WATER AVAILABILITY AND QUALITY FROM THE STRATIFIED DRIFT IN ANGUILLA BROOK BASIN, STONINGTON AND NORTH STONINGTON, CONNECTICUT

By James W. Bingham

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CONVERSION TABLE AND ABBREVIATIONS

For the benefit of readers who prefer metric (International System) units rather than the inch-pound units in this report, the following conversion factors may be used:

Multiply inch-pound unit	by	To obtain metric unit
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]
gallon per minute (gal/min)	0.06308	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
million gallons per day (Mgal/d)	3,785	cubic meters per day (m^3/d)
million gallons per day per square mile [$(Mgal/d)/mi^2$]	1,460	cubic meters per day per square kilometer [$(m^3/d)/km^2$]

	Hydraulic Conductivity	
hydraulic conductivity, foot per day (ft/d)	0.3048	hydraulic conductivity, meter per day (m/d)
	Transmissivity	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
	Temperature	
degree Fahrenheit (°F)	°C = 5/9 × (°F-32)	degree Celsius (°C)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)-- geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929".

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ABSTRACT

The valley of Anguilla Brook is underlain by saturated stratified-drift deposits that, where thick and transmissive, have the potential to yield large quantities of ground water. These deposits are collectively termed the Anguilla Brook aquifer. Long-term yields of four subareas within this aquifer are estimated to range from less than 0.3 to 1.0 million gallons per day. The total yield of all four subareas is estimated to be 2.6 million gallons per day. These yield estimates are based on using the 90-percent duration flow of Anguilla Brook as an index of the water potentially available and on maximum sustainable pumping rates calculated by a mathematical model that used the Theis nonequilibrium equation and image well theory. Development of one or more subareas assumes that most ground water would be derived from induced recharge. This would reduce the flow of Anguilla Brook, and the effect will be most significant during periods when streamflow is low.

Limited sampling and analysis indicate that the quality of both surface and ground water in the Anguilla Brook basin is excellent. The concentrations of all constituents analyzed, with the exception of dissolved manganese and iron, were below the drinking-water limits established by the State of Connecticut, or recommended by the U.S. Environmental Protection Agency.

INTRODUCTION

Purpose and Scope

Saturated deposits of stratified drift drained by Anguilla Brook and its tributaries comprise the Anguilla Brook aquifer, which has the potential for large-scale ground-water development in the Stonington area. The Anguilla Brook aquifer is the only major ground-water source, other than the stratified drift adjacent to the Pawcatuck River, that is within reasonable distance of Pawcatuck, a community of 7,400 that is presently served by public water supply from Westerly, Rhode Island. Planners and town officials are considering the Anguilla Brook aquifer as a possible source of long-term water supply to meet present and future needs of the region.

This report provides estimates of the amounts of ground water available from the Anguilla Brook aquifer and assesses the present quality of surface water and ground water in the area. Four subareas of the Anguilla Brook aquifer have been evaluated to determine their long-term ground-water yield. The analytical technique used in these evaluations first estimates the total amount of ground water potentially available in an area and then employs a mathematical model to determine how much of that total amount can be withdrawn over the long term without excessive drawdowns in the pumping wells. Water samples from Anguilla Brook and the Anguilla Brook aquifer were collected and analyzed to evaluate the present quality of surface water and ground water with respect to drinking-water standards established by the State of Connecticut (Connecticut General Assembly, 1975).

Physical Setting

The Anguilla Brook basin is located in southeastern Connecticut, in the towns of Stonington and North Stonington (fig. 1). It has an area of about 10 mi^2 (square miles) and lies midway between the communities of Pawcatuck and Stonington. Land use is mostly rural and the basin is traversed by Interstate Route 95, U.S. Route 1, Connecticut Route 184, and an Amtrak rail line. In 1982, the populations of Stonington and North Stonington were 16,580 and 4,270, respectively (Connecticut Secretary of the State, 1982). An estimated 2,000 persons live in the Anguilla Brook basin.

The climate is moderated by the proximity of Fishers Island Sound but the area is frequently visited by winter and summer continental air masses (Brumbach, 1965). The mean annual air temperature is about 51 °F (degrees Fahrenheit). Mean monthly air temperatures range from a low in January of 22 °F to a high in July of 81 °F (Smith, 1974). The frost-free season extends, on the average, from April 15 to October 25 and results in an average growing season of 193 days. Mean annual precipitation at Groton, Connecticut (the nearest long-term weather station) is 47.51 inches for the 1931-81 period of record.

Previous Investigations

The ground-water resources of the Anguilla Brook area were briefly discussed by Thomas and others (1968), who used ground-water outflow estimates to conclude that the stratified-drift aquifer might yield as much as 3.4 Mgal/d (million gallons per day) over the long term. Surficial geology of the area was mapped and briefly discussed by Flint (1930). Detailed surficial maps of the eastern and southern parts of the Anguilla Brook basin that lie in the Ashaway and Mystic 7.5-minute quadrangles have been published by the U.S. Geological Survey (Schafer, 1968; Upson, 1971). Mapping in the western part of the area (Old Mystic 7.5-minute quadrangle) is in progress.

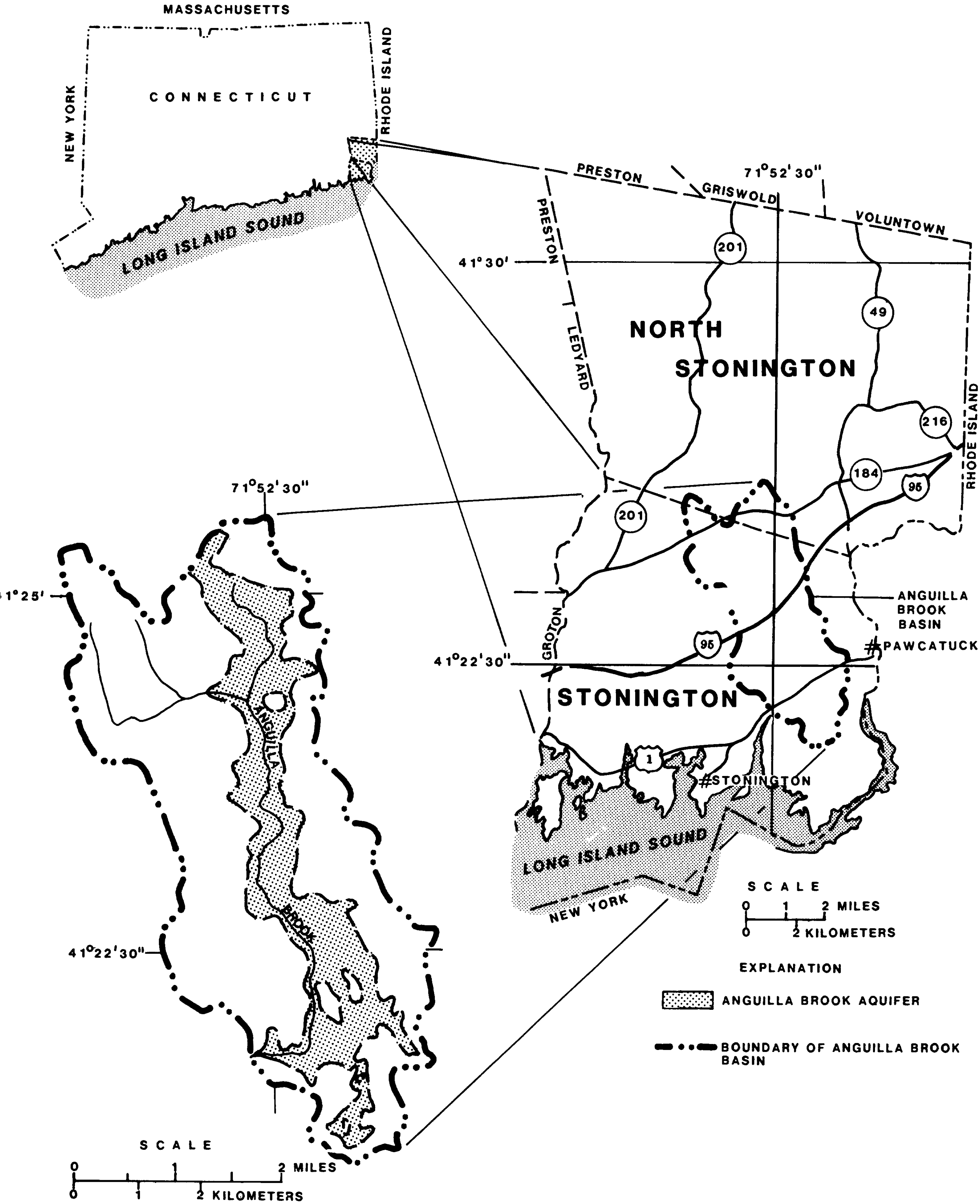


Figure 1.--Location of Anguilla Brook basin and Anguilla Brook aquifer, Stonington and North Stonington, Connecticut.

Acknowledgments

This investigation was conducted by the U.S. Geological Survey in cooperation with the Town of Stonington, Connecticut. The author is grateful for the assistance provided by officials of Stonington and concerned citizens and property owners in Stonington and North Stonington; their cooperation and contributions are sincerely appreciated.

DATA COLLECTION

During this investigation, a variety of hydrogeologic data were collected in the Anguilla Brook basin. The data are the basis for evaluating the long-term yield of the Anguilla Brook aquifer and assessing present water-quality conditions.

Seismic-refraction surveys were run along six profile lines that extend across the Anguilla Brook aquifer in order to determine depths to bedrock and depths to the water table. The seismic information was also used to design a subsequent test-drilling program. Interpretive hydrogeologic cross-sections along the six survey lines are shown in figure 15 (located at the end of this report). Fifteen test borings were made with a hollow-stem power auger to determine or verify depths to bedrock and depths to the water table and to collect samples of stratified drift for grain-size analysis. At nine of these sites, observation wells with 2-inch diameter PVC (polyvinyl chloride) plastic screens were installed to collect ground-water samples for chemical analysis and to periodically measure ground-water levels. Descriptions of these wells and test holes are given in table 8 (located at the end of this report); descriptions of other wells and test holes that provided additional hydrogeologic information are also given in this table.

The earth materials encountered while drilling the wells and test holes are described in table 9 (located at the end of this report). Selected samples of stratified drift, collected during the test drilling phase, were dried and sieved in order to determine the grain-size distribution of the material. As noted in a later section of this report, this information is used to estimate some of the hydrogeologic characteristics of stratified drift. The results of the grain-size analyses are given in table 10 (located at the end of this report).

Locations of the seismic-refraction profile lines, wells, test holes, streamflow measurement sites, and water-quality sampling sites are shown on plate 1.

DATA ANALYSIS

The first phase of data analysis consisted of integrating information on depths to the water table and bedrock with average hydraulic conductivity (estimated from grain-size characteristics and lithologic descriptions of stratified drift) to produce maps of saturated thickness and transmissivity of the Anguilla Brook aquifer. Subareas were selected from these maps that had relatively high saturated thickness and average transmissivity. The four subareas shown in figure 10 were selected for evaluation of their long-term yields.

The subarea evaluation consisted of estimating the water potentially available. Each subarea is traversed by Anguilla Brook and the water potentially available from this source is much greater than the recharge from precipitation. For this reason, and to simplify the evaluation, a low-flow characteristic (the 90-percent duration flow) of Anguilla Brook was selected as the water potentially available over the long term. The criteria for selection and computation process are discussed in more detail in the section of this report entitled "Ground-Water Potentially Available". Maximum pumping rates that could be sustained in each subarea on the basis of the hydrogeologic characteristics and assumed boundary conditions of the aquifer were computed by a simple mathematical model. The model elements and assumptions and the modeling procedure are outlined in the section of this report entitled "Maximum Long-Term Pumping Rates".

Long-term ground-water yields for each subarea are estimated for two different conditions. The first condition assumes no development of any upstream areas and the water potentially available is compared to the maximum pumping rates and the lesser quantity is considered to be the long-term ground-water yield. The second condition assumes maximum development of all upstream subareas and the water potentially available is adjusted to reflect the upstream withdrawals. The maximum pumping rates are then compared to these adjusted values and the lesser quantity is the long-term ground-water yield.

BASIN HYDROGEOLOGY

Geologic Framework

Stratified drift comprises the principal aquifer in the Anguilla Brook basin and is the focus of this study. This material was deposited by meltwater streams flowing southward away from the margin of glacial ice that stood against the low ridge located between Rocky Hollow Road and Assekonk Swamp in North Stonington (plate 1). The materials that make up the stratified-drift deposits were sorted by the actions of the meltwater streams--coarse-grained material was deposited in the northern part of the valley and finer-grained material was deposited to the south. In the southern part of the valley, the fine-grained sediments are overlain by several feet of coarse material. The geologic conditions that produced this "gravel cap" are unknown. As the ice mass continued its northward retreat, a drainageway opened up down the Shunock River valley and diverted meltwaters away from the Anguilla Brook valley.

Till and bedrock are the other major geologic units in the Anguilla Brook basin. These units underlie and are adjacent to the stratified-drift deposits as shown in figure 6, and are considered to form relatively impermeable boundaries for the Anguilla Brook aquifer. Wells tapping till and bedrock are much less productive than those in the stratified drift, but may yield water supplies adequate for homes, farms, or small businesses. Yields typically range from 1 to 10 gal/min (gallons per minute)--an amount too small for public-supply purposes.

Till is composed of unconsolidated and unsorted glacial material deposited near the margin of an ice sheet. In Connecticut, it commonly forms a layer of debris, less than 15 feet thick, that mantles much of the bedrock surface. This till has a low permeability in comparison to stratified drift and can be considered an effective barrier that significantly limits the flow of ground water between these two units.

Bedrock underlies both till and stratified drift in Stonington and North Stonington. It consists of metamorphic rock, generally gneiss (Rodgers, 1982). Bedrock also has a relatively low permeability, except where networks of open joints and fractures provide conduits for ground-water movement. Wells drilled into bedrock generally intercept these joints and fractures. Depending in part on the number and size of fractures encountered, the yield from a drilled well tapping bedrock in the Anguilla Brook area averages about 5 gal/min, and rarely exceeds 15 gal/min.

Circulation of Water

All the water in Anguilla Brook basin is derived from precipitation falling on the land surface. This water is constantly in motion. Some moves overland to streams (Wheeler and Anguilla Brooks and their tributaries) and leaves the basin as a component of streamflow; some moves downward through the soil, recharges the stratified-drift aquifer, and then leaves the basin either as ground-water runoff (another component of streamflow), or underflow; and some is stored temporarily on the land surface or in the soil zone and leaves by means of evapotranspiration. Water that is lost from the basin is eventually replenished by precipitation.

The hydrologic system in the Anguilla Brook basin is in balance and water entering, stored within, and leaving can be accounted for. This balance is represented by the equation:

$$P = SW(ro) + GW(ro) + U + ET \pm S$$

where:

P = Precipitation,
SW(ro) = Surface-water runoff (streamflow component),
GW(ro) = Ground-water runoff (streamflow component),
U = Underflow,
ET = Evapotranspiration, and
S = Changes in storage

Precipitation

Precipitation in the study area occurs throughout the year and monthly averages range from 2.5 to 5 inches. Figure 2 shows average monthly precipitation at nearby Groton, Connecticut (National Weather Service Index Number 3207), for the 1941-70 period. Annual precipitation at Groton for 1931-81 is shown in figure 3. During this 51-year period, precipitation averaged 47.51 inches annually. Figure 3 also includes a 5-year moving average that shows dry cycles, indicated by a declining line (1940-47, 1962-66) and wet cycles, indicated by a rising line (1947-55, 1966-73).

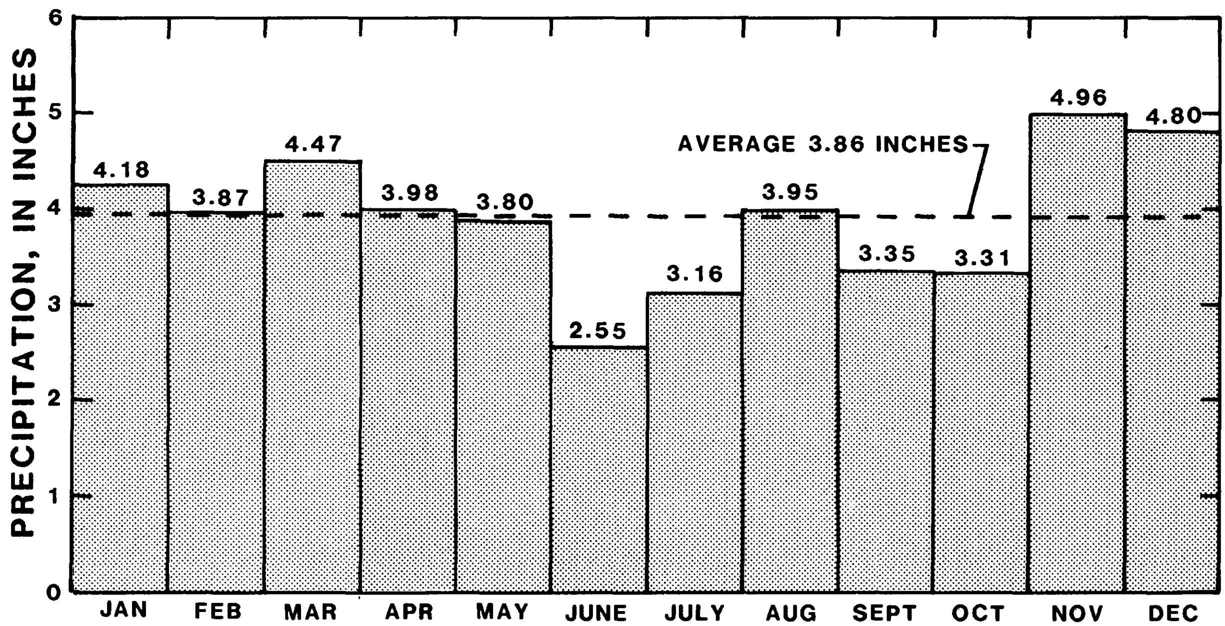


Figure 2.--Monthly average precipitation at Groton, Connecticut, 1941-70.

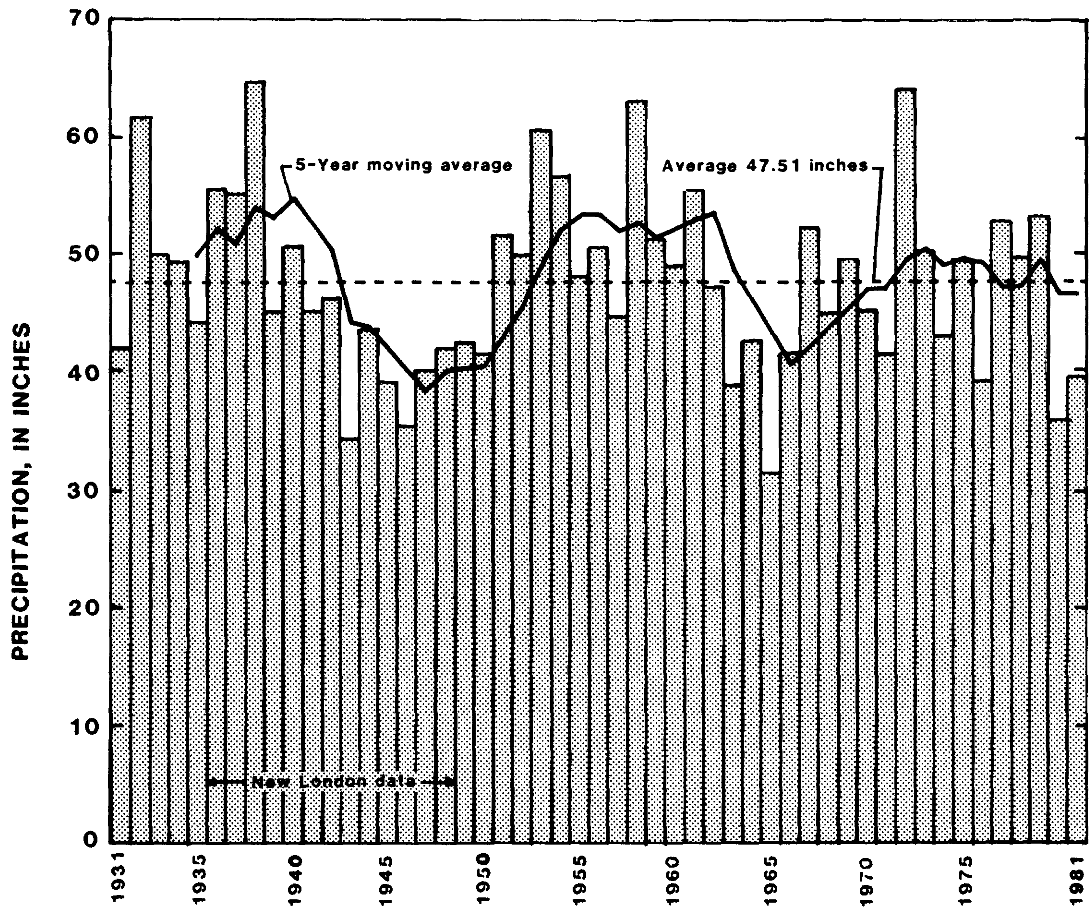
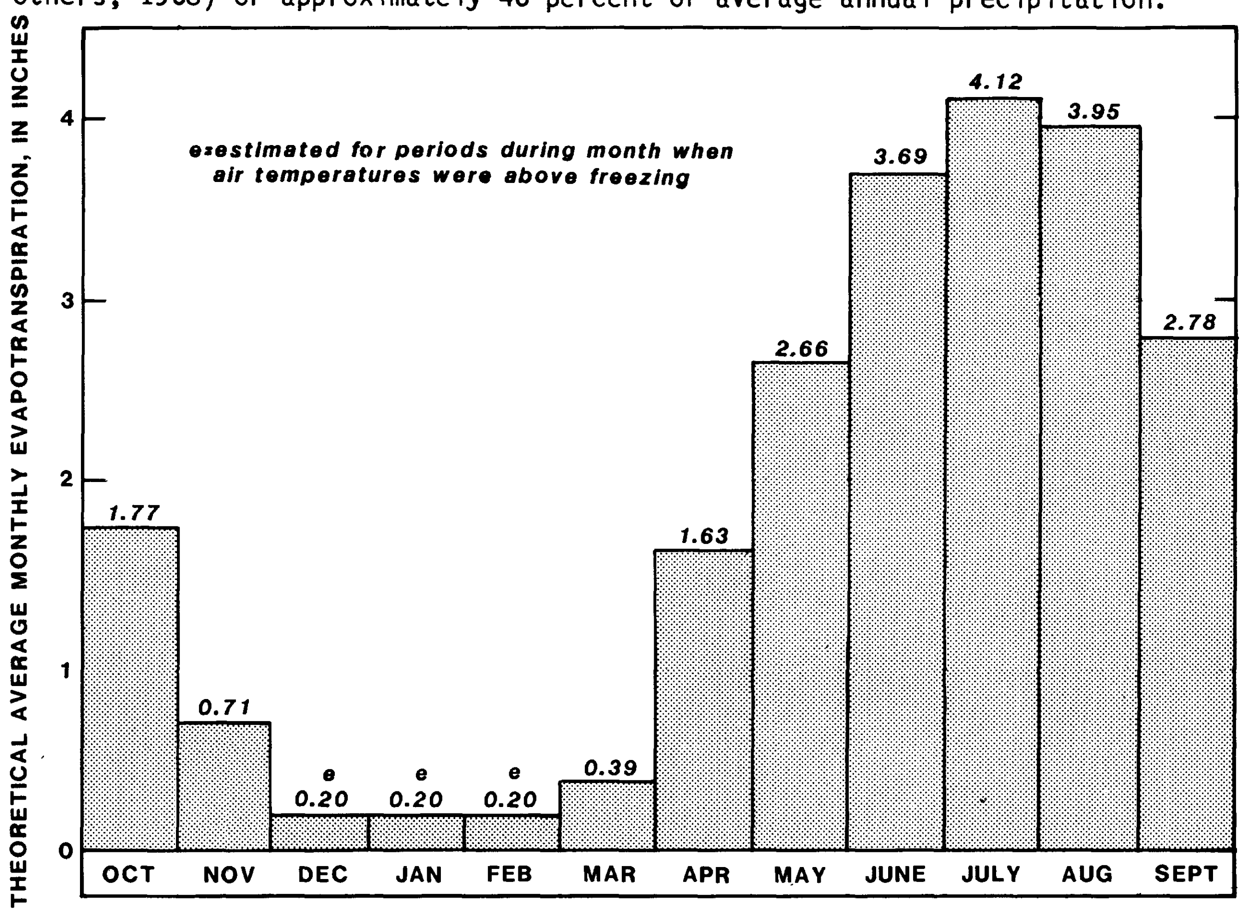


Figure 3.--Annual precipitation and 5-year moving average of annual values at Groton, Connecticut, 1931-81.

Evapotranspiration

Evapotranspiration is the direct loss of water to the atmosphere by evaporation from water surfaces and moist soil, and transpiration from living plants. Evapotranspiration is seasonal; plants are most active and may transpire large amounts of water during the frost-free growing season. Some plants such as evergreens also transpire during the winter months but at a reduced rate. Evaporation occurs all year long but is greatest during the summer months. These seasonal fluctuations are illustrated in figure 4, which shows how the theoretical monthly average evapotranspiration ranges from 0.20 inches in the winter months (December, January, and February) to 4.12 inches in the summer (July). The values in figure 4 are computed by a method similar to that of Thornwaite and Mather (1957) and are adjusted to account for changes in storage.

The estimated average annual evapotranspiration in the Anguilla Brook area during the 1931-60 period of record was about 22.3 inches (Thomas and others, 1968) or approximately 46 percent of average annual precipitation.



(From Thomas and others, 1968, fig.6)

Figure 4.--Estimated average monthly evapotranspiration in southeastern Connecticut, 1931-60.

Streamflow

Streamflow in the Anguilla Brook basin is estimated to have averaged about 2.0 $(ft^3/s)/mi^2$ (cubic feet per second per square mile) or about 12.8 Mgal/d during the 1931-60 period (Cervione and others, 1968). Long-term, average streamflow values include flood flows. For water-supply planning purposes, low-flow values are needed that reflect conditions during dry periods. Indices of low flow that are commonly used for water-resources planning in Connecticut are (1) the average streamflow equaled or exceeded 90 percent of the time or its approximate equivalent, the 30-day, 2-year low flow, and (2) the average streamflow equaled or exceeded 99 percent of the time or its approximate equivalent, the 7-day, 10-year low flow. Detailed discussion of these low-flow indices and how they are derived are found in Weiss and others (1982). Low-flow characteristics can be determined from records of stream-gaging stations or estimated by various regionalization techniques. The flow of Anguilla Brook has not been gaged and the low-flow values cited in this report are based on regional flow-duration curves developed by Thomas (1966). Adjustments representing drier than average and wetter than average conditions followed the procedures outlined in Weiss and others (1982, p. 12-17).

Figure 5 is a flow-duration curve for Anguilla Brook, for the period 1931-60 prepared by regionalization methods. It shows flows that are equaled or exceeded for various percentages of time in average, wettest, and driest years. The 90-percent duration flow of Anguilla Brook above Green Haven Road ranges from 1.5 Mgal/d during the driest year to about 5.0 Mgal/d during the wettest year. The average 90-percent duration flow at this site is about 2.5 Mgal/d.

Table 1, a summary of the low-flow characteristics of Anguilla Brook, lists the annual lowest mean flows for 2- and 10-year recurrence intervals that will occur for time periods ranging from 3 to 365 consecutive days. As noted above, the 90-percent duration flow value is approximately equal to the 30-day, 2-year low flow.

Low flows of Anguilla Brook were measured directly at four stations on August 19, 1982. The locations of these streamflow-measurement sites are shown on plate 1. The flow at nearby Pendleton Hill Brook, a long-term gaging station (station 01118300) was 0.86 ft^3/s (cubic feet per second) on this date; this was approximately equal to the 84-percent duration flow. The measured flow of Anguilla Brook ranged from 0.11 ft^3/s at Minor Pentway (station 01118530) to 2.5 ft^3/s at Connecticut Route 1 (station 01118550). The flows at Nathan Wheeler farm (station 01118535) and South Anguilla Road (station 01118548) were 1.4 ft^3/s and 2.1 ft^3/s respectively.

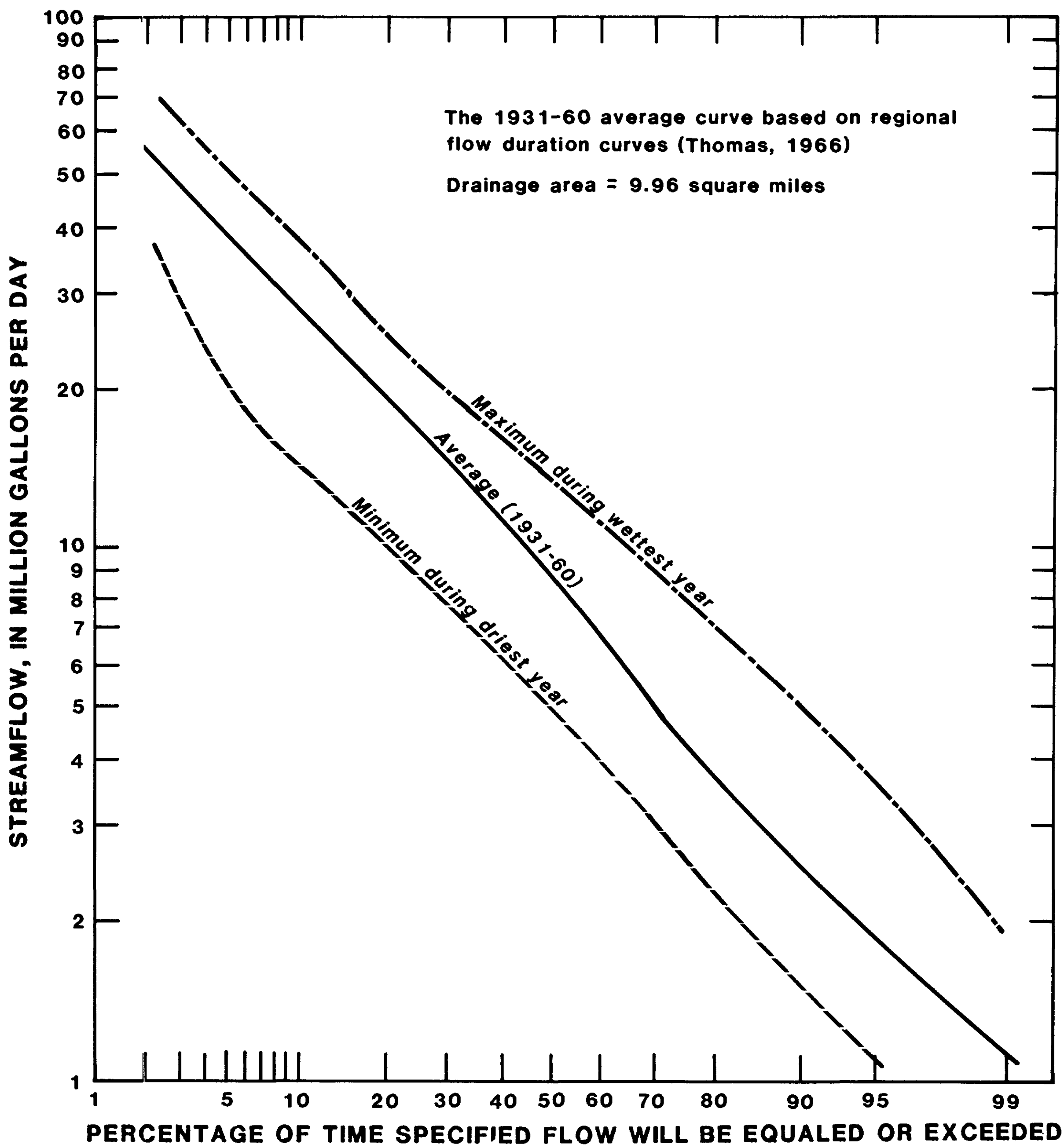


Figure 5.--Duration of daily flows of Anguilla Brook above Green Haven Road, 1931-60.

Table 1.--Annual lowest mean flows for Anguilla Brook above Green Haven Road
[All flows are in million gallons per day]

Recurrence interval (years)	Consecutive days						
	3	7	30	60	120	183	365
2	1.6	2.0	2.6	3.2	4.1	5.4	11.6
10	1.1	1.4	1.8	1.9	2.6	3.2	5.8

Ground-Water Recharge

The precipitation that does not flow directly over the land surface to streams and is not evapotranspired, percolates downward and recharges the aquifers in Anguilla Brook basin. Measurements of ground-water recharge are difficult to obtain and none are available in Connecticut. However, recharge can be estimated over a period of time by subtracting surface runoff and total evapotranspiration from precipitation. This technique assumes that the amount of ground water in storage at the beginning and end of the specified time is the same. Otherwise, the differences in ground-water storage must be taken into account. In southeastern Connecticut during the 1931-60 period, annual precipitation averaged 48.2 inches, surface runoff averaged 14.8 inches, and evapotranspiration averaged 22.3 inches (Thomas and others, 1968). These figures suggest that an average recharge of about 11.1 inches per year from precipitation is reasonable for the Anguilla Brook basin. Recharge to the stratified-drift aquifer is somewhat higher and is estimated to average about 20 inches per year.

Under conditions of development, induced recharge from streams can significantly augment recharge from precipitation. Pumping wells near a stream often cause the water table to fall below the level of the stream. This ultimately results in the infiltration of water from the stream into the adjacent aquifer. The amount of water available for this induced recharge, on a sustained basis, is limited by the flow of the stream.

HYDROGEOLOGIC CHARACTERISTICS OF STRATIFIED DRIFT

The amount of ground water that can be developed from a stratified-drift aquifer is affected by many factors. Of major importance are the hydrogeologic characteristics: saturated thickness, hydraulic conductivity, transmissivity (the product of average hydraulic conductivity and saturated thickness), and specific yield. Test holes, stratified-drift samples from these holes, water-level measurements, and seismic-refraction profiles provided information about these characteristics that are discussed in this section.

The saturated thickness of stratified drift that forms the Anguilla Brook aquifer is equal to the vertical distance from the water table to the underlying till or bedrock surface (fig. 6). It was determined by seismic-refraction profiling, test drilling, and evaluating information from existing wells. The locations of these data sites are shown on plate 1. The saturated thickness of the four subareas of the aquifer where long-term ground-water yields have been estimated is shown in figures 11 to 14.

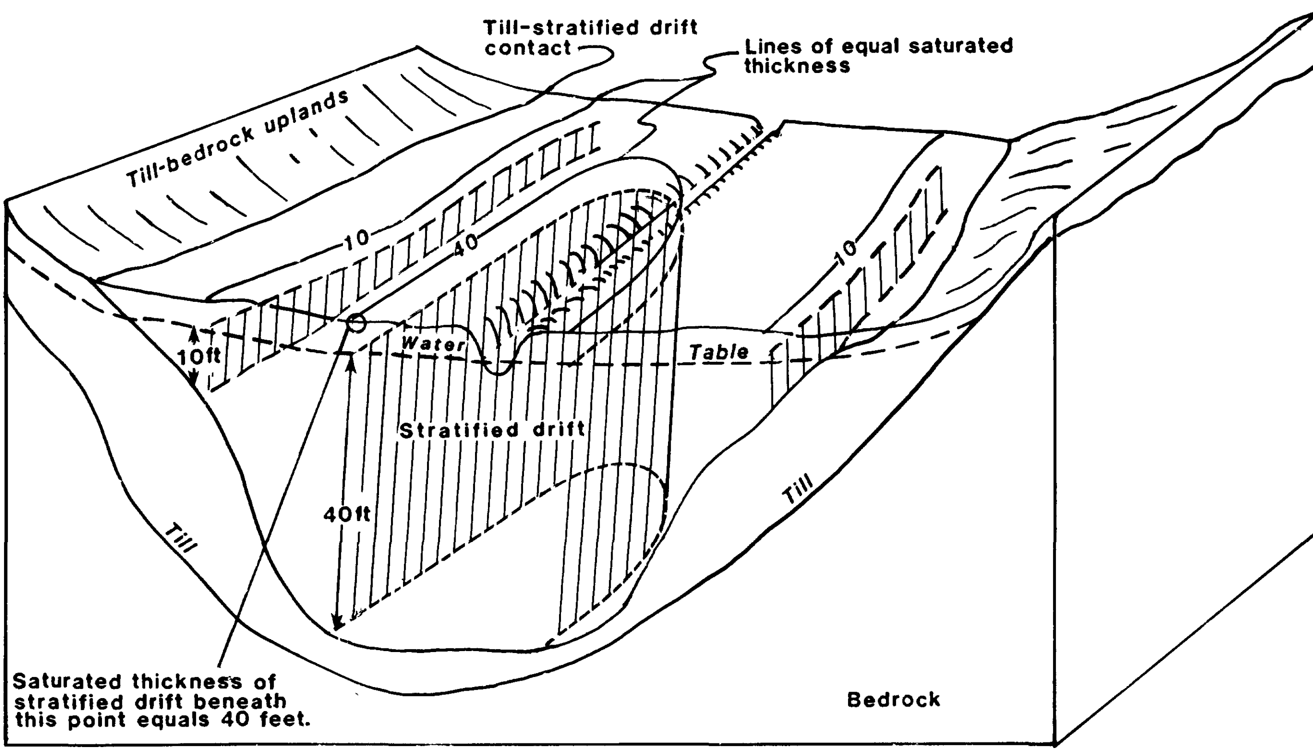
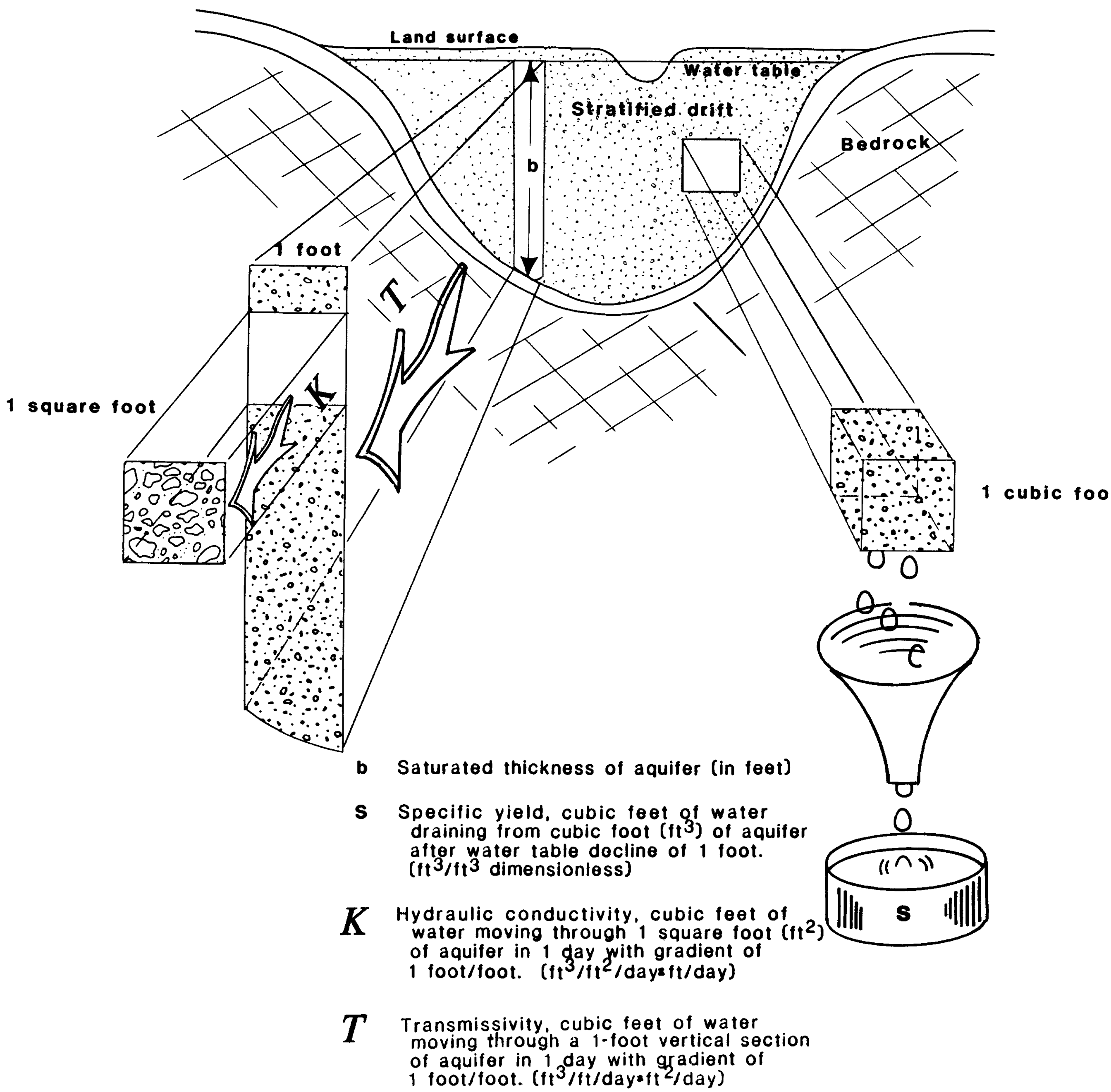


Figure 6.--Spatial relations between a stratified-drift aquifer and adjacent till and bedrock and the saturated thickness of the stratified drift.

The hydraulic conductivity of stratified drift is a measure of its ability to transmit water. In English units, a material would have a hydraulic conductivity of 1 foot per day if it transmitted 1 cubic foot of water in 1 day's time through a cross-sectional area of 1 square foot. The water is assumed to be at field viscosity, and to be under a hydraulic gradient of 1-foot change in head over 1-foot in length of flow path. Hydraulic conductivity is illustrated in figure 7. In the Anguilla Brook aquifer, the estimated hydraulic conductivity of the coarse-grained stratified drift generally ranges from 50 to 200 ft/d (feet per day).



(from Weiss and others, 1982)

Figure 7.--Hydraulic characteristics of a stratified-drift aquifer.

In this investigation, hydraulic conductivities are based on relations between this characteristic and the median-grain size and sorting of the stratified drift developed in previous Connecticut studies and summarized by Ryder and others (1970). The theoretical basis for these relations is discussed by Krumbein and Monk (1942), and Masch and Denny (1966). Estimates of the average hydraulic conductivity at different sites were developed from logs of test holes that have grain-size analyses of samples of the materials penetrated.

The transmissivity of an unconfined stratified-drift aquifer is a measure of the rate at which a fluid will pass through a section of it. In English units, an aquifer would have a transmissivity of 1 square foot per day if it transmitted 1 cubic foot of water through a section 1 foot in width that extended from the water table to the bottom of the aquifer. The water is assumed to be at field viscosity and to be under a hydraulic gradient of 1-foot change in head over 1-foot length of flow path. Transmissivity is equivalent to the average hydraulic conductivity times the saturated thickness and is illustrated in figure 7. In the Anguilla Brook aquifer, estimated transmissivity generally ranges from 2,000 to 6,000 ft^2/d (feet squared per day).

Transmissivities for the Anguilla Brook aquifer are based on the average hydraulic conductivity values determined for samples of stratified drift from test holes and information about changes in saturated thickness. Transmissivity was estimated at test-hole sites by summing the individual hydraulic conductivities of each foot of aquifer over the total saturated thickness. The technique is described by Weiss and others (1982). Zones of equal transmissivity for the four subareas of the Anguilla Brook aquifer evaluated for long-term yield were mapped by interpolating between data points. The resulting transmissivity distributions are shown in figures 11 through 14.

Specific yield is the ratio of the volume of water that a saturated earth material will yield, by gravity drainage, to its own volume. It is a term in flow equations used for calculating water-table drawdowns over different time periods in unconfined aquifers and is analogous to the storage coefficient of confined aquifers. Specific yield is controlled, in part, by the number and size of the intergranular pore spaces of the aquifer materials. Figure 7 illustrates the concept of specific yield and shows it is a dimensionless value obtained by measuring the volume of water drained by gravity, from a known volume of aquifer, over a relatively long period of time (100 to 200 days).

In the Anguilla Brook aquifer, specific yield was not measured directly. It is estimated to range from 0.15 to 0.30 and average 0.20, based on studies of similar unconsolidated sediments conducted elsewhere.

GROUND-WATER AVAILABILITY

Ground Water Potentially Available

The ground water potentially available for development from the Anguilla Brook aquifer, over the long term, is assumed to be equal to the 90-percent duration flow of Anguilla Brook (or this value adjusted for the effects of upstream development) at the point of anticipated withdrawal. This particular flow is commonly used in evaluating the yields of stratified-drift aquifers in Connecticut (Cervione and others, 1972; Mazzaferro and others, 1979) as it represents a fairly dependable quantity available for induced recharge 90 percent of the time. Selection of a higher flow could result in higher estimated long-term yields but would also result in potentially greater reductions in streamflow, particularly in summer months when streamflow is low and ground-water withdrawals are high. In fact, if all of the 90-percent flow was to infiltrate into the aquifer, all or parts of Anguilla Brook would be dry 10 percent of the time.

While the 90-percent duration streamflow is used as a limiting factor for estimating long-term yields, it is unlikely that all the water would come from the stream; some would be derived from recharge from precipitation and depletion of storage in the aquifer. This means that (1) if all or parts of Anguilla Brook are allowed to go dry 10 percent of the time, long-term yields based on the 90-percent duration flows are conservative, and (2) if withdrawals are limited to this flow value, all or parts of Anguilla Brook would go dry less than 10 percent of the time.

The water assumed to be potentially available for development in the four subareas over the long term is computed using a unit area 90-percent duration flow of 0.4 $(ft^3/s)/mi^2$ [0.26 $(Mgal/d)/mi^2$ (million gallons per day per square mile)]. This is the estimated average value for the entire basin as determined from figure 5. Estimated amounts of water potentially available over the long term for the four subareas and their upstream drainage areas are given in tables 3 and 4.

Maximum Long-Term Pumping Rates

In southern New England, long-term pumping rates and yields of stratified-drift aquifers have been estimated by mathematical models that use the Theis nonequilibrium equation (Theis, 1935) to describe flow, and the theory of image wells (Ferris and others, 1962) to simulate hydraulic boundary conditions (Allen and others, 1966; Rosenshein and others, 1968; Ryder and others, 1970). The model analysis requires hydrologic information about the aquifer under investigation (saturated thickness, average transmissivity, average specific yield, location and type of hydraulic boundaries), and physical information about the method and pattern of withdrawals (number and spacings of hypothetical pumping wells, well-construction characteristics, period of pumping).

The modeling procedure for calculating maximum long-term pumping rates in the Anguilla Brook aquifer is the same as in previous Connecticut studies and is described by Cervione and others (1972) and Mazzaferro and others (1979). To facilitate the analysis, a Fortran-language program was used that allows a computer to calculate the drawdowns and yields of as many as 16 pumping wells. The calculation process also adjusts the drawdowns and yields to account for the effects of dewatering of the aquifer, partial penetration of each well, pumping of nearby wells, and hydraulic boundaries.

After selecting initial pumping rates for the wells, the adjusted drawdowns are calculated at each well. The maximum pumping rate is specified at the rate that results in an adjusted drawdown that is about 1 foot above the top of the well screen. Pumping rates are incrementally increased or decreased at each well until the adjusted drawdown meets the criteria (1 foot above the top of the well screen) for all wells in the modeled area. The following assumptions regarding aquifer and well characteristics and period of pumping are incorporated into the models of each of the four subareas.

(1) Specific yield of the aquifer is equal to 0.20;
(2) Maximum available drawdown, at each well, is 70 percent of the saturated thickness;
(3) Screen length for each well is 30 percent of the saturated thickness;
(4) Effective well radius is 2 feet;
(5) Pumping period is 180 days, and there is no recharge during this period (this is approximately equal to the length of time that there is little or no recharge from precipitation each year and if pumpage can be sustained over this period, it is likely the same rate can be sustained indefinitely);
(6) Wells are 100-percent efficient;
(7) Vertical-to-horizontal hydraulic conductivity ratio (K_v:K_h) is 0.10;
(8) Wells are generally located in the thickest, most transmissive parts of the aquifer.

Models of the four subareas of the Anguilla Brook aquifer analyzed during the course of this investigation have two to six hypothetical pumping wells, generally located in the most favorable sites. The number of hypothetical wells is partly controlled by the transmissivity and saturated-thickness distribution in each subarea but they are also spaced at distances ranging from 750 to 1,800 feet to reduce the effects of well interference. Locations of the hypothetical pumping wells are shown in figures 11 to 14.

One of the assumptions of the nonequilibrium equation (Theis, 1935), the basis of this method of analysis, is that the aquifer is of infinite areal extent. The Anguilla Brook aquifer is finite--limited by natural features that also form hydraulic boundaries. Two different boundary conditions are considered in the mathematical models of the four subareas. They are impermeable-barrier or no-flow boundaries and line-source or constant head boundaries.

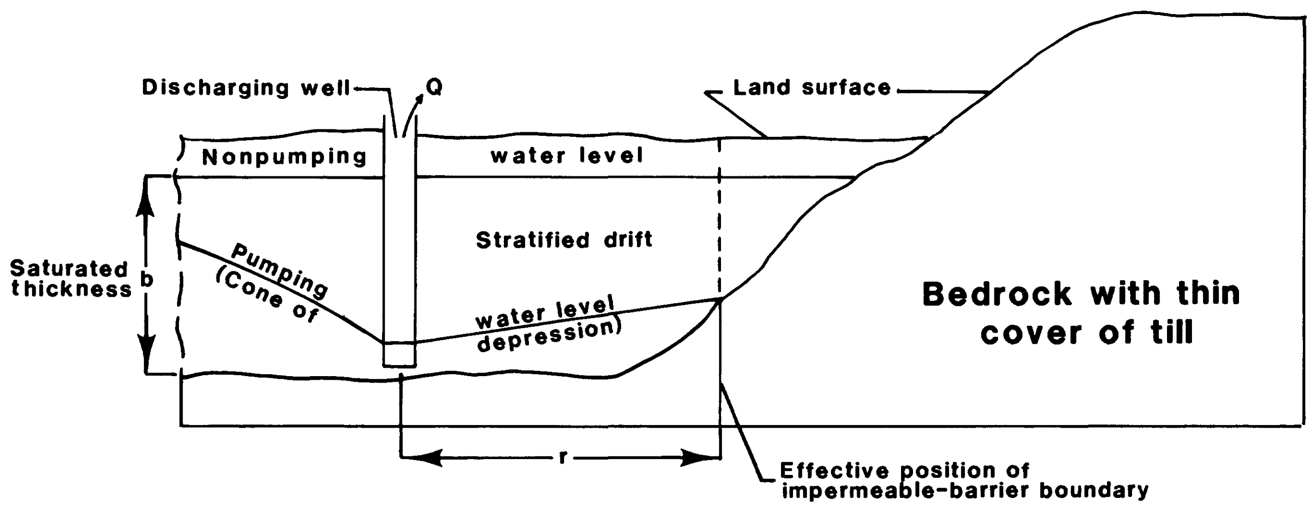
The first boundary type is formed by relatively impermeable materials or features that are in contact with the aquifer, and little or no ground water flows across the contact (eg., adjacent till, bedrock, and thin, fine-grained stratified drift). The second boundary type is formed by streams or other surface-water bodies that contribute large amounts of water to the aquifer. Both types of hydraulic boundaries are illustrated in figure 8.

In the models of the four subareas, impermeable-barrier boundaries are idealized as straight, vertical planes placed to approximately coincide with the 10-foot saturated thickness contour lines along the aquifer margins. Some ground water may flow into the aquifer across these planes which would tend to make the maximum long-term pumping rates derived by the models more conservative. Line-source boundaries are also idealized as vertical planes and, in most place, are located along the axis of Anguilla Brook. They represent a constant source of water recharging the aquifer. In theory, the water level is constant along the line-source boundary and the effects of pumping are not felt across the vertical plane. Field conditions differ from ideal in that Anguilla Brook is relatively small and does not fully penetrate the aquifer (fig. 8). Consequently, large pumpage on one side of the stream would likely affect water levels in the stream and in the aquifer on the other side.

Image wells are used in the mathematical model to simulate the effects of the specified boundary conditions as shown in figure 9. Image wells may be either discharging or recharging, depending on the boundary condition they are simulating. When more than one boundary is involved, it is necessary to account for the multiple boundaries using repeated image well arrays (Ferris and others, 1962, p. 156). In theory, these image wells can be repeated infinitely, but in this study they are terminated after 13 repetitions or when the drawdown or buildup of the water table due to the image well is less than 0.00001 foot.

Well and aquifer characteristics, assumed boundary conditions and estimated maximum long-term pumping rates for the four subareas shown in figure 10 are summarized in table 2. In three of the four subareas, two different boundary conditions are incorporated into and evaluated by the mathematical model. The first assumed that two or three sides of the subarea act as impermeable-barrier boundaries. The second assumed that one or two sides of the subarea act as impermeable-barrier boundaries and one side acts as a line-source boundary. It is also assumed that the remaining one or two sides have neither type of boundary and the aquifer is continuous in those directions. These alternative boundary configurations result in two values of estimated, maximum long-term pumpage for three of the subareas. The smaller value represents the long-term pumpage if only impermeable-barrier boundaries are effective. The larger value represents a more optimistic situation where Anguilla Brook acts as a line-source boundary. In the northern subarea, only one boundary configuration (three impermeable-barrier boundaries and one side open or continuous) was evaluated because the size and flow of Anguilla Brook at this point are so small it is unlikely to constitute a line-source boundary. Consequently, only one estimate of maximum long-term pumping rate for this subarea is listed in tables 2, 3, and 4.

A. IMPERMEABLE-BARRIER BOUNDARY



B. LINE-SOURCE BOUNDARY

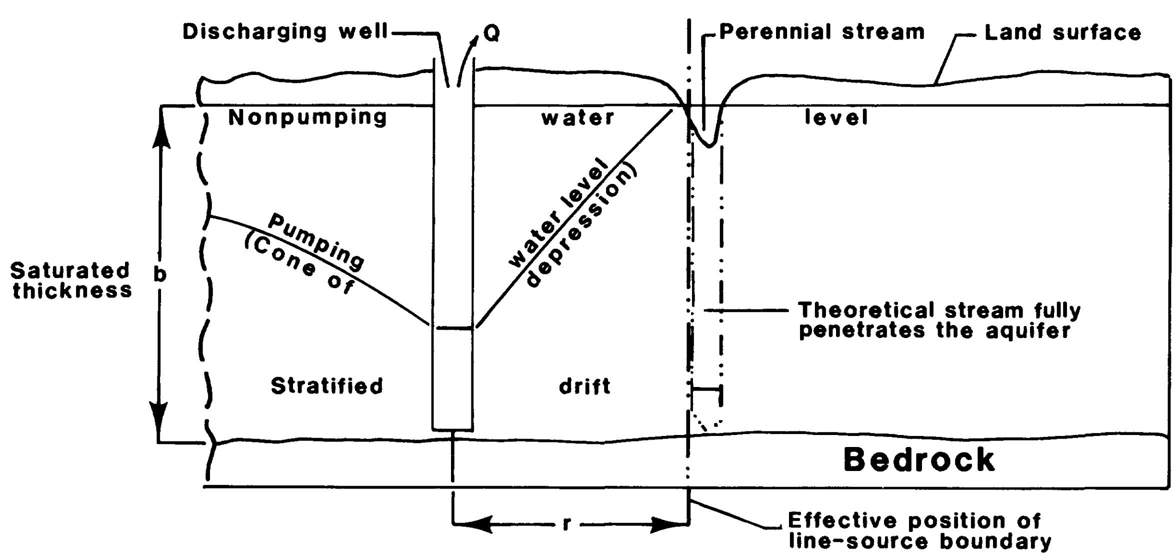
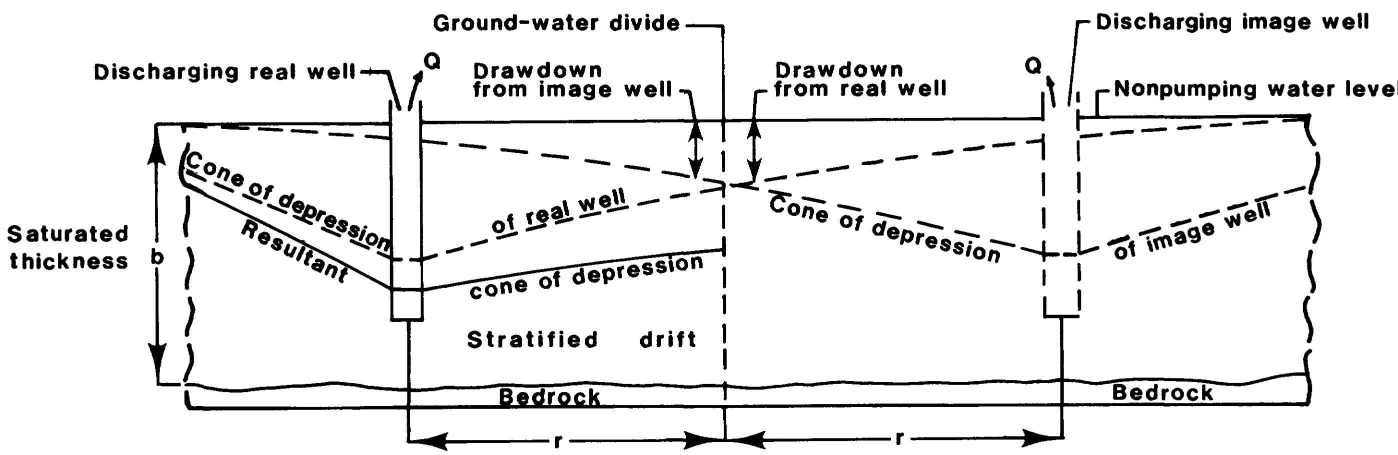


Figure 8.--Cross sections of a stratified-drift aquifer showing hydraulic boundaries and their effect on pumping water levels. (Modified from Ferris and others, 1962, figs. 35, 37.)

A. Discharging image well simulating the effects of an impermeable-barrier boundary.
The hydraulic conditions in the infinite aquifer shown below are the same as in figure 8A.
The ground-water divide across which there is no flow is in the same location as the impermeable-barrier boundary in figure 8A.



B. Recharging image well simulating the effects of a line-source boundary.
The hydraulic conditions in the infinite aquifer shown below are the same as in figure 8B.
The line of zero drawdown (constant head) is in the same location as the line-source boundary in figure 8B.

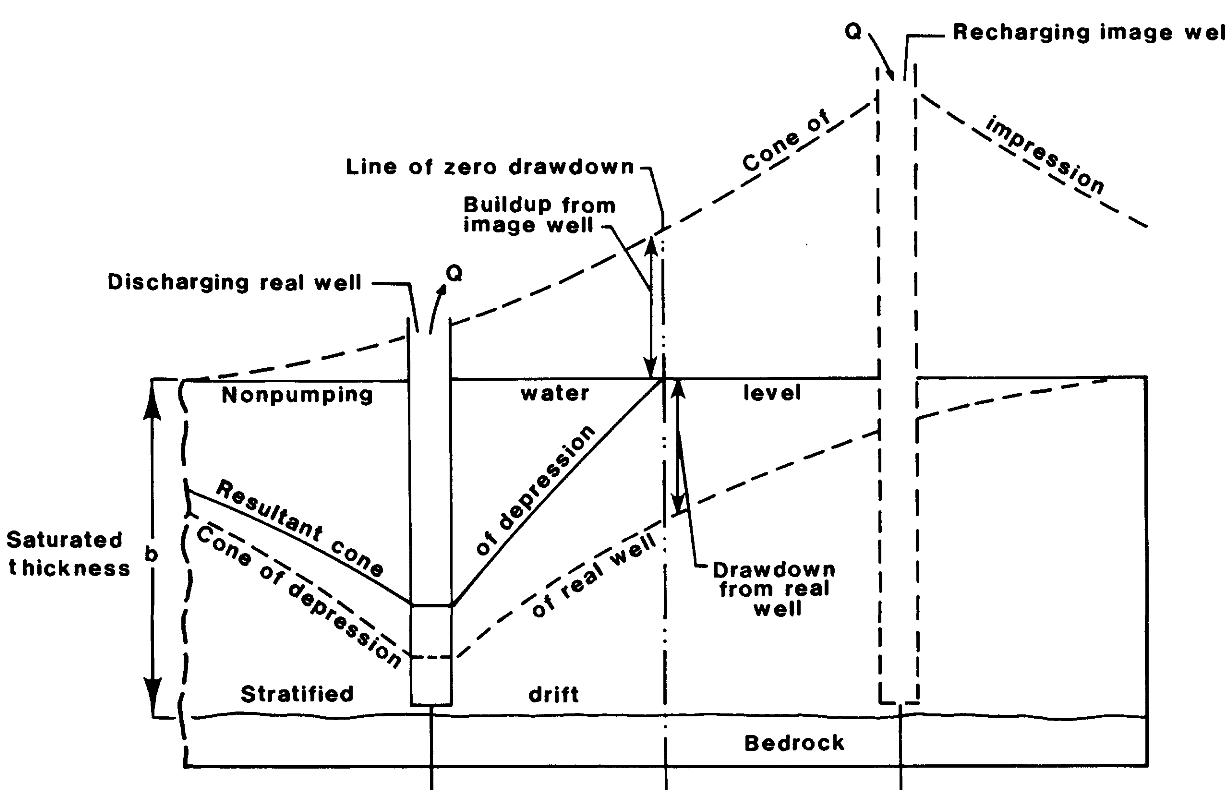


Figure 9.--Cross sections showing how image wells are used to simulate the hydraulic effects of boundaries. (Modified from Ferris and others, 1962, figs. 35, 37.)

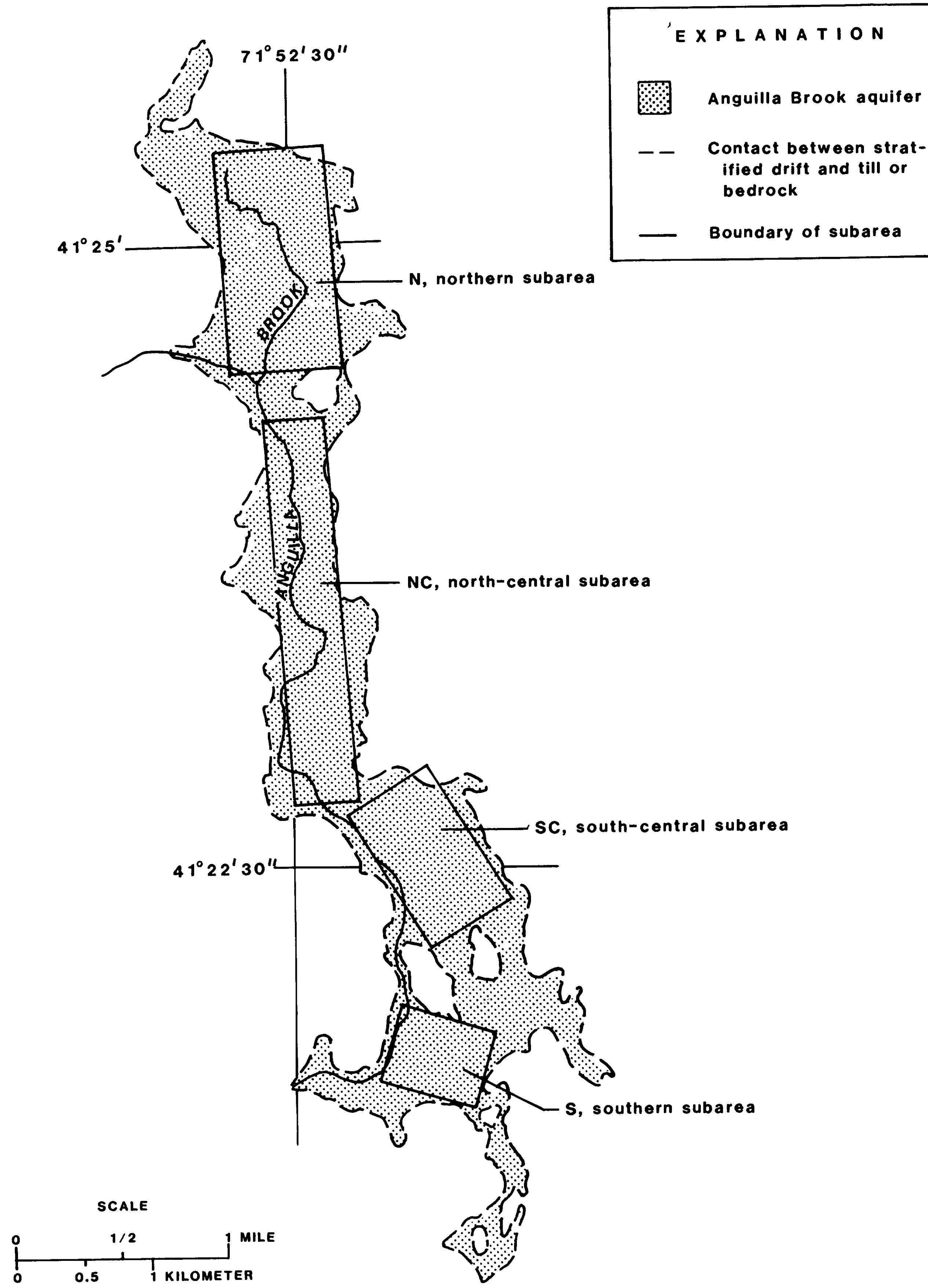


Figure 10.--Locations of favorable subareas of the Anguilla Brook aquifer.

Table 2.--Boundary conditions, selected well and aquifer characteristics, and estimated maximum long-term pumping rates for four subareas of the Anguilla Brook aquifer

[Position of boundary indicated by letter: W, west; E, east; N, north; S, south. Type of boundary indicated by letter: B, impermeable-barrier boundary; L, line-source boundary; O, no boundary. K_v:K_h, ratio of vertical to horizontal hydraulic conductivity]

Name and map symbol (See fig. 10 for location)	Boundary conditions W E N S	Number of wells	Effective well radius (feet)	Saturated thickness (feet)	Average aquifer transmissivity (feet squared per day)	K_v:K_h ratio	Maximum long-term pumping rate: Per well (gallons per minute)	Maximum long-term pumping rate: All wells (million gallons per day)
Northern	B B B O	5	2.0	40	4,000	0.1	163	1.5
N				40			145	
				50			216	
				40			153	
				75			380	
North-central	L B B O	6	2.0	20	2,000	.1	71	.7
NC				20			72	
				25			80	
				25			79	
				25			81	
				35			115	
North-central	B B B O	6	2.0	20	2,000	.1	61	.6
NC				20			54	
				25			65	
				25			57	
				25			56	
				35			98	
South-central	L B O B	4	2.0	30	3,000	.1	148	1.0
SC				35			171	
				40			194	
				30			157	
South-central	B B O B	4	2.0	30	3,000	.1	91	.7
SC				35			112	
				40			142	
				30			111	
Southern	L B O O	2	2.0	25	2,500	.1	104	.3
S				25			104	
Southern	B B O O	2	2.0	25	2,500	.1	93	.3
S				25			93	

Long-Term Ground-Water Yields

The following discussion of long-term ground-water yields from the Anguilla Brook aquifer is based on (1) estimates of the ground water potentially available over the long term, and (2) estimates of the maximum long-term pumping rates. The aquifer is divided into four subareas, each traversed by Anguilla Brook (fig. 10). The ground water potentially available over the long term in each subarea is initially assumed to be equal to the 90-percent duration flow of Anguilla Brook. Water available from recharge from precipitation or storage in the aquifer is assumed to be negligible compared to that from induced recharge from the brook. The maximum long-term pumping rates in each subarea are estimated by use of the previously described mathematical model that is based on the Theis nonequilibrium equation (Theis, 1935) and the theory of image wells (Ferris and others, 1962).

Maximum long-term pumping rates (table 2) can be sustained in each subarea as long as they do not exceed the water potentially available. If this is the case, the long-term ground-water yield is considered to be equal to the maximum pumping rate. Conversely, where the maximum long-term pumping rate is greater than the water potentially available, the long-term ground-water yield is considered to be equal to the water potentially available.

In estimating long-term ground-water yields in all but the northern subarea, two different conditions of development have been considered. The first condition assumes there is no development of any of the upstream subareas that would affect the amount of water potentially available. The analysis under this condition compares the ground water potentially available with the maximum pumping rate and considers the smaller of these to be the estimated long term ground-water yield. The results of this evaluation are summarized in table 3. The second condition assumes maximum development of all upstream subareas and that the water withdrawn from these areas is exported from the basin. Consequently, the water potentially available to a downstream subarea (the 90-percent duration flow) is reduced by an equivalent amount. The impacts of upstream development are cumulative and reductions in the amount of water potentially available are greater in each succeeding downstream subarea. The analysis under this condition of development compares the adjusted value of the ground water potentially available and the maximum pumping rate and considers the smaller of these to be the estimated long-term ground-water yield. The results of the evaluation under this development alternative are summarized in table 4.

Table 3.--Long-term ground-water yields in subareas of the Anguilla Brook aquifer with no upstream development

A	B	C	D	E
Subarea name and map symbol (See fig. 10 for location)	Upstream drainage area (square miles)	Estimated amount of water potentially available (equal to 90-percent duration flow of Anguilla Brook) (million gallons per day)	Maximum long-term pumping rate determined from mathematical models (million gallons per day)	Long-term ground-water yields (the lesser of column C or D) (million gallons per day)
Northern (N)	3.4	0.9	1.5	0.9
North-central (NC)	7.0	1.8	[1]0.6 - 0.7	0.6 - 0.7
South-central (SC)	9.6	2.5	[1]0.7 - 1.0	0.7 - 1.0
Southern (S)	9.9	2.6	0.3	0.3

[1] Smaller number is the rate calculated with only impermeable-barrier boundaries and larger number is the rate calculated with a line-source boundary. See table 2.

Northern Subarea

This subarea, located in the upper part of the Anguilla Brook aquifer, contains the thickest and most coarse-grained stratified drift in the basin. Transmissivities generally range from 3,000 to 6,000 ft^2/d and saturated thickness, in places, exceeds 75 feet. The geologic contact between till and stratified drift, altitude of the bedrock surface, saturated thickness, transmissivity, assumed boundary conditions, and locations of hypothetical pumping wells are shown in figure 11. The aquifer characteristics and other features of the mathematical model of this area are given in table 2. Five hypothetical wells, placed at approximately 1,000-foot intervals, are used to withdraw water for a 180-day period. Only one boundary configuration, consisting of three impermeable-barrier boundaries, was assumed in evaluating this subarea. The maximum, long-term pumping rate calculated for these conditions was 1.5 Mgal/d, nearly 70 percent greater than the 0.9 Mgal/d estimated to be potentially available at this site over the long term. Thus, the long-term ground-water yield in the northern subarea, as indicated in tables 3 and 4, is estimated to be 0.9 Mgal/d, the lesser of these two values.

Table 4.--Long-term ground-water yields in subareas of the Anguilla Brook aquifer with maximum upstream development

A	B	C	D	E	F
Subarea name and map symbol (See fig. 10 for location)	Estimated amount of water potentially available (equal to 90-percent duration flow of Anguilla Brook) (million gallons (per day)	Cumulative ground-water withdrawals from upstream subareas (million gallons per day)	Water potentially available adjusted for effects of upstream development (90-percent duration flow of Anguilla Brook minus cumulative withdrawals) (million gallons per day)	Maximum long-term pumping rate determined from mathematical models (million gallons per day)	Long-term ground-water yields (the lesser of column D or E) (million gallons (per day)
Northern (N)	0.9	0	0.9	1.5	0.9
North-central (NC)	1.8	0.9	0.9	1/ 0.6 - 0.7	0.6 - 0.7
South-central (SC)	2.5	1.5 - 1.6	0.9 - 1.0	1/ 0.7 - 1.0	0.7 - 1.0
Southern (S)	2.6	2.2 - 2.6	0 - 0.4	0.3	0 - 0.3

1/ Smaller number is the rate calculated with only impermeable-barrier boundaries and larger number is the rate calculated with a line-source boundary. See table 2.

North-Central Subarea

The north-central subarea includes a long, narrow section of the Anguilla Brook aquifer that extends about 1.7 miles north from Pequot Trail. It consists of relatively thin, saturated stratified drift (saturated thickness less than 20 feet) except near the southern end. Transmissivity ranges from 1,500 to over 3,000 ft^2/d in the most favorable parts and the saturated thickness, in places, may be as much as 35 feet. The geologic contact between till and stratified drift, altitude of the bedrock surface, saturated thickness, transmissivity, assumed boundary conditions, and locations of hypothetical pumping wells are shown in figure 12. Six hypothetical wells with spacings that ranged from 800 to 1,750 feet were used to withdraw water for a 180-day period. Two different boundary configurations were assumed in evaluating this subarea; the first consists of two impermeable-barrier boundaries and one line-source boundary, while the second consists of three impermeable-barrier boundaries. The maximum long-term pumping rate calculated with the first set of boundary conditions was 0.7 Mgal/d, and the rate calculated for the second, more conservative set, was 0.6 Mgal/d. The amount of water estimated to be potentially available over the long term in this subarea is 1.8 Mgal/d if no upstream development occurs and 0.9 Mgal/d if it does. This means that the long-term ground-water yield in the north-central subarea, as indicated in tables 3 and 4, is between 0.6 and 0.7 Mgal/d, regardless of upstream development.

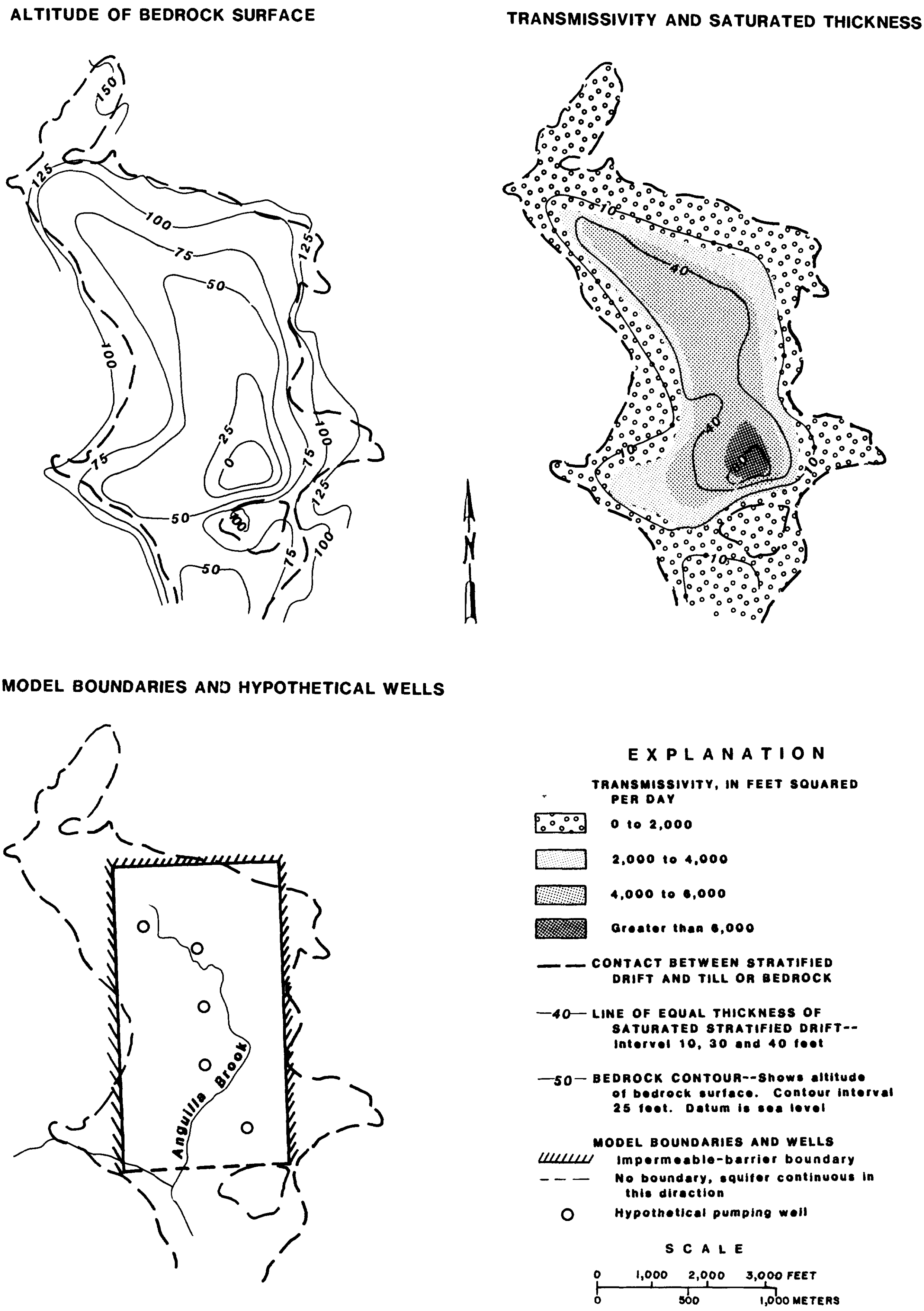


Figure 11.--Hydrogeologic features, assumed boundary conditions, and hypothetical pumping wells in the northern subarea of the Anguilla Brook aquifer.

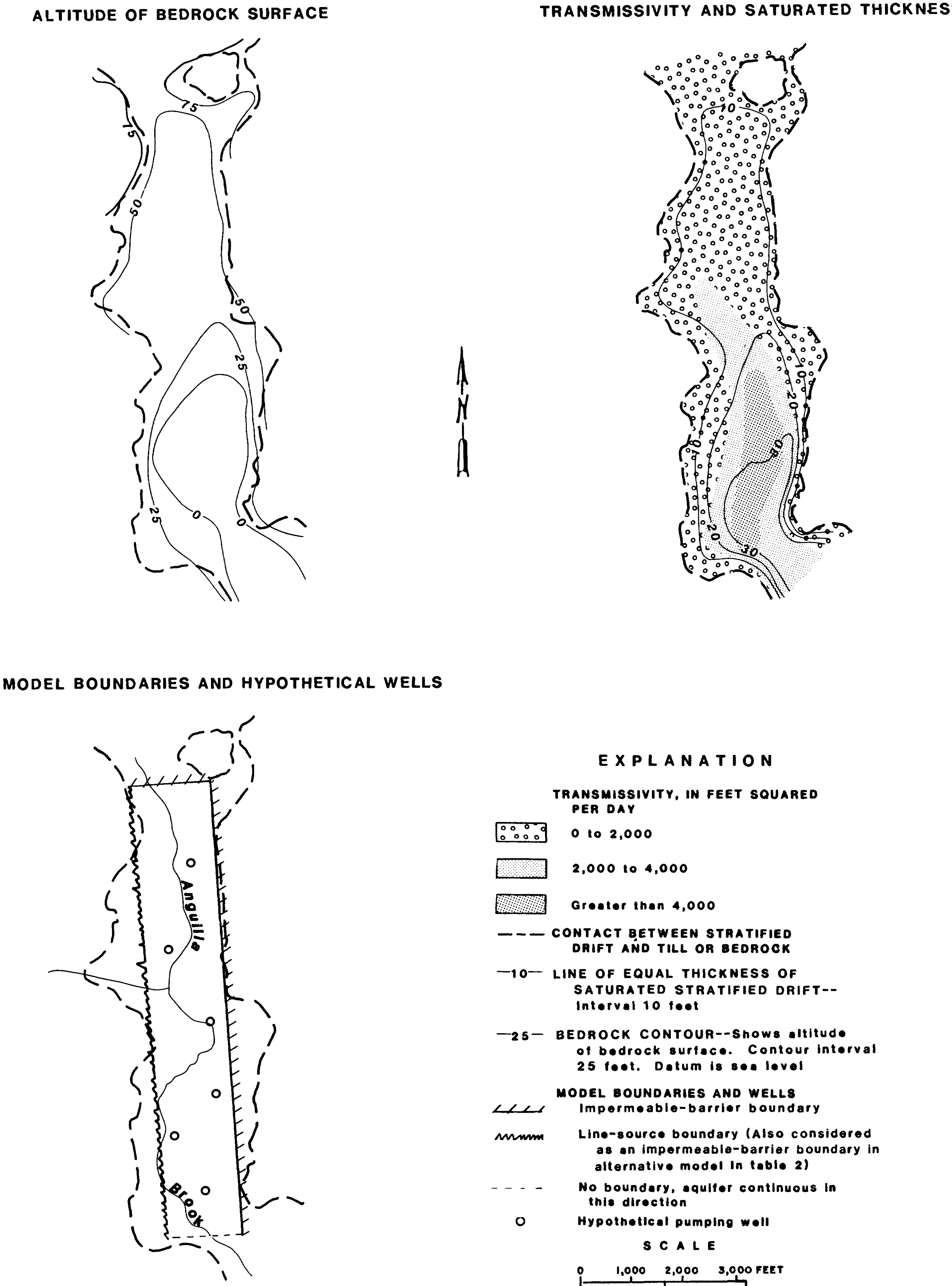


Figure 12.--Hydrogeologic features, assumed boundary conditions, and hypothetical pumping wells in the north-central subarea of the Anguilla Brook aquifer.

South-Central Subarea

The south-central subarea extends from Pequot Trail to U.S. Route 1. It contains coarse- to fine-grained stratified drift that tends to become finer with depth. Transmissivity ranges from 3,000 to about 3,700 ft^2/d in the most favorable parts, and the saturated thickness, in places, may be as much as 40 feet. The geologic contact between till and stratified drift, altitude of the bedrock surface, saturated thickness, transmissivity, assumed boundary conditions, and locations of hypothetical pumping wells are shown in figure 13. Four hypothetical wells with approximately 1,000-foot spacings were used to withdraw water for a 180-day period and two boundary configurations were assumed. The first set of boundaries included two impermeable-barrier boundaries and one line-source boundary, while the second included three impermeable-barrier boundaries. The maximum, long-term pumping rate calculated with the first set of boundary conditions was 1.0 Mgal/d, and the rate calculated for the second set was 0.7 Mgal/d. The amount of water estimated to be potentially available over the long term in this subarea is 2.5 Mgal/d if no upstream development occurs and between 0.9 and 1.0 Mgal/d if it does. This means that the long-term ground-water yield in the south-central subarea, as indicated in tables 3 and 4, is 0.7 to 1.0 Mgal/d regardless of upstream development.

Southern Subarea

The southern subarea includes a small part of the Anguilla Brook aquifer, south of U.S. Route 1. Relatively little data is available from this subarea. Transmissivity is estimated to average about 2,500 ft^2/d and saturated thickness may exceed 25 feet. The geologic contact between till and stratified drift, altitude of the bedrock surface, saturated thickness, transmissivity, assumed boundary conditions, and locations of hypothetical pumping wells are shown in figure 14. Two hypothetical wells, 750 feet apart, were used to withdraw water for a 180-day period. Two boundary configurations were assumed; the first consists of two impermeable-barrier boundaries and one line-source boundary, while the second has two impermeable-barrier boundaries. The maximum, long-term pumping rate calculated for both conditions was about 0.3 Mgal/d. The amount of water estimated to be potentially available over the long term is 2.6 Mgal/d if no upstream development occurs, and 0 to 0.4 Mgal/d if it does. The cumulative effect of upstream development is significant, and the long-term ground-water yield of the southern subarea, as indicated in tables 3 and 4, is 0.3 Mgal/d with no upstream development, and 0.3 Mgal/d or less with upstream development.

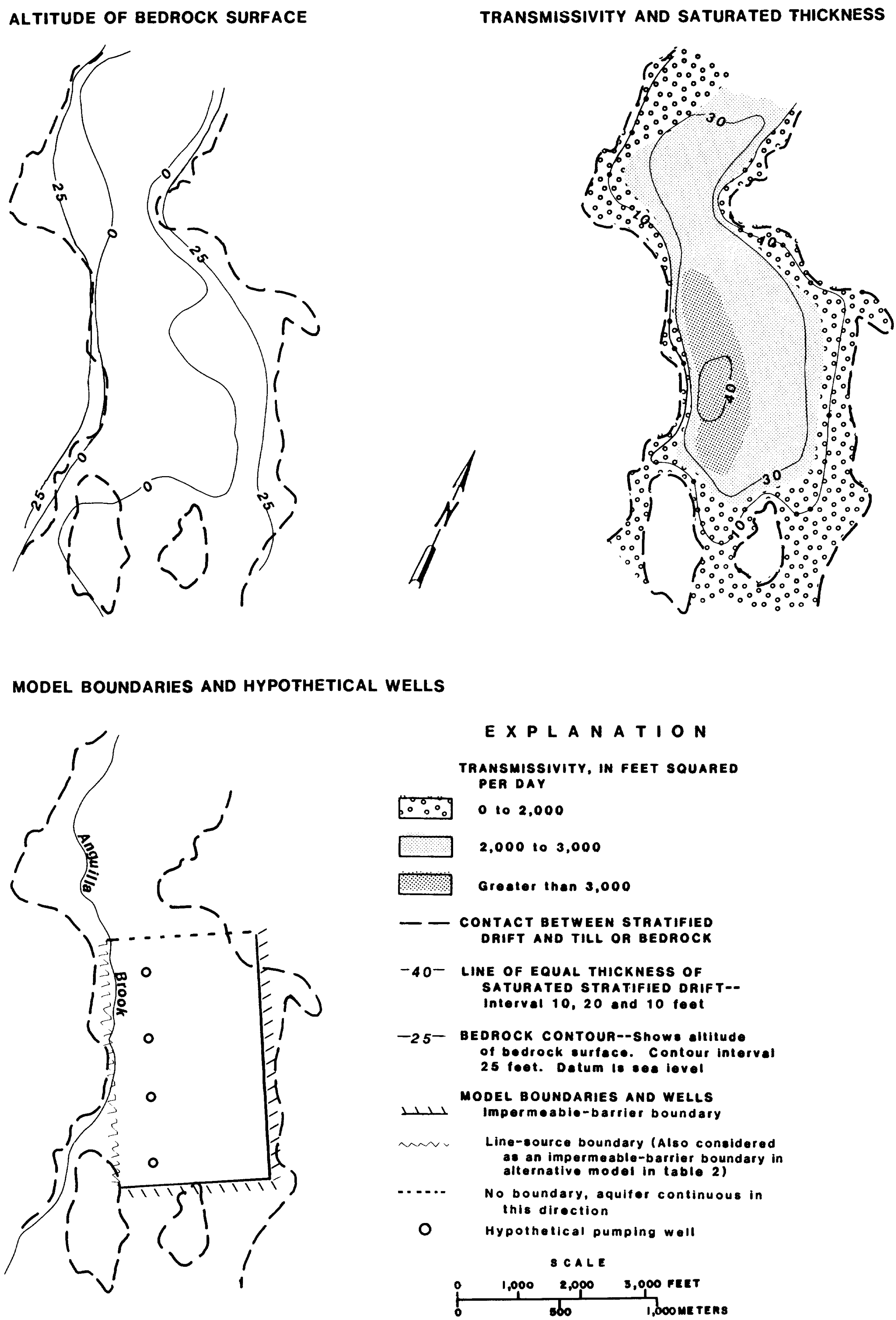


Figure 13.--Hydrogeologic features, assumed boundary conditions, and hypothetical pumping wells in the south-central subarea of the Anguilla Brook aquifer.

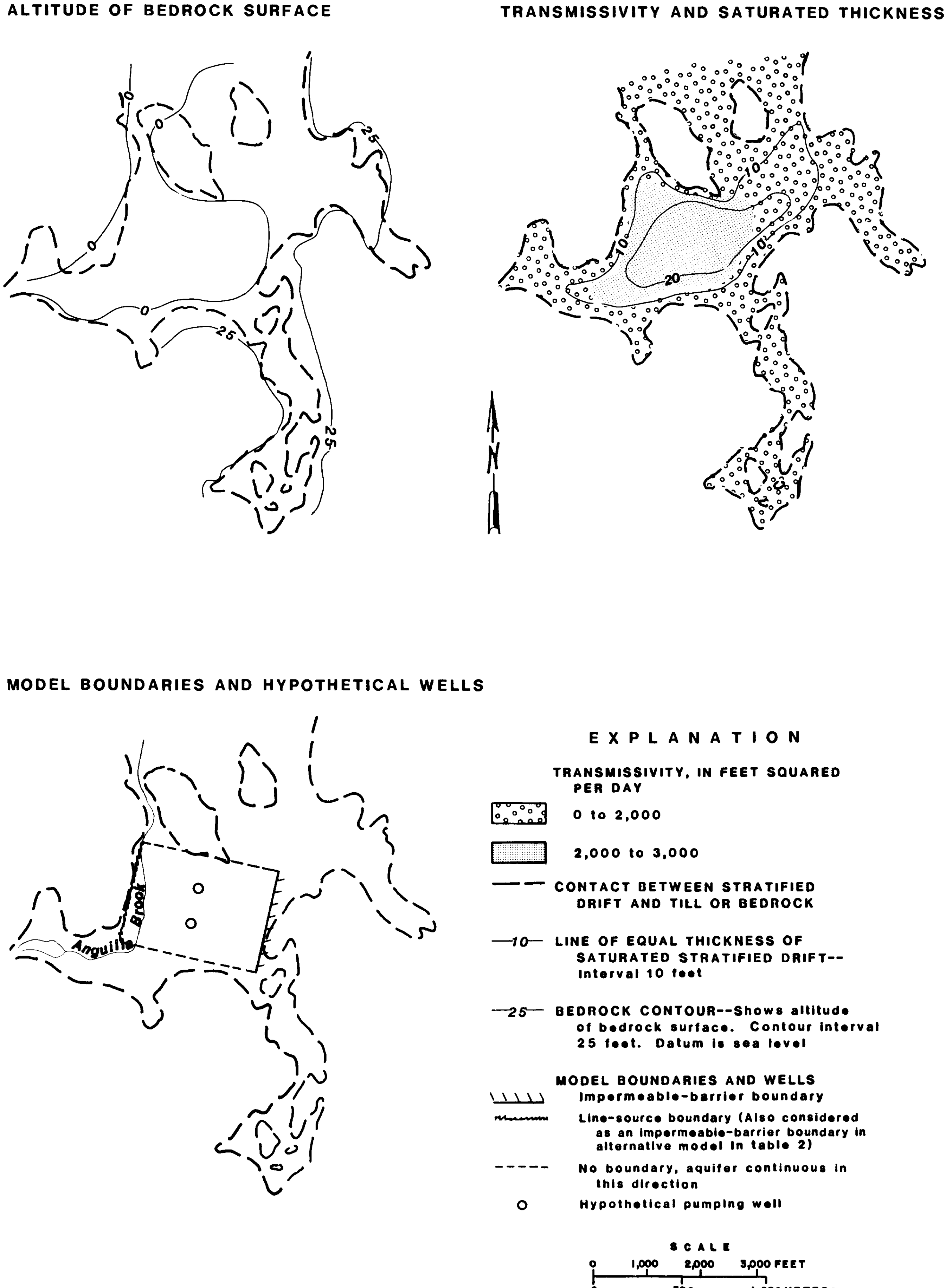


Figure 14.--Hydrogeologic features, assumed boundary conditions, and hypothetical pumping wells in the southern subarea of the Anguilla Brook aquifer.

WATER QUALITY

Surface Water

The water in Anguilla Brook and its tributaries was sampled and analyzed to see if it met drinking-water standards established by the State of Connecticut (Connecticut General Assembly, 1975), and the U.S. Environmental Protection Agency (1975). Table 5 includes the principal constituents that comprise the U.S. Environmental Protection Agency standards as well as the limiting values for drinking water. When a constituent exceeds the limiting value, the water is considered unsuitable for domestic supply without treatment.

Anguilla Brook was sampled at two sites, during average and low-flow conditions, to see if differences in water quality occur along the stream and as flow conditions vary. The sites were at Nathan Wheeler farm (station 01118535) where Anguilla Brook leaves the northern part of the basin and flows over bedrock outcrop, and at Wequetequock (station 01118550) near the downstream end of the basin. The concentrations of most constituents were greater at the downstream sampling site. Iron and manganese had the largest increase probably due to drainage from large areas of swampland in the central part of the basin.

Water samples were collected at both sites when discharges were representative of both average and low-flow (90-percent duration flow) conditions. Concentrations of most constituents were similar at average and low flows except for iron and manganese. Concentrations of these two dissolved metals decreased at low flows, probably due to reduced contributions of runoff from swamplands during low-flow periods. Water-quality data for the two sites, for samples collected at average (May 24, 1982) and low (August 19, 1982) flows are summarized in table 6. Analytical results for 55 organic compounds, including most common herbicides and pesticides, are not included in table 6 as none were present at the analytical detection limits. The organic compounds analyzed for are listed in Water Resources Data for Connecticut, Water Year 1982 (U.S. Geological Survey, 1982).

As the data indicate, water from Anguilla Brook exceeded recommended maximum limits for drinking water for only one constituent--dissolved iron, measured in the sample collected at Wequetequock (station 01118550) during average flow conditions. The dissolved iron concentration for this sample was 340 μg/L (micrograms per liter), slightly above 300 μg/L which is recommended as the maximum limit for this constituent.

Table 5.--Water-quality criteria

[The Federal Water Pollution Control Act Amendment of 1972 (P.L. 92-500) stipulated that water-quality criteria were to be developed to assure the integrity of ground and surface waters of the United States. Criteria were set for various types of water use. These criteria indicate limiting values of various parameters in water to provide adequate protection of water users, essential aquatic life, and consumers of such aquatic life. Abbreviations: mg/L = milligrams per liter; µg/L = micrograms per liter; mL = milliliter; col/100 mL = colonies per 100 milliliters]

Parameter name	Limiting value	Units	Use 1/	Basis for selection 2/
	General inorganics			
Alkalinity, total (as $CaCO_3$)	3/ 20	mg/L	2	A
Arsenic	50	µg/L	4,6	A,B
	100	µg/L	3	A
Barium	1,000	µg/L	4,6	A,B
Beryllium	11	µg/L	2a	A
	100	µg/L	3	A
	1,100	µg/L	2b	A
Boron	750	µg/L	3	A
Cadmium	0.4	µg/L	1a	A
	1.2	µg/L	1b	A
	4.0	µg/L	2a	A
	5.0	µg/L	8	A
	10	µg/L	4,6	A,B
	12	µg/L	2b	A
Chloride	250	mg/L	6a	C
Chromium, total	50	µg/L	4,6	A,B
	100	µg/L	2	A
Color	15	color units	6a	C
	75	color units	4	A
Copper	1,000	µg/L	4,6a	A,C
Cyanide	5	µg/L	2,8	A
Fecal coliform, MF	4/ 200	col/100 mL	7	A
Iron	300	µg/L	4,6a	A,C
	1,000	µg/L	2	A
Lead, dissolved	50	µg/L	4,6	A,B
Manganese	50	µg/L	4,6a	A,C
Mercury	0.05	µg/L	2	A
	0.1	µg/L	8	A
	2	µg/L	4,6	A,B
Nickel	100	µg/L	2,8	A
Nitrate (as N)	10	mg/L	4,6	A,B
Nitrite (as N)	1	mg/L	4	A
Oxygen, dissolved	3/ 5	mg/L	2	A
pH	6.5-8.5		6a,8	A,C
	6.5-9.0		2	A
	5.0-9.0		4	A
	General inorganics - continued			
Selenium	10	µg/L	4,6	A,B
Silver	50	µg/L	4,6	A,B
Solids, dissolved	500	mg/L	6a	C
Sulfate	250	mg/L	6a	C
Zinc	5,000	µg/L	4,6a	A,C
	Organics			
Aldrin-dieldrin	0.003	mg/L	2	A
Chlordane	0.004	µg/L	8	A
	0.01	µg/L	2	A
DDT 5/	0.001	µg/L	2,8	A
Demeton	0.1	µg/L	2,8	A
Endosulfan	0.001	µg/L	8	A
	0.003	µg/L	2	A
Endrin	0.004	µg/L	2,8	A
	0.2	µg/L	4,6	B
Guthion	0.01	µg/L	2,8	A
Heptachlor	0.001	µg/L	2,8	A
Lindane	0.004	µg/L	8	A
	0.01	µg/L	2	A
	4	µg/L	4,6	A,B
Malathion	0.1	µg/L	2,8	A
MBAS (foaming agents)	0.5	mg/L	6a	C
Methoxychlor	0.03	µg/L	2,8	A
	100	µg/L	4,6	A,B
Mirex	0.001	µg/L	2,8	A
Parathion	0.04	µg/L	2,8	A
PCB	0.001	µg/L	2,8	A
Phenols	1.0	µg/L	4	A
Toxaphene	0.005	µg/L	2,8	A
	5.0	µg/L	4,6	A,B
Silvex	10	µg/L	4,6	A,B
2,4-D	100	µg/L	4,6	A,B

1/ Water use and/or for the protection of:

- 1a. Sensitive salmonoid species in soft water
- 1b. Sensitive salmonoid species in hard water
- 2. Freshwater aquatic life
- 2a. Freshwater aquatic life in soft water
- 2b. Freshwater aquatic life in hard water
- 3. Crop irrigation
- 4. Domestic water supply source
- 6. Potable drinking water, based on health effects
- 6a. Potable drinking water, based on aesthetic considerations
- 7. Primary contact
- 8. Marine aquatic life

2/ Basis for selection:

- A. Maximum levels recommended by: Quality Criteria for Water, 1976, U.S. Environmental Protection Agency
- B. Maximum contaminant level established by: National Interim Primary Drinking Water Regulations, U.S. Environmental Protection Agency, 1975
- C. Maximum contaminant level recommended for the Proposed Secondary Drinking Water Regulations, U.S. Environmental Protection Agency, 1977

3/ Minimum recommended value

4/ Log mean, based on not less than five samples

5/ Including metabolites (DOD and DDE)

Table 6.--Analysis of surface-water samples from Anguilla Brook
[<, less than; cfs, cubic feet per second; μS/cm, microsiemens per centimeter; °C, degrees Celsius; mg/L, milligrams per liter; μm, micron; μg/L, micrograms per liter; dashes indicate data not available]

Constituent or property	Station 01118535 Anguilla Brook near North Stonington		Station 01118550 Anguilla Brook at Wequetequock	
	Date of sample collection			
	5/25/82	8/19/82	5/24/82	8/19/82
Streamflow, instantaneous (cfs)	8.6	1.4	11	2.5
Specific conductance (μS/cm)	81	89	87	98
pH (units)	6.7	6.3	6.8	6.5
Temperature (°C)	15.0	18.0	--	18.5
Color (platinum-cobalt units)	50	20	60	57
Turbidity (Nephelometric turbidity units)	--	1.0	--	2.0
Oxygen, dissolved (mg/L)	12.6	8.0	--	8.9
Oxygen, dissolved (percent saturation)	123	84	--	95
Coliform, fecal, 0.45-μm filter (colonies per 100 mL)	--	200	--	100
Streptococci, fecal, KF agar (colonies per 100 mL)	--	190	--	320
Hardness (mg/L as $CaCO_3$)	22	25	24	28
Hardness, non-carbonate (mg/L as $CaCO_3$)	7.0	10	5.0	10
Calcium, dissolved (mg/L as Ca)	5.7	6.5	6.4	7.5
Magnesium, dissolved (mg/L as Mg)	1.9	2.0	1.9	2.2
Sodium, dissolved (mg/L as Na)	6.0	5.9	6.3	7.3
Percent sodium	36	34	36	35
Sodium adsorption ratio	0.6	0.6	0.6	0.6
Potassium, dissolved (mg/L as K)	.7	.7	.8	.9
Alkalinity (lab) (mg/L as $CaCO_3$)	15	15	19	18
Sulfate, dissolved (mg/L as SO_4)	10	9.0	8.0	9.0
Chloride, dissolved (mg/L as Cl)	9.4	9.2	10	10
Fluoride, dissolved (mg/L as F)	< .1	< .1	< .1	< .1
Silica, dissolved (mg/L as SiO_2)	7.5	9.5	8.0	8.2
Solids, residue at 180 °C, dissolved (mg/L)	75	71	82	85
Solids, sum of constituents, dissolved (mg/L)	51	52	53	56
Nitrogen, NO_2 + NO_3, dissolved (mg/L as N)	.38	.57	--	.21
Phosphorus, dissolved (mg/L as P)	.010	< .010	--	< .010
Aluminum, dissolved (μg/L as Al)	50	30	90	40
Arsenic, dissolved (μg/L as As)	1	1	1	1
Barium, dissolved (μg/L as Ba)	42	39	32	32
Boron, dissolved (μg/L as B)	40	40	40	50
Cadmium, dissolved (μg/L as Cd)	1	< 1	< 1	< 1
Chromium, dissolved (μg/L)	< 1	< 1	< 1	< 1
Cobalt, dissolved (μg/L as Co)	4	< 1	3	< 1
Copper, dissolved (μg/L as Cu)	2	2	2	2
Iron, dissolved (μg/L as Fe)	260	120	340	240
Lead, dissolved (μg/L as Pb)	2	1	2	1
Lithium, dissolved (μg/L as Li)	5	< 4	6	< 4
Manganese, dissolved (μg/L as Mn)	22	7	37	20
Mercury, dissolved (μg/L as Hg)	.1	< .1	.1	< .1
Nickel, dissolved (μg/L as Ni)	2	2	< 1	< 1
Selenium, dissolved (μg/L as Se)	< 1	< 1	< 1	< 1
Silver, dissolved (μg/L as Ag)	< 1	< 1	< 1	< 1
Zinc, dissolved (μg/L as Zn)	6	< 4	4	5
Cyanide, dissolved (mg/L as Cn)	< .01	--	< .01	--
Methylene blue active substance (mg/L)	.03	.03	.02	.04

Ground Water

Ground-water samples were collected from seven wells in the Anguilla Brook basin. Samples for analysis were obtained from each well at two different times (June and August, 1982) to insure that they accurately represented the quality of water in the aquifer. The results of the analyses of these water samples are given in table 7, and the locations of the sampled wells are shown on plate 1. Analytical results for 55 organic compounds are not included in table 7, as none were present at the analytical detection limits. The organic compounds analyzed for in the ground-water samples are also listed in the previously cited reference (U.S. Geological Survey, 1982).

Ground-water quality in the Anguilla Brook aquifer based on these samples indicates no evidence of contamination due to man's activities. Concentrations of dissolved manganese in five of the wells sampled (as much as 1,800 μg/L in SN 172), and dissolved iron in one of the wells sampled (3,600 μg/L in SN 174) exceeded limits recommended by the U.S. Environmental Protection Agency (1976) for domestic supply and are probably due to natural conditions. Excessive concentrations of dissolved manganese are evident only in newly constructed wells; chemical analyses of water samples from older wells and low-flow samples from Anguilla Brook show dissolved manganese concentrations below recommended limits. Except for the high concentrations of dissolved manganese and iron, none of the 14 ground-water samples analyzed exceeded limits for drinking water established by the State of Connecticut (Connecticut General Assembly, 1975) and established or recommended by the U.S. Environmental Protection Agency (1975, 1976).

SUMMARY AND CONCLUSIONS

Estimates of the long-term ground-water yields from four areas of the Anguilla Brook aquifer are based on evaluations of the amounts of water potentially available and calculations of maximum pumping rates. The 90-percent duration flow of Anguilla Brook [0.4 $(ft^3/s)/mi^2$] is used as a measure of the amount of water potentially available from the aquifer. This flow value is dependent upon upstream drainage area and ranges from 0.9 Mgal/d for the northern (upstream) subarea to 2.6 Mgal/d for the southern (downstream) subarea.

Maximum long-term pumping rates are calculated with a mathematical model that considers boundary conditions, and well and aquifer characteristics. How effective a hydraulic boundary Anguilla Brook would be under conditions of development cannot be determined. Therefore, two boundary configurations are analyzed in the north-central, south-central, and southern subareas. One configuration assumes Anguilla Brook constitutes a line-source boundary; the other assumes only impermeable-barrier boundaries. This results in two values expressed as a range for long-term yield for these three subareas. The larger yield values represent the results of the analysis where Anguilla Brook is assumed to be a line-source boundary.

Two conditions of ground-water development are considered in calculating the long-term ground-water yields. The first condition treats each of the four subareas independently, and assumes that there are no upstream withdrawals. The long-term yields under this condition are 0.9 Mgal/d in the northern subarea, 0.6 to 0.7 Mgal/d in the north-central subarea, 0.7 to 1.0 Mgal/d in the south-central subarea, and 0.3 Mgal/d in the southern subarea.

The second condition assumes that development will take place throughout the aquifer and that any water withdrawn from an upstream subarea will be unavailable for downstream use. This reduces the water potentially available in three of the four subareas. The long-term yields under this condition are the same as in the first condition, with the exception of the southern area where there may be no water available because of the development of upstream areas. The total yield of all subareas is 2.6 Mgal/d and would require no reuse of water. Under both conditions, reductions in the flow of Anguilla Brook would occur, and in places, the stream channel could be dry as much as 10 percent of the time.

Analysis of water quality in the Anguilla Brook basin from both surface- and ground-water sources indicates that concentrations of all constituents, with the exception of dissolved manganese and iron, were below the drinking-water limits established by the State of Connecticut (Connecticut General Assembly, 1975) and established or recommended by the U.S. Environmental Protection Agency (1975, 1976).

Table 7. Analysis of ground-water samples from the Anguilla Brook aquifer

[All wells tap stratified drift. Selected well characteristics listed in tables 8 and 9. Locations shown on plate 1. Symbols: <, less than; K, results based on colony count outside the accepted range. Abbreviations: µS/cm, microsiemens per centimeter; µm, microns; mL, milliliters; mg/L, milligrams per liter; °C, degrees Celsius; µg/L, micrograms per liter; dash indicates no data]

	Local well number and site identification number					
	NSN 69		SN164		SN165	
	412511071523901		412311071522301		412240071520801	
	Date of sample collection					
Constituent or property	6/3/82	8/18/82	6/1/82	8/17/82	6/2/82	8/17/82
Specific conductance (µs/cm)	96	102	-	102	134	130
pH (units)	-	5.7	-	5.7	-	5.7
Temperature (°C)	10.0	10.0	-	14.5	11.0	12.0
Color (platinum-cobalt units)	< 1	-	< 1	-	< 1	-
Coliform, fecal,0.45 µm-filter(colonies per 100 mL)	< 1	< 1	-	< 1	< 1	< 1
Streptococci, fecal, KF agar (colonies per 100 mL)	< 1	2	-	84	50	4
Hardness (mg/L as $CaCO_3$)	21	23	27	36	38	42
Hardness, non carbonate (mg/L as $CaCO_3$)	10	15	13	23	24	31
Calcium, dissolved (mg/L as Ca)	5.9	6.6	7.0	9.2	11	12
Magnesium, dissolved (mg/L as Mg)	1.5	1.6	2.2	3.1	2.6	2.8
Sodium, dissolved (mg/L as Na)	5.6	7.1	2.3	2.9	4.8	5.6
Percent sodium	35	38	16	15	21	22
Sodium adsorption ratio	0.6	0.7	0.2	0.2	0.4	0.4
Potassium, dissolved (mg/L as K)	1.3	1.3	.5	.5	.9	.8
Alkalinity lab. (mg/L as $CaCO_3$)	11	8.0	14	13	14	11
Sulfate, dissolved (mg/L as SO_4)	12	12	10	9.0	19	18
Chloride, dissolved (mg/L as Cl)	9.0	9.7	4.4	9.0	12	11
Fluoride, dissolved (mg/L as F)	< .1	< .1	< .1	< .1	< .1	< .1
Silica, dissolved (mg/L as SiO_2)	8.5	9.5	7.2	7.9	8.9	9.7
Solids, residue at 180°C, dissolved (mg/L)	62	80	68	103	84	98
Solids, sum of constituents, dissolved (mg/L)	51	53	42	50	68	67
Nitrogen, NO_2 + NO_3, dissolved (mg/L as N)	1.4	1.3	2.5	2.8	.48	1.7
Phophorus, dissolved (mg/L as P)	< .010	< .010	< .010	< .010	< .010	< .010
Aluminum, dissolved (µg/L as Al)	20	10	20	20	30	30
Arsenic, dissolveds (µg/L as As)	< 1	1	< 1	1	< 1	1
Barium, dissolved (µg/L as Ba)	48	54	24	31	40	40
Boron, dissolved (µg/L as B)	<10	30	<10	30	30	50
Cadmium, dissolved (µg/L as Cd)	< 1	< 1	< 1	< 1	< 1	< 1
Chromium, dissolved (µg/L as Cr)	< 1	< 1	< 1	< 1	< 1	< 1
Cobalt, dissolved (µg/L as Co)	6	< 1	2	< 1	3	1
Copper, dissolved (µg/L as Cu)	< 1	59	< 1	22	1	2
Iron, dissolved (µg/L as Fe)	35	< 3	5	< 3	7	20
Lead, dissolved (µg/L as Pb)	2	< 1	< 1	2	1	2
Lithium, dissolved (µg/L as Li)	< 4	< 4	< 4	< 4	< 4	< 4
Manganese, dissolved (µg/L as Mn)	110	14	3	7	4	9
Mercury, dissolved (µg/L as Hg)	< .1	.1	< .1	.2	< .1	< .1
Nickel, dissolved (µg/L as Ni)	1	11	< 1	10	2	2
Selenium, dissolved (µg/L as Se)	< 1	< 1	< 1	< 1	< 1	< 1
Silver, dissolved (µg/L as Ag)	< 1	< 1	< 1	< 1	< 1	< 1
Zinc, dissolved (µg/L as Zn)	< 4	< 4	< 4	7	< 4	5
Cyanide, dissolved (mg/L as Cn)	< .01	-	< .01	-	-	-
Methylene blue active substance (mg/L)	.02	-	.03	-	-	-

Table 7. Analysis of ground-water samples from the Anguilla Brook aquifer--Continued

Local well number and site identification number							
SN171 412443071523201		SN172 412433071523901		SN174 412241071515401		SN175 412252071522001	
Date of sample collection							
6/2/82	8/18/82	6/1/82	8/18/82	6/2/82	8/17/82	6/3/82	8/17/82
84	87	133	120	185	180	128	125
6.8	6.5	6.8	6.4	6.9	6.4	-	6.3
10.0	16.0	10.0	11.5	11.0	11.5	11.0	12.5
< 1	-	< 1	-	< 1	-	< 1	-
< 1	< 1	< 1	K3	< 1	-	< 1	< 1
< 1	1	K1	2	-	< 1	< 1	< 1
19	20	39	36	57	59	36	39
3.0	2.0	0.00	1.0	5.0	9.0	9.0	10
5.0	5.2	11	10	15	15	9.4	9.8
1.6	1.7	2.8	2.7	4.7	5.3	3.1	3.5
4.9	6.9	6.1	6.2	8.1	9.7	6.0	7.5
34	41	24	26	23	25	25	28
0.5	0.7	0.5	0.5	0.5	0.6	0.5	0.6
1.0	1.2	1.7	1.4	2.8	2.7	2.0	2.0
16	18	41	35	52	50	27	29
10	9.0	13	11	17	15	15	12
8.4	7.7	7.7	7.5	10	11	8.0	8.1
.1	.1	.2	.3	.1	.1	< 1	< 1
6.5	9.0	9.3	11	21	25	15	18
50	58	80	90	123	127	84	96
48	52	78	73	113	118	75	79
.22	.12	.27	.49	.48	.53	1.8	2.0
< .010	< .010	< .010	< .010	< .010	< .010	< .010	< .010
20	30	40	10	90	200	20	10
< 1	1	< 1	1	< 1	1	< 1	1
26	29	34	33	130	130	23	22
<10	40	10	30	10	30	10	40
< 1	< 1	< 1	< 1	1	< 1	< 1	< 1
< 1	< 1	< 1	< 1	< 1	1	< 1	1
4	< 1	3	< 1	5	2	6	< 1
< 1	2	2	5	< 1	2	< 1	2
4	24	66	140	2,700	3,600	7	20
< 1	2	2	< 1	< 1	1	< 1	2
< 4	< 4	< 4	< 4	4	< 4	< 4	< 4
350	470	1,800	1,700	440	570	450	460
.1		< .1	< .1	.1	< .1	< .1	.2
2	2	2	2	1	1	2	3
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 4	5	6	< 4	9	11	< 4	6
< .01	-	< .01	-	< .01	-	< .01	-
.02	-	.04	-	.01	-	.02	-

Table 8.--Well and test-hole characteristics.

[Locations shown on plate 1. Well, test-hole, and site-location numbering systems explained in table 9.]

Well or test hole number	Site location number	Owner	Date drilled	Land surface altitude (feet above NGVD of 1929)	Depth of well (feet below land surface)	Depth to bedrock (feet below land surface)1/	Water level (feet below land surface)	Date of water level measurement	Aquifer	Remarks2/
				W E L L S						
				North Stonington						
NSN 29	4125160715259.01	E.J. Murphy & Sons	1958	105	30	-	2	11-18-58	Stratified drift	Published in CWRB 16
NSN 69	4125110715239.01	Mrs. Jessie Lee	1982	112	36.2	35(R)	20.5	8-18-82	Stratified drift	L.O.Q.
NSN 70	4125170715229.01	Roger Beaucage	1977	115	275	25	25	4-6-77	Bedrock	L.
NSN 71	4125130715211.01	W.A. Clark, Est.	1968	140	52	18	12	8-29-68	Bedrock	0-18 feet, till and boulders
NSN 73	4125210715322.01	Varian York	1976	160	405	22	35	9-29-76	Bedrock	0-22 feet, gravel and till
				Stonington						
SN 56	4121170715139.01	W.N. Siegel	-	78	14.1	-	6.6	4-28-60	Till	Published in CWRB 16.
SN 57	4121080715111.01	S. Zaremba, Jr.	-	13	13	-	4.7	4-28-60	Till	Do.
SN 70	4121420715124.01	Town of Stonington	-	25	95	-	5.5	4-29-60	Bedrock	Do.
SN 72	4122220715111.01	Ubald Ravenelle	-	50	23	-	12.5	4-29-60	Till	Do.
SN 75	4122220715113.01	E. Morgan	1943	47	77	19	-	-	Bedrock	Do.
SN 76	4122160715123.01	W.E. Medinger	1955	35	9.5	-	1.2	4-29-60	Stratified drift	Do.
SN 78	4122050715142.01	Town of Stonington	1924	38	15.1	15?	11.1	5-2-60	Till	Do.
SN 80	4121560715157.01	Joseph Cangelosi	1959	20	180	22	10	1959	Bedrock	Do.
SN 134	4121390715125.01	Town of Stonington	1962	22	7.8	-	6.0	8-20-63	Till	Do.
SN 135	4121560715105.01	Town of Stonington	1962	30	10.7	-	8.0	8-20-63	Stratified drift	Do., backfilled from 13 feet
SN 136	4121420715124.02	Town of Stonington	1963	24	85	-	5	-	Bedrock	Do.
SN 141	4121520715205.01	Thomas Bolton	1959	25	35	-	3	1959	Till	Do.
SN 142	4121560715157.02	Joseph Cangelosi	1959	20	18	19	4	1959	Stratified drift	Do.
SN 143	4121430715225.01	Frank and Stanley Prachniak	1957	15	7.4	-	3.7	8-14-63	Stratified drift	Do.
SN 145	4122190715113.01	Henry Richards	1953	50	16.2	-	14.3	8-14-63	Till	Do.
SN 164	4123110715223.01	Town of Stonington	1976	48	19.6	44(R)	7.34	8-17-82	Stratified drift	L.O.Q.
SN 165	4122400715208.01	Thomas F. Canaan, Jr.	1976	36	22.2	57(R)	2.79	5-18-82	Stratified drift	L.O.Q.
SN 170	4124520715228.01	Ralph Minor	1982	80	38.5	53(R)	3.62	6-2-82	Stratified drift	L.O. .
SN 171	4124430715232.01	Alfred Minor	1982	80	39.0	42(R)	3.57	6-1-82	Stratified drift	L.O.Q.
SN 172	4124330715239.01	Dudley Wheeler	1982	74	30.4	43(R)	2.49	5-20-82	Stratified drift	L.O.Q.
SN 173	4124330715223.01	Nathan Wheeler	1982	75	41.7	94(R)	3.06	5-20-82	Stratified drift	L.O.
SN 174	4122410715154.01	Thomas F. Canaan, Jr.	1982	38	30.0	32(R)	3.82	5-18-82	Stratified drift	L.O.Q.
SN 175	4122520715220.01	Carlton Cripps	1982	41	20.8	41(R)	6.25	5-17-82	Stratified drift	L.O.Q.
SN 179	4122510715222.01	Robert Cripps	1973	43	84	40	5	7-9-73	Bedrock	
SN 180	4123130715223.01	Town of Stonington	1972	48	30	>30	-	2-18-72	Stratified drift	2-inch diameter driven well.
SN 181	4125070715331.01	Andrew Latham, Jr.	1968	235	77	27	12	8-19-68	Bedrock	
SN 182	4124260715211.01	Howard Chapman	1965	125	200	100	30	12-22-65	Bedrock	
SN 183	4121270715151.01	Town of Stonington	1975	50	400	20	30	6-f '5	Bedrock	Water supply for landfill.
				T E S T H O L E S						
				Stonington						
SN 48 th	4123330715229.01	Conn. DOT	1962	47	16.5	11.5	0	1962	Stratified drift	L. Deepest of 4 holes.
SN 49 th	4123310715225.01	Conn. DOT	1962	46.5	18.5	>18.5	0	1962	Stratified drift	L. Deepest of 4 holes.
SN 136 th	4122250715157.01	Thomas Canaan, Jr.	1976	30	50	>50	5	9-30-76	Stratified drift	L.
SN 138 th	4124280715252.01	Dudley Wheeler	1982	76	36	32	2	4-20-82	Stratified drift	L.
SN 139 th	4124230715245.01	Dudley Wheeler	1982	74	24	24(R)	3	4-21-82	Stratified drift	L.
SN 140 th	4124250715237.01	Nathan Wheeler	1982	79	44.5	44.5(R)	7	4-23-82	Stratified drift	L.
SN 141 th	4122270715152.01	Thomas Canaan, Jr.	1982	32	43	43(R)	4	4-29-82	Stratified drift	L.
SN 142 th	4124060715232.01	Edward Davis	1982	68	25	25(R)	10	4-30-82	Stratified drift	L.

1/ Depth to bedrock: (R), Refusal. Penetration of auger flight stopped by boulder or bedrock.
> , Greater than depth indicated.

2/ Remarks: CWRB 16, Connecticut Water Resources Bulletin 16 (Cervione and others, 1968)
L., Log in table 9,
O., Observation well,
Q., Quality of water analysis in table 7.

Table 9.--Logs of wells and test holes.

[Under each town, the logs are listed by their town well or test-hole number followed by the location number (latitude and longitude), owner, altitude, the year drilled where available, driller, depth to water, length of screen and depth that bottom of screen is set, and measuring point for observation wells in feet above land surface datum (LSD)]

Well and test-hole identification and site-location numbers:
U.S. Geological Survey number assigned to each site. The letter prefix denotes the town in which it is located followed by a sequential number. The test holes are identified by the "th" suffix. Location number is the latitude and longitude. Number after decimal point is a sequential number used to identify closely spaced wells and test holes.

Altitude: The land surface at the site, in feet above NGVD of 1929, estimated from a topographic map with a contour interval of 10 feet, except at Connecticut Department of Transportation sites where land surface altitude is determined by leveling.

Depth to water: Expressed in feet below land surface.

Description of earth materials: The descriptive terms are those of the driller or geologist; logs of test holes of the U.S. Geological Survey and of the Connecticut Department of Transportation are based on the corresponding grain-size classification shown in the table at the right. Some Connecticut Department of Transportation logs use terms that approximate the percentage of a grain size within the described interval as follows:

	Percent
trace :	0-10
little:	10-20
some :	20-35
and :	35-50

Grain size in millimeters (mm)	Wentworth grade scale for U.S. Geological Survey logs		Grade scale used by Conn. Dept. of Transportation before 1959	AASHO Classification used by Conn. Dept. of Transportation since about 1959
	Boulders		Gravel	Boulders
256				203 mm
	Cobbles			Cobbles
64				76.2 mm
	Pebbles	Very coarse gravel		
32				
		Coarse gravel		25.4 mm
16				Medium gravel
		Medium gravel		9.5 mm
8				Fine gravel
		Fine gravel		
4				
	Granules	Very fine gravel		
2			2 mm	2 mm
	Very coarse sand		Coarse sand	Coarse sand
1				
	Coarse sand		0.6 mm	
0.5				
	Medium sand		Medium sand	0.42 mm
0.25			0.2 mm	
	Fine sand		Fine sand	Fine sand
0.125				0.074 mm
	Very fine sand			Silt
0.062			0.06 mm	
	Silt		Silt	
0.004			0.002 mm	0.004 mm
	Clay		Clay	Clay

NSN 69. 4125110715239.01. Mrs. Jessie Lee. Altitude 112 ft. Drilled 1982 by U.S. Geological Survey. Depth to water 20.5 ft on 8-18-82. Set 4.8 ft of slotted screen at 35.0 ft. Measuring point: Top of PVC casing 1.75 ft above LSD.

Material Description	Depth (ft below LSD) From To	Thickness (ft)
Soil, sandy loam	0 - 1	1
Gravel, granule to boulder, and sand, very coarse; little sand, very fine to medium; trace of silt	1 - 9	8
Sand, coarse to very coarse, and gravel, granule to cobble, little silt and very fine sand; fewer cobbles with depth	9 - 35	26
Refusal	at 35	

NSN 70. 4125170715229.01. Roger Beaucage. Altitude 115 ft. Drilled 1977 by Carl Anderson. Depth to water 25 ft on 4-6-77.

Material Description	Depth (ft below LSD) From To	Thickness (ft)
Gravel, dry	0 - 12	12
Gravel, dirty, wet	12 - 25	13
Granite, gray	25 -234	209
Seam, water-bearing	234 -235	1
Ledge, soft	235 -275	40

SN 164. 4123110715223.01. Town of Stonington. Altitude 48 ft. Drilled 1976 by U.S. Geological Survey. Depth to water 7.34 ft on 8-17-82. Set 5 ft of screen at 19.6 ft. Measuring point: Top of PVC casing 0.3 ft above LSD.

Material Description	Depth (ft below LSD) From To	Thickness (ft)
Fill	0 - 2	2
Gravel, medium, and sand, fine to coarse, little silt	2 - 10	8
Sand, medium to coarse	10 - 13	3
Sand, coarse to very coarse, little gravel, medium	13 - 17	4
Sand, coarse to very coarse, and gravel, fine	17 - 27	10
Sand, medium to coarse, some very coarse	27 - 32	5
Sand, very fine to fine, some silt	32 - 39	7
Till, sandy, gravelly, and silty (dirty sand and gravel)	39 - 44	5
Refusal	at 44	

SN 165. 4122400715208.01. Thomas F. Canaan, Jr. Altitude 36 ft. Drilled 1976 by U.S. Geological Survey. Depth to water 2.79 ft on 5-18-82. Set 5 ft of screen at 22.2 ft. Measuring point: top of PVC casing 1.7 ft above LSD.

Material Description	Depth (ft below LSD) From To	Thickness (ft)
Topsoil	0 - 2	2
Gravel, medium, and sand, medium to coarse, little silt	2 - 7	5
Sand, medium to coarse, clean	7 - 17	10
Sand, fine to medium, some very fine sand	17 - 30	13
Sand, very fine, some fine sand	30 - 37	7
Sand, very fine, and silt, some clay	37 - 49	12
Till, clayey, silty, sandy, firm; angular pebbles	49 - 57	8
Refusal	at 57	

SN 170. 4124520715228.01. Ralph Minor. Altitude 80 ft. Drilled 1982 by U.S. Geological Survey. Depth to water 3.62 ft on 6-2-82. Set 2 ft of screen at 38.5 ft. Measuring point: top of PVC casing, 2.9 ft above LSD.

Material Description	Depth (ft below LSD) From To	Thickness (ft)
Silt, light brown	0 - 7	7
Sand, fine to very coarse, and pebble gravel	7 - 20	13
Sand, fine to very coarse, layered, brown; occasional layers of silt or granule gravel	20 - 38	18
Sand, very fine to very coarse, and granule to pebble gravel, trace of silt, firm, layered	38 - 53	15
Refusal	at 53	

SN 171. 4124430715232.01. Alfred Minor. Altitude 80 ft. Drilled 1982 by U.S. Geological Survey. Depth to water 3.57 ft on 6-1-82. Set 4.8 ft of screen at 39.0 ft. Measuring point: top of PVC casing 2.8 ft above LSD.

Material Description	Depth (ft below LSD) From To	Thickness (ft)
Soil, silty loam, black	0 - 2	2
Sand, very fine to very coarse, brown; trace of silt, trace of granule gravel	2 - 21	19
Sand, very fine to very coarse, and granule to small pebble gravel, layered, brown, gray, and iron-stained	21 - 25	4
Sand, medium to very coarse, and pebble gravel, trace of very fine sand	25 - 38	13
Sand, medium to very coarse, and pebble gravel	38 - 42	4
Refusal	at 42	

SN 172. 4124330715239.01. Dudley Wheeler. Altitude 74 ft. Drilled 1982 by U.S. Geological Survey. Depth to water 2.49 ft on 5-20-82. Set 4.8 ft of screen at 30.4 ft. Measuring point: top of PVC casing 2.0 ft above LSD.

Material Description	Depth (ft below LSD) From - To	Thickness (ft)
Soil, silty, and sandy	0 - 4	4
Sand, very fine to very coarse, silty, light brown	4 - 8	4
Sand, very fine to very coarse, and pebble to granule gravel, trace of very fine sand, rusty brown	8 - 18	10
Gravel, granule to pebble, and sand, medium to very coarse	18 - 26	8
Gravel, granule to pebble, and sand, fine to very coarse, trace of silt	26 - 29	3
Sand, coarse to very coarse, and granule gravel, some fine to medium sand	29 - 39	10
Sand, medium to very coarse, granule to pebble gravel, trace of silt and very fine sand	39 - 43	4
Refusal	at 43	

SN 173. 4124330715223.01. Nathan Wheeler. Altitude 75 ft. Drilled 1982 by U.S. Geological Survey. Depth to water 3.06 ft on 5-20-82. Set 4.8 ft of screen at 41.7 ft. Measuring point: top of PVC casing, 2.6 ft above LSD.

Material Description	Depth (ft below LSD) From - To	Thickness (ft)
Soil, gravelly sand	0 - 0.5	0.5
Gravel, granule to pebble, and sand, very fine to very coarse, little silt	0.5- 7	6.5
Sand, very fine to very coarse, and gravel, granule to pebble	7 - 14	7
Sand, very fine to medium, trace of silt	14 - 27	13
Sand, fine to very coarse, and gravel, granule; occasional layers of well-sorted very fine sand and silt, or medium to very coarse sand	27 - 42	15
Sand, very fine to fine, laminated, clean; layered with fine to medium sand	42 - 52	10
Sand, very fine, and silt	52 - 53	1
Sand, medium to very coarse	53 - 56	3
Sand, fine to medium, with silt layers	56 - 64	8
Gravel and sand	64 - 68	4
Sand, fine to coarse	68 - 90	22
Till	90 - 94	4
Refusal	at 94	

SN 174. 4122410715154.01. Thomas F. Canaan, Jr. Altitude 38 ft. Drilled 1982 by U.S. Geological Survey. Depth to water 3.82 ft on 5-18-82. Set 4.5 ft of screen at 30.0 ft. Measuring point: top of PVC casing 2.0 ft above LSD.

Material Description	Depth (ft below LSD) From - To	Thickness (ft)
Soil, silt, black	0 - 2	2
Sand, very fine to very coarse, and gravel, granule to small pebble, some silt	2 - 7	5
Sand, fine to very coarse, and gravel, granule, brown	7 - 14	7
Sand, very fine to fine, and silt, gray	14 - 25	11
Sand, very fine to very coarse, and gravel, granule to large pebble	25 - 32	7
Refusal	at 32	

SN 175. 4122520715220.01. Carlton Cripps. Altitude 41 ft. Drilled 1982 by U.S. Geological Survey. Depth to water, 6.25 ft on 5-17-82. Set 3.4 ft of screen at 20.8 ft. Measuring point: top of PVC casing, 2.0 ft above LSD.

Material Description	Depth (ft below LSD) From - To	Thickness (ft)
Soil, silt, black	0 - 1	1
Gravel, granule to large pebble, sand, very fine to very coarse, and silt	1 - 12	11
Sand, fine to very coarse, and gravel, granule to small pebble	12 - 21	9
Sand, very fine to fine, gray, very soft	21 - 31	10
Silt, gray; laminated, interbedded with thin layers of medium sand	31 - 35	4
Gravel, granule to large pebble, and sand, very fine to very coarse; trace of silt	35 - 41	6
Refusal	at 41	

TEST HOLES

SN 48 th. 4123330715229.01. Conn. Department of Transportation. Drilled 1962. Altitude 47 ft. Water level 0 ft. Three additional borings (not shown) 11.5 to 15 ft deep, at this site.

Material Description	Depth (ft below LSD) From - To	Thickness (ft)
Water	0 - 2	2
Sand, fine to coarse, gray, and fine to coarse gravel; little silt; trace of clay	2 - 5	3
Sand, coarse to fine, brown to gray, and fine to coarse gravel; little silt	5 - 11.5	6.5
Rock, decomposed	11.5- 13.5	2
Gneiss, dark-gray, micaceous	13.5- 16.5	3

SN 49 th. 4123310715225.01. Conn. Department of Transportation. Drilled 1962. Altitude 46.5 ft. Water level 0 ft. Three additional borings (not shown), 11.5 to 15 ft deep, at this site.

Material Description	Depth (ft below LSD) From - To	Thickness (ft)
Water	0 - 0.5	0.5
Sand, coarse to fine, brown, and fine to coarse gravel; trace of silt	0.5- 8.5	8
Sand, fine to coarse, gray-brown; trace of fine gravel; trace of silt	8.5- 12.5	4
Sand, fine to coarse, brown to gray; some fine to coarse gravel; trace of silt	12.5- 18.5	6

SN 136 th. 4122250715157.01. Thomas Canaan, Jr. Altitude 30 ft. Drilled 1976 by U.S. Geological Survey. Depth to water, 5 ft.

Material Description	Depth (ft below LSD) From - To	Thickness (ft)
Topsoil	0 - 2	2
Sand, coarse to very coarse, some gravel	2 - 7	5
Sand, coarse to very coarse	7 - 10	3
Sand, fine to coarse, some silt, gray	10 - 13	3
Silt, gray, some clay	13 - 25	12
Sand, very fine to fine, some silt and clay	25 - 36	11
Gravel, fine to coarse, and sand, medium to very coarse, silty; some layers of very clean fine sand	36 - 45	9
Till	45 - 50	5
Refusal	at 50	

SN 138 th. 4124280715252.01. Dudley Wheeler. Altitude 76 ft. Drilled 1982 by U.S. Geological Survey. Depth to water 2 ft.

Material Description	Depth (ft below LSD) From - To	Thickness (ft)
Soil, silty, black	0 - 2	2
Gravel, pebble to cobble, and sand, fine to very coarse, some silt, brown	2 - 4	2
Sand, fine to very coarse, some silt	4 - 7	3
Gravel, pebble, and sand, fine to very coarse	7 - 16	9
	16 - 17	1
Gravel, granule to cobble, and sand, fine to very coarse; with layers of gray silt and very fine sand	17 - 27	10
Sand, fine to very coarse, some silt, gray, very hard	27 - 32	5
Weathered bedrock (gneiss)	32 - 36	4
Bottom of hole	at 36	

SN 139 th. 4124230715245.01. Dudley Wheeler. Altitude 74 ft. Drilled 1982 by U.S. Geological Survey. Depth to water 3 ft.

Material Description	Depth (ft below LSD) From - To	Thickness (ft)
Soil, silty, black	0 - 2	2
Silt, pebbly, brown	2 - 5	3
Gravel, granule to small pebble, and sand, medium to very coarse, with some very fine sand between 5-7 ft	5 - 18	13
Sand, very fine to very coarse, silty; few pebbles, firm	18 - 23	5
Till, silty, sandy, gray; few pebbles	23 - 24	1
Refusal	at 24	

SN 140 th. 4124250715237.01. Nathan Wheeler. Altitude 79 ft. Drilled 1982 by U.S. Geological Survey. Depth to water 7 ft.

Material Description	Depth (ft below LSD) From - To	Thickness (ft)
Soil, loam, black	0 - 1	1
Gravel, granule to cobble, and sand, medium to very coarse, little very fine sand	1 - 7	6
Sand, medium to very coarse, and gravel, granule to pebble, trace of fine sand	7 - 22	15
Sand, very fine to very coarse, and gravel, pebble	22 - 27	5
Sand, fine to very coarse, trace of very fine sand	27 - 30	3
Silt, laminated, interbedded with very fine sand beds	30 - 35	5
Sand, very fine to very coarse, silty, and gravel, granule to pebble, firm	35 - 44	9
Refusal	at 44.5	

SN 141 th. 4122270715152.01. Thomas F. Canaan, Jr. Altitude 32 ft. Drilled 1982 by U.S. Geological Survey. Depth to water 4 ft.

Material Description	Depth (ft below LSD) From - To	Thickness (ft)
Soil, sandy silt, brown	0 - 1	1
Gravel, granule to pebble, and sand, medium to very coarse	1 - 10	9
Gravel, granule, and sand, fine to very coarse	10 - 13	3
Sand, very fine to very coarse	13 - 24	11
Silt, gray and brown, laminated	24 - 30	6
Gravel, pebble, and sand, very fine to coarse; with clay layers; some cobbles	30 - 40	10
Till, sandy, silty, brown, very hard	40 - 43	3
Refusal	at 43	

SN 142 th. 4124060715232.01. Edward Davis. Altitude 68 ft. Drilled 1982 by U.S. Geological Survey. Depth to water 10 ft.

Material Description	Depth (ft below LSD) From - To	Thickness (ft)
Gravel, granule to cobble, sand, very fine to very coarse, and silt, gray-brown	0 - 20	20
Till, clayey, silty; yellowish brown, some granules to pebbles; firm	20 - 23	3
Bedrock, weathered	23 - 25	2
Refusal	at 25	

Table 10.--Grain-size analyses of samples of stratified drift from the Anguilla Brook aquifer

[All samples are disturbed but uncontaminated. They were collected from a split-spoon sampler or auger flight during U.S. Geological Survey drilling. The well and test-hole locations are shown on plate 1 and the logs are in table 9. All analyses and calculations were made by the U.S. Geological Survey. Well, test-hole, and site-location numbering systems explained in table 9. Abbreviations: ft, feet; mm, millimeter; in., inch]

Depth sampled: Interval in feet below land surface from which sample was taken.

Grain-size distribution in percent of total weight finer than given size. Size intervals are those of the Wentworth scale (shown at the beginning of table 9).

Median grain size: The grain size at which 50 percent of the material is coarser and 50 percent finer. The size is read from a graph at the midpoint of the cumulative distribution curve.

				Percent of total weight finer than given size									
Well or test-hole identification number	Site location number	Depth sampled (ft)	Median grain size (mm)	32 mm	16 mm	8 mm	4 mm	2 mm	1 mm	0.5 mm	0.25 mm	0.125 mm	0.062 mm
				Gravel				Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt and clay
				W E L L S									
				Town of North Stonington									
NSN 69	4125110715230.01	16-19	3.8	100	84	64	52	43	35	27	19	12	7
		31-33	0.6	100	96	88	80	73	61	46	32	22	13
				Town of Stonington									
SN 164	4123110715223.01	17-18.5	0.8			100	95.8	82.1	63.8	25.6	10.7	3.8	1.9
		22-23.5	1.8		100	91.1	67.5	51.7	41.6	26.5	9.4	3.1	1.1
		27-28.5	0.75		100	95.6	86.6	76.3	64.2	32.9	12.2	3.2	1.4
		32-33.5 (top 3 in.)	0.14			100	99.3	98.7	97.0	93.3	77.7	40.6	19.5
		32-33.5 (bottom 3 in.)	0.06					100	99.9	99.6	98.3	84.4	53.3
		42-43.5 (top 6 in.)	0.15			100	99.2	96.2	86	75.6	64.5	43.4	26.3
		42-43.5 (bottom 6 in.)	0.3		100	91.2	82.1	71.8	64.1	57.7	48.6	36.0	25.1
SN 165	4122400715208.01	22-23.5	0.22		100	99.5	95.6	94.0	93.0	88.7	53.4	19.2	7.2
		27-28.5	0.08					100	99.8	99.6	97.7	67.7	32.3
		37-38.5	0.6					100	99.9	99.8	99.6	91.4	49.6
SN 170	4124520715228.01	17-18	1.8	100	91	76	63	53	43	33	24	16	10
		22-24	0.3		100	99	94	90	79	62	42	21	11
		27-28	0.3		100	96	89	84	77	62	45	29	19
		32-34	0.6		100	95	84	73	61	46	31	18	10
		37-39	1.4		100	86	67	56	45	36	27	18	11
		52-53	0.4		100	96	92	86	73	56	41	24	12
SN 171	4124430715232.01	10-15	0.6		100	98	93	88	72	44	18	8	4
		22-24	0.5		100	83	74	68	61	51	40	29	15
		27-29	1.8	100	82	70	60	52	42	29	20	12	6
		32-34	0.6	100	96	91	82	74	61	46	35	20	9
		37-38	0.6		100	92	77	68	57	47	39	20	8
		38-39	4.5	100	92	63	46	39	33	28	24	16	7
SN 172	4124330715239.01	4- 6	0.8		100	91	79	68	56	40	17	8	4
		9-12	0.7		100	88	77	69	57	41	17	7	4
		22-24	3.0		100	84	58	42	29	19	12	6	3
		27-29	1.1		100	83	64	56	49	42	23	15	3
		32-34	1.1		100	85	77	64	49	30	17	5	1
		37-39	0.8	100	96	82	72	64	55	44	32	21	12
		42-43	0.3		100	96	87	79	71	61	49	34	22
SN 173	4124330715223.01	16-18	0.3					100	98	76	39	21	12
		21-23	0.2					100	99	91	61	23	8
		26-28	0.5				100	78	63	50	36	22	13
		31-33	0.6			100	95	87	67	44	26	12	6
		36-38	0.5		100	99	87	79	68	49	29	15	8
		41-43	0.13						100	99	90	42	13
		46-48	0.10						100	99	96	61	22
		51-53	0.05							100	99	96	65
		56-58	0.20			100	99	95	85	70	58	28	9
		61-63	0.07						100	99	94	76	44
		76-79	0.11						100	96	88	53	17

Well or test-hole identification number	Site location number	Depth sampled (ft)	Median grain size (mm)	Percent of total weight finer than given size: 32 mm	16 mm	8 mm	4 mm	2 mm	1 mm	0.5 mm	0.25 mm	0.125 mm	0.062 mm
				Gravel				Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt and clay
				W E L L S									
				Town of Stonington--Continued									
SN 174	4122410715154.01	3- 6	0.8	100	92	79	71	64	54	40	28	21	16
		8-11	2.6	100	88	71	57	46	33	18	10	7	6
		18-20	0.08					100	99	98	91	69	39
		21-23	0.03							100	99	97	81
		31-32	1.0		100	80	65	58	50	41	31	20	12
SN 175	4122520715220.01	5- 6	1.5		100	83	66	55	45	36	25	15	9
		10-11	2.9	100	76	61	53	47	40	31	23	16	12
		16-18	0.6		100	89	79	71	61	48	30	14	8
		26-31	0.06								100	90	42
		31-33	0.01							100	99	98	94
		36-38	1.5	100	92	71	62	55	46	37	26	16	10
				T E S T H O L E S									
				Town of Stonington									
SN 138 th	4124280715252.01	11- 13	1.2	100	97	76	65	58	47	35	23	14	8
		16 -17	0.3					100	98	75	30	6	2
		17.3-18	4.5	100	77	58	47	40	32	24	17	11	6
		21- 23	0.8	100	96	81	72	64	53	42	29	19	11
		26- 27	0.5		100	98	84	69	59	50	35	20	10
		31- 32	0.3			100	96	92	82	64	36	14	5
SN 139 th	4124230715245.01	16- 18	1.1		100	79	67	59	49	39	28	18	11
		21- 23	0.3			100	93	88	81	67	46	26	15
SN 140 th	4124250715237.01	18- 20	0.5		100	88	82	76	65	51	37	20	9
		22- 24	0.8		100	93	85	73	57	39	26	16	8
		26- 28	0.3			100	99	96	88	72	47	22	11
		31- 32	0.09						100	99	97	76	25
		36- 38	1.0	100	87	78	65	58	49	40	30	21	13
		42- 43	0.21		100	91	85	81	74	65	54	40	26
SN 141 th	4122270715152.01	4- 6	0.7	100	93	77	69	63	56	44	28	14	8
		8- 10	3.5	100	78	65	52	46	39	31	20	11	7
		14- 16	3.5	100	90	65	53	45	36	26	14	8	5
		18- 20	0.10			100	98	95	90	80	75	61	24
		23- 25	0.02					100	99	98	97	95	76
		31- 33	1.5	100	95	78	60	52	45	38	29	20	14
		41- 42.5	0.5	100	95	80	72	65	58	50	38	25	14
		43	0.5		100	82	72	66	59	49	38	26	15
SN 142 th	4124060715232.01	8- 16	1.8	100	98	77	60	52	43	32	22	14	8
		20- 23	0.08		100	96	92	88	85	78	66	54	42

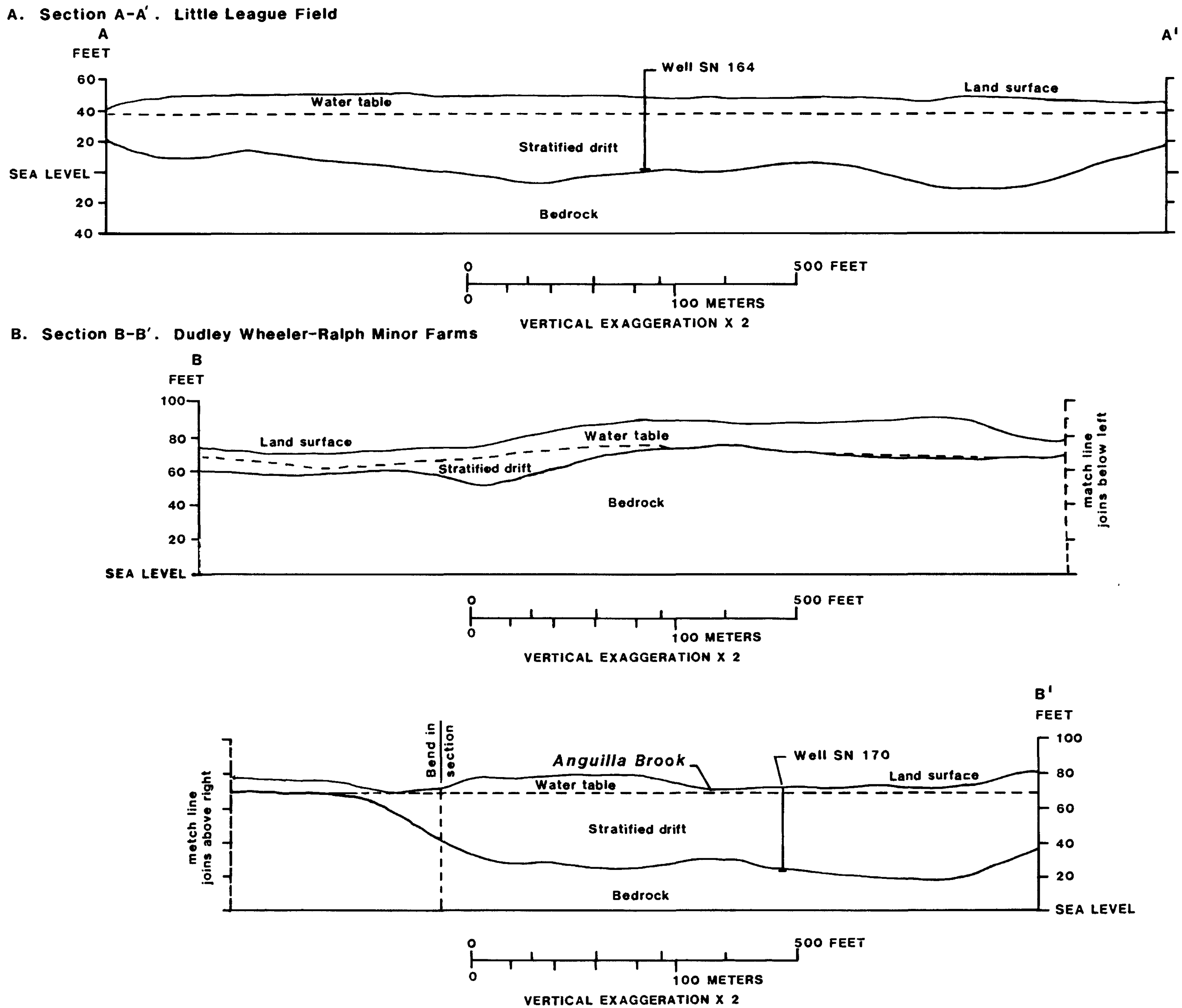
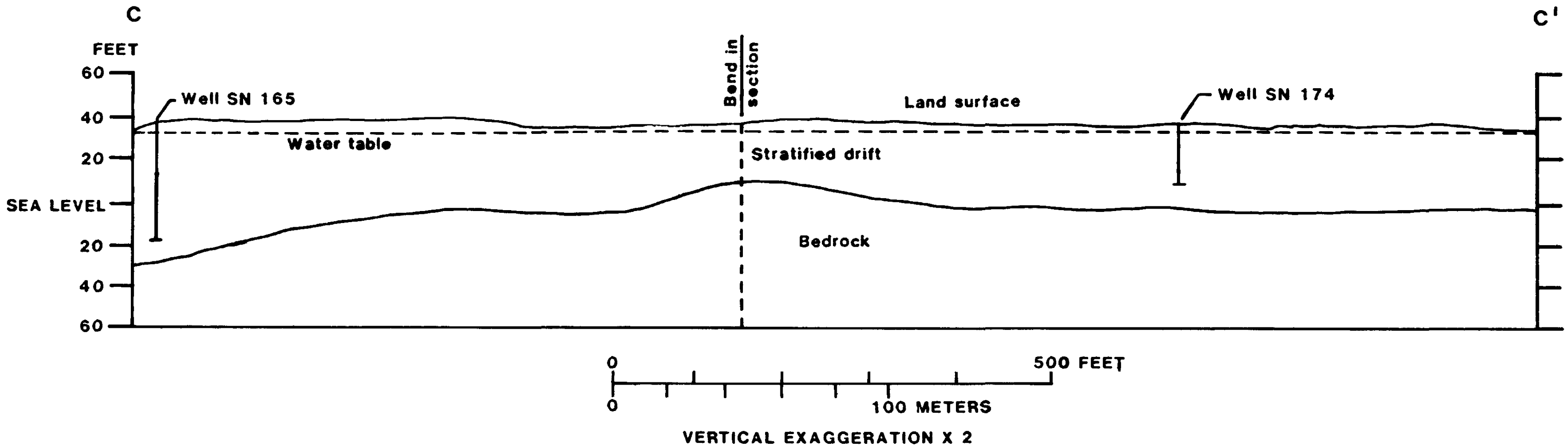
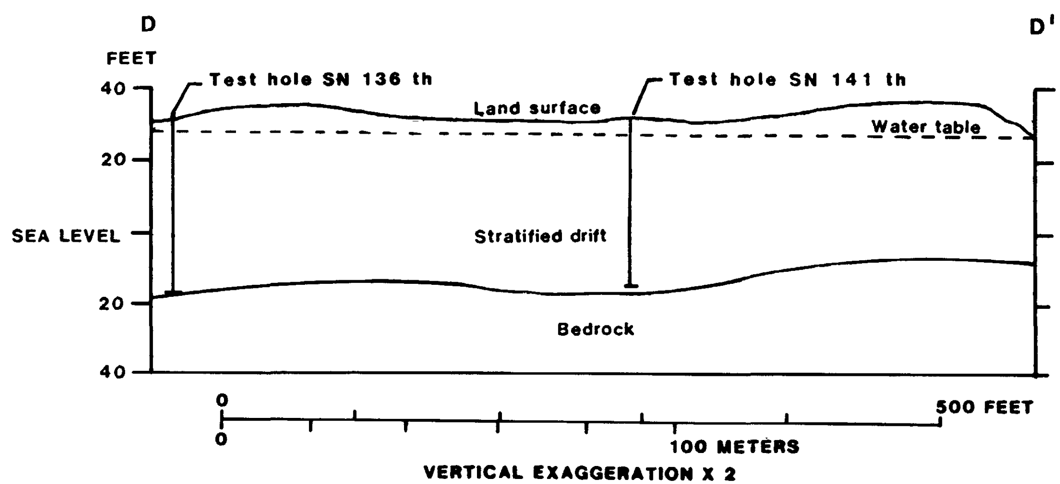


Figure 15.--Cross sections showing hydrogeologic units as interpreted from seismic-refraction data in Anguilla Brook valley, Stonington, Connecticut.

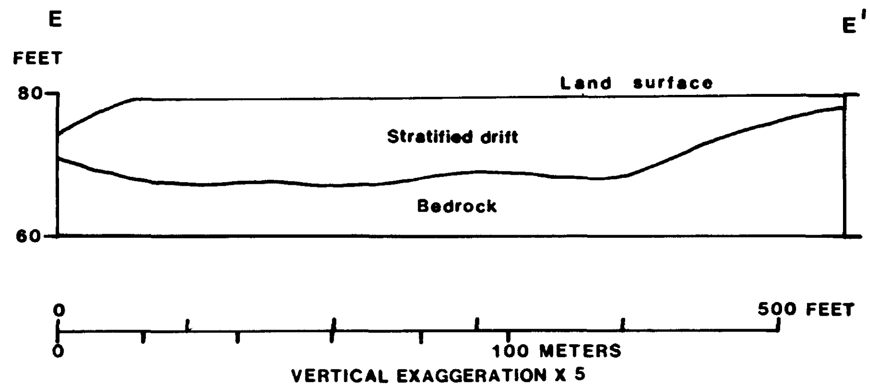
C. Section C-C'. Thomas F. Canaan, Jr. Farm



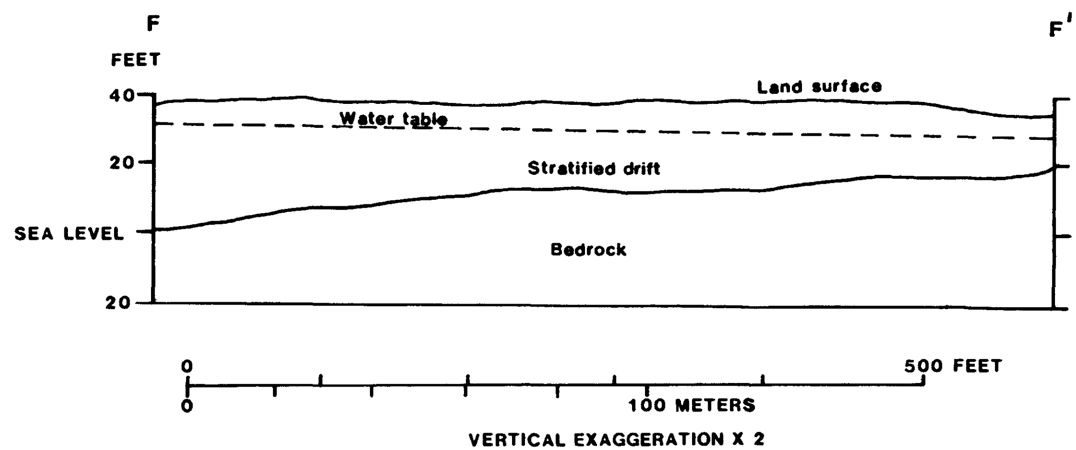
D. Section D-D'. Thomas F. Canaan, Jr. Farm



E. Section E-E'. Nathan Wheeler Farm



F. Section F-F'. High School athletic field



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