water.

Drawdown: The lowering of the water table or potentiometric surface caused by the withdrawal of water from an aquifer by pumping; equal to the difference between the static water level and the pumping level.

Duration of flow, of a stream: The percentage of time during which specified daily discharges have been equaled or exceeded in magnitude within a given time period.

Effective recharge: Water that percolates to, and supplies the saturated zone. It is total recharge minus ground-water evapotranspiration.

Evapotranspiration: Loss of water to the atmosphere by direct evaporation from water surfaces and moist soil, combined with transpiration from living plants.

Glacier: A large mass of ice formed, at least in part, on land by the compaction and recrystallization of snow; glaciers move slowly over the land surface and spread outward in all directions due to the stress of their own weight, and survive from year to year.

Gravel: Unconsolidated rock debris composed principally of particles larger than 2 millimeters in diameter.

Ground water: Water in the saturated zone.

Ground-water evapotranspiration: Ground water discharged into the atmosphere in the gaseous state either by direct evaporation or by the transpiration of plants.

Ground-water outflow: The sum of ground-water runoff and underflow; it includes all natural ground-water discharge from a drainage area exclusive of ground-water evapotranspiration.

Ground-water recharge: The amount of water that is added to the saturated zone.

Ground-water runoff: Ground water that has discharged into stream channels by seepage from saturated earth materials.

Hardness, of water: The property of water generally attributable to salts of the alkaline earths. Hardness has soap-consuming and encrusting properties and is expressed as the concentration of calcium carbonate ($CaCO_3$) that would be required to produce the observed effect.

Head, static: The height of the surface of a water column above a standard datum that can be supported by the static pressure at a given point.

Hydraulic boundary: A physical feature that limits the areal extent of an aquifer. Two common types of boundaries are termed impermeable-barrier boundaries and line-source boundaries.

Hydraulic conductivity: A measure of the ability of a porous medium to transmit a fluid. The material has a hydraulic conductivity of unit length per unit time if it will transmit in unit time a unit volume of water at the prevailing kinematic viscosity through a cross section of unit area, measured at right angles to the direction of flow, under a hydraulic gradient, of unit change in head over unit length of flow path.

Hydraulic gradient: The change in static head per unit of distance in a given direction. If not specified, the direction is generally understood to be that of the maximum rate of decrease in head.

Impermeable-barrier boundary: The contact between an aquifer and adjacent impermeable material that limits the areal extent of the aquifer. For example, the termination of permeable valley-fill deposits of sand and gravel against the bedrock valley walls. Its significant hydraulic feature is that ideally no ground water flows across it.

Inches of water: Water volume expressed as the depth, in inches, to which it would accumulate if spread evenly over a particular area.

Induced infiltration: The process by which water in a stream or lake moves into an aquifer by establishing a hydraulic gradient from the surface-water body toward a pumping well or wells.

Induced recharge: The amount of water entering an aquifer from an adjacent surface-water body by the process of induced infiltration.

Line-source boundary: A boundary formed by a surface-water body that is hydraulically connected to an adjacent aquifer. Ideally, there is no drawdown along such a boundary.

Long-term well yield: The yield of a well or group of wells that can be reasonably expected under conditions of continuous pumping over extended time periods.

Mean (arithmetic): The sum of the individual values of a set, divided by their total number. Also referred to as the "average."

Metamorphic rock: Any rock derived from pre-existing rocks by mineralogical, chemical, and structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment at depth in the earth's crust.

Methylene-blue active substance (MBAS): A measure of apparent detergents, as indicated by the formation of a blue color when methylene-blue dye reacts with synthetic-detergent compounds.

Micrograms per liter (ug/L): A unit for expressing the concentration of chemical constituents in solution by weight per unit volume of water.

Milligrams per liter (mg/L): A unit for expressing the concentration of chemical constituents in solution by weight per unit volume of water.

National Geodetic Vertical Datum (NGVD) of 1929: A geodetic datum derived from a general adjustment of the first order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

Noncarbonate hardness: A measure of the amount of alkaline-earth cations in excess of available carbonate (and bicarbonate) anions.

Organohalide: A compound comprised of a halogen, especially flourine, chlorine, and bromine, attached to a hydrocarbon molecule. Typically, the halogen replaces one or more of the hydrogen atoms.

Partial penetration: A condition in which a water well is not open to the entire saturated thickess of the aquifer.

Perennial stream: A stream that flows during all seasons of the year.

pH: The negative logarithm of the hydrogen-ion concentration. A pH of 7.0 indicates neutrality; values below 7.0 denote acidity, those above 7.0 denote alkalinity.

Precipitation: The discharge of water from the atmosphere, either in a liquid or solid state.

Recharge: Water that percolates to, and supplies the saturated zone. Recharge may be natural or artificial, depending upon the source of the water and the process that allows it to infiltrate to an aquifer.

Runoff: The part of the precipitation that appears in streams. It is the same as streamflow unaffected by artificial diversions, storage, or other works of man in or on the stream channels.

Saturated thickness: Thickness of an aquifer below the water table.

Specific conductance, of water: A measure of the ability of water to conduct an electric current, expressed in micromhos per centimeter at 25°C. It is related to the dissolved-solids content and serves as an approximate measure thereof.

Specific yield: The ratio of the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. In an unconfined aquifer, the storage coefficient is virtually equal to the specific yield.

Steady-state: A term that describes conditions in an aquifer when flow is essentially steady and water levels cease to decline. In nature, absolute steady-state conditions do not exist; however, if recharge and discharge to an aquifer is held constant over a sufficiently long period of time, steady-state conditions are approximated.

Storage coefficient: The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. In an unconfined aquifer, the storage coefficient is virtually equal to the specific yield.

Stratified drift: A predominantly sorted sediment laid down by or in bodies of meltwater from a glacier; includes gravel, sand, silt, or clay deposited in layers of similar grain size.

Stream-aquifer system: Consists of an aquifer that is hydraulically connected to an adjacent system.

Till: Nonsorted, nonstratified sediments deposited directly by a glacier and composed of boulders, gravel, sand, silt, and clay.

Total recharge: Water that percolates to, and suppies the saturated zone. It includes two components, effective recharge, and ground-water evapotranspiration.

Turbidity, of water: The extent to which penetration of light is restricted by suspended sediment, microorganisms, or other insoluble material. Residual or "permanent" turbidity is that caused by insoluble material that remains in suspension after a long settling period.

Unconfined aquifer (water-table aquifer): One in which the upper surface of the saturated zone, the water table, is at atmospheric pressure and is free to rise and fall.

Unconsolidated: Loose, not firmly cemented or interlocked; for example, sand in contrast to sandstone.

Underflow: The downstream movement of ground water through the permeable deposits that underlie a stream.

Water table: The upper surface of the saturated zone.

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