COMPUTER MODELING OF GROUND-WATER AVAILABILITY

IN THE POOTATUCK RIVER VALLEY, NEWTOWN, CONNECTICUT

U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS 78-77

Prepared in cooperation with the
town of Newtown, Connecticut

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No.
4. Title and Subtitle COMPUTER MODELING OF GROUND-WATER AVAILABILITY IN THE POOTATUCK RIVER VALLEY, NEWTOWN, CONNECTICUT			5. Report Date July 1978 6.
7. Author(s) F. P. Haeni			8. Performing Organization Rept. No. USGS/WRI-78-77
9. Performing Organization Name and Address U.S. Geological Survey, Water Resources Division Rm. 235 135 High Street Hartford, Conn. 06103			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address U.S. Geological Survey, Water Resources Division Rm 235 135 High Street Hartford, Conn. 06103			13. Type of Report & Period Covered Final 14.

15. Supplementary Notes

Prepared in cooperation with the town of Newtown, Conn.

16. Abstracts A hydrologic analysis based on available data, test drilling, seismic refraction profiling, and the stream-aquifer connection was performed using a digital computer model. Simulated pumping indicates that a total of 4.0 million gallons of water per day (mgd) can be withdrawn from the stream-aquifer system. Further, ground-water development is limited by the hydrologic characteristics of the aquifer in the northern part of the study area, by the existing pumpage by Fairfield Hills Hospital in the center of the area, and by the streamflow available for induced recharge in the southern part of the area. Induced recharge from the river supplies 65 percent of the total pumpage, and captured ground-water outflow supplies the remaining 35 percent. Consequently, the streamflow equaled or exceeded 90 percent of the time is reduced from 3.0 to 0.5 mgd at Hospital wells no. 7 and 8. The simulated yields are for long-term average hydrologic conditions; unusually dry periods or extended droughts would significantly reduce the water available from the aquifer.

The quality of surface water in the valley meets the Connecticut standards for public drinking water except for excessive coliform bacteria. Ground-water quality also meets these standards, but high manganese (up to 15 mg/L) and iron (up to 1.7 mg/L) would require treatment prior to use. Trace metals from one surface-water and four ground-water samples are also within these standards, except for a high cadmium concentration, 26 ug/L in water from one well (NT 57).

17. Key Words and Document Analysis. 17a. Descriptors

Aquifers, Computer models, Ground water, Aquifer characteristics, Aquifer-stream relationships, Hydrologic models, Hydrologic cycle, Recharge, Ground-water movement

17b. Identifiers/Open-Ended Terms

POOTATUCK RIVER, Aquifer long-term yields, Newtown, Glacial outwash, saturated thickness

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
No restriction on distribution	UNCLASSIFIED	76
	20. Security Class (This Page)	22. Price
	UNCLASSIFIED	

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July 1978
Reprinted September 1981

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

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GLOSSARY

Acid: A substance containing hydrogen, which dissociates to yield excess hydrogen ions when dissolved in water. Acid solutions can dissolve many metals.

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

Base: A substance containing hydrogen and oxygen, which dissociates to form hydroxide ions when dissolved in water. Basic solutions neutralize acidic solutions.

Bedrock: Solid rock, commonly 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 300 feet of unconsolidated deposits.

Coefficient of permeability: The rate of flow of water, in gallons per day, through a cross sectional area of 1 sq ft of a saturated material under a hydraulic gradient of 1 foot per foot at a temperature of 16°C. Replaced by the U.S. Geological Survey with a new term--hydraulic conductivity (in this Glossary).

Coliform bacteria: Any of a group of bacteria, some of which inhabit the intestinal tracts of vertebrates. Their occurrence in a water sample is regarded as evidence of possible sewage pollution and fecal contamination, although these bacteria 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.

Crystalline bedrock: Pertaining to igneous and metamorphic rocks; the most common types in the basin are granite, gneiss, and schist.

Cubic feet per second (cfs): 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.

Direct runoff: Water that moves over the land surface directly to streams or lakes shortly after rainfall or snowmelt.

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 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 water 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.

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

Fracture: A structural break or opening in bedrock along which water may move.

Gaging station: A site on a stream, canal, lake, or reservoir selected for systematic observations of gage height or discharge.

Glacier: A large mass of ice formed, at least in part, on land by the compaction and recrystallization of snow, moving slowly over the land surface outward in all directions due to the stress of its own weight, and surviving from year to year.

Ground water: Water in the saturated zone.

Ground-water discharge: The discharge of water from the saturated zone by 1) natural processes such as ground-water runoff and ground-water evapotranspiration and 2) artificial discharge through wells and other man-made structures.

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 calcium, magnesium and the other 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 conductivity (K): 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, or 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.

Ice-contact deposit: Stratified drift deposited in contact with melting glacial ice.

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.

Ion: An atom or group of atoms that carries an electric charge as a result of having lost or gained electrons.

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

Median: The middle value in a set of values arranged according to rank. It is an average of position, whereas the mean is an average of quantity.

Metamorphic rock: Any rock derived from preexisting 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.

Micrograms per liter (ug/L): A unit for expressing the concentration of chemical constituents in solution by weight per unit volume of water. One thousand micrograms is equivalent to 1 milligram.

Milliequivalents per liter: A measure of concentration of chemical constituents whereby unit concentrations of all ions are chemically equivalent.

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

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, in either a liquid or solid state.

Runoff: That 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.

Saturated zone: The subsurface zone in which all open spaces are filled with water. The water table is the upper limit of this zone. Water in the saturated zone is under pressure greater than atmospheric.

Specific capacity, of a well: The rate of discharge of water divided by the corresponding drawdown of the water level in the well (gpm/ft).

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

Specific yield: The ratio of the volume of water which a saturated rock or soil will yield by gravity, to its own volume.

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 equal to the specific yield.

Stratified drift: A sorted sediment laid down in layers, by or in meltwater from a glacier; includes sand and gravel and minor amounts of silt and clay deposited in layers.

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

Till: A nonsorted, nonstratified sediment deposited directly by a glacier and composed of boulders, gravel, sand, silt, and clay mixed in various proportions.

Transpiration: The process whereby plants release water vapor to the atmosphere.

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.

Water table: The upper surface of the saturated zone.

Water year: A continuous 12-month period, October 1 through September 30, during which a complete streamflow cycle takes place from low to high flow and back to low flow. It is designated by the calendar year in which it ends, and that includes 9 of its 12 months.

FACTORS FOR CONVERTING U.S. CUSTOMARY UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

U.S. customary units	Multiplied by	Are converted to SI units
Length		
inch (in)	25.4	millimeter (mm)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
square mile (mi^2)	2.590	square kilometer (km^2)
Flow		
cubic foot per second (cfs)	28.32	liter per second (L/s)
gallon per minute (gpm)	.06309	liter per second (L/s)
million gallons per day (mgd)	43.81	liter per second (L/s)
Gallon per day per foot (gpd/ft)	.00014	liter per second meter (L/s/m)
Hydraulic Units		
transmissivity, foot squared per day (ft^2/d)	.0929	meter squared per day (m^2/d)
hydraulic conductivity, foot per day (ft/d)	.3048	meter per day (m/d)
foot per mile (ft/mi)	.1894	meter per kilometer (m/km)

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ABSTRACT

The growing need for water and the stresses resulting from intensified land use in Newtown, Connecticut, necessitated a quantitative estimate of the long-term availability of water from the stratified-drift aquifer underlying much of the Pootatuck River valley.

A hydrologic analysis based on available data, test drilling, seismic refraction profiling, and the stream-aquifer connection was performed using a digital computer model. Simulated pumping indicates that a total of 4.0 million gallons of water per day (mgd) can be withdrawn from the stream-aquifer system. A minimum of 2.5 mgd is available for future development because Fairfield Hills Hospital is capable of withdrawing 1.5 mgd. Further, ground-water development is limited by the hydrologic characteristics of the aquifer in the northern part of the study area, by the existing pumpage by Fairfield Hills Hospital in the center of the area, and by the streamflow available for induced recharge in the southern part of the area. Induced recharge from the river supplies 65 percent, or 2.6 mgd of the total pumpage, and captured ground-water outflow supplies the remaining 35 percent, or 1.4 mgd. Consequently, the streamflow equaled or exceeded 90 percent of the time is reduced from 3.0 to 0.5 mgd at Hospital wells no. 7 and 8. The simulated yields are for long-term average hydrologic conditions; unusually dry periods or extended droughts would significantly reduce the water available from the aquifer.

The quality of surface water in the valley, shown by seven samples from five sites, meets the Connecticut standards for public drinking water except for excessive coliform bacteria. Ground-water quality also meets these standards, as indicated by analyses of 20 samples from 14 wells and 1 spring, but high manganese (up to 15 mg/L) and iron (up to 1.7 mg/L) would require treatment prior to use. Trace metals from one surface-water and four ground-water samples are also within these standards, except for a high cadmium concentration, 26 ug/L in water from one well (NT 57).

INTRODUCTION

Purpose and Scope

The town of Newtown, Connecticut, is evaluating several major land-use proposals for the Pootatuck River Valley. Part of this valley is underlain by a stratified-drift aquifer that is hydraulically connected to the Pootatuck River. This potentially important stream-aquifer system is used for water supply by Fairfield Hills Hospital. The town recognized that quantitative hydrologic information is needed for future water-resources utilization and land-use planning and accordingly, in 1976, entered into a cooperative agreement with the U.S. Geological Survey to conduct a water-resources investigation. The objectives were to:

(1) quantify the availability of water over a long period from the stratified-drift aquifer. (2) predict the effects of withdrawing this amount of water on the stream-aquifer system. (3) locate favorable areas for future pumping centers. (4) assess the quality of ground water and surface water.

To meet these objectives, different types of hydrologic data were collected and analyzed by the U.S. Geological Survey. The quantity of water available and the effects of increased withdrawals were then determined by use of a mathematical simulation model of the stream-aquifer system. The model utilizes digital computer techniques for solving numerical problems.

The first section of this report describes the elements of the hydrologic system and how they function in the Pootatuck River valley. Its purpose is to provide background information for the non-technical reader. Subsequent sections contain the hydrologic data for the Pootatuck River valley, the elements of the mathematical simulation model, the results obtained from the model simulations, and an assessment of the quality of water from the aquifer and the Pootatuck River.

Location

Newtown is in southwestern Connecticut about 45 miles southwest of Hartford and 15 miles east of the New York State line. (See figure 1.) The Pootatuck River originates in the towns of Easton and Monroe, flows north through the eastern part of Newtown, and eventually discharges into the Housatonic River near Rocky Glen, where it drains a total of 26.1 square miles. The study area, shown in figure 1, is underlain by a stratified-drift aquifer composed of unconsolidated sand and gravel (Wilson and others, 1974).

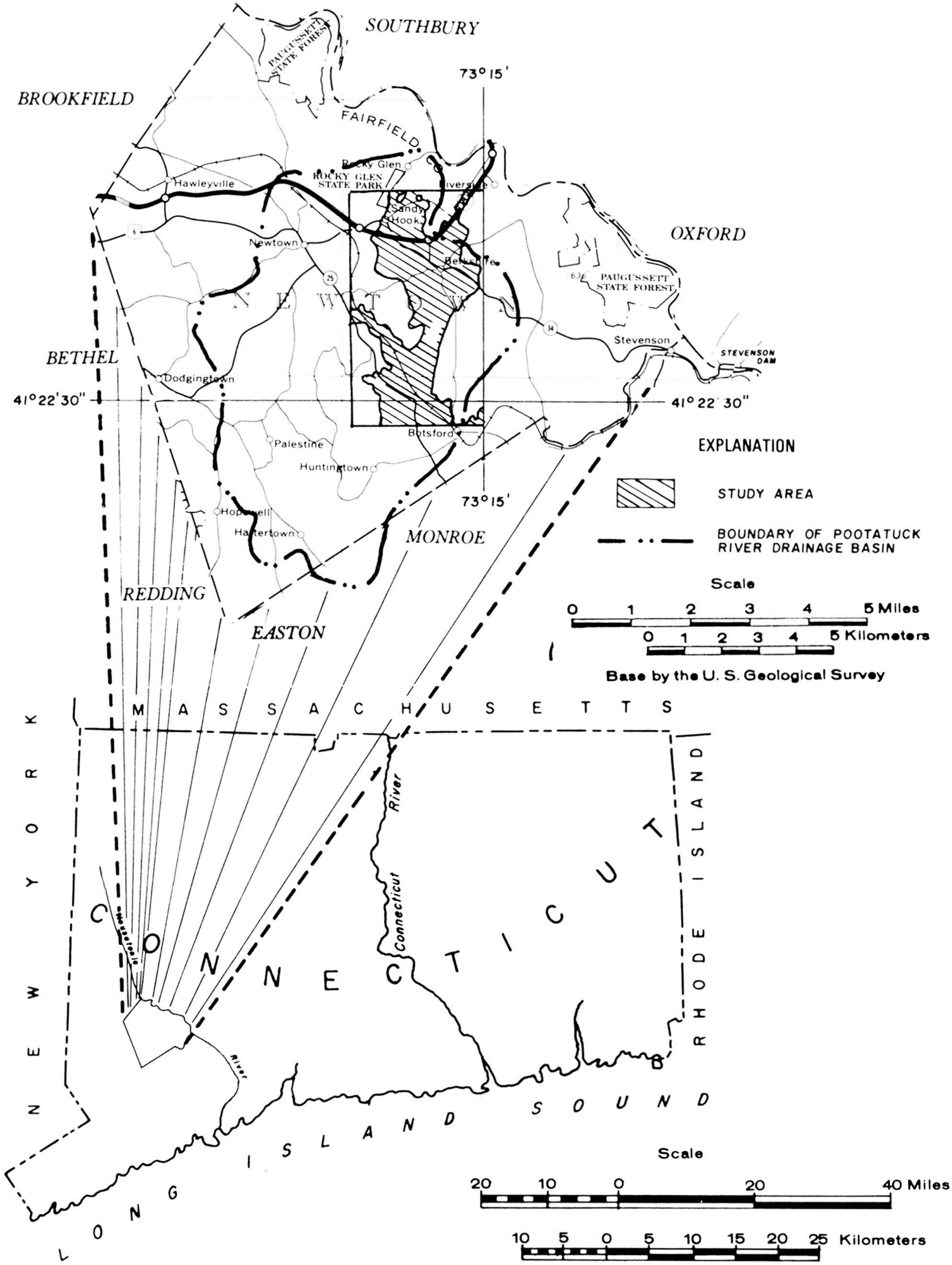


Figure 1.--Generalized location and drainage area map of the Pootatuck River valley

Acknowledgments

During the study, data were collected and analyzed by the U.S. Geological Survey. Additional information was obtained from previous hydrologic studies (Wilson and others, 1974; Grossman and Wilson, 1970) and from the files of the Connecticut Department of Environmental Protection, the Connecticut Department of Health, and the Connecticut Department of Transportation.

Appreciation is extended to the officials of the town of Newtown, to Mr. E. Fenn, supervisor of plant maintenance, Fairfield Hills Hospital, to the Pootatuck Fish and Game Club; and to engineering consultants, corporation officials, and private citizens who provided useful information and granted access to their properties.

HYDROLOGIC SYSTEM

Hydrogeologic Setting

The Pootatuck River basin, like most of western Connecticut, is underlain by three principal geologic units; crystalline bedrock, till, and stratified drift. These units form the physical framework for the storage and movement of ground water; they differ significantly in geologic origin and in water-yielding characteristics. Crystalline bedrock underlies the entire basin and is discontinuously covered by unconsolidated deposits consisting of till and stratified drift. All the subsurface units have openings that can store and transmit water; in the granular till and stratified-drift deposits the openings are between the individual grains, whereas in crystalline bedrock they are formed by a network of fractures. The areal distribution of these materials in the Pootatuck River valley, as shown in figure 2, is based on Wilson and others (1974, plate B). Their general spatial relationships are shown in figure 3.

There are two distinct zones beneath the land surface with respect to subsurface water. In the upper zone, which may extend a few inches to several tens of feet below the land surface, the openings are filled with air and water under lower-than-atmospheric pressure. In the lower zone, the openings are filled with water at higher than atmospheric pressure. The surface that divides these two zones is termed the water table. Within the basin the water table intersects the land surface at streams, ponds, and swamps. (See figure 5.)

Crystalline bedrock, till, and stratified-drift deposits that extend several feet below the water table are generally capable of yielding usable quantities of water to wells and, therefore, constitute

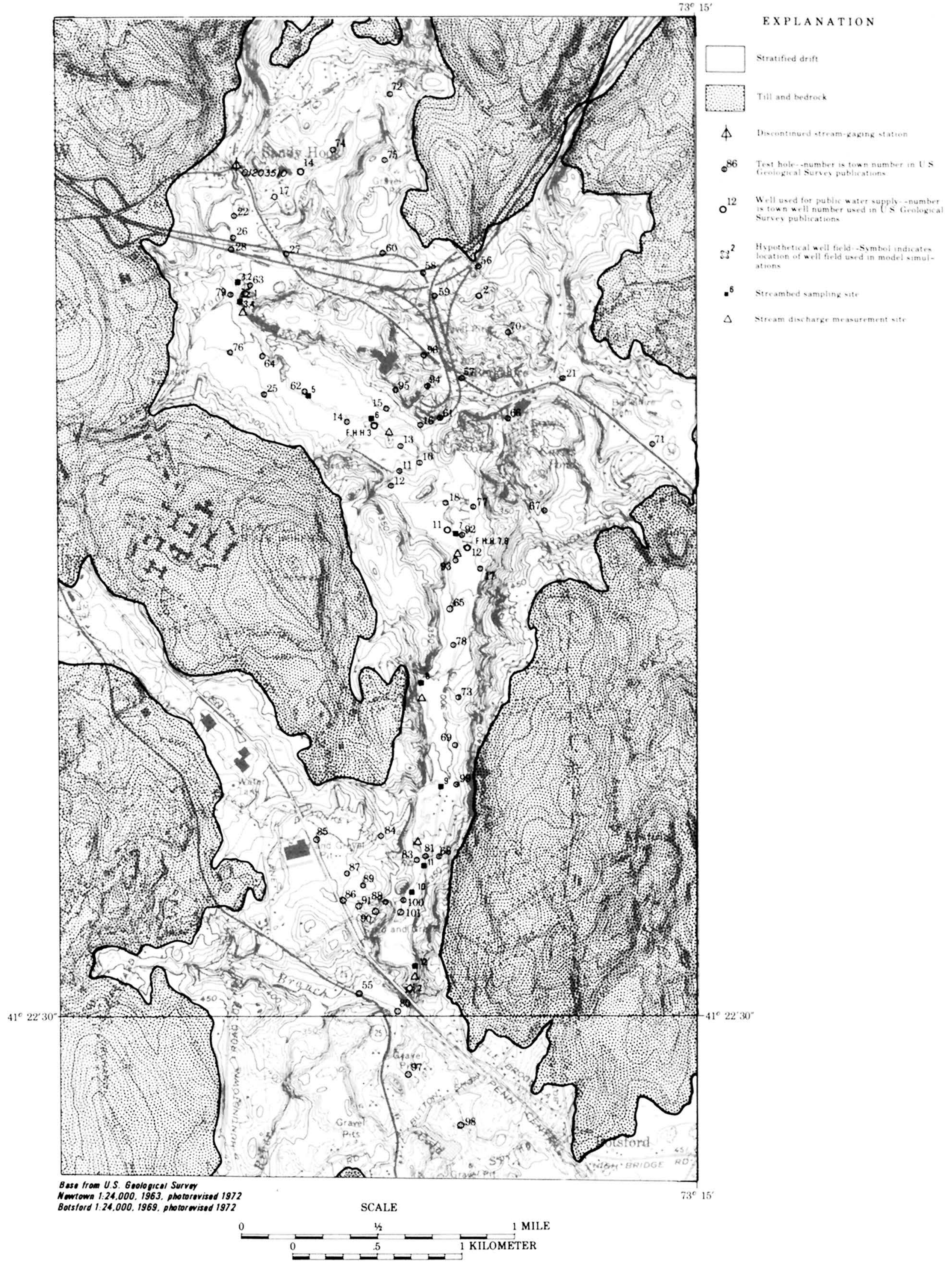


Figure 2.--Areal distribution of hydrogeologic units

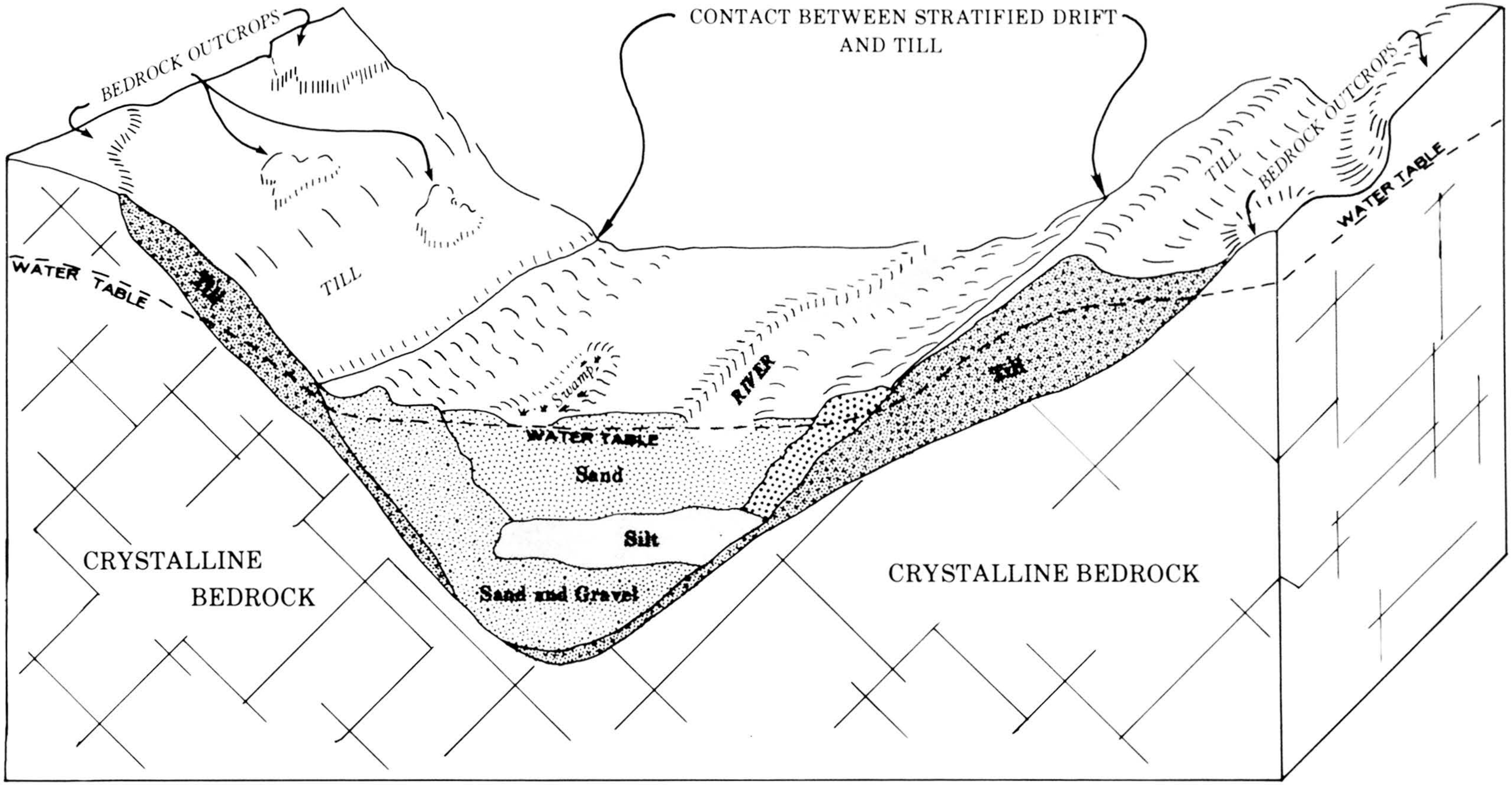


Figure 3.--Idealized section showing spatial relationships between stratified drift, till, and crystalline bedrock.

aquifers. Crystalline bedrock underlies the entire basin at various depths below the land surface. It is composed of several rock types, ranging in age from 400 to 500 million years (Stanley and Caldwell, 1976), that have been altered in composition, folded, and fractured over long periods of geologic time. Water-bearing fractures are present throughout most of the bedrock and may extend 300 feet or more below the land surface. This aquifer is used for water supply by most individual home owners or small commercial establishments in areas not served by public systems. The yield of an individual bedrock well is dependent on the distribution, orientation, size, continuity, and degree of interconnection of the fractures at a site (Wilson and others, 1974).

During the Ice Age, which began 2 to 3 million years ago, continental glaciers advanced from the north and covered this area one or more times. They deposited rock debris, called "drift," consisting of very fine to very coarse fragments. Most of the drift in Connecticut was deposited during the advance and retreat of the last ice sheet.

Nonstratified, heterogeneous material deposited directly by the ice is called till, or commonly "hardpan". Because it is not sorted or stratified by water, till is generally a variable mixture of all sizes of rock fragments, ranging from clay to boulders. Dug wells in till were an important source of water for domestic and agricultural use in the past. Inadequate yields with respect to modern requirements, however, led to a widespread abandonment of this aquifer over the last 30 years.

Stratified drift is rock debris from a glacier that has been transported and sorted by water. It is composed of interbedded layers of sand, gravel, silt, and clay. These materials were deposited approximately 15,000 years ago during the last retreat of the glacial ice from the region (Schafer and Hartshorn, 1965). In general, the stratified-drift deposits are restricted to valleys, such as the Pootatuck, that were drainageways for glacial meltwater streams. Figure 4 shows the origin of stratified drift and till. Aquifers composed of stratified drift are the only ones capable of supplying large quantities of water for public or industrial supplies in most parts of Connecticut; therefore, the stream-aquifer system, consisting of the Pootatuck River and the adjacent stratified-drift aquifer within Newtown, is the principal subject of this report. The aquifer and the river are interdependent, and respond together to imposed hydrologic stresses. The physical and hydrologic characteristics of this aquifer are discussed in detail in the section, "The stratified-drift aquifer."

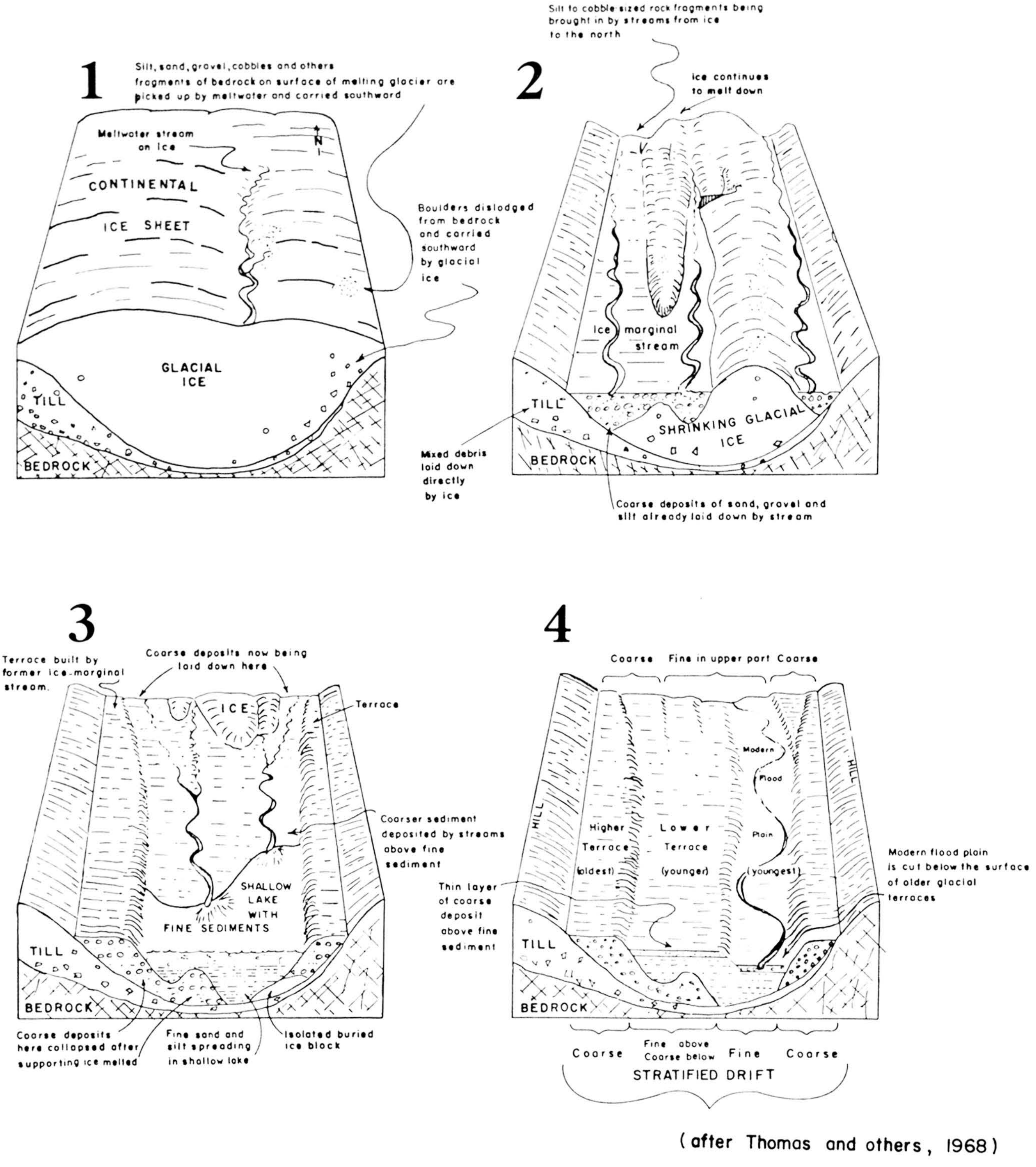


Figure 4.--Diagrams showing the origin of stratified drift deposits

Movement of water in the basin

Water in the Pootatuck River basin is derived entirely from precipitation within its drainage area. (See figure 1.) This precipitation may be temporarily stored within the basin, but eventually it is discharged, either in liquid or vapor form. It is estimated that 30 to 50 percent of the precipitation that fell on the basin annually during 1967-76 was returned directly to the atmosphere by evaporation and plant transpiration. Water may evaporate from the surface of vegetation, the land surface, lakes, ponds, and streams and from the soil, whereas that transpired by plants may be derived from above or below the water table. These processes are referred to collectively as evapotranspiration. The remainder of the water leaves the basin as streamflow. Streamflow consists of either surface runoff to a nearby stream or lake or water that has infiltrated into the ground, reached the water table, and eventually discharged through streambed materials into streams. This latter component of streamflow is termed ground-water runoff. Water movement within the Pootatuck River basin may be quantitatively expressed in the form of a water budget in which the inflow to the system is equal to the outflow plus or minus changes in storage. The components of the water budget are summarized below. Movement of water in the basin is further illustrated in figure 7.

$$\text{Inflow} = \text{outflow} \pm \text{changes in storage}$$

where:

Inflow = precipitation

Outflow = evaporation (direct, soil and ground water) + transpiration by plants (from soil and ground water) + surface runoff + ground-water runoff + pumpage from wells not returned to the system

Changes in storage = changes in ground-water levels; in contents of lakes, ponds, and stream channels; in soil moisture, snow, and ice cover

Movement of ground water within the basin is governed by the nature and size of the saturated openings in the aquifer materials and by pressure or head differences within the saturated zone. Unconsolidated materials, such as stratified drift and till, have many openings between their individual grains that store and transmit water. Coarse-grained stratified drift, such as sand and gravel, has large interconnected openings which allow water to flow freely. Till, on the other hand, generally contains silt- and clay-sized particles between the larger grains of material, resulting in more resistance to ground-water flow. In crystalline bedrock most openings are fractures. The movement of water within a single fracture can be rapid, but the fractures are seldom well connected, and the overall flow in such openings is small. An idealized diagram of ground-water circulation in the Pootatuck River valley is shown in figure 5.

The head in a ground-water flow system is a measure of the potential energy of the fluid above a common datum. In the Pootatuck River basin, as elsewhere, the difference in the water-table altitude between two points above a common datum commonly represents the head difference and indicates a component of the horizontal direction of ground-water flow. Figure 13 is a water table map of the study area in which arrows indicate the direction of horizontal ground-water flow in November 1976.

The hydrologic system within the basin is dynamic and responds to changes in the amounts of water that are gained or lost over a period of time. Figure 6 illustrates the interdependence of inflow, outflow, and storage of components of this system. The top curve in this figure shows the average annual precipitation over an 11 year period, the inflow to the system. The middle curve shows the average annual runoff of the Pootatuck River for 10 years of the same period, the major outflow from the system. The bottom curve shows the fluctuations in water levels in a well in the stratified drift for nine years of this period; it represents the major storage changes in the stream aquifer system.

Ground-water recharge under natural conditions is derived entirely from precipitation and occurs principally during the non-growing season (mid-October to mid-May). Ground-water discharge consists of ground-water runoff to the Pootatuck River and its tributaries and ground-water evapotranspiration. Both processes occur at varying rates throughout the year, but ground-water runoff is generally greater in the non-growing season, and ground-water evapotranspiration is greater in the growing season. The difference between ground-water recharge and ground-water discharge during any period is equal to the change in ground-water storage.

Effects of development

Under natural conditions, the ground-water flow system and the larger hydrologic system of which it is part are in a state of "dynamic equilibrium." The systems are dynamic in that they constantly change in response to changes in recharge or discharge. Over long periods of time, however, the recharge and discharge balance, a condition of equilibrium. Pumping from wells upsets this balance (Lohman, 1972) by taking water from storage. A new equilibrium is established when losses from storage cease because of (1) an increase in recharge to the aquifer (2) a decrease in the natural discharge from the aquifer or (3) both.

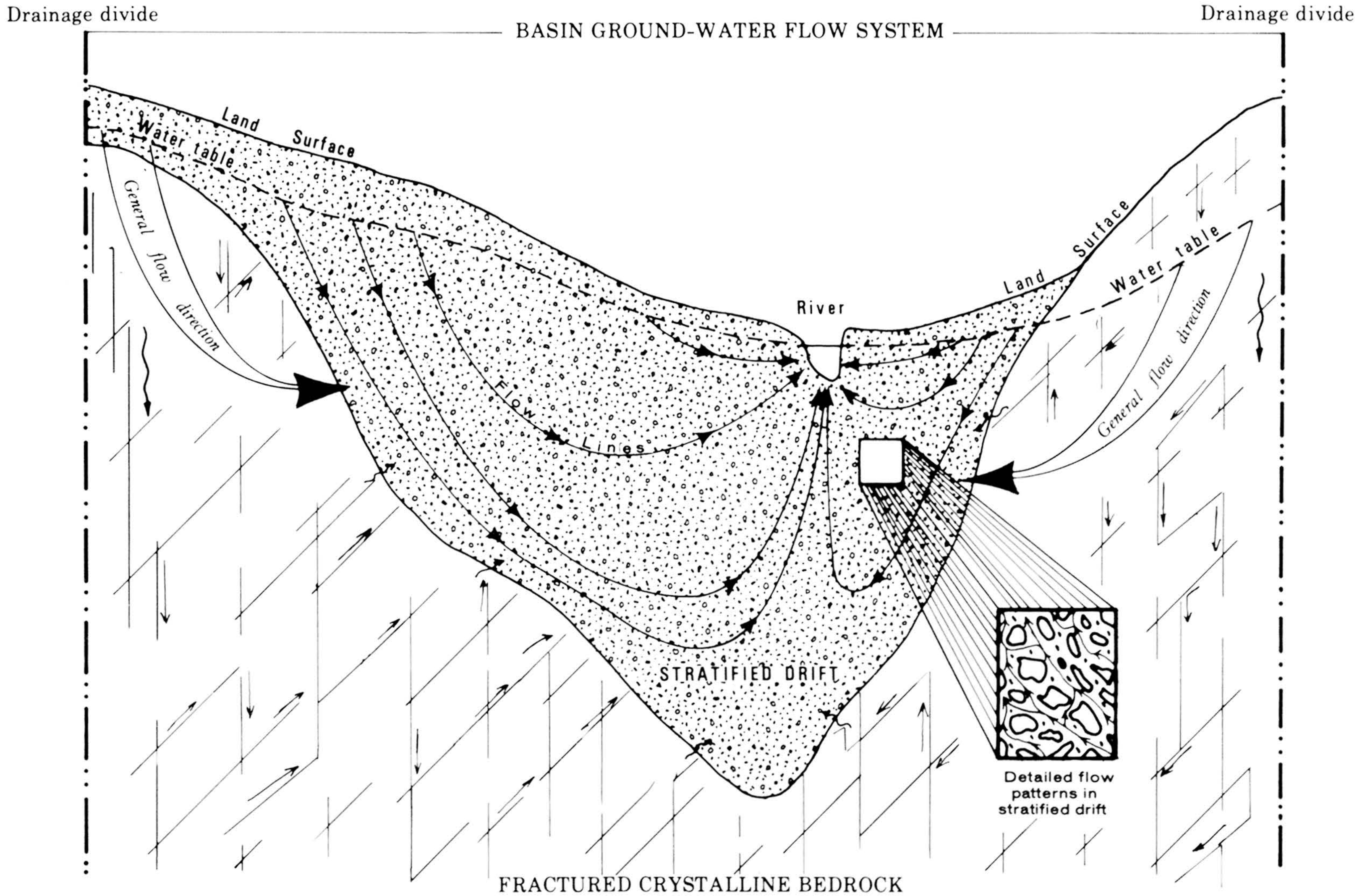


Figure 5.--Idealized pattern of ground-water circulation in stratified drift and crystalline bedrock (the actual flow pattern is more complicated than shown, owing to local variations in the water-bearing properties of the earth materials)

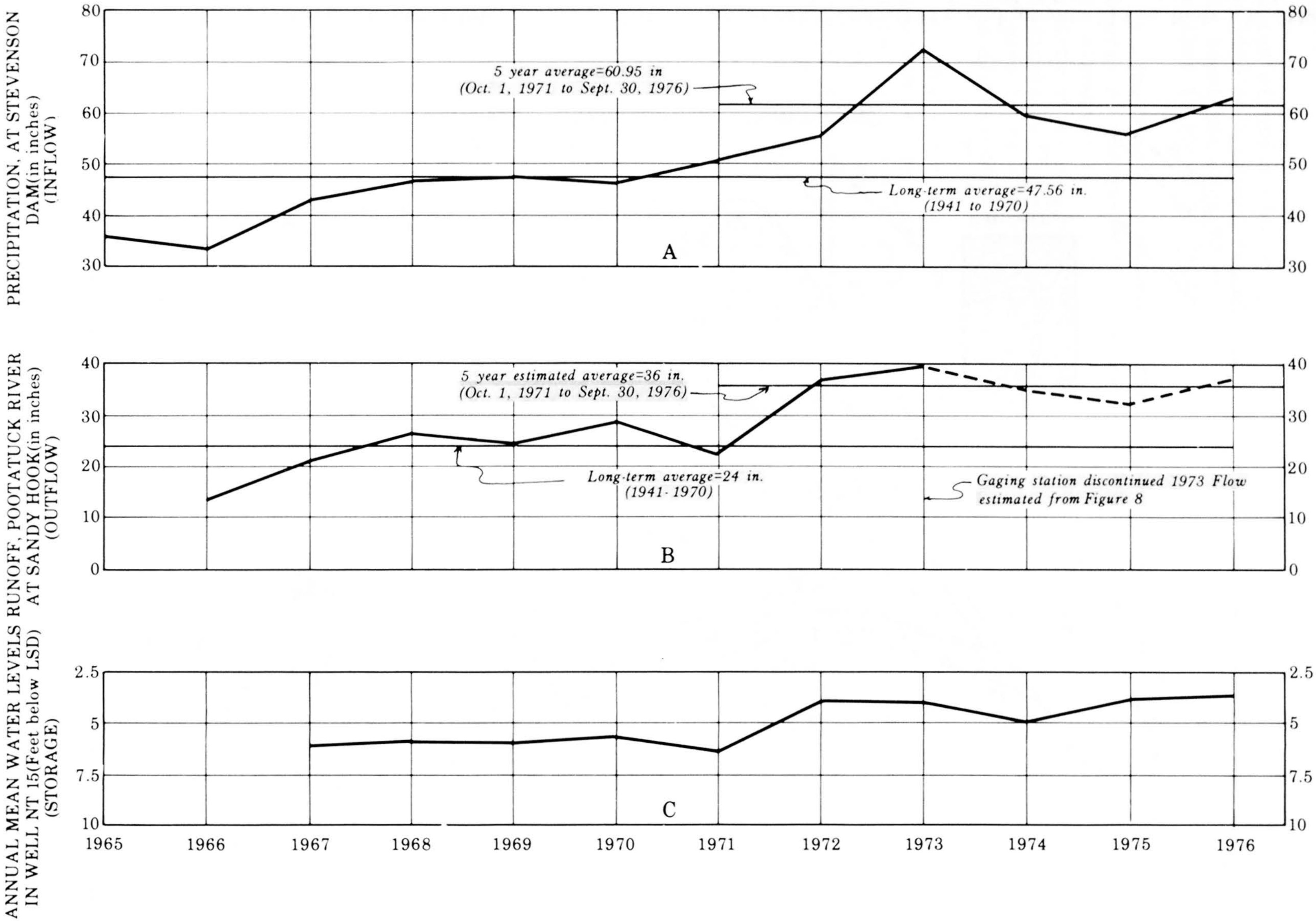


Figure 6.--Relation between inflow, outflow, and storage of water in the basin

To obtain the maximum amount of ground water economically, wells are usually placed in the thickest, most permeable parts of an aquifer located near a stream. The general effects of pumpage under these conditions are as follows:

(1) The initial withdrawal from storage creates a cone-shaped depression of the water table (cone of depression) that has its apex at the center of pumping.

(2) As the cone grows, ground water that would naturally discharge to the adjacent stream as ground-water runoff or to the atmosphere as ground-water evapotranspiration is decreased and this water is discharged by the well.

(3) The cone of depression grows laterally until it reaches equilibrum. Large withdrawals will cause the cone of depression to spread to or under the stream, causing reversal of the natural gradient and the movement of stream water toward the well (fig. 7).

Effects of (2) and (3) above result in a decrease in streamflow equivalent to the pumpage within that reach of the stream intersected by the cone of depression. In many cases induced recharge from the stream may be the principal source of water and pumpage may be limited by the available streamflow. Decreased streamflow resulting from pumping ground-water may also affect surface-water quality or interfere with water rights of downstream users unless the pumped water is returned to the stream nearby.

THE STRATIFIED-DRIFT AQUIFER

The stratified-drift deposits that underlie the Pootatuck River valley between Route 25 and the village of Sandy Hook (fig. 2) are composed of sand and gravel, with small amounts of silt and clay; they are bounded on the east and west by till-covered bedrock hills and on the north and south by thin stratified-drift deposits that have little potential for large water development. An important feature of the aquifer is its hydraulic connection to the Pootatuck River. Pumping from the aquifer in 1976 was small and restricted to four locations. The major user is the Fairfield Hills Hospital, which has two well fields. Newtown High School and Sandy Hook Elementary School also have wells in this aquifer. The following table summarizes 1976 withdrawals and the maximum tested capacity of the Fairfield Hills Hospital wells.

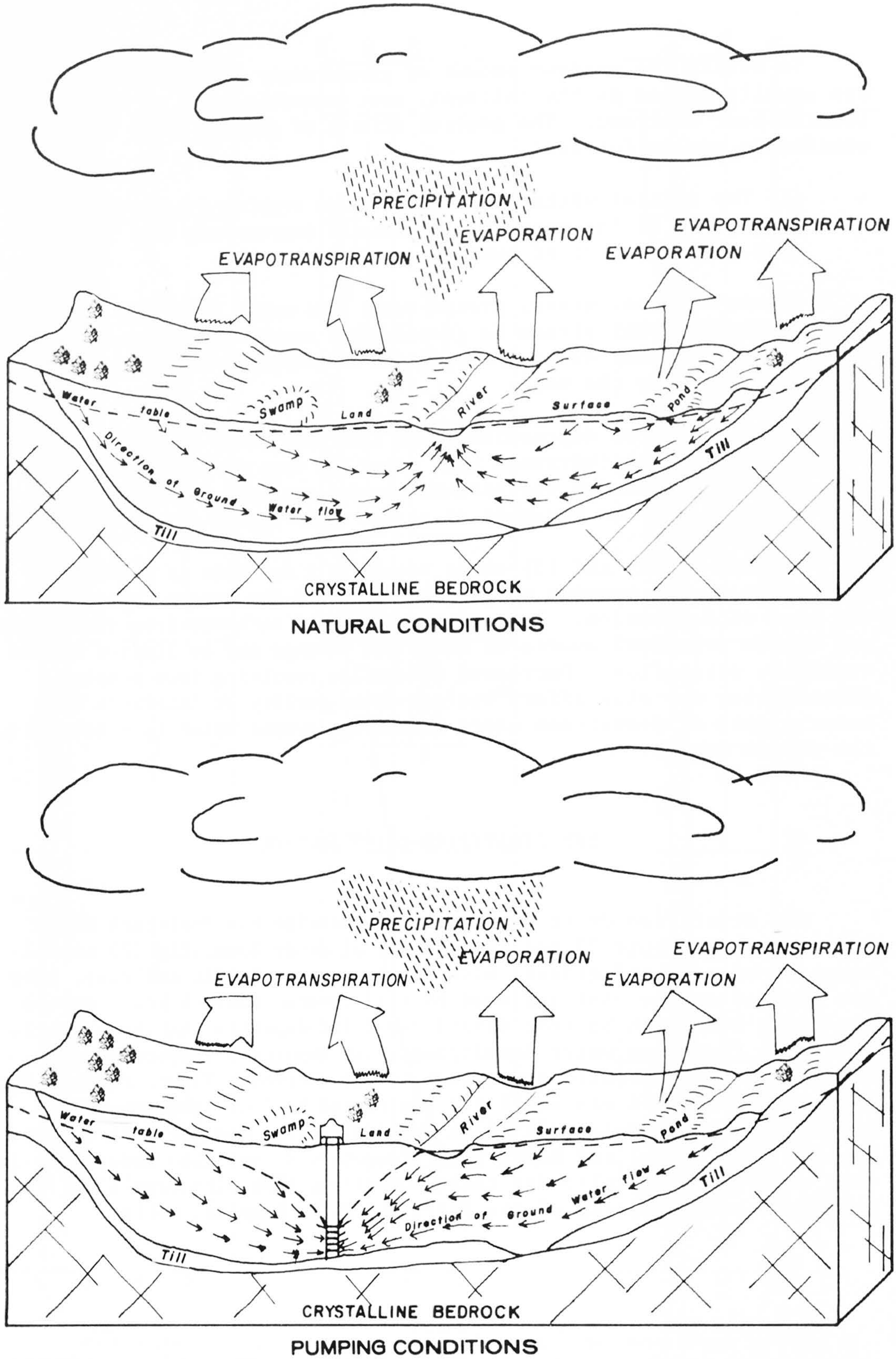


Figure 7.--Hypothetical cross sections showing major elements of the hydrologic cycle under natural and pumping conditions

Table 1.--Withdrawals from the stratified-drift aquifer

Site (location in fig. 2)	Amounts withdrawn in 1976: Average rate (gpm) 1/	Amounts withdrawn in 1976: Total (mgd) 1/	Maximum tested capacity 7/: Average rate (gpm) 1/	Maximum tested capacity 7/: Total (mgd) 1/
Fairfield Hills Hospital well field 2/	170	0.25	751	1.1
Fairfield Hills Hospital well field 3/	80	.12	279	.4
Sandy Hook Elementary School 4/	10 6/	.02 6/	-	-
Newtown High School 5/	5 6/	.01 6/	-	-

1/ gpm, gallons per minute; mgd, millions of gallons per day.
2/ U.S. Geological Survey wells NT 11 and 12 (Fairfield Hills Hospital wells no. 7 and 8)
3/ No local U.S. Geological Survey well no. assigned; hospital well no. 3.
4/ U.S. Geological Survey well NT 14.
5/ Test holes NT 94th and 96th.
6/ Estimates based on known school size and amount used by other schools.
7/ Based on pump capacity test conducted in May 1975.

Factors affecting the availability of ground water

Several components of a stream-aquifer system require analysis and definition before a quantitative assessment of well yields and predictions of the system's response to stress can be made. These components include:

(1) Recharge from precipitation
(2) Stream-aquifer interconnection
(3) Hydraulic characteristics of the aquifer
(4) The physical boundaries of the system

Quantitative information on these components in the Pootatuck valley is based on direct field measurements made for this study and on indirect regional methods developed in earlier studies. (See Cervione and others, 1972, Wilson and others, 1974).

Recharge from precipitation

The major source of recharge to the aquifer is precipitation directly on the stratified-drift aquifer and on the adjacent till and bedrock uplands, from which it flows downgradient into the aquifer. Variations in precipitation cause changes in recharge. National Weather Service records from Stevenson Dam (National Weather Service station 068065) (fig. 2) show that average annual precipitation during 1941-70 was 47.56 inches and is fairly evenly distributed from month to month (Joseph Brumbach, National Weather Service, oral communication, 1977). Annual precipitation during the 1966-76 water years ranged from 33 inches in 1966 to 72 inches in 1973. Precipitation during the last 5 water years, 1970-76, averaged 60.95 inches, well above the 1941-70 long-term value.

The amount of precipitation that recharges the stratified-drift aquifer can be estimated by determining the ground-water discharge over a period of time when there is no significant net change in ground-water storage. Ground-water discharge under natural conditions consists of ground-water outflow (ground-water runoff and underflow) and ground-water evapotranspiration.

Figure 8 shows precipitation at Stevenson Dam (National Weather Service station 068065) versus mean annual runoff for the Pootatuck River at Sandy Hook (U.S. Geological Survey station 01203510) (fig. 2) for the 1966-73 water years. This plot enables one to estimate the total annual runoff for any known annual precipitation. Using the relationship shown on page 48 and discussed on page 46 by Cervione and others, (1972) ground-water outflow is estimated to be 95 percent of the total runoff in stratified drift areas and 34 percent of the total runoff in till and bedrock areas.

Ground-water evapotranspiration is considered to occur only in those parts of the stratified-drift aquifer where the water table is within 5 feet of land surface. These areas are in lowlands adjacent to the Pootatuck River. The overall effect of the ground-water evapotranspiration on the aquifer is to reduce effective recharge in these areas. In the absence of direct measurements, the rate of ground-water evapotranspiration is considered to be approximately equal to that in the nearby Pomperaug River basin of 6 inches per year. (Meinzer and Stearns, 1929, p. 138).

Natural recharge rates used in this study for the areas underlain by stratified drift are the sum of (1) ground-water outflow determined from the total runoff-ground-water outflow relationship (2) ground-water evapotranspiration assumed to be equivalent to that in the Pomperaug River basin. For till-and-bedrock areas, the ground-water evapotranspiration is assumed to be negligible, and natural recharge is equal to the

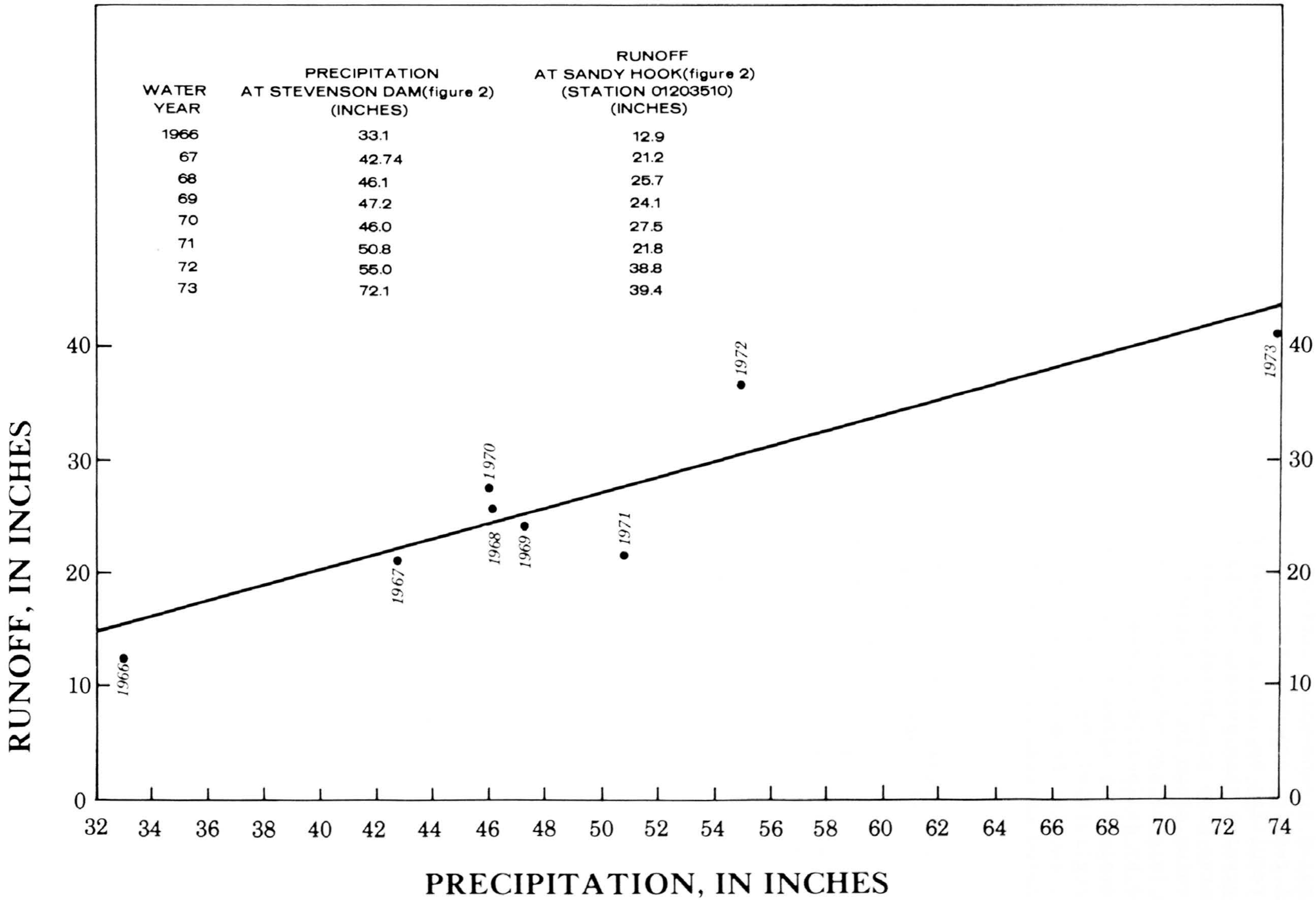


Figure 8.--Relation between precipitation and runoff in the Pottatuck River basin, upstream from Sandy Hook, Connecticut. 1966-73 Water Years

estimated ground-water outflow. Table 2 summarizes the precipitation, total runoff, ground-water outflow, ground-water evapotranspiration, and the resulting estimated natural recharge rates for average (48 inches) and greater than average (60 inches) precipitation periods. Estimated recharge from precipitation directly on the stratified-drift aquifer is the value shown in the table for stratified drift. Recharge resulting from lateral ground-water inflow across the aquifer boundary is determined by delineating areas of adjacent till-and-bedrock upland that are not drained by streams. On an annual basis (assuming storage changes are negligible) the amount of ground-water inflow to the stratified-drift aquifer from the till-and-bedrock upland will be equivalent to the estimated natural recharge to these till-and-bedrock areas.

Table 2.--Annual natural recharge in the Pootatuck River basin
(All data are reported in inches per water year)

Condition	Precip-itation	Estimated mean annual runoff(R) 1/	Estimated average annual ground-water outflow: From stratified drift 2/ (0.95R)	From till and bedrock 2/ (0.34R)	Ground-water evapotranspiration in stratified-drift areas 3/	Estimated natural recharge: to stratified drift (GW outflow & GW evapotransporation)	to till and bedrock (GW outflow)
Long-term average (1941-70)	48	26	25	9	6	31	9
Wetter-than-average (1971-76)	61	35	33	12	7	40	12

1/ From figure 8. This includes ground-water outflow from stratified drift and till plus overland flow.
2/ From Cervione and others (1972, fig. 37).
3/ From data collected in the Pomperaug River basin (Meinzer and Stearns, 1929, p. 138).

Stream-aquifer interconnection

Under natural conditions ground water moves from the aquifer through the stream bottom deposits into the stream. However under pumping conditions the natural water-table gradient is reversed, and water from the stream will infiltrate the aquifer and flow toward the center of pumping. Because most areas favorable for the installation of high-capacity wells are near the Pootatuck River, most of the water pumped from the aquifer will be derived from induced recharge. The amount of this induced recharge is governed by the vertical hydraulic conductivity and thickness of the streambed materials, the area of the streambed through which infiltration occurs, the viscosity of the water (which is temperature dependent), the average head difference between stream and aquifer in the area of induced recharge, and by the quantity of water in the stream.

The Pootatuck River streambed is generally composed of sand and gravel that forms a good hydraulic connection between the stream and underlying stratified-drift aquifer. Estimates of the average vertical hydraulic conductivity of the streambed sediments are based on streamflow measurements taken during baseflow conditions. Measurements of the flow in the Pootatuck River were made at 6 sites shown in figure 2, on October 18, 1976, 9 days after the last precipitation. Consequently, all the water in the stream is assumed to be derived from ground-water runoff. The head difference between the stream and aquifer is based on measurements of stream stage and water-level measurements in a shallow observation well(NT 67) on the stream bank. Using this information and the procedure outlined by Walton (1962, p. 22), the average vertical hydraulic conductivity of the streambed sediments is calculated to be 1.9 ft/day.

In order to check this value, the composition of the streambed was evaluated with a split-spoon sampler by taking 6- to 30-inch-long samples from the river bottom at 12 sites. (See fig. 2.) The sediments consisted of poorly sorted sand and gravel. The grain-size distribution was determined for all the samples, and the vertical hydraulic conductivity of two undisturbed samples was measured by the U.S. Geological Survey's Hydrologic Laboratory. The typical grain-size distribution of the streambed materials is shown in figure 9. The laboratory determined vertical hydraulic conductivities of undisturbed samples (11 and 12) are 1.3 ft/day and 3.9 ft/day, respectively.

The thickness of these deposits overlying the aquifer averages 2 feet and ranges from 1 to 3 feet. The streambed width averages approximately 25 feet within the study area.

The quantity of streamflow at any time imposes obvious limits on the amount of water available for induced recharge to the aquifer. Continuous records of daily discharge for the Pootatuck River at Sandy Hook (U.S. Geological Survey station 01203510) from October 1, 1965, to September 30, 1973, indicate that during most of this period the anticipated reduction in streamflow resulting from pumping of wells would not be significant. During each low-flow period (normally August to October), however, the quantity of water capable of being pumped could exceed the available streamflow.

A more precise estimate of available streamflow is the duration of daily mean flow--the percentage of time a given flow is equaled or exceeded. For this study the flows equaled or exceeded 90 and 95 percent of the time during water years 1941-70 have been considered as indices of the streamflow available for induced recharge to the stratified-drift aquifer. As determined from regional flow-duration curves, these values at Sandy Hook are 5.3 mgd and 4.3 mgd for the 90- and 95-percent durations respectively. During the short period for which streamflow records are available, the Pootatuck River had a flow of at least 4.8 mgd 90 percent of the time and 3.5 mgd 95 percent of the time.

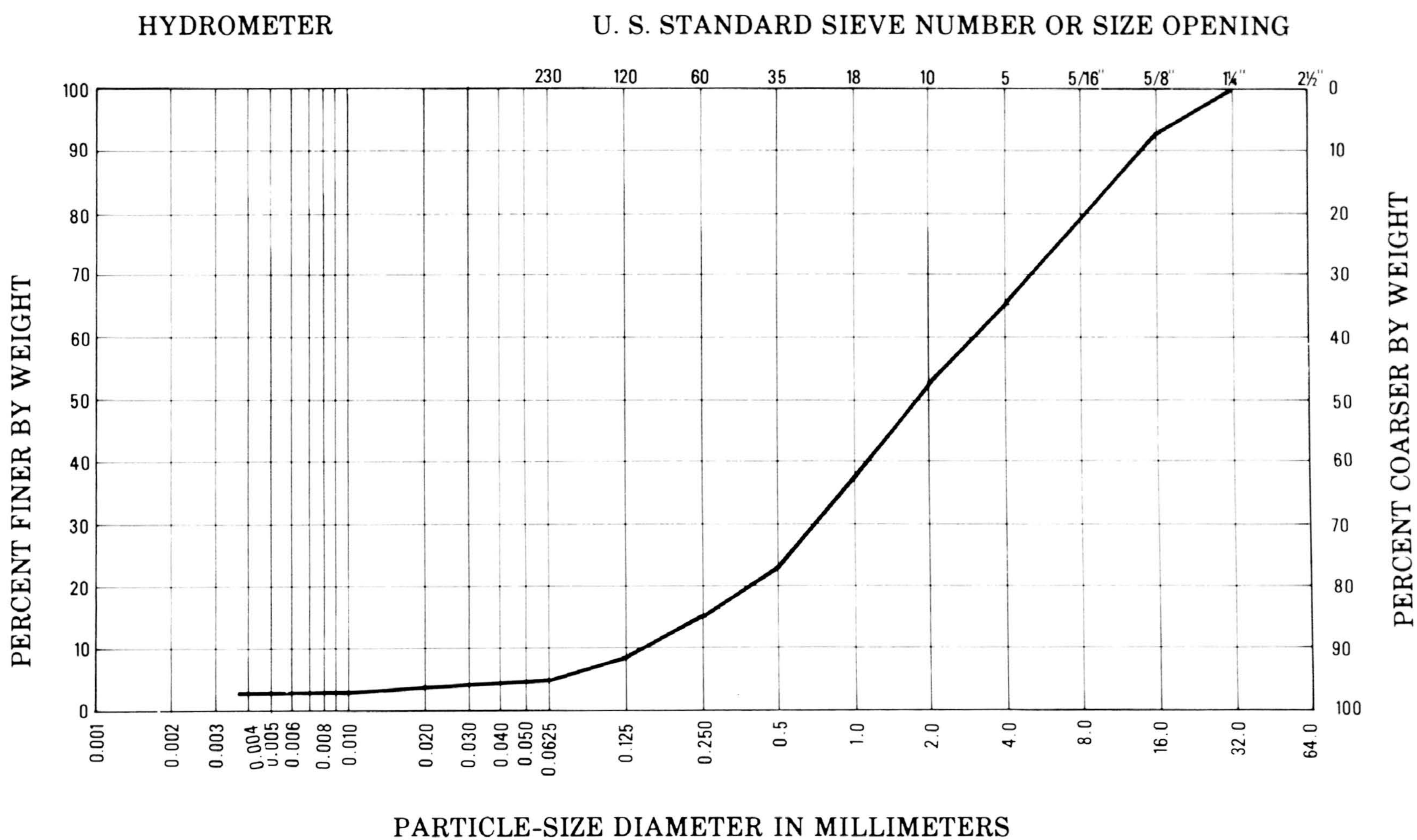


Figure 9.--Representative grain size distribution of streambed sediments underlying the Pootatuck River in Newtown, Connecticut. Sample collected at site 12; for location see figure 2.

Under extremely dry conditions, such as those prevailing during the 1960's drought, smaller quantities of streamflow would be available for fairly long periods.

Hydraulic characteristics of the aquifer

Saturated thickness, hydraulic conductivity, and storage coefficient are the hydraulic properties that determine the capacity of an aquifer to transmit, store, and yield water. These terms are defined in the glossary. Saturated thickness of a stratified-drift aquifer is the vertical distance from the water-table to the till or bedrock base of the aquifer. The configuration of the water table is based on monthly measurements from August 1976 to February 1977 in 16 observation wells which were installed for this study, supplemented by altitude determinations of surface-water bodies, such as the Pootatuck River. Figure 13 shows the approximate configuration of the water table in the stratified-drift aquifer in November 1976. The figure shows that the general movement of ground water is toward the Pootatuck River and that the main discharge of ground-water runoff is along the stream-aquifer interface.

The altitude of the bedrock-till surface beneath the aquifer, shown in figure 10, was determined from seismic refraction profiles (table 9) from logs of wells and test holes (table 10), and from bedrock outcrops. The locations of seismic profiles, test holes, and bedrock outcrops are shown in figure 10.

The seismic work was done by the Geological Survey in April of 1976 and interpretation of field data is based on delay-time and ray-tracing techniques described by Scott and others (1972).

The well- and test-hole data were obtained from consultants, well drilling contractors, the Connecticut Department of Transportation, and 23 test holes drilled for the study.

The location of bedrock outcrops is based on geologic mapping by Wilson and others, (1974), by Fred Pessl (written communication, 1976) and by the author.

Superimposing the water-table and bedrock-altitude maps allows the saturated thickness of the stratified-drift aquifer to be determined at any point (fig. 11). Although the altitude of the water table in the unconfined aquifer varies from month to month and from year to year, depending on the amount of recharge, the resulting short-term changes in saturated thickness are not considered to be significant. Long-term changes are taken into account in the analyses of aquifer yields in later sections of this report.

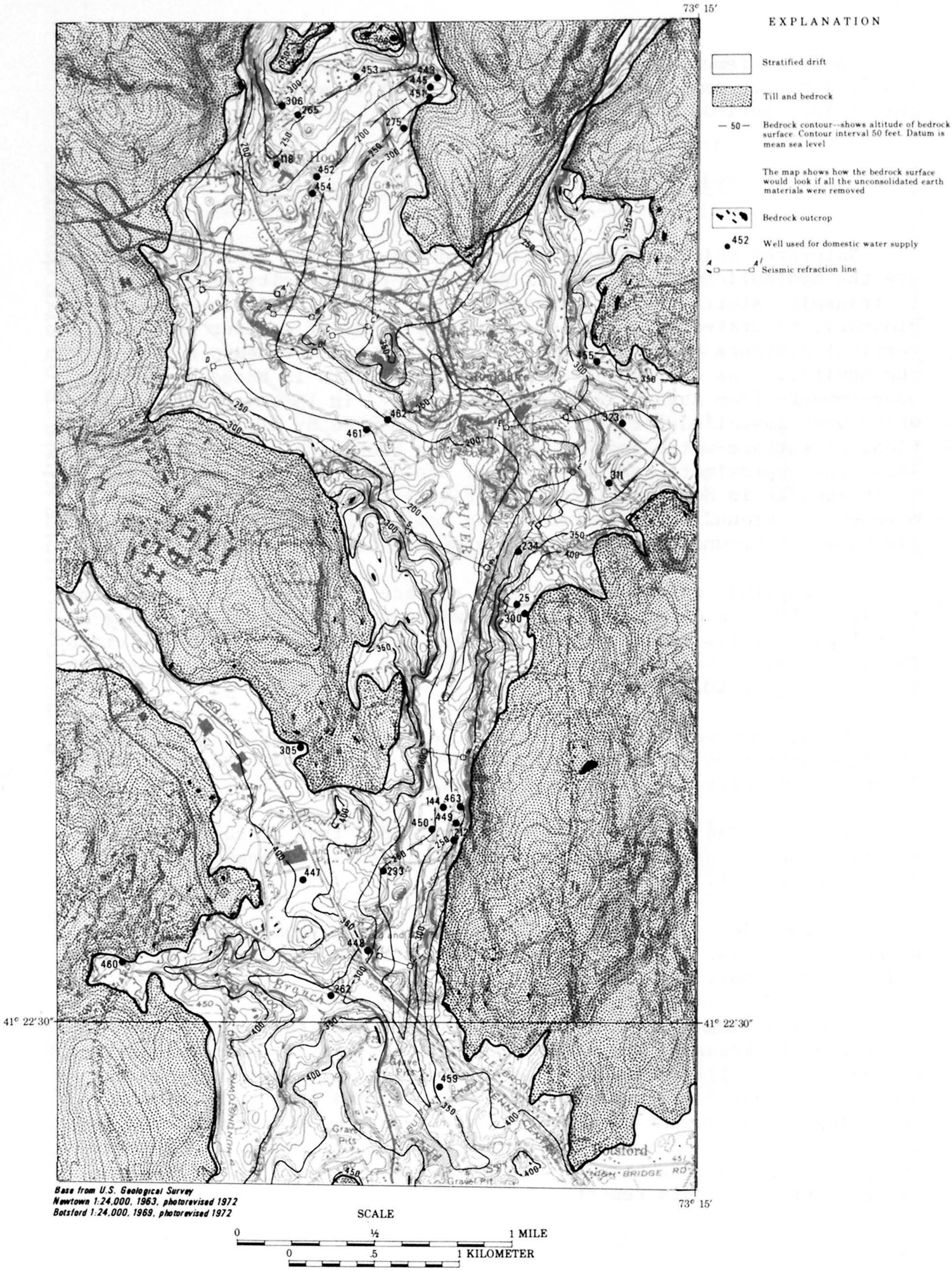


Figure 10.--Contour map of the bedrock surface

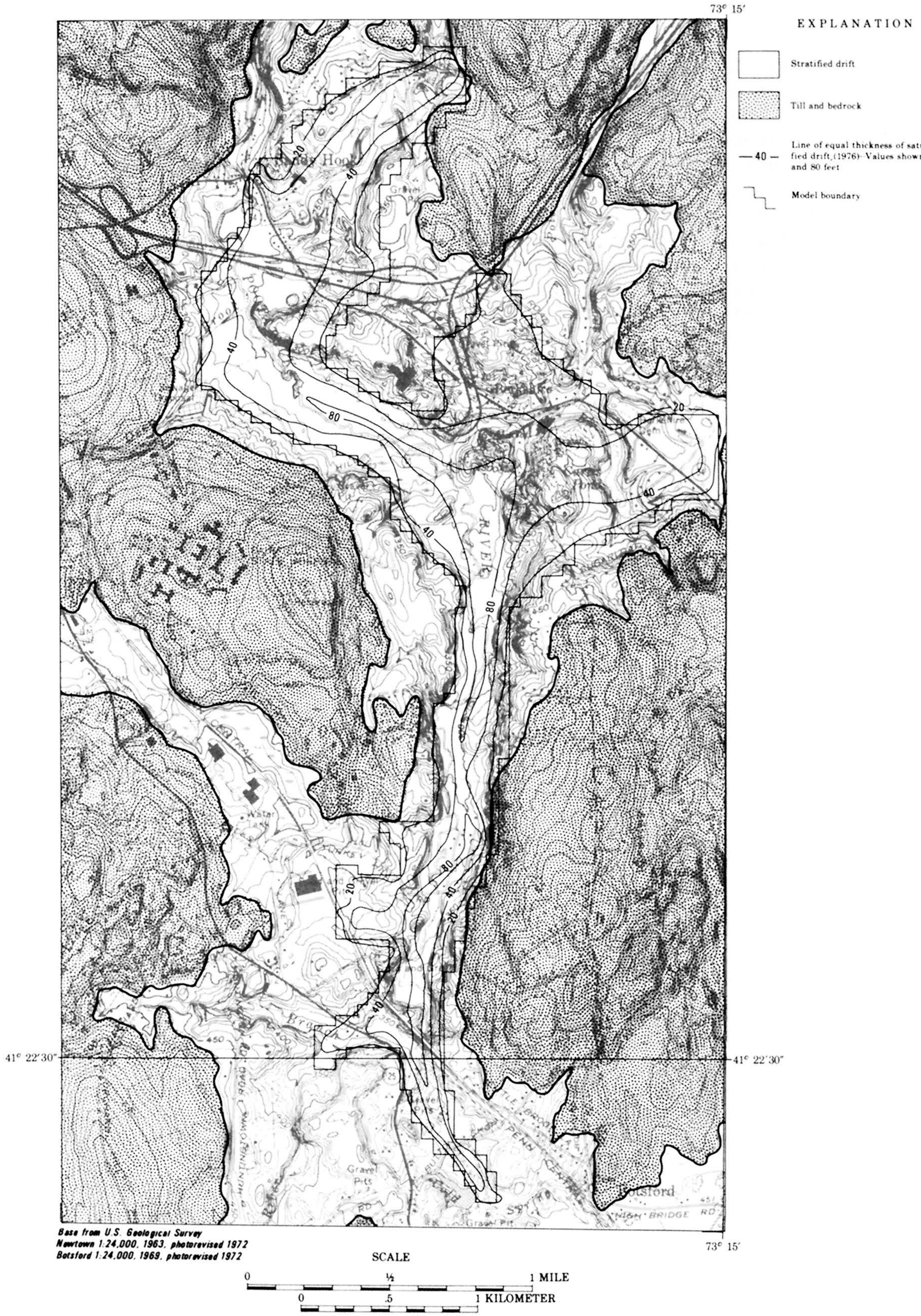


Figure 11.--Saturated thickness of stratified drift

The average hydraulic conductivity of the stratified-drift aquifer was estimated at each test hole or well site for which a reliable driller's or geologist's log was available. These estimates are based on the relationship between grain-size parameters of stratified drift and hydraulic conductivity in the horizontal direction (Wilson and others, 1974). Specific-capacity data from wells were also used to estimate average hydraulic conductivity, using the technique described ty Theis (1963). The distribution of average hydraulic conductivity in the stratified-drift aquifer, as shown in figure 12, ranged from .1 ft/day near the till-stratified drift boundary to 100 ft/day near ice-contact deposits. The values shown in figure 12 are based on interpolation of the data between known control points and knowledge of the geology of the area.

The storage coefficient of an unconfined aquifer is equivalent to the specific yield, which is important in analysis of hydrologic problems where water level changes with time are of interest. The following analyses of the stratified-drift aquifer assume steady-state conditions. Thus, the storage coefficient is set to zero in all simulations.

Physical boundaries

The boundaries of the stratified-drift aquifer are the till-covered uplands to the east and west, thin discontinuous stratified drift to the north and south, and the underlying surface of till and bedrock. The Pootatuck River also constitutes an aquifer boundary; its location is shown on the standard U.S. Geological Survey topographic maps of the Newtown and Botsford quadrangles.

The following section describes a mathematical simulation model of this system and predicts its response to additional pumpage.

AQUIFER SIMULATION AND ANALYSIS BY DIGITAL MODEL

Through the use of high speed computers and powerful numerical techniques, it has become feasible to develop mathematical models that simulate ground-water flow in complex hydrologic systems. These models enable hydrologists to predict the effects of manmade and natural stresses on stream-aquifer systems. The hydrologic impact of alternative water-resource and land-use proposals, for example, can be evaluated before decisions are made.

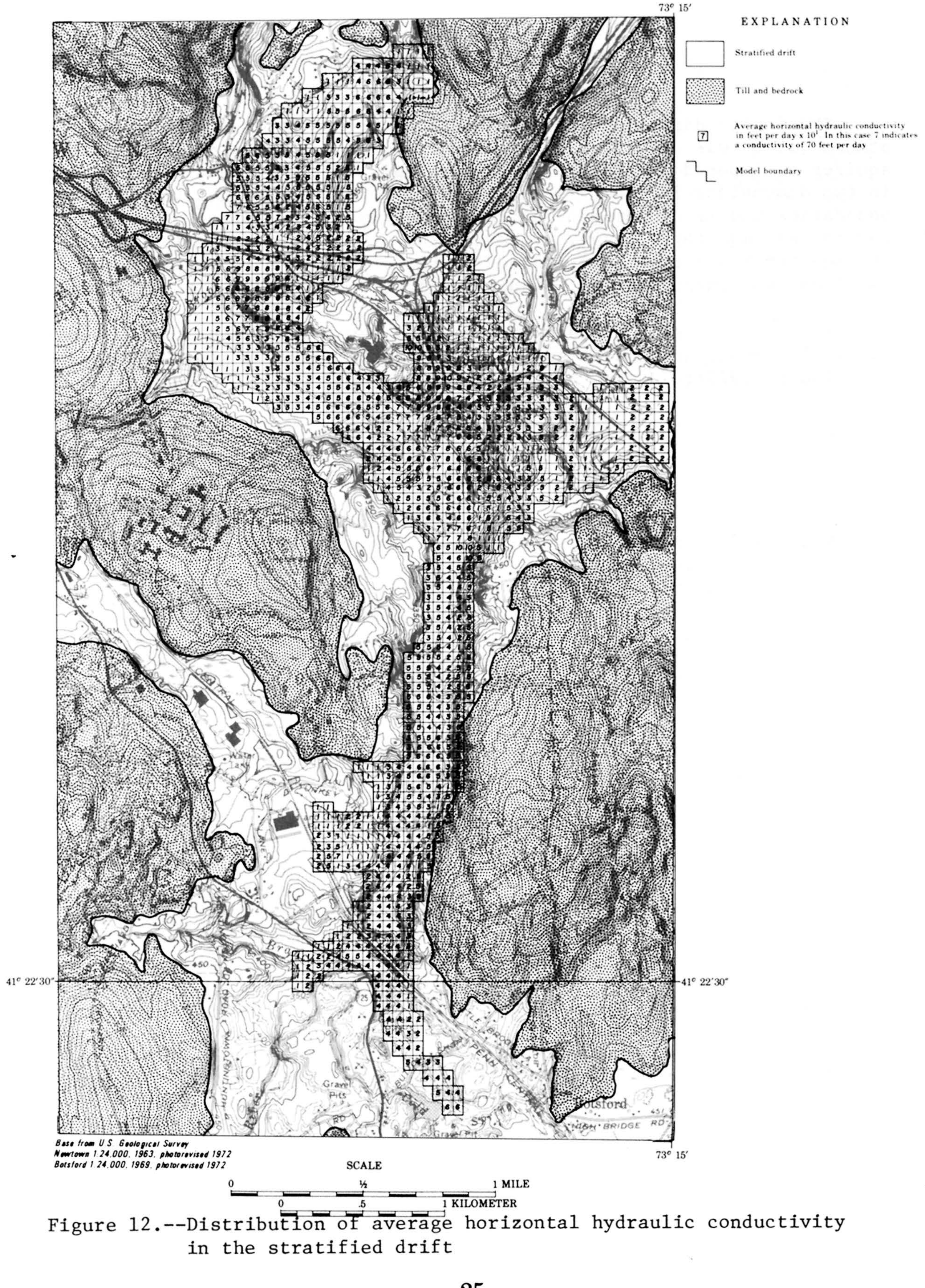


Figure 12.--Distribution of average horizontal hydraulic conductivity in the stratified drift

Model description

The finite difference aquifer model described by Trescott and others (1976) was used to simulate the response of the stratified-drift aquifer to imposed stresses. This model can simulate ground-water flow in two dimensions in a water-table (unconfined) aquifer that has irregular boundaries and is nonhomogeneous in composition. The source of water may include aquifer storage, recharge from precipitation, inflow across the aquifer boundaries, and induced recharge through streambeds. Water is discharged through wells, evapotranspiration and leakage to streams.

For flow in an unconfined aquifer, the basic two-dimensional ground-water flow equation that is approximated in the model is given by Bredehoeft and Pinder (1970):

$$\frac{\partial}{\partial x}\left(Kxx\,b\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(Kyy\,b\,\frac{\partial h}{\partial y}\right) = Sy\,\frac{\partial h}{\partial t} \pm W\,(x,y,t)$$

Where

Kxx and Kyy are the principal components of the hydraulic conductivity tensor (Lt^{-1})
h is hydraulic head (L)
Sy is the specific yield of the aquifer (dimensionless)
b is the saturated thickness of the aquifer (L)
t is time
x,y are rectangular coordinates along the principal major and minor flow axes.

w (x, y, t) is the volumetric flux of recharge or withdrawal per unit surface of the aquifer (Lt^{-1})

Many numerical methods can be used to solve the two-dimensional flow equation. For this study, a finite difference method using the strongly implicit procedure was used (Trescott and others, 1976).

A conceptual model of the stream-aquifer system in the Pootatuck River valley was developed from the available hydrologic information. This model necessarily includes simplifying assumptions that make it possible to simulate the system mathematically. These basic assumptions are as follows:

(1) Flow in the stratified-drift aquifer is horizontal, and the aquifer is isotropic. These assumptions are considered to be reasonably valid from available information. Any significant vertical flow components, however, could cause errors in predicted water levels.

(2) Recharge to the aquifer from precipitation and inflow across boundaries is uniformily distributed and does not vary with time.

(3) The average stream stage remains constant for each simulation

(4) The continuous aquifer system is divided into a finite number of rectangular blocks in which the aquifer properties are assumed to be uniform, and the aquifer properties can vary linearly from block to block.

(5) All pumping wells are considered to be screened through the full saturated thickness of the aquifer and are 100-percent efficient. To compensate for both of these idealized well-construction characteristics, the maximum allowable drawdown under pumping conditions is limited to 30 percent of the initial saturated thickness.

(6) Ground water is discharged only by pumping from wells, by ground-water evapotranspiration, and by leakage to streams (ground-water runoff).

(7) Ground-water evapotranspiration decreases linearly with depth of the water table from a maximum at land surface to zero at 5 feet or more below land surface. Because most of this evapotranspiration takes place in lowlands bordering the Pootatuck River, its effect is to reduce the net recharge to these areas.

Although these assumptions do not always represent actual conditions in the stream-aquifer system, the deviations probably do not produce large errors in the simulation process.

The modeled area, shown in figure 11, is slightly smaller than the stratified-drift aquifer because its boundaries are positioned between the 10- and 20-foot contour lines of saturated thickness. Consequently, the entire model area consists of saturated stratified-drift deposits under water-table conditions.

Solution of finite difference approximations of the ground-water flow equations requires the simulated subdivision of the modeled area into blocks by a rectangular grid. This grid network for the stratified-drift aquifer model consists of 45 rows and 102 columns. It defines 4,590 blocks, the centers of which are termed "nodes". The simulated blocks are 200 feet on a side, except near the margins of the modeled area, where they are larger. The resulting network is referred to as a block-centered, finite-difference grid with variable grid spacing. (See figure 12.)

The flow equation is evaluated at each node of the grid. The properties of the aquifer and other hydrologic parameters must, therefore, be defined over the entire model area. Appropriate values of hydraulic conductivity and saturated thickness for each node are determined from the maps of average hydraulic conductivity (fig. 12), bedrock altitude (fig. 10), and water-table altitude (fig. 14). The grid network is superimposed over these maps, and parameter values are assigned to the respective nodes. The recharge rate to the aquifer, as discussed previously, is calculated on a per-unit-area basis and is applied uniformly over the entire modeled area. The amount of recharge simulated at each node is proportional to the actual area of each cell. Ground-water evapotranspiration takes place in all cells where the water table is within 5 feet of the land surface.

The streambed of the Pootatuck River is treated in the model as a leaky confining layer of restricted areal extent. The grid nodes representing the streambed are in approximately the same location as the river. A constant value of the altitude of the river surface is used for the average head on the other side of the leaky confining layer because the Pootatuck River is broad and very shallow during periods of low flow. The vertical hydraulic conductivity of the streambed, its thickness, and its area are based on field and laboratory measurements. Because the area of the streambed is smaller than the node-centered block representing it, the ratio of streambed hydraulic conductivity to thickness is proportionately reduced, in order to approximate the correct amount of leakage.

Boundary conditions

An important part of the model is accurately representing conditions at its boundaries. The 10- to 20-foot saturated-thickness lines were selected as the boundaries for the east and west margins of the modeled area. The area outside of this boundary, consisting of thinly saturated stratified drift and till-covered bedrock, contributes a significant amount of ground-water inflow to the modeled area. This lateral inflow is estimated by the method discussed in the previous section, and appropriately proportioned over the length of the model boundaries. To simulate lateral inflow in the model, a constant-flux boundary is used. This is accomplished by placing recharging wells at each affected boundary node (Trescott and others, 1976, p. 30). Ground-water inflow or outflow across the northern and southern edges of the model are considered negligible and they are treated as no-flow impermeable boundaries.

Although inflow to the model area is assumed to occur along the lateral boundary only, some water probably flows upward into the aquifer from underlying bedrock. However, the amount of this flow is probably small enough, so that no significant error would be introduced into the model if this flow were to be ignored. The underlying bedrock therefore, was treated as an impermeable boundary in the analyses.

Model calibration

Before a ground-water flow model can be reliably used to simulate the effects of future imposed stresses, it should be capable of duplicating the response of the system to known historical stresses. For example, the model can be programmed to simulate the pumping history of the aquifer or its long-term changes in recharge to the aquifer. The water levels thus simulated can then be compared with records of actual water levels. The adequacy of the comparison becomes then a measure of the model's ability to predict the results of future stresses on the system. No long-term records are available for the Pootatuck River valley. Consequently, it was necessary to utilize the estimated natural recharge to the aquifer as a stress and compare observed water levels with those predicted by the model under steady state conditions, and to ensure that the input data to the model was as accurate and realistic as possible.

The first step in the calibration procedure consisted of selecting a time period during which recharge from precipitation and the resulting water-table configuration could be determined. Monthly water-level measurements were made at U.S. Geological Survey observation wells beginning in October 1976. These measurements, together with data from surface-water bodies, and information on wells and test holes, represent the altitude of the water table surface in November 1976. Examination of records from four surface-water index stations indicated that in November 1976 monthly mean runoff for streams in the state was approximately equal to the yearly mean runoff values. Water levels in two of the three key observations wells in stratified drift in the state were at or near their yearly mean levels. Long-term water-level measurements in well NT 15 (located in fig. 13) indicated that water levels in the aquifer at that time were at a level that approximated the mean annual average for the preceding six years (1971-76 water years). Based on these data, the November 1976 water-table configuration was assumed to represent the steady state, average water table condition for the wetter-than-average 1971-76 water years. Mean annual precipitation in 1976 was 62 inches, close to the average of 61 inches for the 1971-76 water years and consequently the annual recharge rate to stratified drift is estimated to be 40 inches and to till and bedrock, 12 inches (See table 2).

The measured or estimated values of the model input parameters of; aquifer properties, ground-water evapotranspiration, and recharge were entered into the model to produce a steady-state water-table configuration. The streambed hydraulic conductivity was assigned a wide range of values during this calibration to determine its effects on model results. Best results were obtained when the streambed hydraulic conductivity ranged from 1 to 5 feet per day; very close to the measured values discussed previously. The final value chosen for this parameter was 2 ft/day.

Figure 13 shows the steady-state water table configuration determined by model simulation that approximates the observed November 1976 configuration.

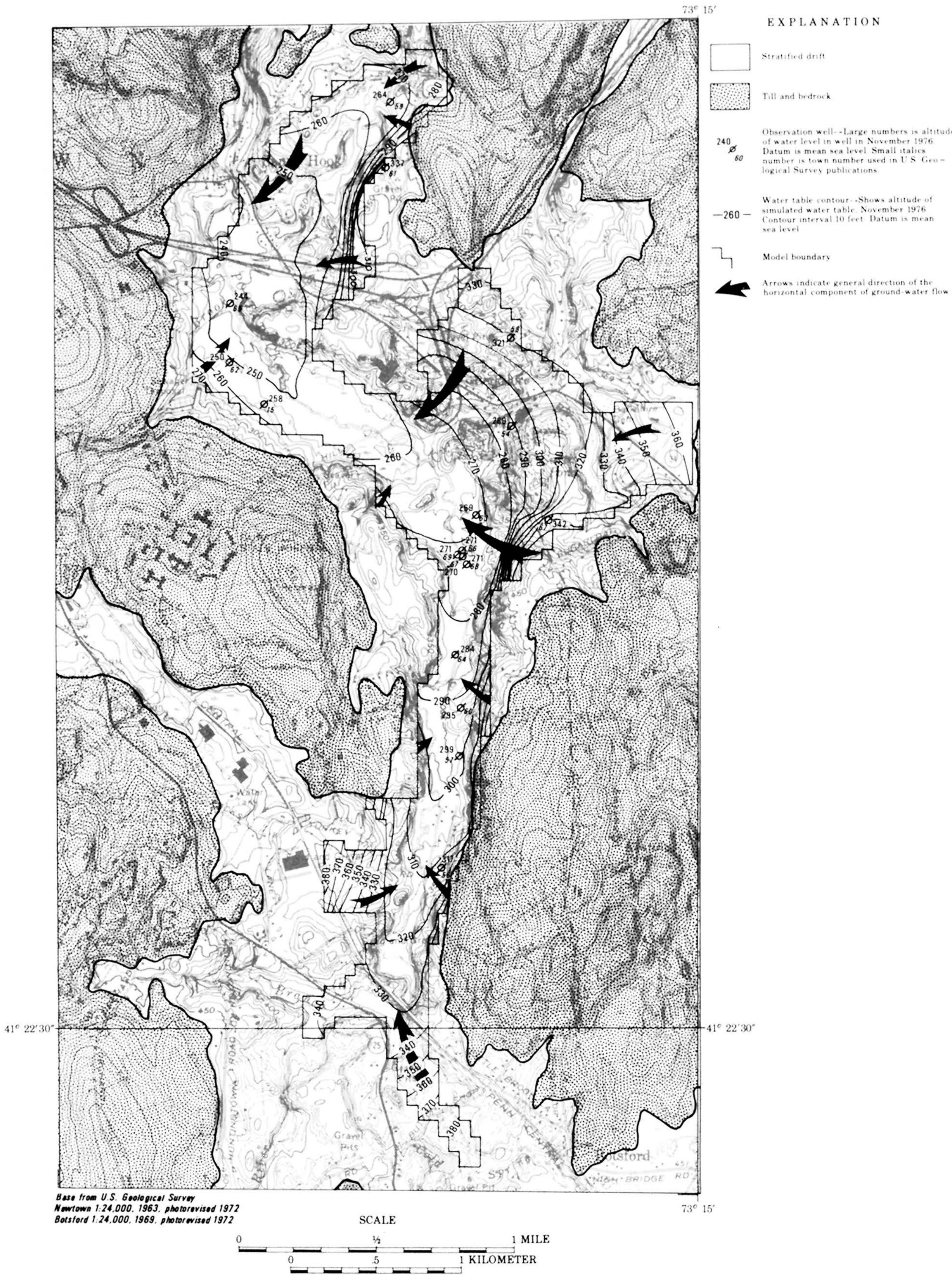


Figure 13.--Simulated steady-state ground-water levels in November 1976

The data points show U.S. Geological Survey observation wells and the water-level altitudes measured on that date. Differences between the predicted and observed water-table altitude were considered acceptable if they were within 5 feet of each other, owing to inherent errors in the observed altitudes. In a few places, particularly near the eastern and western margins of the modeled area where data are sparse, discrepancies of up to 10 feet were considered acceptable. Where the observed and predicted water levels did not correspond within acceptable limits, the average hydraulic conductivity values were adjusted accordingly. In such areas the hydraulic conductivity was considered to be the least accurate parameter and adjustments were made that were consistent with the hydrogeology of the area. Correspondence was generally good however throughout the model area.

Steady-state conditions are not always applicable. For example, short-term seasonal fluctuations in recharge and discharge result in water-level changes throughout the stratified-drift aquifer. Seasonal variations could be simulated based on water-level fluctuations measured in observation wells, but such simulations are beyond the scope of the present study.

Model simulations

Reduced recharge

The objective of the first simulation of the calibrated model was to determine the effect of reduced recharge on the aquifer system. Instead of using the recharge rate prevailing during the recent wetter-than-average period, the estimated long-term natural recharge rate was used as a model input. The water level at each node was then calculated for steady state conditions. The results, in the form of a water table map, are shown in figure 14. In general the water table declined 1 to 2 feet near the center of the model and 6 to 7 feet along the edges. In a few areas near the model boundaries, 10- to 15-foot water-level declines developed. Water levels were measured in NT 15 during 1969 and 1971, when natural recharge is believed to have been close to average recharge values, and 1976, when recharge rates were high. The difference between the observed mean annual water levels (1969 and 1971 versus 1976) was 1.6 feet. The difference at this location as determined by the model, was 2.1 feet.

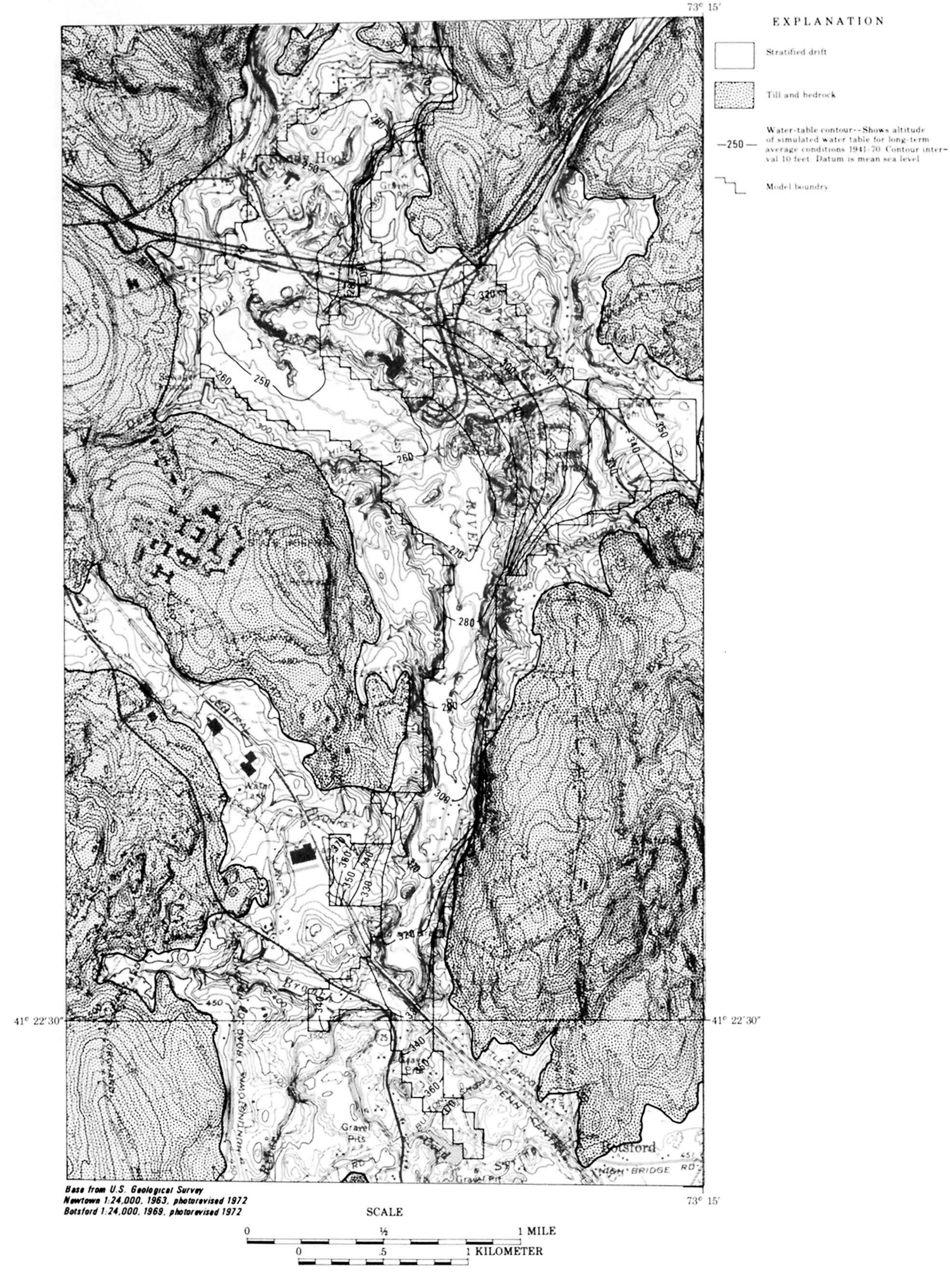


Figure 14--Simulated steady-state ground-water levels for long-term average conditions, 1941-70.

Ground-water development

The principal objective of this study was to determine the quantity of ground water available from the stratified-drift aquifer and the effect of withdrawing this water on the stream-aquifer system. To make this determination the long-term (1941-70) average recharge rates from precipitation listed in table 2, and the resulting simulated water-table altitudes (fig. 14) are used as a basis to assess the effects of the ground-water development on the aquifer. As discussed earlier induced recharge from the Pootatuck River is an important source of water under conditions of ground-water development. For this study the 90- and 95-percent duration of flow of the Pootatuck River are used as indices of streamflow available for induced recharge. These values, listed in table 3, are estimated by regional methods at points adjacent to each pumping center and at other sites within the model area. These data allow estimates to be made of the minimum amounts of water in the river 90 and 95 percent of the time, upstream and downstream of each pumping center.

The general simulation scheme consists of withdrawing the maximum possible amounts of ground water while maintaining minimal flow in the Pootatuck River. The two Fairfield Hills Hospital well fields (fig. 15) that pumped 0.4 mgd in 1976 are withdrawing their maximum tested capacity of 1.5 mgd. It is assumed that there are no additional wells at these sites that would increase existing pumping capacity, and that 100 percent of the hospital's pumpage is eventually returned to the Pootatuck River through Deep Brook as sewage effluent (fig. 15), and is available for reuse. Two additional hypothetical well fields are added in order to withdraw the maximum amount of ground water. It is assumed that no pumpage from the hypothetical well fields is returned to the stream-aquifer system within the modeled area. Individual yields of wells in these hypothetical pumping centers are limited in this analysis to pumping rates that result in a steady-state drawdown in each well, equal to 30 percent of the initial saturated thickness of the aquifer. This restriction compensates for the additional drawdown that would occur under real pumping conditions because of partial penetration and well loss.

The northernmost hypothetical well field (no. 1 in fig. 15) is near the junction of Deep Brook and the Pootatuck River. It is adjacent to a prominent knoll of stratified drift on the east side of the valley and contains the only thick, permeable deposits in the northern part of the modeled area. Three wells 2 feet in diameter are positioned at this site (fig. 15) and under long-term average conditions the steady state model simulations indicate they are capable of yielding a total of 1.1 mgd. The ground-water withdrawals are limited by the hydrologic properties of the aquifer and not by the amount of stream water available.

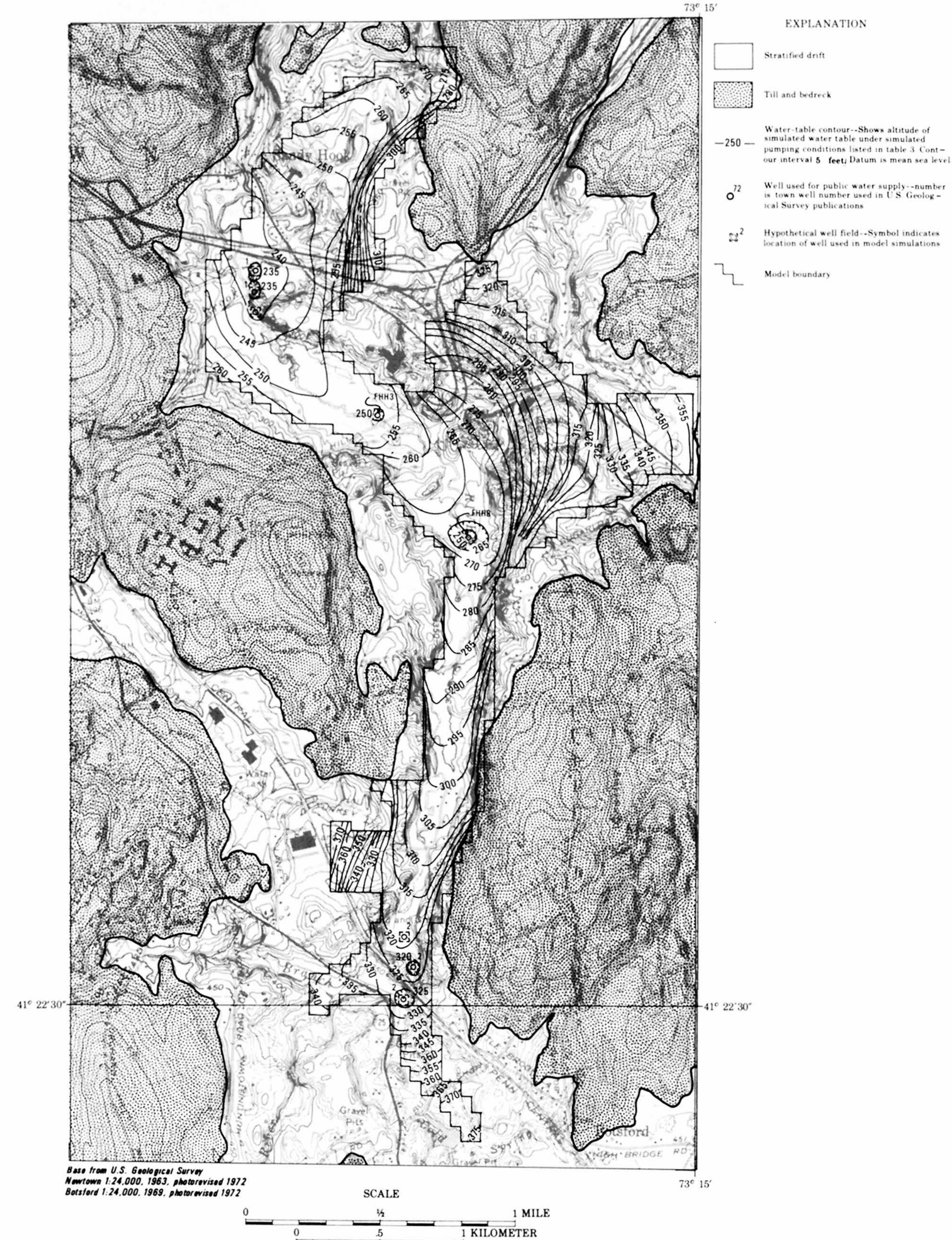


Figure 15.--Altitude of ground-water levels under simulated pumping conditions.

The second hypothetical well field (no. 2 in fig. 15) is near the junction of the railroad overpass and the Pootatuck River at the south or upstream end of the model area. This area is also underlain by thick permeable sand and gravel deposits. Three hypothetical wells 2 feet in diameter are simulated at this site (fig. 15) and under long-term average conditions the steady state model simulations indicate they are capable of yielding a total of 1.4 mgd. The maximum yield of this well field is limited by the small amount of water available for induced recharge during periods of low streamflow.

The simulated total withdrawal from the four pumping centers is 4.0 mgd. Figure 15 shows the effects of this total withdrawal on the configuration of the water table. A cone of depression surrounds each pumping site and the water-table declines extend as far as 1,600 feet from some wells. The effects on the streamflow under the two selected low-flow conditions are shown in table 3. This table shows (1) the amount of water available in the Pootatuck River near the well fields at least 90 and 95 percent of the time under both pumping and nonpumping conditions (2) the quantity of water pumped, and (3) the sources of the pumped water at all of the well fields, hypothetical and real.

According to table 3, the 90-percent duration of flow of the Pootatuck River as it enters the model area is about 2.3 mgd. The maximum pumpage of the southernmost well field (hypothetical well field no. 2) is 1.4 mgd. The simulation results indicate that 1.0 mgd would be derived from induced recharge and 0.4 mgd from captured ground-water runoff, leaving 0.9 mgd in the stream. By the time the river reaches the second well field (Fairfield Hills Hospital wells no. 7 and 8) streamflow has increased to approximately 1.6 mgd. This pumping center is capable of yielding 1.1 mgd of which 0.8 mgd would be derived from induced recharge and 0.3 from captured ground-water runoff. The remaining streamflow is approximately 0.5 mgd. At the third well field (Fairfield Hills Hospital well no. 3) the estimated streamflow has increased to 1.2 mgd. Maximum pumpage is 0.4 mgd, half of which is derived from induced recharge and half from captured ground-water runoff. The streamflow for this section of the river is 0.8 mgd. At the fourth well field (hypothetical well field no. 1) located near the junction of Deep Brook and the Pootatuck River, the available streamflow is increased to 3.4 mgd because of the addition of Fairfield hospital's sewage effluent to Deep Brook. Upstream from this site it is assumed that the water pumped is not returned directly to the stream before the next pumping center is reached. The estimated maximum withdrawal at the last pumping center is 1.1 mgd, a little more than half of which is induced recharge. The remaining streamflow in the river is 2.3 mgd.

Of the total simulated withdrawal of 4.0 mgd, 1.5 mgd is available to Fairfield Hills Hospital from its existing well fields whereas the remaining 2.5 mgd can be developed at the two additional sites under the stated conditions. Although total pumpage under both low flow conditions is the same, the impact on streamflow differs considerably. For example,

Table 3.--Results of simulated pumping at two hypothetical well fields under steady state conditions
(All quantities of water are in millions of gallons per day. See fig 2 for location of sites)

Index of water available for induced recharge		(1) Hypothetical well field no. 2	(2) Fairfield Hills Hospital well field (wells no. 7 and 8)	(3) Fairfield Hills Hospital well field (well no. 3)	(4) Hypothetical well field no. 1	(5) U.S.G.S. gaging station at Sandy Hook, Conn. (01203510)
Streamflow of the Pootatuck River equaled or exceeded 90 percent of the time	Streamflow in Pootatuck River with no pumping	2.3	3.0	3.7	4.8	5.3
	Streamflow in Pootatuck River with pumping	2.3	1.6	1.2	3.4 [1]	2.8
	Total pumpage	1.4	1.1	.4	1.1	-
	Pumpage derived from induced recharge	1.0	.8	.2	.6	-
	Pumpage derived from capture of ground-water outflow	.4	.3	.2	.5	-
	Water remaining in stream reach near well field	.9	.5	.8	2.3	2.8
Streamflow of the Pootatuck River equaled or exceeded 95 percent of the time	Streamflow in Pootatuck River with no pumping	1.9	2.5	3.0	3.9	4.3
	Streamflow in Pootatuck River with pumping	1.9	1.1	.5	2.5 [1]	1.8
	Total pumpage	1.4	1.1	.4	1.1	-
	Pumpage derived from induced recharge	1.0	.8	.2	.6	-
	Pumpage derived from capture of ground-water outflow	.4	.3	.2	.5	-
	Water remaining in stream reach	.5	0	.1	1.4	1.8

[1] Assume 100% of pumpage described in column (2) and (3) returned to the Pootatuck River as sewage disposal.

under conditions of 95-percent duration of flow, the Pootatuck River at Fairfield Hills Hospital wells no. 7 and 8 dries up as it passes over the well field. Under the 90-percent duration of flow, however, streamflow is 0.5 mgd at this point. It should also be noted that under very dry conditions, such as occurred during the early and middle 1960s, the flow of the Pootatuck River and natural recharge will be significantly less than values used in this simulation analysis. Ground-water availability under these critically dry conditions can be estimated with the existing digital model used here, but such analyses are beyond the scope of the present study. In general, however, maximum development would have a correspondingly greater impact in reducing the flow of the Pootatuck River.

If the minimum river flows under conditions of development are not acceptable, pumpage could be reduced at one or more well fields or other water development schemes could be used.

QUALITY OF WATER

by Elinor H. Handman

As water moves through the hydrologic cycle its physical, chemical, and biological properties change. Water vapor in the atmosphere incorporates aerosols, gases and particulates as it condenses and falls as rain or snow. Thus when it reaches the ground it already contains dissolved and particulate matter. The type and amount of matter contained in precipitation depend on wind direction and duration; intensity and duration of precipitation; urban, industrial and agricultural activities; and chemical elements contained in the water vapor. Rain from storms which have passed over the ocean, for example, may contain high concentrations of sodium and chloride, whereas rain from storms which have passed over industrial areas may contain impurities derived from fumes and smoke.

The quality of streamflow is determined by the composition of precipitation and dry fallout, the type of earth materials in the drainage area, the length of time runoff is in contact with these materials, and land use. During high flow, much of the water in streams is derived from surface runoff and the stream composition may be close to that of surface runoff. During low flow, ground water is the major source of streamflow and dissolved-solids concentrations are generally higher. Ground water is more mineralized because water percolating through the ground dissolves more minerals from soil and rocks than does water flowing over the surface.

Ground-water quality changes in response to changes in temperature, precipitation, residence time, flow path, and land use. These changes are especially pronounced in shallow stratified drift. Some are related to seasonal changes in recharge, to vegetal growth and decay, and to the effects of man-made stresses, such as induced recharge.

The most common constituents in water in the area are calcium, magnesium, sodium, bicarbonate, sulfate and chloride. They are derived from many sources: calcium and bicarbonate are derived from soil and rock weathering; sulfate is contributed by precipitation and by organic material in sediments and sulfide minerals in rocks; and sodium and chloride come from soil and rock weathering and precipitation. Abnormal values can result from sewage and road salts.

Interpretation of water quality in the study area is based primarily on analyses of 20 samples collected in 1976 and 1977 from 4 sites on the Pootatuck River, 1 site on Deep Brook, and 10 wells. Table 4 summarizes

Table 4.--Summary of chemical and physical properties of surface water and ground water
(Concentrations of chemical constituents in milligrams per liter)

Constituent or property	Surface water 7 samples, 5 sites 1/		Ground water 13 samples, 10 wells 2/	
	Median	Range	Median	Range
Iron (Fe)	0.14	0.07 - 0.21	0.06	0.01 - 1.7
Manganese (Mn)	.01	.00 - .02	.44	.03 -15
Calcium (Ca)	12	6.5 -25	22	2.3 -49
Magnesium (Mg)	3.7	2.1 - 6.7	5.8	.7 -20
Sodium (Na)	6.9	4.4 -20	5.8	1.8 -53
Potassium (K)	-	-	3.6	.9 - 6.4
Bicarbonate (HCO_3)	40	23 -58	43	12 -270
Sulfate (SO_4)	11	9.2 -30	11	1.8 -66
Chloride (Cl)	18	6.4 -43	10	1.2 -160
Fluoride (F)	-	-	.1	.1 - .5
Nitrogen ammonia (N)	.00	.00 - .03	.04	.02 - .40
Nitrite + nitrate (N)	.36	.32 - 1.6	.35	.01 - 3.4
Dissolved oxygen				
(mg/L)	10.0	9.6 -10.3	-	-
Percent saturation	98	94 -107	-	-
Phosphorus (P)	.04	.02 - 1.3	4.3	.66 -23
Dissolved solids (residue at 180°C)	95	53 -203	155	29 -409
Hardness				
(Ca,Mg)	45	25 - 90	90	9 -200
Noncarbonate	13	5 - 42	5	0 -100
Alkalinity (as $CaCO_3$)	33	19 - 48	35	10 -221
Specific conductance (umohs per cm at 180°C)	132	87 -291	236	40 -650
pH	7.2	6.8 - 7.5	7.2	6.5 - 8.2

1/ Two sites sampled May 1976; 5 sites sampled September 1976; 4 sites on Pootatuck River; 1 site on Deep Brook near its mouth
2/ Ten wells sampled September 1976; 3 wells resampled February 1977

these analyses. Individual analyses, along with data collected for previous studies from 4 additional wells and one spring, are presented at the back of this report. (See table 11.) The locations of the sample-collection sites are shown in figure 16.

Precipitation

Nine composite monthly samples of precipitation and dry fallout were collected near Seymour in 1966 as part of the water-resources inventory of the lower Housatonic River basin (Wilson, and others, 1974). Composition of this precipitation is believed to be similar to that in the study area. Sulfate is the predominant dissolved constituent in the samples. (See table 5.) The pH ranges from 4.6 to 6.2, which is in the normal range. (A pH of 5.7 is normal for water in the atmosphere), (Barrett and Brodin, 1955, p. 252). The precipitation-weighted mean concentration of dissolved solids is 21 mg/L, which is equivalent to about 4.8 pounds of material falling on each acre with every inch of rain.

Table 5.--Average concentrations of principal dissolved constituents in precipitation, surface water and ground water (in milligrams per liter)

Constituent	Precipitation 1/ at Seymour, Conn. (weighted average)	Surface water: High flow 2/ 2 sites	Surface water: Low flow 3/ 5 sites	Ground water 4/ 10 wells
Calcium	1.1	7.1	15	20
Sodium (Na)	2.2	4.6	9.9	12
Chloride (Cl)	1.2	7.4	23	27
Sulfate (SO_4)	5.9	10	12	18
Bicarbonate (HCO_3)	1.0	24	42	72

1/ Includes dry fallout; collected monthly, April - December, 1966.
2/ Sampled once at each site, May 1976.
3/ Sampled once at each site, September 1976.
4/ Sampled once at each site, September 1976.

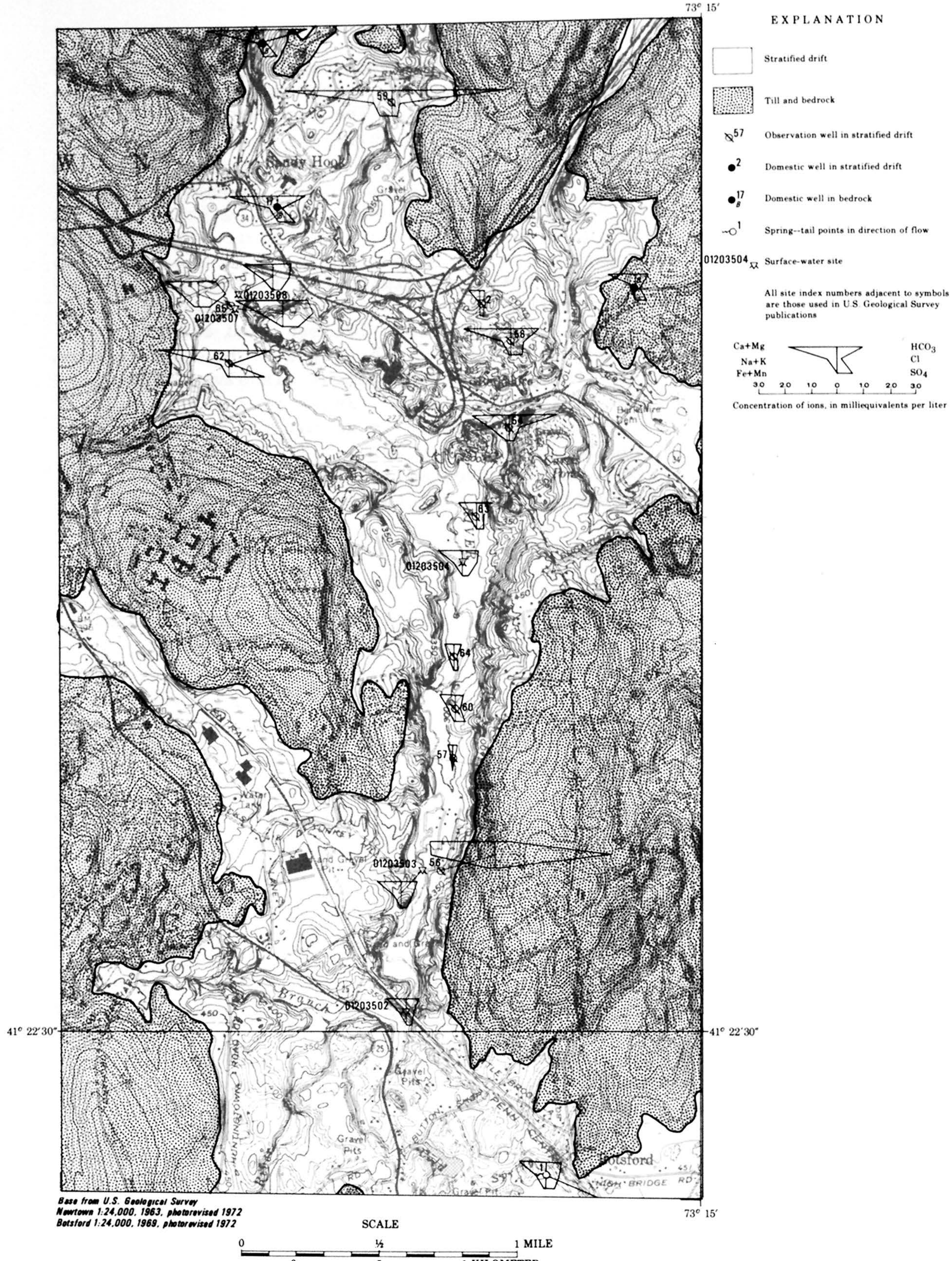


Figure 16.--Quality of surface water and ground water

Surface Water

The quality of the Pootatuck River, and of Deep Brook near its mouth is summarized in table 4. Concentrations of dissolved constituents are plotted in figure 16 and the resulting points are connected to form irregular polygons. Polygon shapes emphasize similarities and differences in water composition (Stiff, 1951). Dissolved-solids concentration, as indicated by the width of the modified Stiff patterns, gradually increases in a downstream direction, owing to the increase in solutes from the area being drained. (Compare U.S. Geological Survey stations 01203502 and 01203503.) The quality of water from station 01203503 at Turkey Hill Road near Botsford, showed no effects from the nearby landfill.

Deep Brook at Sandy Hook is affected by discharge from the sewage treatment plant, as indicated by the shape and width of the Stiff pattern at U.S. Geological Survey 01203507. This water is diluted by the Pootatuck River, but it affects the Pootatuck's quality. (See station 01203508.)

The concentrations of most solutes are lower during high streamflow than during low flow. Variations with flow result primarily from changes in the relative contributions to streams of ground-water and surface runoff. At high flow contributions from less mineralized surface runoff are larger and wastes are more diluted. Table 6 shows the quality of the Pootatuck River at Botsford and Berkshire at relatively high and low flows.

All surface-water samples meet the requirements for untreated sources of drinking water set by the Connecticut Department of Health (Connecticut General Assembly, 1975) except for total coliform bacteria (table 11). Total coliform bacterial concentrations range from 1,600 col/100 ml (colonies per 100 ml of water) at Botsford (station 01203502) at high flow, to 9,200 col/100 ml near Botsford (station 01203503) at low flow. Fecal coliform concentrations range from 20 col/100 ml in Deep Brook at Sandy Hook, to 700 col/100 ml in the Pootatuck River at Berkshire. Fecal streptococci concentrations range from 51 col/100 ml in Deep Brook at Sandy Hook at low flow to 390 col/100 ml in the Pootatuck at Botsford (station 01203502) at high flow. Bacterial concentration does not seem to correlate with the two flow conditions sampled.

Although chemical solutes commonly remain in solution, bacteria are normally filtered out of surface water when it is induced into an aquifer by pumping (Kazmann, 1948, p. 412). Therefore, the water in the Pootatuck River should be acceptable for induced recharge to the adjacent stratified-drift aquifer.

Table 6.--Chemical and physical properties of water from the Pootatuck River at high and low flow
(Concentrations of chemical constituents in milligrams per liter)

Constituent or property	Station 01203502 Botsford, Conn.		Station 01203504 Berkshire, Conn.	
	High flow 1/	Low flow 2/	High flow 1/	Low flow 3/
Streamflow (cfs)	26	8.7	36	11
Iron (Fe)	.21	.18	.17	.13
Manganese (Mn)	.02	.02	.01	.00
Calcium (Ca)	6.5	10	7.7	13
Magnesium (Mg)	2.1	2.8	2.5	3.7
Sodium (Na)	4.4	5.6	4.9	6.9
Bicarbonate (HCO_3)	24	29	23	40
Sulfate (SO_4)	11	9.2	9.6	12
Chloride (Cl)	6.4	11	8.3	21
Nitrogen ammonia (N)	.03	.00	.02	.00
Nitrite + Nitrate (N)	.27	.32	.32	.36
Dissolved oxygen				
Percent saturation	99	97	98	103
mg/L	10.0	9.9	10.3	10.2
Phosphorus (P)	.04	.04	.03	.03
Dissolved solids (residue at 180°C)	53	72	95	92
Hardness				
(CaMg)	25	37	30	48
Noncarbonate	5	13	11	15
Alkalinity (as $CaCO_3$)	20	24	19	33
Specific conductance (umhos per cm at 180°C)	87	107	97	132
pH, units	7.2	6.8	7.2	7.2
Turbidity, units	2	1	2	1

1/ Sampled May 17, 1976.
2/ Sampled September 13, 1976.
3/ Sampled September 14, 1976.

Ground Water

The quality of ground water in the stratified-drift aquifer is summarized in table 4 and illustrated in figure 16. Dissolved-solids concentration, as indicated by the width of the modified Stiff patterns in the figure, differs widely from place to place as a result of differences in aquifer composition, subsurface flow patterns, and human factors such as waste disposal, fertilizer use, and road-salt application.

Calcium and bicarbonate predominate in water from 80 percent of the wells sampled. This type of water is slightly basic and is generally soft to moderately hard. (Table 7 describes hardness classification).

Table 7.--Hardness of water and resultant suitability 1/

Descriptive rating	Hardness as $CaCO_3$, range in mg/l	Suitability
Soft	0- 60	Suitable for many uses without softening
Moderately hard	61-120	Usable except for some industrial applciations
Hard	121-180	Softening required by laundries and for most domestic uses
Very hard	181 or more	Softening required for most purposes

1/ Modified from Durfor and Becker, 1964, p. 27.

Water from bedrock wells NT 1, NT 16, and NT 17, (sampled April, 1967), contains high proportions of sulfate (fig. 16). Well NT 62, which is screened in stratified drift, has a modified Stiff pattern similar to those of the bedrock wells. This indicates an influence from water which has passed through bedrock or through sediments similar to local bedrock in composition.

Water from wells NT 56 and NT 65 is relatively high in sodium and chloride, probably as a result of infiltration of waste water or runoff containing road salt or fertilizer. Samples from NT 56, taken September 1, 1976, and February 2, 1977, had sodium concentrations of 53 mg/L and 27 mg/L. Both are above the 20 mg/L maximum for drinking by people restricted to a low sodium diet. Nitrate concentrations are also above normal in the February analyses. NT 56 is downgradient from a developed area which may be affecting ground-water quality. Within the development, chloride and nitrate concentrations in well water are above background levels (Connecticut Department of Health, 1976.)

Manganese and iron constitute only a small part of the dissolved solids in ground water (fig. 16), but they can be troublesome. The Connecticut Department of Health has not established limits for manganese or iron in public drinking water because they are not known to be harmful to health. However, dissolved manganese exceeding 0.05 mg/L and dissolved iron exceeding 0.3 mg/L precipitate on exposure to air, causing staining problems for domestic and industrial users.

Manganese and iron are dissolved from rocks and minerals, and from organic materials that accumulate in soils, marshes, bogs, and lakes. Their concentrations vary with time depending on changes in the acidity and dissolved-oxygen content of water. In the study area, manganese and iron in ground water may be put into solution, in part, by buried organic materials. Although these dissolved constituents are objectionable, they can be removed from water by suitable treatment.

Iron content is higher than manganese content in all surface-water samples, although none contain objectionable amounts. On the other hand, nine out of 10 ground-water samples contain excessive manganese and in eight of these, its concentration is higher than that of iron. Out of 10 ground-water samples, two contain excessive iron. Water from well NT 59 has the highest manganese concentration: 15 mg/L in the September 1976 sample and 13 mg/L in the February 1977 sample.

Three wells, NT 56, NT 57, and NT 65, one spring, NT 1SP, and the Pootatuck River at low flow, were sampled for trace-metal analyses in June and July, 1977. The results of the subsequent analyses (table 8) can be compared with the standards for public drinking water set by the Connecticut Department of Health (Connecticut General Assembly, 1975). All samples meet State requirements for drinking water, except that from NT 57, which contains 26 ug/L cadmium. This metal is not essential or beneficial in human nutrition and is highly toxic (Hem, 1970). On the basis of limited sampling for trace metals in Connecticut ground waters, the cadmium concentrations in water from NT 57 appear to be above background levels. It is not possible to determine from these few samples whether this is a result of local or widespread contamination; long term, seasonal or unusual hydrologic conditions; or errors in sampling or analysis. Periodic sampling of several wells in the area is necessary in order to confirm the existence of the problem, to ascertain its source, and to delineate its extent.

Table 8.--Trace metals in surface water and ground water (concentrations of chemical constituents in micrograms per liter)

Constituent or property	Station 01203502 1/	Spring NTISP 1/	Well NT 57 1/	Well NT 64 2/	Well NT 65 3/	Standard for drinking water 4/
	Sample site					
Aluminum (Al)	90	40	50	60	70	-
Cadmium (Cd)	0	0	26	4	4	10
Chromium (Cr)	7	6	8	0	5	50
Lead (Pb)	30	22	35	8	5	50
pH	7.1	6.5	6.2	6.6	6.2	-
Specific conductance (micromhos per cm at 180°C)	124	133	32	67	240	-

1/ Sampled July 7, 1977.
2/ Sampled June 24, 1977.
3/ Sampled July 5, 1977.
4/ Limit for drinking water set by Connecticut Department of Health (Connecticut General Assembly, 1975).

CONCLUSIONS

Results of a hydrologic analysis using a mathematical simulation model indicate that about 4.0 million gallons per day of water could be withdrawn from the stratified-drift aquifer under long-term average conditions. The total amount of ground water that can be withdrawn is limited by the hydrologic characteristics of the aquifer in the northern part of the area, by existing pumping in the center of the area, and by the streamflow available for induced recharge in the southern part of the area. In 1976, 0.4 mgd was pumped from the aquifer, almost all of it by Fairfield Hills Hospital in the center of the area. This amount is substantially below the 1.5 mgd tested capacity of the existing Hospital well fields.

The model was stressed by "pumping" 1.5 mgd from the two Fairfield Hills Hospital well fields and an additional 2.5 mgd from two hypothetical pumping centers. These yields are long-term sustained values based on estimated long-term natural recharge rates and utilizing the 90- and 95-percent duration flow of the Pootatuck River as indices of the amount of water available for induced recharge. The simulation results indicate that 65 percent, or 2.6 mgd, of the total pumpage would be derived from induced recharge of water from the Pootatuck River and that 35 percent, or 1.4 mgd, would be derived from capture of ground-water runoff. The effects on streamflow within the model area are summarized in table 3. The most significant flow reductions would occur in reaches of the Pootatuck River adjacent to the existing hospital well fields.

Because ground-water withdrawals from the stratified-drift aquifer depend heavily on the available streamflow, protracted or even short periods of below-average rainfall would significantly reduce the amount of water available for pumping. Conversely, during periods of high streamflow it may be possible to pump more than 4.0 mgd. Low-flow augmentation by various methods would increase the total amount of ground water that can be withdrawn from the aquifer on a sustained basis. The effects of severe drought conditions and of seasonal variations of the water table can also be simulated, but such modeling is beyond the scope of the present study.

The most favorable sites for future pumping centers within the study area are at the two hypothetical well fields. Both locations are underlain by thick, permeable sand and gravel. Prior to development, a site investigation of these areas could be undertaken to determine the most advantageous locations for production wells. Hypothetical well field no. 1, located in the northern end of the study area, would have the smallest impact on the stream-aquifer system.

The quality of water from all sources in the study area is good except at a few sites adversely affected by aquifer composition or by human activities. Surface-water samples meet the standards for public drinking water set by the Connecticut Department of Health (Connecticut General Assembly, 1975) except for excessive coliform bacteria. Ground-water samples also meet these standards except for a high concentration of cadmium in one sample. Water from both sources is low in dissolved solids and is mostly soft to moderately hard. The median dissolved-solids concentration of stream samples is 95 mg/L, and the median hardness is 45 mg/L. In contrast, the median dissolved-solids concentration of ground water is 155 mg/L, and the median hardness is 90 mg/L. Trace metal analyses show a little chromium and lead in both surface- and ground-water samples. The high cadmium concentration in water from one well may indicate a contamination problem or may be the result of sampling error. Further investigation is needed in order to define the extent of the problem.

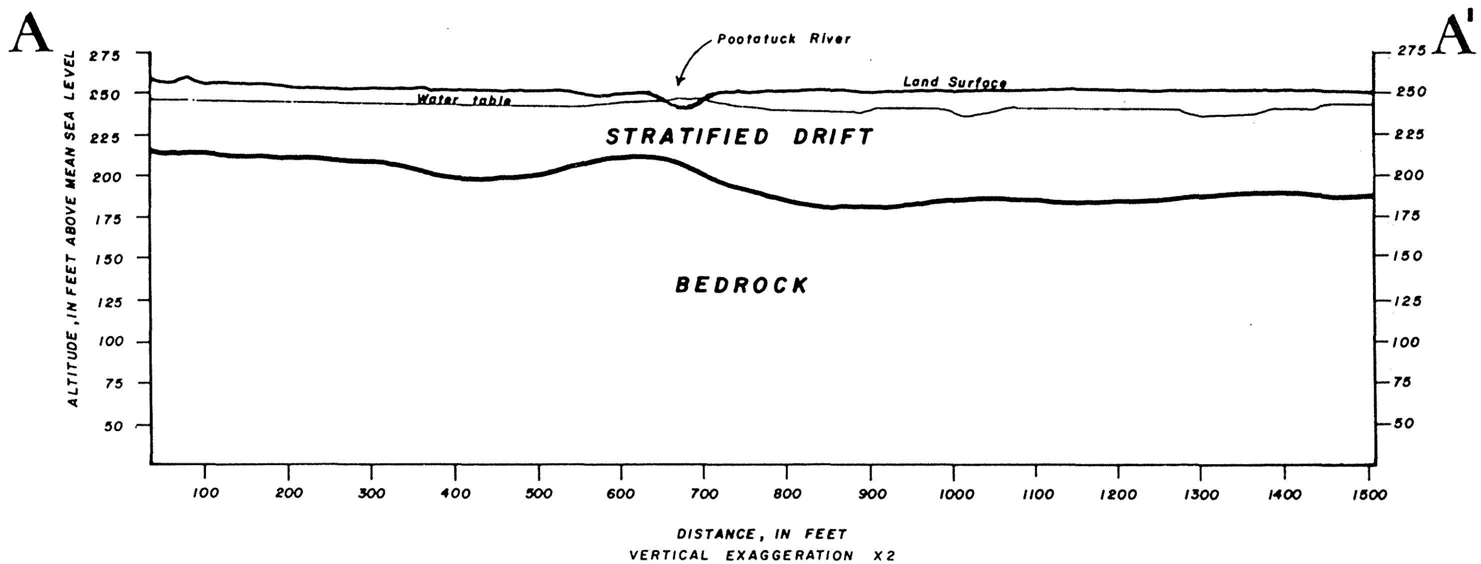
Most ground water in the area contains enough dissolved manganese to cause stains on plumbing fixtures and laundry, thus restricting its use without treatment. Iron concentration in some ground water is high enough to cause similar problems. Treatment can reduce manganese and iron content.

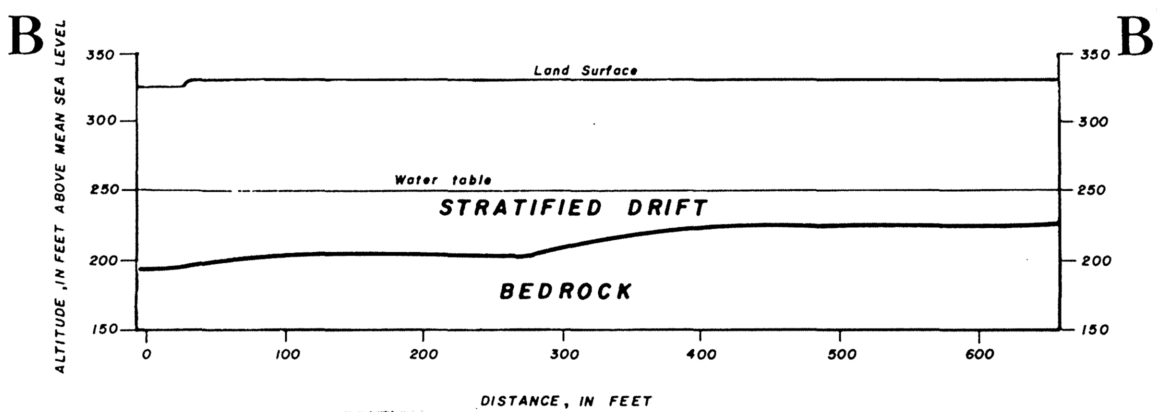
Chloride concentration is above natural background level in two areas affected by human activities, as shown by ground water from well NT 56 downgradient from a developed area, and by ground water and surface water near the mouth of Deep Brook.

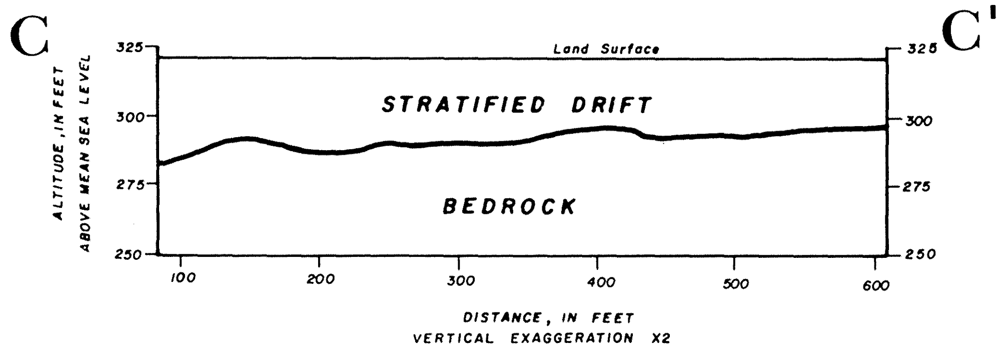
The water-quality assessment is based on only one or two samples from each site. Moreover, a disproportionately large number were collected in one season, the fall of 1976. A thorough interpretation of seasonal and long-term changes requires periodic sampling lasting several years.

TABLE 9--SEISMIC REFRACTION PROFILES

Hydrogeologic sections from seismic refraction surveys conducted by the U.S. Geological Survey in April 1976. Locations of individual profiles are shown in figure 2. Interpretation of field data based on a computer modeling technique described by Scott and others (1972).



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Land Surface
STRATIFIED DRIFT
BEDROCK
ALTITUDE, IN FEET ABOVE MEAN SEA LEVEL
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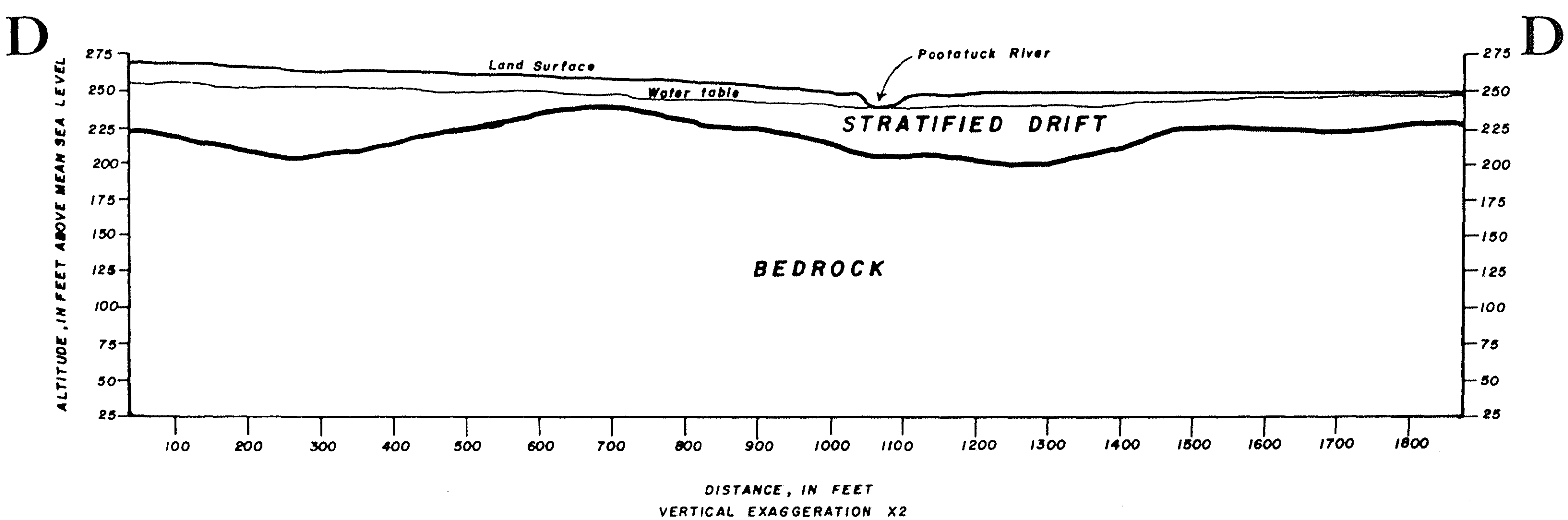
DISTANCE, IN FEET
VERTICAL EXAGGERATION X2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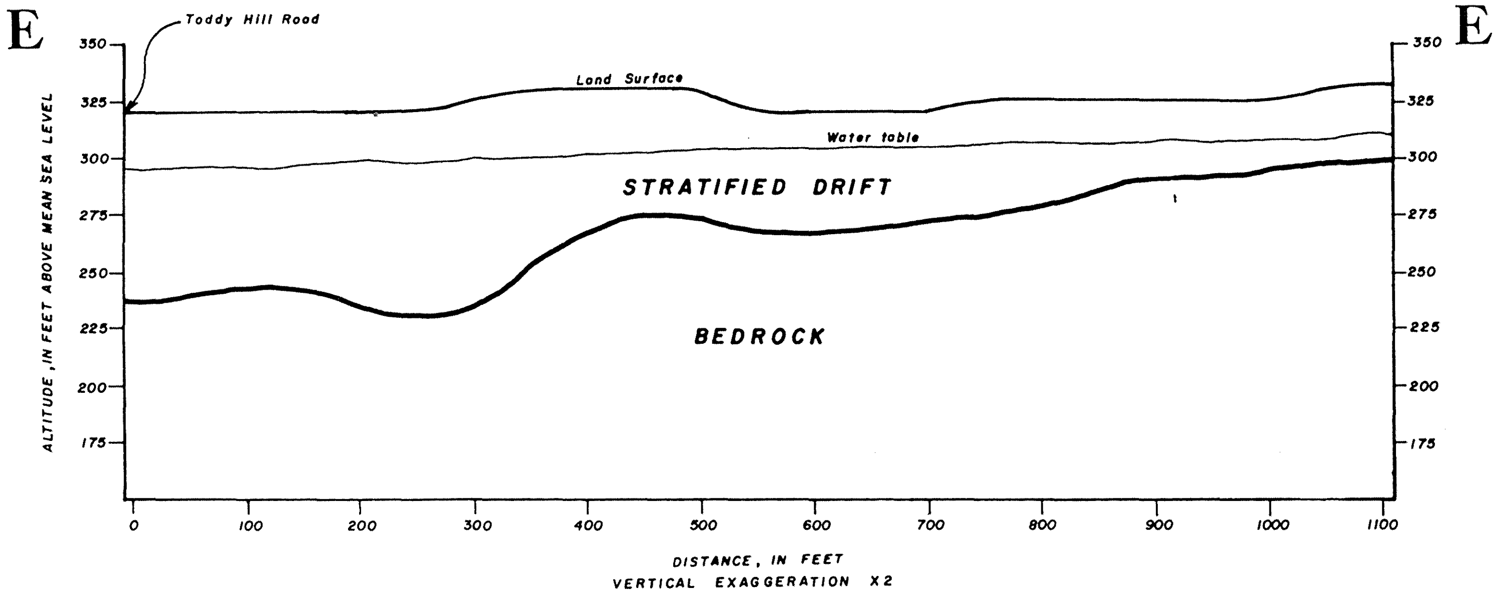
DISTANCE, IN FEET
VERTICAL EXAGGERATION X2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ALTITUDE, IN FEET ABOVE MEAN SEA LEVEL
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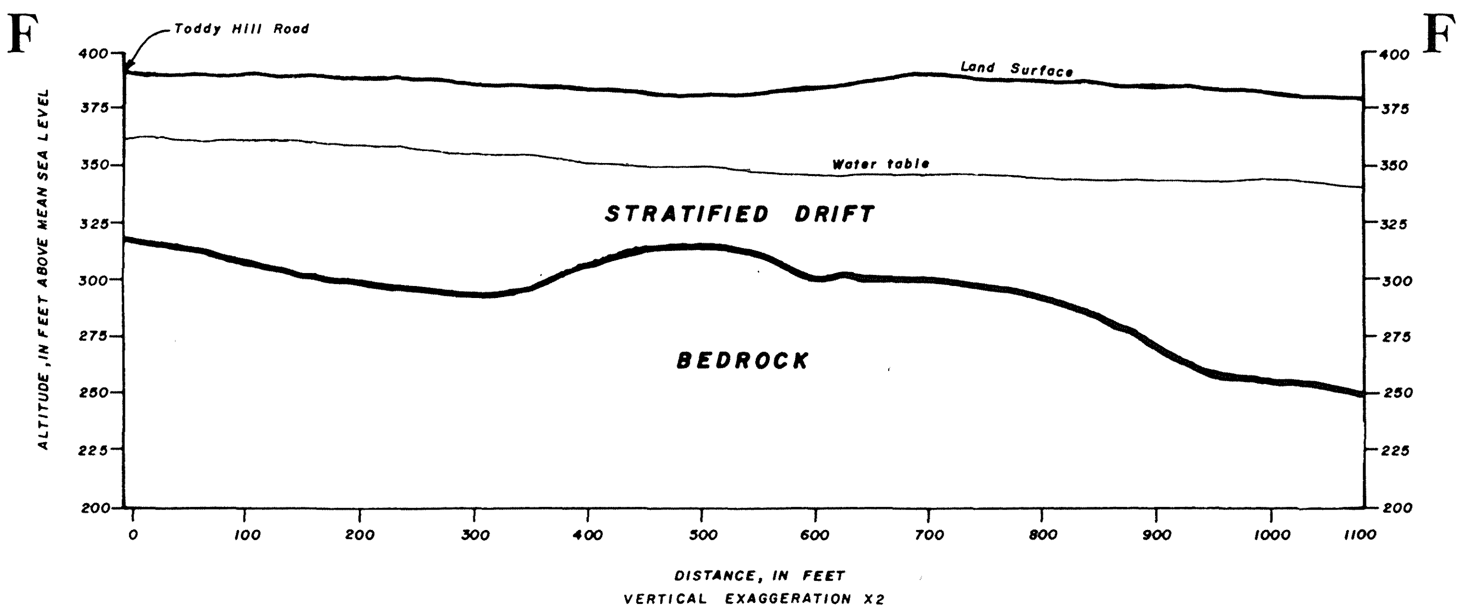
VERTICAL EXAGGERATION X2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Land Surface
Water table
STRATIFIED DRIFT
BEDROCK
ALTITUDE, IN FEET ABOVE MEAN SEA LEVEL
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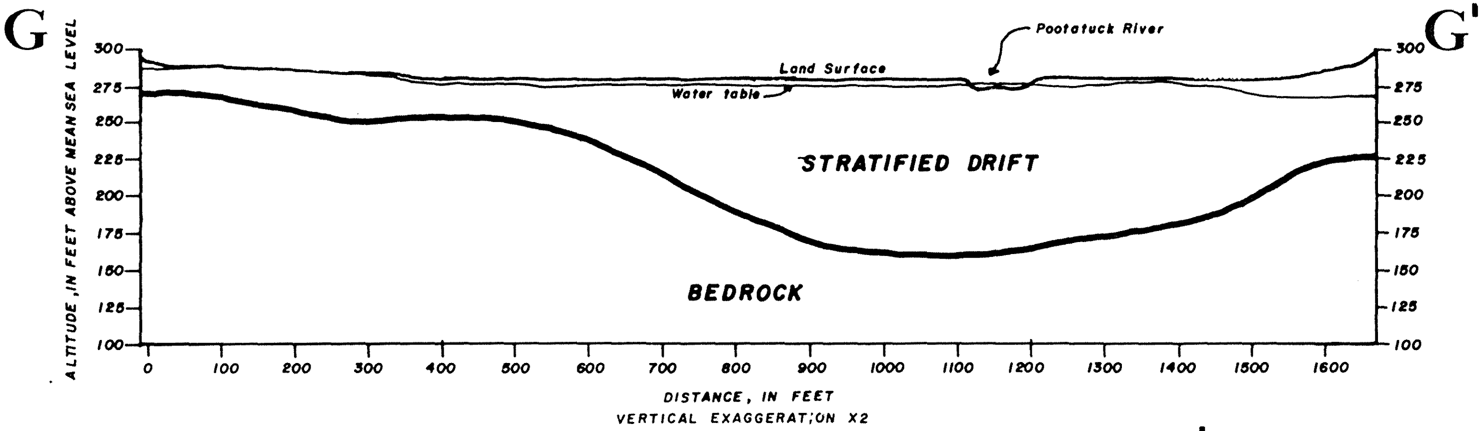
DISTANCE, IN FEET
VERTICAL EXAGGERATION X2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Pootatuck River
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STRATIFIED DRIFT
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ALTITUDE, IN FEET ABOVE MEAN SEA LEVEL
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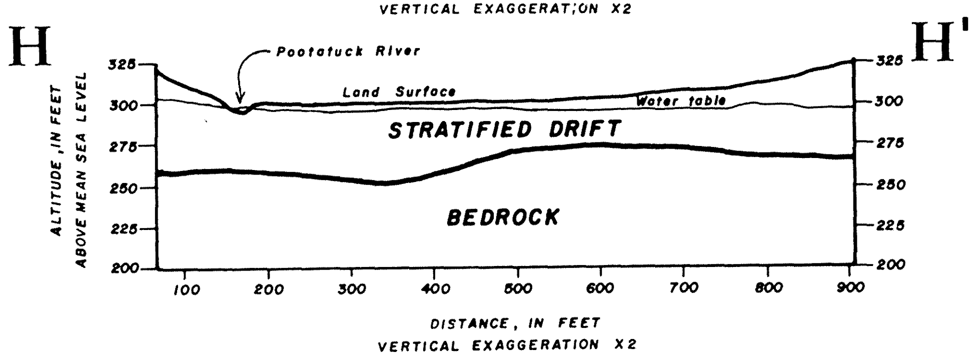
DISTANCE, IN FEET
VERTICAL EXAGGERATION X2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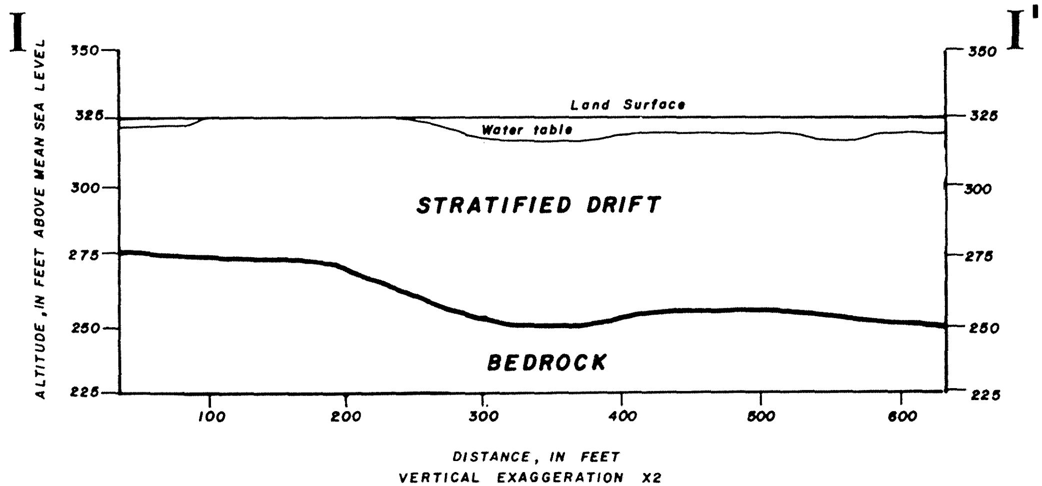
DISTANCE, IN FEET
VERTICAL EXAGGERATION X2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Land Surface
Water table
STRATIFIED DRIFT
BEDROCK
ALTITUDE, IN FEET ABOVE MEAN SEA LEVEL
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DISTANCE, IN FEET
VERTICAL EXAGGERATION X2

TABLE 10--LOGS OF SELECTED TEST HOLES

Each entry lists U.S. Geological Survey test-hole number, location, owner, year drilled, altitude of land surface, depth to water (if available), source of log, and description of earth materials penetrated.

Location number: Location number is the latitude and longitude of test-hole site.

Altitude: Land surface at test-hole site, in feet above mean sea level, estimated from topographic map with 10-ft contour interval. Altitude of Connecticut Dept. of Transportation test holes chiefly determined by leveling.

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

Source of log: Well drilling or test boring contractor, as indicated.

Description of earth materials: Logs of test holes of the U.S. Geological Survey and Connecticut Dept. of Transportation are based on the appropriate grain-size classification shown in the table to the right.

Terms used in logs of test holes of the U.S. Geological Survey.

Sand and gravel--Sorted stratified sediment varying in size from boulders to very fine sand.
Parentheses enclose the major grain size in sample.
"Poorly sorted" indicates approximately equal amounts, by weight, of all grain sizes.

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

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

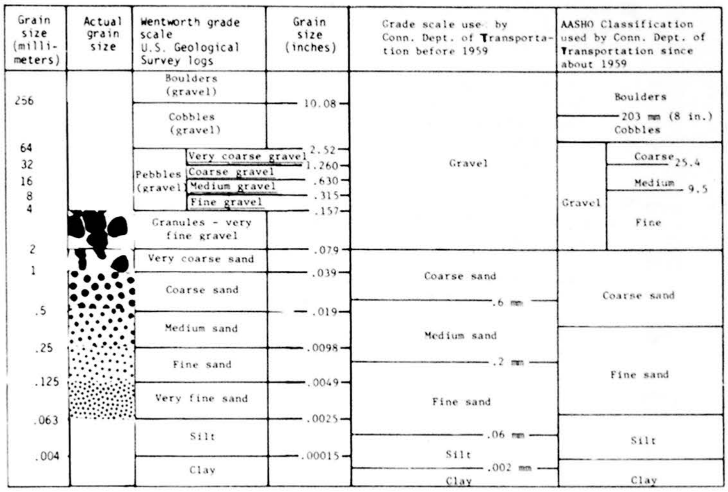
Refusal--Depth at which the drill equipment could not penetrate farther.

Percentage by weight of individual components in the sample.

Trace	0 10
Little	10 - 20
Some	20 - 35
..and..	35 - 50

Terms on all other logs are those used by drillers; however, some are rearranged for uniformity of presentation.

Terms in parentheses are interpretations by F. P. Haeni.



NT 10 th. 412416N0731611.1. Fairfield Hills Hospital. Drilled 1930. Altitude 260 ft. Depth to water 5 ft. Log by S. B. Church Co.

	Depth (feet)	Thickness (feet)
Gravel, brown	0 - 10	10
Sand, medium to fine, gray	10 - 45	35
Sand, medium, gray	45 - 84	39
Till	at 84	

NT 11 th. 412414N0731616.1. Fairfield Hills Hospital. Drilled 1947. Altitude 265 ft. Depth to water 5 ft. Log by R. E. Chapman Co.

	Depth (feet)	Thickness (feet)
Gravel, brown	0 - 5	5
Sand, medium, gray	5 - 10	5
Sand, fine, gray	10 - 15	5
Sand, fine to medium, brown	15 - 35	20
Sand, medium, grayish-brown	35 - 40	5
Sand, fine to medium, gray	40 - 80	40
Gravel (till?)	80 - 85	5
Bedrock	at 85	

NT 12 th. 412412N0731619.1. Fairfield Hills Hospital. Drilled 1947. Altitude 275 ft. Depth to water 5 ft. Log by R. E. Chapman Co.

	Depth (feet)	Thickness (feet)
Gravel	0 - 10	10
Sand, fine to medium, brown	10 - 60	50
Till	60 - 65	5
Bedrock	at 65	

NT 13 th. 412419N0731615.1. Fairfield Hills Hospital. Drilled 1947. Altitude 265 ft. Depth to water 5 ft. Log by R. E. Chapman Co.

	Depth (feet)	Thickness (feet)
Gravel	0 - 10	10
Sand, very fine to fine	10 - 90	80
Bedrock	at 90	

NT 14 th. 412424N0731630.1. Fairfield Hills Hospital. Drilled 1947. Altitude 255 ft. Depth to water 5 ft. Log by R. E. Chapman Co.

	Depth (feet)	Thickness (feet)
Gravel	0 - 5	5
Sand, medium, tan	5 - 20	15
Sand, fine, gray	20 - 30	10
Gravel	30 - 35	5
Sand and gravel, gray (till?)	35 - 43	8
Bedrock	at 43	

NT 15 th. 412427N0731619.1. Fairfield Hills Hospital. Drilled 1947. Altitude 260 ft. Depth to water 5 ft. Log by R. E. Chapman Co.

	Depth (feet)	Thickness (feet)
Gravel	0 - 10	10
Sand, very fine to fine, gray	10 - 30	20
Sand, medium, gray	30 - 40	10
Sand, medium to coarse, gray	40 - 45	5
Till	45 - 53	8
Bedrock	at 53	

	Depth (feet)	Thickness (feet)
NT 16 th. 412423N0731611.1. Fairfield Hills Hospital. Drilled 1947. Altitude 260 ft. Depth to water 5 ft. Log by R. E. Chapman Co.		
Gravel, brown	0 - 15	15
Sand, fine to medium, brown	15 - 35	20
Sand, medium to very coarse, grayish-brown	35 - 41	6
Bedrock	at 41	
NT 17 th. 412355N0751557.1. Fairfield Hills Hospital. Drilled 1947. Altitude 275 ft. Depth to water 5 ft. Log by R. E. Chapman Co.		
Sand, fine, brown	0 - 5	5
Sand, coarse, and fine gravel, brown	5 - 10	5
Gravel, fine, pebble, angular	10 - 15	5
Sand, coarse, and fine gravel, brownish-gray	15 - 25	10
Sand, fine to medium, brown	25 - 65	40
Sand, medium to coarse, brown	65 - 70	5
Till	70 - 78	8
Bedrock	at 78	
NT 18 th. 412408N0731604.1. Fairfield Hills Hospital. Drilled 1947. Altitude 270 ft. Depth to water 5 ft. Log by R. E. Chapman Co.		
Gravel	0 - 10	10
Sand, very fine; trace silt, gray.	10 -100	90
Bedrock	at 100	
NT 21 th. 412432N0731535.1. L. G. Warner. Drilled 1966. Altitude 320 ft. Depth to water 2 ft. Log by U.S. Geol. Survey.		
Sand and gravel, dark yellowish-brown	0 - 27	27
Till(?), sandy and gravelly, compact, gray	27 - 42	15
Till, sandy, gray	42 - 43	1
NT 22 th. 412503N0731658.1. D. Digilio. Drilled 1966. Altitude 240 ft. Depth to water 4 ft. Log by U.S. Geol. Survey.		
Gravel with cobbles and boulders .	0 - 6	6
Sand, fine to coarse; trace fine gravel	6 - 20	14
Gravel	20 - 21	1
Till, sandy, gray	21 - 32	11
Refusal (bedrock)	at 32	
NT 25 th. 412429N0731651.1. Fairfield Hills Hospital. Drilled 1966. Altitude 265 ft. Depth to water 7 ft. Log by U.S. Geol. Survey.		
Sand and topsoil	0 - 5	5
Gravel	5 - 13	8
Sand, very fine to fine; little medium sand; little coarse sand; trace gravel	13 - 30	17
Gravel, very fine to medium, and sand	30 - 34	4
Sand, very fine; little silt	34 - 54	20
Gravel (till?), compact	54 - 57	3
Refusal	at 57	

	Depth (feet)	Thickness (feet)
NT 26 th. 412457N0731700.1. State of Connecticut. Drilled 1955. Altitude 241 ft. Depth to water 6 ft. Log by Conn. Dept. of Transportation.		
Sand, coarse, and silt, gray	0 - 5	5
Sand, medium, and silt, gray	5 - 10	5
Sand, medium to fine, and silt, gray and brown	10 - 49	39
Till	49 - 58	9
Rock, soft	58 - 63	5
Refusal	at 63	
NT 27 th. 412456N0731645.1. State of Connecticut. Drilled 1955. Altitude 267 ft. Depth to water 15 ft. Log by Conn. Dept. of Transportation.		
Sand, fine, to gravel, tan	0 - 4	4
Sand, fine, and silt, tan	4 - 8	4
Sand, fine, to gravel	8 - 10	2
Sand, fine, silt, tan	10 - 15	5
Gravel, sand, and silt, tan	15 - 18	3
Sand, fine, and silt, tan	18 - 27	9
Sand, fine to medium, and silt, tan	27 - 29	2
Sand, fine, and silt, tan	29 - 47	18
Sand, fine to medium, and silt, tan	47 - 51	4
Till(?); fine to coarse sand; silt; little clay and gravel, gray	51 - 85	34
Till(?), gravel, sand, silt, and cobbles; little clay	85 - 88	3
Rock	88 - 91	3
NT 28 th. 412456N0731659.1. State of Connecticut. Drilled 1967. Altitude 250 ft. Depth to water 10 ft. Log by Conn. Dept. of Transportation.		
Sand and fine gravel, brown	0 - 5	5
Sand, fine; little to some silt; at 6.5 ft black silt with trace of organics and fine sand	5 - 10	5
Sand, coarse to fine; some gravel	10 - 15	5
Sand; some gravel; trace silt	15 - 17	2
Sand, coarse to fine	17 - 19	2
Sand, fine, brown	19 - 45	26
Sand, very fine; trace silt	45 - 52	7
Till: sand and gravel	52 - 60	8
Bedrock	60 - 65	5
NT 55 th. 412239N0731526.1. State of Connecticut. Drilled 1969. Altitude 340 ft. Depth to water 9 ft. Log by Conn. Dept. of Transportation.		
Topsoil	0 - 1	1
Sand, coarse to fine; trace silt; trace gravel	1 - 39	38
Bedrock	39 - 49	10
NT 56 th. 412458N0731454.1. State of Connecticut. Drilled 1967. Altitude 345 ft. Depth to water 6 ft. Log by Conn. Dept. of Transportation.		
Topsoil	0 - 1	1
Sand, coarse to fine; some gravel; trace silt	1 - 10	9
Sand, coarse to fine; trace silt .	10 - 40	30
Bedrock	40 - 50	10
Refusal	at 50	

NT 57 th. 412438N0731457.1. State of Connecticut. Drilled 1967. Altitude 303 ft. Depth to water 17 ft. Log by Conn. Dept. of Transportation.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 1	1
Sand, coarse to fine; trace silt; trace gravel	1 - 8	7
Silt; some medium to fine sand	8 - 18	10
Sand, coarse to fine; some fine to coarse gravel; trace silt	18 - 47	29
Bedrock	47 - 50	3

NT 58 th. 412458N0731507.1. State of Connecticut. Drilled 1967. Altitude 370 ft. Depth to water 38 ft. Log by Conn. Dept. of Transportation.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 1	1
Silt and fine sand	1 - 36	35
Sand, coarse to fine; little gravel; little silt	36 - 40	4
Bedrock	40 - 70	30

NT 59 th. 412453N0731504.1. State of Connecticut. Drilled 1967. Altitude 376 ft. Depth to water 45 ft. Log by Conn. Dept. of Transportation.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 1	1
Sand, coarse to fine; little silt.	1 - 49	48
Bedrock	49 - 72	23

NT 60 th. 412501N0731516.1. State of Connecticut. Drilled 1967. Altitude 349 ft. Depth to water 22 ft. Log by Conn. Dept. of Transportation.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 1	1
Sand, coarse to fine; some gravel; little silt	1 - 39	38
Bedrock	39 - 50	11

NT 61 th. 412430N0731501.1. State of Connecticut. Drilled 1967. Altitude 294 ft. Depth to water 4 ft. Log by Conn. Dept. of Transportation.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 1	1
Sand, coarse to fine; little silt; little gravel	1 - 28	27
Sand, coarse to fine; trace silt..	28 - 51	23
End of hole	at 51	

NT 62 th. 412434N0731536.1. Potatuck Fish and Game Club. Drilled 1976. Altitude 254 ft. Depth to water 4 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Fill, sand and gravel	0 - 2	2
Swamp deposits mixed with gravel..	2 - 7	5
Sand and gravel, poorly sorted; little silt and clay	7 - 13	6
Sand, very fine; some silt; little fine sand	13 - 30	17
Sand, fine; some very fine sand; some silt; little medium sand; trace clay	30 - 40	10
Sand, fine to very fine; trace medium sand; little silt and clay	40 - 81	41
Sand and gravel, poorly sorted; little silt and clay (or very sandy till)	81 - 84	3
End of hole	at 84	

NT 63 th. 412454N0731551.1. Watkins Bros. Development Corp. Drilled 1976. Altitude 250 ft. Depth to water 5 ft. Log by U.S. Geol. Survey.

Sand, very fine to fine, brown

NT 63 th. 412454N0731551.1. Watkins Bros. Development Corp. Drilled 1976. Altitude 250 ft. Depth to water 5 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Sand, very fine to fine, brown	0 - 2	2
Sand and gravel (mostly fine to medium sand)	2 - 10	8
Sand, fine to medium	10 - 12	2
Sand and gravel, poorly sorted, 6 in to 1 ft fine sand; some medium sand; layered	12 - 30	18
Sand, fine; some medium sand; little very fine sand; little coarse sand; trace silt and clay	30 - 35	5
Sand, medium to coarse; trace very coarse sand; trace fine sand; little very fine sand, silt, and clay	35 - 38	3
Sand and gravel (mostly coarse to very coarse sand); trace silt and clay	38 - 39	1
Sand, medium; some fine sand; little coarse sand; trace very fine sand; trace very coarse sand; trace silt and clay	39 - 48	9
Sand and gravel, poorly sorted; trace silt and clay	48 - 49	1
Sand, medium; some fine sand; some coarse sand	49 - 54	5
Sand and gravel, poorly sorted	54 - 55	1
Sand, medium; some coarse sand; some fine sand	55 - 59	4
Sand and gravel, poorly sorted	59 - 61	2
Sand, medium to coarse, little very coarse sand; some very fine to fine sand	61 - 63	2
Till, gray, mixed with fine sand layers	63 - 69	6
End of hole	at 69	

NT 64 th. 412441N0731548.1. Fairfield Hills Hospital. Drilled 1976. Altitude 251 ft. Depth to water 12 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 1	1
Sand and gravel (mostly fine to medium sand with 3/4 to 1 in stones)	1 - 11	11
Sand, very fine, and brown silt	11 - 15	4
Sand and gravel, poorly sorted (till?); some silt and clay	15 - 22	7
Sand, very fine, and silt	22 - 26	4
Sand and gravel, poorly sorted, trace silt and clay	26 - 29	3
Sand, very fine to fine; little silt and clay; trace medium sand mixed with thin layer of poorly sorted gravel	29 - 37	8
Sand and gravel, poorly sorted; trace silt and clay	37 - 39	2
Sand and gravel, poorly sorted (or sandy and loose till)	39 - 41	2
Refusal)	at 41	

NT 65 th. 412353N0731501.1. Potatuck Fish and Game Club. Drilled 1976. Altitude 282 ft. Depth to water 10 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 1	1
Sand and gravel, 2-3 in stones	1 - 7	6
Sand, fine to very fine; some medium sand; trace silt and clay	7 - 30	23
Sand and gravel, poorly sorted; little silt and clay; some small medium to fine sand layers	30 - 61	31
Sand, medium, and fine sand; little very fine sand; trace coarse sand; trace silt and clay	61 - 62	1
Sand, very fine; some fine sand	62 - 66	4
Till	66 - 75	9
Refusal	at 75	

NT 66 th. 412407N0731457.1. S. Curtis & Son, Inc. Drilled 1976. Altitude 320 ft. Depth to water 34 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Sand, fine to very fine	0 - 15	15
Sand and gravel (mostly very fine to fine sand with 1-2 in stones)	15 - 27	12
Sand, fine to very fine	27 - 40	13
Sand and gravel (mostly fine sand, some medium sand; little very fine sand; little coarse sand; little silt and clay)	40 - 42	2
Sand, very fine to fine; little medium sand; some small gravel layers	42 - 52	10
Sand and gravel (mostly medium to very coarse sand); trace silt and clay	52 - 60	8
Sand, very fine, and silt; some fine sand; trace medium sand; trace clay	60 - 63	3
Till, gray	63 - 98	35
Refusal	at 98	

NT 67 th. 412405N0731457.1. Fred Hain. Drilled 1976. Altitude 390 ft. Depth to water 46 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 1	1
Sand and gravel (mostly medium to coarse sand; some very coarse sand and very fine gravel; ¼-½ in stones)	1 - 6	5
Sand, very fine to fine, with small 1-ft layers of gravel	6 - 26	20
Sand and gravel (mostly fine to coarse sand, ½-1 in stones)	26 - 39	13
Sand, fine; some medium sand; some very fine sand; trace coarse sand; trace silt and clay	39 - 50	11
Sand and gravel, poorly sorted; little silt and clay (till?)	50 - 63	13
End of hole	at 63	

NT 68 th. 412404N0731457. F. Francis D'Addarrio. Drilled 1976. Altitude 335 ft. Depth to water 17 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 2	2
Sand, very fine, and silt	2 - 7	5
Sand and gravel (mostly medium to coarse sand with ½-1 in stones); trace silt and clay	7 - 12	5
Sand, fine to very fine, with few thin gravel zones	12 - 20	8
Sand and gravel	20 - 21	1
Sand, very fine, and silt with thin gravel zones	21 - 32	11
Sand and gravel, poorly sorted; little silt and clay (till?)	32 - 46	14
Refusal	at 46	

NT 69 th. 412405N0731458.1. Potatuck Fish and Game Club. Drilled 1976. Altitude 304 ft. Depth to water 7 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 2	2
Sand and gravel (mostly medium to coarse sand with 1-1½ in stones)	2 - 9	7
Sand, very fine to fine; trace silt and clay; trace medium sand; some small gravel layers	9 - 14	5
Sand, fine; some medium sand; some very fine sand; some small gravel layers	14 - 22	8
Sand, very fine to fine	22 - 30	8
Sand, fine; some medium sand; little coarse sand; little very fine sand with small sand and gravel layers (mostly medium to coarse sand and very fine to fine gravel; some ½ in stones)	30 - 38	8
Sand and gravel, poorly sorted	38 - 41	3
Sand, fine; some medium sand; little coarse sand	41 - 42	1
Sand and gravel, poorly sorted, or till	42 - 45	3
Refusal	at 45	

NT 70 th. 412446N0731503.1. William D. Murphy. Drilled 1976. Altitude 350 ft. Depth to water 25 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Fill (gravel)	0 - 2	2
Sand and gravel (mostly medium to coarse sand, 1-4 in stones)	2 - 12	10
Sand, medium to very coarse; some very fine gravel; some small gravel zones	12 - 17	5
Sand, coarse to very coarse; some medium sand; some very fine gravel	17 - 20	3
Sand and gravel (mostly very fine to medium sand); trace silt and clay	20 - 28	8
Sand, very fine, and silt; little fine sand	28 - 53	25
Till, gray	53 - 63	10
Refusal	at 63	

NT 71 th. 412425N0731540.1. 11 Realty Co. Drilled 1976. Altitude 370 ft. Depth to water 12 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 2	2
Sand and gravel (mostly fine to medium sand with ½-1 in stones)	2 - 5	3
Sand, very fine to fine	5 - 12	7
Sand, very fine, and silt with some small clay layers	12 - 71	59
Till, gray	71 - 72	1
End of hole	at 72	

NT 72 th. 412525N0731619.1. Mary G. Stefanko. Drilled 1976. Altitude 270 ft. Depth to water 10 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Fill, gravel	0 - 3	3
Sand, very fine, and silt	3 - 7	4
Sand and gravel	7 - 10	3
Sand, fine to medium; little very fine sand; trace silt and clay	10 - 17	7
Sand, medium; some very fine sand; little fine sand; little coarse sand; trace silt and clay	17 - 22	5
Sand and gravel, poorly sorted; trace silt and clay	22 - 75	53
Sand, very coarse; little coarse sand; little very fine gravel; little very fine to medium sand; little fine to medium gravel; very compact	75 - 79	4
Till(?)	79 - 82	3
Refusal	at 82	

NT 73 th. 412337N0731501. Potatuck Fish and Game Club. Drilled 1976. Altitude 321 ft. Depth to water 26 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 2	2
Sand, fine to very fine	2 - 17	15
Sand, fine to medium; little very fine sand; little coarse sand; trace silt and clay	17 - 52	35
Sand, very fine; some fine and medium sand; trace silt and clay	52 - 57	5
Sand, fine; some very fine sand; little medium sand; little silt and clay	57 - 67	10
Sand, coarse; some medium sand; trace very coarse sand; some fine sand; trace of very fine sand	67 - 72	5
Sand, fine to medium; little very fine sand; little coarse sand, little silt and clay	72 - 73	1
Sand and gravel, poorly sorted; trace silt and clay, with small fine to medium sand layers	73 -102	29
Till(?)	102 -103	1
Refusal	at 103	

NT 74 th. 412515N0731633.1. Elizabeth Keane. Drilled 1976. Altitude 258 ft. Depth to water 3 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 2	2
Sand and gravel (mostly fine to coarse sand; few ½-1 in stones).	2 - 15	13
Sand and gravel, poorly sorted, or till(?)	15 - 20	5
Refusal (grinding on rock or boulder)	at 20	

NT 75 th. 412513N0731620.1. Town of Newtown. Drilled 1976. Altitude 342 ft. Depth to water 6 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Sand and gravel, poorly sorted	0 - 10	10
Sand, very fine to medium; trace very coarse sand; trace silt and clay; some small zones of gravel	10 - 22	12
Till, red-brown	22 - 31	9

NT 76 th. 412442N0731557.1. Fairfield Hills Hospital. Drilled 1976. Altitude 257 ft. Depth to water 7 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Topsoil with sand and gravel	0 - 2	2
Sand and gravel	2 - 4	2
Sand, very fine, and silt; trace clay	4 - 36	32
Sand, very fine, to very fine gravel; trace silt and clay	36 - 37	1
Sand, very fine, and silt	37 - 39	2
Sand and gravel, poorly sorted; trace silt and clay	39 - 50	11
Till, gray	50 - 51	1
Refusal	at 51	

NT 77 th. 412413N0731454.1. Potatuck Fish and Game Club. Drilled 1976. Altitude 278 ft. Depth to water 9 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 2	2
Sand, fine to medium; little silt and clay	2 - 7	5
Sand and gravel	7 - 9	2
Sand, fine to coarse	9 - 17	8
Sand and gravel, poorly sorted;, little silt and clay	17 - 19	2
Sand, fine, and very fine sand; trace silt and clay	19 - 24	5
Sand, medium to very coarse sand; little very fine to fine gravel; some small poorly sorted sand and gravel layers	24 - 42	18
Sand, fine, to very fine gravel; trace fine to medium gravel; trace silt and clay; some small poorly sorted sand and gravel layers	42 - 47	5
Sand, very fine to fine; trace medium sand; trace silt and clay	47 - 53	6
Sand and gravel, poorly sorted	53 - 57	4
Sand, fine to medium; trace silt and clay	57 - 69	12
Sand and gravel, poorly sorted; trace silt and clay	69 -110	41
Till(?)	110 -113	3
End of hole	at 113	

NT 78 th. 412341N0731500.1. Fairfield Hills Hospital. Drilled 1976. Altitude 285 ft. Depth to water 7 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 2	2
Sand, very fine; some fine sand; little silt and clay; trace medium to coarse sand	2 - 15	13
Sand and gravel, poorly sorted; little silt and clay	15 - 27	12
Sand, fine; little medium sand; little very fine sand; little coarse sand; trace silt and clay	27 - 35	8
Sand and gravel, poorly sorted; trace silt and clay	35 - 46	11
Sand and gravel, poorly sorted; little silt and clay (till?)	46 - 52	6
Till(?)	52 - 56	4

NT 79 th. 412423N0731555.1. Fairfield Hills Hospital. Drilled 1976. Altitude 246 ft. Depth to water 3 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 2	2
Organic swamp deposits	2 - 7	5
Sand and gravel	7 - 12	5
Sand, medium to very coarse; little very fine to fine sand; little very fine to medium gravel; trace silt and clay	12 - 21	9
Sand, very fine to fine; little medium sand; trace silt and clay	21 - 26	5
Sand, fine; some medium sand; trace silt and clay	26 - 40	14
Till	40 - 50	10
Refusal	at 50	

NT 80 th. 412236N0731515.1. H. G. Hempstead. Drilled 1976. Altitude 338 ft. Depth to water 6 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 2	2
Organic swamp deposits mixed with gravel	2 - 7	5
Sand, fine to medium; some coarse sand and very fine gravel	7 - 25	18
Sand and gravel, poorly sorted; trace silt and clay	25 - 29	4
Sand, coarse to very coarse; some very fine to medium sand; some very fine to medium gravel; trace silt and clay	29 - 47	18
Sand and gravel, poorly sorted; little silt and clay	47 - 73	26
Sand, fine to medium; little coarse sand; little very fine sand	73 - 82	9
Sand and gravel, poorly sorted; trace silt and clay	82 - 86	4
Sand and gravel, poorly sorted; little silt and clay (till?)	86 -102	16
Till	102 -105	3

NT 81 th. 412306N0731509.1. State of Connecticut. Drilled 1975. Altitude 310 ft. Depth to water 0 ft. Log by General Borings, Inc.

	Depth (feet)	Thickness (feet)
Sand, fine to coarse, yellow-brown; little silt; some medium to fine gravel; trace coarse gravel	0 - 10	10
Sand, very fine, tan; trace silt; medium to coarse sand; trace fine gravel	10 - 15	5
Sand, very fine, tan; trace silt; trace fine gravel	15 - 20	5
Sand, very fine, tan; some silt; trace medium gravel	20 - 30	10
Sand, very fine, tan; some silt; trace fine gravel; some fine to coarse sand; little fine to medium sand	30 - 35	5
Sand, very fine, tan; some silt; trace coarse sand; trace fine gravel	35 - 45	10
Sand, fine, tan; trace medium sand; trace silt	45 - 50	5
Sand, fine, tan; trace medium sand; trace silt; trace fine to medium sand	50 - 55	5
Rock	55 - 60	5

NT 82 th. 412306N0731510.1. State of Connecticut. Drilled 1975. Altitude 314 ft. Depth to water 6 ft. Log by General Borings, Inc.

	Depth (feet)	Thickness (feet)
Sand, fine, tan; some medium to coarse sand; little fine to coarse gravel; trace silt	0 - 10	10
Sand, fine to coarse, tan; trace fine to coarse gravel	10 - 15	5
Sand, fine, tan; trace fine gravel; trace coarse sand; trace silt	15 - 20	5
Sand, fine to medium, tan	20 - 30	10
Sand, fine to medium, tan; trace coarse sand	30 - 35	5
Sand, very fine to fine, tan; trace medium sand	35 - 40	5
Sand, fine, yellow-brown	40 - 65	25
Refusal	at 65	

NT 83 th. 412306N0731510.2. State of Connecticut. Drilled 1970. Altitude 315 ft. Depth to water 2 ft. Log by Conn. Dept. of Transportation.

	Depth (feet)	Thickness (feet)
Sand, fine to coarse, gray-brown; little fine to medium gravel; little silt	0 - 4	4
Sand, coarse to fine, tan; little medium to fine gravel; little silt	4 - 8	4
Sand, fine to coarse, tan-gray; little silt	8 - 20	12
Sand, fine, tan; little silt; trace coarse sand	20 - 28	8
Sand, fine, tan; little silt	28 - 40	12
Sand, fine, tan; some silt	40 - 65	25
Sand, fine to coarse, tan; little silt	65 - 69	4
Sand, coarse to fine; some medium to fine gravel; little silt; (till?)	69 - 71	2
Rock	71 - 81	10

NT 84 th. 412309N0731509.1. State of Connecticut. Drilled 1970. Altitude 362 ft. Depth to water 33 ft. Log by Conn. Dept. of Transportation.

	Depth (feet)	Thickness (feet)
Topsoil, brown	0 - 4	4
Sand, fine, rust-brown; silt	4 - 7	3
Sand, fine, gray; silt	7 - 9	2
Gravel, fine to medium, and coarse sand; little fine sand; trace silt	9 - 14	5
Gravel, gray, and coarse sand; little fine sand; trace silt (till)	14 - 29	5
Rock	29 - 39	10

NT 85 th. 412309N0731535.1. Town of Newtown. Drilled 1976. Altitude 397 ft. Depth to water 3 ft. Log by American Drilling and Boring Co.

	Depth (feet)	Thickness (feet)
Silt, gray-brown; little fine sand	0 - 15	15
Sand, coarse to fine; little silt, cobbles, and fine to medium gravel (till)	15 - 19	4

NT 86 th. 412258N0731528.1. Town of Newtown. Drilled 1976. Altitude 390 ft. Depth to water 30 ft. Log by American Drilling and Boring Co.

	Depth (feet)	Thickness (feet)
Sand, fine to medium, brown; little silt; trace fine to medium gravel	0 - 30	30
Sand, coarse to fine, brown; coarse to fine gravel; cobbles and boulders; trace silt (til?).	30 - 52	22
Granite gneiss, pink-brown, fractured	52 - 57	5

NT 87th. 412302N0731528.1. Town of Newtown. Drilled 1976. Altitude 395 ft. Depth to water 13 ft. Log by American Drilling and Boring Co.

	Depth (feet)	Thickness (feet)
Silt, brown-gray; little fine sand	0 - 4	4
Sand, fine to medium, brown-gray; some fine to medium gravel; trace silt; trace coarse sand	4 - 9	5
Sand, fine to coarse, brown-gray; some fine to medium gravel; trace silt	9 - 19	10
Sand, fine, brown, and silt; trace fine gravel	19 - 24	5
Silt, brown-gray; trace clay; trace fine sand	24 - 69	45
Silt, brown-gray; fine to medium sand; cobbles (till)	69 - 74	5
Rock, pink-brown, weathered gneiss	74 - 81	7

NT 88 th. 412257N0731518.1. Town of Newtown. Drilled 1976. Altitude 359 ft. Depth to water 37 ft. Log by American Drilling and Boring Co.

	Depth (feet)	Thickness (feet)
Sand, fine to medium; little silt; little fine to medium gravel	0 - 15	15
Sand, coarse to fine; coarse to fine gravel; trace silt	15 - 25	10
Sand, fine to medium, brown-gray; little silt; trace fine to medium gravel (layered)	25 - 30	5
Sand, coarse to fine, brown; coarse to fine gravel; little silt; cobbles	30 - 40	10
Sand, fine to medium, brown	40 -100	60
Sand, fine to medium, brown; little fine to coarse gravel; cobbles.	100 -116	16
Rock	116 -121	5

NT 89 th. 412256N0731525.1. Town of Newtown. Drilled 1976. Altitude 383 ft. Depth to water 60 ft. Log by American Drilling and Boring Co.

	Depth (feet)	Thickness (feet)
Silt, gray-brown, and fine sand	0 - 40	40
Sand, fine, brown; some silt	40 - 80	40
Refusal	at 80	

NT 90 th. 412255N0731521.1. Town of Newtown. Drilled 1976. Altitude 369 ft. Depth to water, dry. Log by American Drilling and Boring Co.

	Depth (feet)	Thickness (feet)
Fill, garbage and sand	0 - 5	5
Sand, fine to medium, brown; little silt; trace fine to medium gravel; cobbles	5 - 38	33
Rock	38 - 43	5

NT 91 th. 412300N0731554.1. Town of Newtown. Drilled 1976. Altitude 379 ft. Depth to water 41 ft. Log by American Drilling and Boring Co.

	Depth (feet)	Thickness (feet)
Fill, garbage	0 - 20	20
Sand, fine, brown-gray; little silt	20 - 35	15
Silt, brown; some fine sand	35 - 40	5
Sand, coarse to fine, brown; trace silt (till?)	40 - 45	5
Sand, coarse to fine, brown; little silt; little fine to coarse gravel (till?)	45 - 55	10
Rock, granite gneiss	55 - 64	9

NT 92 th. 412408N0731457.1. Town of Newtown. Drilled 1946. Altitude 274 ft. Depth to water 5 ft. Log by R. E. Chapman Co.

	Depth (feet)	Thickness (feet)
Gravel, coarse	0 - 15	15
Sand, fine	15 - 60	45
Clay	60 - 85	25
Hardpan	85 - 90	5
Clay	90 - 95	5
Hardpan (till?)	95 -107	12
Ledge	at 107	

NT 93 th. 412402N0731458.1. Fairfield Hills Hospital. Drilled 1946. Altitude 277 ft. Depth to water 5 ft. Log by R. E. Chapman Co.

	Depth (feet)	Thickness (feet)
Hardpan (gravel?)	0 - 10	10
Sand, fine	10 - 35	25
Gravel and clay	35 - 70	35
Gravel	70 - 80	10
Hardpan	80 - 90	10
Gravel, hard (till?)	90 -100	10
Ledge	at 100	

NT 94 th. 412436N0731503.1. Town of Newtown. Drilled 1968. Altitude 320 ft. Depth to water 37 ft. Log by S. B. Church Co.

	Depth (feet)	Thickness (feet)
Cobble hardpan	0 - 10	10
Sand, coarse, some pea gravel	10 - 25	15
Sand, fine	25 - 35	10
Sand, coarse, very hard	35 - 45	10
Sand, coarse; layers of clay	45 - 55	10
Hardpan (till?)	55 - 60	5
Rock	60 - 63	3

NT 95 th. 412435N0731512.1. Town of Newtown. Drilled 1968. Altitude 280 ft. Depth to water 20 ft. Log by S. B. Church Co.

	Depth (feet)	Thickness (feet)
Sand, coarse, and gravel	0 - 20	20
Gravel hardpan	20 - 44	24
Ledge	44 - 54	10

NT 96 th. 412442N0731504.1. Town of Newtown. Drilled 1968. Altitude 305 ft. Depth to water 8 ft. Log by S. B. Church Co.

	Depth (feet)	Thickness (feet)
Sand, coarse	0 - 10	10
Sand, coarse, and gravel	10 - 20	10
Sand, coarse; some pea gravel	20 - 27	7
Sand, medium, brown	27 - 35	8
Sand, coarse, very hard	35 - 40	5
Sand, medium, layers of clay (till?)	40 - 49	9
Ledge	49 - 58	9

NT 97 th. 412220N0731614.1. F. Francis D'Addario. Drilled 1976. Altitude 370 ft. Depth to water 3 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Sand and gravel	0 - 7	7
Sand, fine to coarse; trace very fine sand, silt, and clay	7 - 12	5
Sand and gravel, poorly sorted; trace silt and clay	12 - 22	10
Till	22 - 27	5

NT 98 th. 412208N0731559.1. F. Francis D'Addario. Drilled 1976. Altitude 387 ft. Depth to water 4 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Sand and gravel	0 - 2	2
Sand, fine to medium; some very fine sand, silt, and clay; some coarse to very coarse sand; little very fine to medium gravel	2 - 15	13
Sand, medium to coarse; little fine sand; little very coarse sand; trace very fine to medium gravel; little very fine sand, silt, and clay	15 - 18	3
Sand, very fine, and silt; trace clay	18 - 19	1
Sand, fine to medium; little very fine sand; trace silt and clay	19 - 24	5
Sand, very fine, and silt; some fine sand; trace clay	24 - 35	11
Sand, fine to medium; trace coarse sand; trace very fine sand; trace silt and clay	35 - 41	6
Till, gray	41 - 49	8
Refusal	at 49	

NT 99 th. 412320N0731458.1. Potatuck Fish and Game Club. Drilled 1976. Altitude 310 ft. Depth to water 12 ft. Log by U.S. Geol. Survey.

	Depth (feet)	Thickness (feet)
Sand and gravel	0 - 6	6
Sand, fine to medium; trace very fine sand; trace coarse sand	6 - 23	17
Till	23 - 30	7

NT 100 th. 412258N0731513.1. Town of Newtown. Drilled 1976. Altitude 320 ft. Depth to water 5 ft. Log by American Drilling Co.

	Depth (feet)	Thickness (feet)
Sand and gravel	0 - 16	16
Sand, fine to medium	16 - 25	9
Sand, fine	25 - 40	15
Sand and gravel, poorly sorted	40 - 68	28
Sand, medium to very coarse; trace gray silt and clay	68 - 72	4
Till	72 - 75	3
Refusal	at 75	

NT 101 th. 412256N0731513.1. Town of Newtown. Drilled 1976. Altitude 320 ft. Depth to water 5 ft. Log by American Drilling Co.

	Depth (feet)	Thickness (feet)
Topsoil	0 - 1	1
Sand, fine to coarse; some fine to medium gravel; trace silt	1 - 8	7
Sand, fine to coarse; trace of fine gravel; trace silt	8 - 13	5
Silt, brown	13 - 19	6
Sand, fine, silty	19 - 39	20
Sand, fine; trace silt	39 - 52	13
Sand, fine; little silt; trace fine gravel	52 - 56	4
Sand, fine; trace silt	56 - 65	9
Sand, fine; some silt; trace fine to medium gravel (till?)	65 - 68	3
Refusal	at 68	

WATER QUALITY DATA

SURFACE WATER

STATION NUMBER	DATE OF SAMPLE	TIME	INSTANTANEOUS DISCHARGE (CFS)	SPECIFIC CONDUCTANCE (MICROMHOS)	PH (UNITS)	TURBIDITY (JTU)	DISSOLVED OXYGEN (MG/L)	PERCENT SATURATION	IMMEDIATE COLIFORM (COL. PER 100 ML)	FECAL COLIFORM (COL. PER 100 ML)	STREPTOCOCCI (COLONIES PER 100 ML)
01203502	76-05-17	1205	26	87	7.2	2	10.0	99	1600	590	390
	76-09-13	1205	8.7	107	6.8	1	9.9	97	5900	80	140
01203503	76-09-14	1015	8.7	136	6.8	1	9.6	94	9200	440	78
01203504	76-05-17	0930	36	97	7.2	2	10.3	98	7400	240	160
	76-09-14	1235	11	132	7.2	1	10.2	103	5000	700	280
01203507	76-09-15	1115	3.2	291	7.5	1	10.1	107	2500	820	51
01203508	76-09-15	0950	13	176	7.0	1	9.6	97	6600	130	200

GROUND WATER

WELL OR SPRING NUMBER	DATE OF SAMPLE	TOTAL DEPTH OF WELL (FT)	SPECIFIC CONDUCTANCE (MICROMHOS)	PH (UNITS)	HARDNESS (CA,MG) (MG/L)	NONCARBONATE HARDNESS (MG/L)	DISSOLVED CALCIUM (CA) (MG/L)	DISSOLVED MAGNESIUM (MG) (MG/L)	DISSOLVED SODIUM (NA) (MG/L)
NT 1	60-10-19	130	298	6.7	137	0	35	12	4.6
NT 2	60-10-19	17	100	6.7	29	9	10	.9	3.8
NT 16	67-04-11	235	238	8.0	111	24	35	5.7	--
NT 17	67-04-17	118	219	7.8	90	34	24	7.3	--
NT 54	76-09-02	62	220	8.2	74	0	23	3.9	16
NT 56	76-09-01	31	650	7.1	130	100	33	11	53
	77-02-02	31	272	6.6	38	3	8.2	4.2	27
NT 57	76-09-01	15	40	7.2	9	0	2.3	.7	1.8
NT 58	76-09-02	49	229	7.2	90	33	22	8.5	5.8
NT 59	76-09-02	19	485	7.4	200	0	49	20	13
	77-02-02	19	372	7.2	150	0	41	11	9.8
NT 60	76-09-01	55	--	--	--	--	--	--	--
	76-09-01	55	110	7.4	32	15	7.7	3.2	5.8
NT 62	76-09-01	20	288	7.2	140	53	36	11	5.5
	77-02-02	20	370	7.3	110	52	29	9.1	4.9
NT 63	76-09-02	20	119	7.6	34	4	8.7	3.0	5.6
NT 64	76-09-02	20	75	7.4	21	5	5.6	1.7	3.9
	77-06-24	20	67	6.6	--	--	--	--	--
NT 65	76-09-01	12	236	6.5	66	35	17	5.8	15
	77-07-05	12	240	6.2	--	--	--	--	--
NT 1SP	68-11-13	430	164	7.1	52	22	15	3.6	8.6

WATER QUALITY DATA

SURFACE WATER

HARDNESS (CA,MG) (MG/L)	NON-CARBONATE HARDNESS (MG/L)	DISSOLVED CALCIUM (CA) (MG/L)	DISSOLVED MAGNESIUM (MG) (MG/L)	DISSOLVED SODIUM (NA) (MG/L)	BICARBONATE (HCO3) (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)	DISSOLVED CHLORIDE (CL) (MG/L)	DISSOLVED SOLIDS (RESIDUE AT 180 C) (MG/L)	TOTAL NITRITE PLUS NITRATE (N) (MG/L)	TOTAL PHOSPHORUS (P) (MG/L)	DISSOLVED IRON (FE) (UG/L)	DISSOLVED MANGANESE (MN) (UG/L)
25	5	6.5	2.1	4.4	24	11	6.4	53	.27	.04	210	20
37	13	10	2.8	5.6	29	9.2	11	72	.32	.04	180	20
45	12	12	3.7	7.1	40	11	18	95	.36	.02	140	10
30	11	7.7	2.5	4.9	23	9.6	8.3	95	.32	.03	170	10
48	15	13	3.7	6.9	40	12	21	92	.36	.03	130	0
90	42	25	6.7	20	58	30	43	203	1.6	1.3	70	0
57	22	16	4.2	9.9	43	13	23	123	.65	.21	130	10

GROUND WATER

DISSOLVED POTASSIUM (K) (MG/L)	BICARBONATE (HCO3) (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)	DISSOLVED CHLORIDE (CL) (MG/L)	DISSOLVED FLUORIDE (F) (MG/L)	DISSOLVED SOLIDS (RESIDUE AT 180 C) (MG/L)	TOTAL NITRITE PLUS NITRATE (N) (MG/L)	TOTAL PHOSPHORUS (P) (MG/L)	DISSOLVED IRON (FE) (UG/L)	DISSOLVED MANGANESE (MN) (UG/L)
1.1	176	6.0	2.7	--	182	--	--	230	200
1.4	24	4.2	13	--	68	--	--	80	--
--	106	28	2.1	--	135	--	--	30	30
--	68	36	5.9	--	130	--	--	20	30
6.4	118	11	13	.5	162	.01	1.7	1300	60
5.3	32	9.8	160	.1	409	.61	4.3	60	4200
3.0	43	11	41	.1	253	3.4	6.1	1400	1600
.9	12	1.8	3;8	.1	29	.01	1.3	40	30
3.8	70	18	16	.1	150	1.9	23	60	140
3.9	270	8.0	10	.2	278	.02	5.6	60	15000
3.6	216	3.6	10	.1	211	.92	6.4	1700	13000
--	--	--	--	--	--	--	--	--	--
3.0	21	17	8.4	.1	77	.97	1.9	300	440
3.8	100	66	2.9	.2	229	.44	.66	60	340
3.6	70	62	1.2	.1	155	.35	5.7	10	390
2.9	37	16	11	.1	77	.05	3.1	60	820
2.9	20	10	5.2	.1	51	.14	2.3	70	250
--	--	--	--	--	--	--	--	--	--
3.3	38	19	36	.1	150	.14	5.6	850 *	3900
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2.0	37	17	18	.0	104	--	--	20	410

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☆U.S. GOVERNMENT PRINTING OFFICE: 1978—700-365/163

FRONT COVER.--Oblique aerial photograph of the Pootatuck River valley, Newtown, Connecticut, looking northwest from Botsford towards Sandy Hook. Fairfield Hills Hospital can be seen in the upper left and Rt. 84 crossing the upper right corner. The Pootatuck River winds through the forested area from the lower left through the center.

Photograph by Kenith Schurwernik,
Western Connecticut State College