WATER RESOURCES INVENTORY OF CONNECTICUT

PART 4

SOUTHWESTERN COASTAL RIVER BASINS

BY

ROBERT B. RYDER, MICHAEL A. CERVIONE, JR., CHESTER E. THOMAS, JR.,

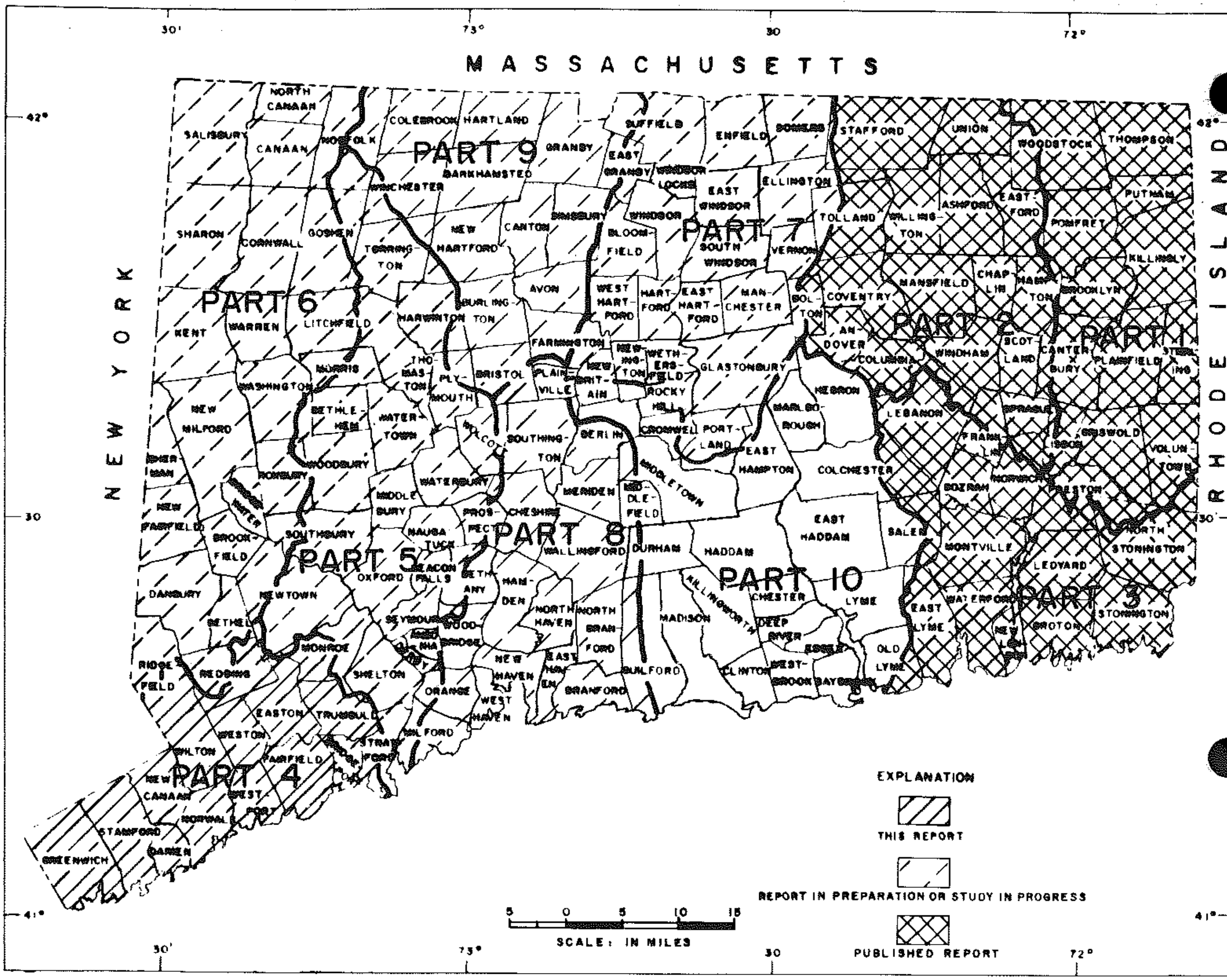
and MENDALL P. THOMAS

U.S. GEOLOGICAL SURVEY

PREPARED BY THE
U.S. GEOLOGICAL SURVEY
IN COOPERATION WITH THE
CONNECTICUT WATER RESOURCES COMMISSION

CONNECTICUT WATER RESOURCES BULLETIN NO. 17

1970



THE WATER RESOURCES INVENTORY OF RIVER BASINS IN CONNECTICUT

PART 1- Quinebaug River Basin
PART 2-Shetucket River Basin
PART 3-Lower Thames and Southeastern Coastal River Basins
PART 4-Southwestern Coastal River Basins
PART 5- Lower Housatonic River Basin
PART 6- Upper Housatonic River Basin
PART 7- Upper Connecticut River Basin
PART 8- Quinnipiac River Basin
PART 9- Farmington River Basin
PART 10-Lower Connecticut River Basin

OUTSIDE COVER.--The valley of the Poquonock River looking north from Bridgeport, near the mouth of the river, to the town of Trumbull in the distance. The Connecticut Turnpike (I-95) is easily visible as it crosses the area of the photo from west to east. All of the river from the right edge of the photograph to within 3,500 feet of Bunnells Pond (dark area in center background) is an estuary containing salty water. The average flow of the river at the outlet of Bunnells Pond is 25 mgd, and the pond holds 147 million gallons of fresh water in usable storage. Most of the area south of the Turnpike and the area flanking the Poquonock River north of it is underlain by the stratified-drift aquifer, the most important aquifer in the valley. This aquifer is thickest under the river. A boring at the east end of the Connecticut Turnpike bridge penetrated 107 feet of stratified sand and silt and reached bedrock at an altitude of 121 feet below mean sea level. During the first half of the 20th century, industries near the estuary of the Poquonock River pumped large quantities of ground water from stratified drift and underlying bedrock aquifers. Subsequently, salt water intruded these aquifers and many wells produced corrosive salty water and were abandoned and later destroyed.

Photograph courtesy of United Illuminating.

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TABLES

SUMMARY

The 440 square miles of the southwestern coastal river basins (394 square miles of which are in Connecticut) yield about 183 billion gallons, or 23.9 inches of runoff during an average year. This amount of runoff is almost entirely derived from precipitation falling on the basins, and is eventually discharged into Long Island Sound. In 1965, some streamflow originated from 5.5 billion gallons of water imported from the Housatonic River basin. Mean annual runoff is generally an index of the water potentially available for development; however, in the basins, large-scale impoundment and diversion of streamflow has preempted most of the surface water available.

The mean annual precipitation on the basins, during the reference period October 1930 - September 1960, was 47.5 inches, and the mean monthly precipitation ranged from 3.0 inches in February to 4.8 inches in August. Almost half of the mean annual precipitation--23.6 inches--is lost from the basins by evapotranspiration. In addition, an undetermined but small amount of water is exported from the basins to the Housatonic River basin and, in 1965, 2.2 million gallons was exported to Port Chester, New York.

The amount of streamflow at any site varies from day to day, and is related to the size of the drainage basin, percent of the drainage basin underlain by the stratified-drift aquifer, amount and intensity of precipitation on the basin, and the season of the year. Runoff from a drainage basin underlain by stratified drift is more evenly distributed in time than runoff from a basin underlain by till. This characteristic is expressed by flow-duration curves that relate the relative areal extent of stratified drift in a basin to the percent of time that a particular runoff was equaled or exceeded. The recurrence intervals of lowest annual mean streamflows for specified periods can be estimated from flow-duration curves. For example, the lowest streamflow for 30 consecutive days at a particular site, which could be expected to recur on the average every other year, is equivalent to the streamflow equaled or exceeded 90 percent of the time.

The storage in an artificial impoundment required to maintain various streamflows at downstream sites on unregulated streams is related to the selected recurrence interval of low streamflow and the percent of the drainage basin underlain by stratified drift. For example, 22 million gallons of impounded storage per square mile of a drainage basin, of which 20 percent is underlain by stratified drift, is required to maintain streamflow of 0.5 mgd per sq mi (million gallons per day per square mile) when the selected recurrence interval of annual lowest mean streamflow is 2 years.

Floods may occur in the basins during any month of the year, although they are common in the spring. During the flood of October 1955, the flow of the Saugatuck River near Westport was 14,800 cfs (cubic feet per second) or 9,560 mgd, and was probably equal to, if not greater than, the largest flow at this site since colonial days. The mean annual flood at any site is related to the effective drainage area, and the recurrence interval of any specified flood flow is related by a variable ratio to the mean annual flood.

Ground water can be obtained from all three aquifers underlying the basins--stratified drift, till, and bedrock--but only stratified drift can yield large quantities for industrial and public-supply uses. The stratified-drift aquifer is made up of sorted silt, sand, and gravel, and underlies about 15 percent of the area of the basins. It has a transmissibility of 0 to over 200,000 gpd per ft (gallons per day per foot), is up to 185 feet thick and is between 30 and 60 feet thick in many places, and yields over 2,000 gpm (gallons per minute) to individual wells in a few places.

Five areas underlain by the stratified-drift aquifer are considered favorable for the development of large supplies (over 1 mgd) of ground water. The potential yield of these areas ranges from 2.5 to 7.3 mgd and was estimated by: 1) calculating the amount of ground water outflowing from the area, 2) use of plate B, which shows the transmissibility, thickness, and impermeable boundaries of the stratified-drift aquifer, 3) use of graphs relating drawdown in the stratified-drift aquifer to distance from a pumping well and rate of pumping, and 4) estimating induced infiltration of streamflow.

The till aquifer is a nonsorted mixture of clay, silt, sand, and gravel that underlies most of the basins. It is estimated to have a permeability of about 5 gpd per sq ft (square foot) everywhere in the basins and can yield marginally adequate supplies to individual domestic wells.

The bedrock aquifer is made up of an interlocking network of mineral grains and underlies the basins everywhere. The yield of a well tapping bedrock is related to the number and width of opening of water-bearing fractures intersected during drilling. Analysis of yield-depth data from 725 bedrock wells indicates that yields of at least 3 gpm may be obtained at most places, whereas yields of 10 gpm or more may be obtained at only a few sites. On the other hand, a weathered-marble bedrock aquifer, which underlies a few small areas, can yield more than 100 gpm to individual fully penetrating wells.

The chemical quality of precipitation on the basins during 1965 was relatively similar at four sites sampled. The mean concentrations of sulfate and chloride ranged from 8.6 mg/l (milligrams per liter) and 1.0 mg/l, respectively, along the northernmost part of the basins to 11.2 mg/l and 3.7 mg/l, respectively, along the shore of Long Island Sound.

Much of the water in the basins is of good to excellent chemical quality and contains a low concentration of dissolved solids. However, the quality of water in many streams, flowing through urban areas is impaired by man's activity. Also, the quality of ground water in localized areas is affected by domestic and industrial wastes, road-salting chemicals, and by salt water from estuaries and Long Island Sound.

Under natural conditions, the dissolved-solids concentration of stream water at any site is inversely

related to streamflow, reflecting the relative proportions of ground-water runoff, which contains a higher dissolved-solids concentration than direct runoff. The dissolved-solids concentration of stream water sampled during high and low streamflow ranged from 38 to 158 mg/l and from 53 to 268 mg/l, respectively.

The dissolved-solids concentration in water sampled from 58 wells tapping bedrock and from 20 wells tapping stratified drift ranged from 52 to 354 mg/l and from 71 to 225 mg/l, respectively. Objectionable quantities of iron are contained in 28 percent of the water samples from bedrock and in 15 percent of the samples from stratified drift, and objectionable quantities of manganese are contained in 36 percent of the samples from bedrock and in 26 percent of the samples from stratified drift.

Many inlets, coves, marshes, wetlands, coastal streams, and estuaries along the southern boundary of the basins contain salt water. The specific conductances of water in the estuaries indicate that chloride concentrations range from 2,600 to 13,500 mg/l. Parts of aquifers adjoining bodies of salty surface water may contain natural or man-induced salty ground water.

The temperature of stream water fluctuates with the seasons. The temperature of the Saugatuck River, during the period October 1964 - September 1966, ranged from 1°C (Celsius) (33° Fahrenheit) to 26°C (79°F). The maximum daily temperature was 21°C (70°F) or less 79 percent of the time, and the mean temperature was 11°C (52°F), or about equal to the mean annual air temperature.

The temperature of ground water is more uniform throughout the year than that of surface water and is about equal to the mean annual air temperature. Seasonal fluctuations of temperature in wells are largest near land surface and decrease with depth.

The total amount of water used in the basins in 1965 was about 36.7 billion gallons or about 165 gpd per capita; 87 percent of the total was supplied by water utilities. The water-utility systems are supplied by many reservoirs, several in the same drainage basin. The largest three reservoirs are Saugatuck Reservoir, Easton Reservoir, and Hemlock Reservoir, which have a usable storage of 11,924, 5,848, and 3,801 million gallons, respectively.

CONTENTS

(Back Cover) Reports dealing with water resources in Connecticut published by the Connecticut Water Resources Commission.

ILLUSTRATIONS

WATER RESOURCES INVENTORY OF CONNECTICUT
PART 4
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WATER RESOURCES INVENTORY OF CONNECTICUT

Connecticut, in common with many other states, has experienced a rapid increase in population in the past few decades, accompanied by industrial expansion, changes in agricultural technology, and a rising standard of living. These changes have contributed to a steadily rising demand for water that is expected to continue in the foreseeable future. Although the water that supplies this demand is ample, it varies in amount and in quality from place to place, from season to season, and from year to year. Therefore, as the need for water increases, so does the need for accurate information and careful planning to obtain the optimum use of existing water-resources developments and to locate new areas for development.

Accordingly, in 1959 the General Assembly, on recommendation of the Water Resources Commission, authorized a water-resources inventory of Connecticut. Under this authorization, and under a supplemental authorization of the General Assembly in 1963, the U.S. Geological Survey, in cooperation with the Water Resources Commission, has undertaken a series of studies to determine the quantity and quality of water available in the State. To simplify the calculation and description of water quantities and relationships, the State has been subdivided into 10 study areas, each bounded by natural drainage divides (see map inside front cover). Reports resulting from studies of these areas will be useful to State, regional, and town planners, town officials, water-utility personnel, consulting hydrologists, well drillers, and others concerned with the development and management of the water resources. Reports are available for the Quinebaug River basin, the Shetucket River basin, and the lower Thames and southeastern coastal river basins (a complete list of reports dealing with water resources in Connecticut published by the Water Resources Commission is given on the back cover). This report covers the fourth of the 10 study areas.

THE SOUTHWESTERN COASTAL RIVER BASINS

The area covered by this report is shown on figure 1; it includes the drainage basins of all streams that enter Long Island Sound between the mouth of the Housatonic River and the western border of the State. For brevity the area is referred to throughout this report as "the basins." Figure 1 also shows ten major drainage basins that have areas in excess of 10 square miles (these are also shown on pl. A-C). The total area of the southwestern coastal river basins is 440 sq mi (square miles), of which 394 sq mi are in Connecticut and 46 sq mi are in New York. The information presented in this report deals mostly with the Connecticut part of the area.

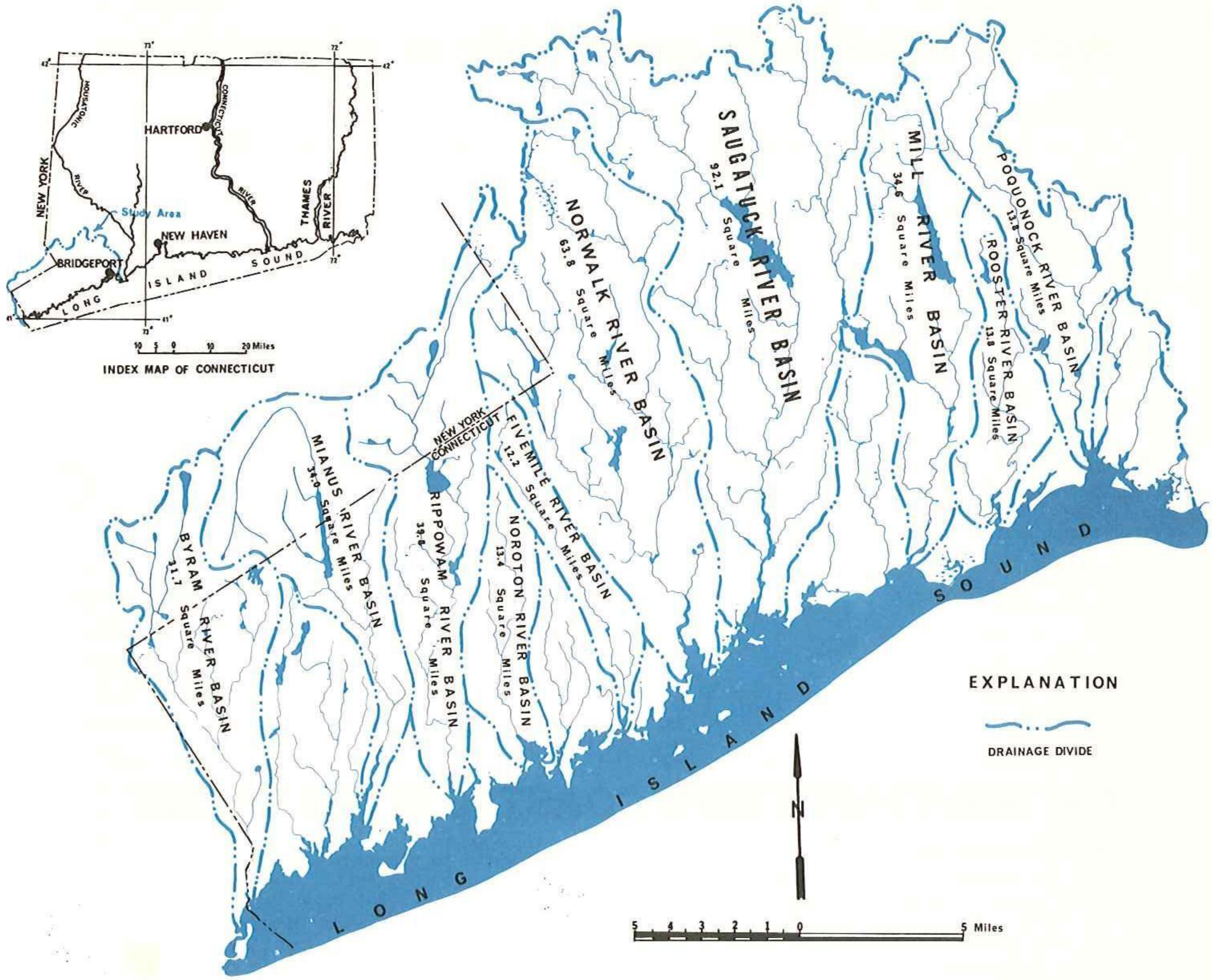


Figure 1.--Ten drainage basins in excess of 10 sq mi make up most of the area of the southwestern coastal river basins.

The basins are characterized by numerous small streams draining to Long Island Sound, many of which are estuaries in their lower reaches.

(1) Precipitation condenses in the atmosphere from water vapor evapotranspired from areas to the south and west, and contains measurable amounts of dissolved mineral matter. The amount falling on the basins is nearly constant throughout the year. Precipitation record is at Saugatuck Reservoir during 1965.

(2) Much of the precipitation moves downslope over the land surface from which small quantities of mineral matter are dissolved. This water quickly enters stream channels as the direct runoff component of streamflow.

(3) Part of the precipitation infiltrates the soil and percolates downward into the unsaturated zone. Here spaces between grains of earth material are filled mostly with air and relatively large quantities of mineral matter are dissolved in the percolating water. During the growing season, plants, trees, and shrubs withdraw much of this soil water.

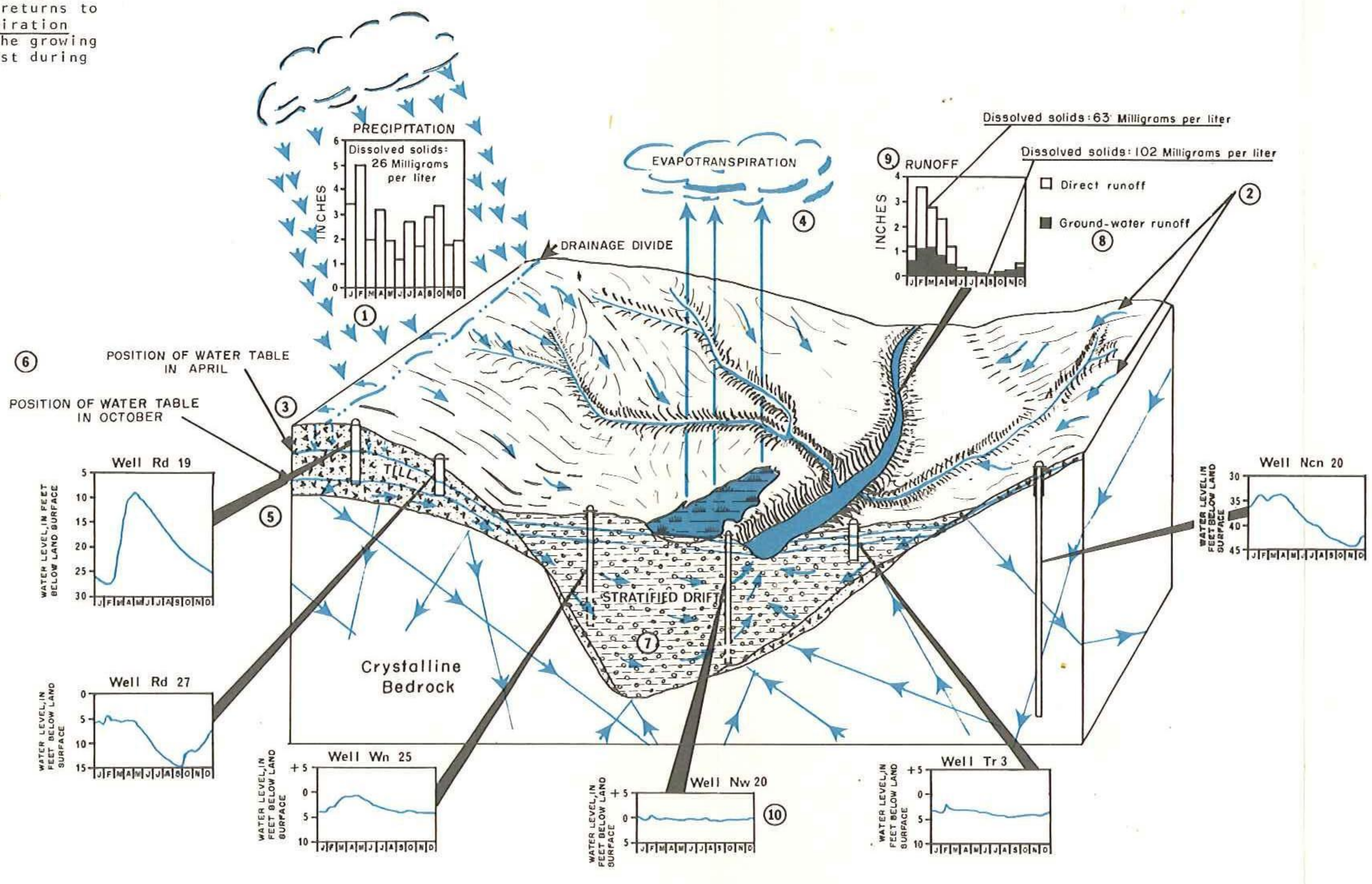
(4) Approximately half of the precipitation falling on the basins is lost through evaporation from swamps, streams, ponds, lakes, and reservoirs, and through transpiration by plants and returns to the atmosphere. Evapotranspiration losses are greatest during the growing season in the summer and least during the winter.

(5) Recharge is water that reaches the saturated zone to become ground water. Here spaces between grains of earth material are completely filled with water. Some plants may withdraw water directly from this zone during the growing season. Recharge is least during the growing season in the summer and greatest during the non-growing season in the winter.

(6) The water table marks the top of the saturated zone. In response to changing rates of recharge and discharge, it is highest in the spring and lowest in the fall. It is generally deepest under hills.

(7) Deposits of stratified drift form the most important aquifer in the basins as they can store and transmit large quantities of water.

(8) Ground water moves downward by gravity from hills to valleys and eventually is discharged into streams as the ground-water runoff component of streamflow.



(9) Total runoff consists of direct runoff and ground-water runoff, and is highly variable during the year. Direct runoff makes up most of the streamflow during February and March because of snow melt; the concentration of dissolved solids in the stream is lowest during this period. Ground-water runoff sustains streamflow during the growing season from May to October when evapotranspiration losses are greatest; the concentration of dissolved solids in the stream is highest during this period. Record is the monthly flow of the Saugatuck River at gaging station 2089.9 during 1965.

Fluctuations of and depth to the water table in a well depend on the topographic position of the well and the type of aquifer. The water table is at land surface in swamps, and at ponds, streams, and lakes, and may be above land surface in some wells located near areas of ground-water discharge and which are open near the bottom of the stratified-drift aquifer, as at (10). Water-level records are for wells Rd 19, Rd 27, Wn 25, Nw 20, Tr 3, and NCn 20 during 1965.

Figure 2.--Representation of the hydrologic cycle in the southwestern coastal river basins.

ACKNOWLEDGMENTS

The data on which this report is based were collected and analyzed by many employees of the Water Resources Division, U.S. Geological Survey. Rino Vitali tabulated much of the water-quality and water-development data and prepared parts of plates B and C. Considerable unpublished information used in the preparation of this report was obtained from the files of various State agencies including the Water Resources Commission, Highway Department, Board of Fisheries and Game, and the Development Commission; also from the files and personnel of Leggette, Brashears, and Graham, Consulting Ground-Water Geologists; Geraghty and Miller, Consulting Ground-Water Geologists; Soil-testing, Inc.; and the S. B. Church Co. The personnel of private and municipal water-utility companies in the basins provided considerable data; especially those of the Bridgeport Hydraulic Co. and the 1st Taxing District, City of Norwalk, Water Department.

GUIDE FOR USE OF THIS REPORT

Water supplies may be obtained from surface sources, such as streams and lakes, and from aquifers. Although these two sources are so closely related as to form one water supply for the basins, the methods used for estimating the amount of water potentially available from each source and the techniques of development of each are sufficiently different to merit discussion in separate sections of this report. The third and fourth sections discuss the quality of water and development of water, respectively.

The availability of surface water anywhere in the basins is summarized on plate B, which locates lakes and ponds that have water in usable storage and indicates the amounts in storage. This map also shows, for all but very small streams, the daily mean streamflow that is equaled or exceeded 90 percent of the time, taking into account effects of diversions existing in 1966. More detailed information is contained in the section entitled "Surface Water", which includes tables and graphs showing flow duration, low-flow frequency and duration, flood peaks, frequency of floods, and storage required to maintain various flows. The quality of water in streams, ponds, and reservoirs and its spatial and temporal variation throughout the basins is summarized on tables 15 and 16, and figures 27, 29, and 30. Specific information on quality of surface water is shown on figures 28 and 31 and is discussed in the section "Quality of Water."

The availability of ground water in the basins is summarized on plate B, which shows the areal distribution of the principal aquifers in the basins. This plate also shows the thickness and transmissibility of the stratified-drift aquifer; these two parameters can be applied to graphs presented in the section entitled "Ground Water" to estimate yields and drawdowns in wells pumped at any constant rate and the distribution of drawdown around pumping wells. Estimates of ground water available for development are also shown on plate B. Areas of the stratified-drift aquifer that are especially favorable for development are shown together with the quantities potentially available in each area. The quality of ground water is discussed in the section "Quality of Water" and is shown on tables 15, 16, 17, and 18, and on figure 27.

Tables and illustrations in this report summarize large amounts of hydrologic data collected and analyzed during this study. These basic data, which include well records, pumping-test data, ground-water level measurements, streamflow records, and chemical analyses of water samples, are included in the companion basic-data report by Thomas and others (1969). Abbreviations used and some convenient equivalents are presented on page 50. For readers unfamiliar with some of the technical terms used in this report a glossary is given on page 51.

THE HYDROLOGIC CYCLE

Water continuously circulates between the atmosphere, the land masses, and the oceans. This hydrologic cycle, as it occurs in its natural state in the basins, is illustrated diagrammatically on figure 2. This illustration describes the components of the cycle and shows the amount of precipitation and runoff and the fluctuation of the water table, as measured in several wells, during 1965. The hydrologic cycle can be considered to begin when water vapor in the atmosphere condenses to form clouds from which precipitation falls on the basins as rain or snow. Part of this water flows across the land surface to streams and lakes (direct runoff--number 2 on fig. 2) and, eventually, to Long Island Sound, and part seeps into the ground. Much of the water that flows on the land surface or seeps into the ground is soon evaporated or taken up by plants and returned to the atmosphere by a process known as transpiration (number 4 on fig. 2). Some, however, moves slowly underground toward nearby streams into which it eventually discharges (ground-water runoff--number 8 on fig. 2). Part of the water that reaches streams, lakes, and oceans is also evaporated to complete the circulation.

As water in the basins circulates through different parts of the cycle, its chemical composition and physical character change profoundly in response to its changing environment. Water is purest as it falls to earth (see number 1 on fig. 2). After reaching the earth's surface, it dissolves many of the materials with which it comes in contact. It reacts with mineral, plant, and animal matter and the products of these reactions are carried away in solution or suspension. Surface reaction rates are generally slow whereas direct runoff is rapid, so that direct runoff is altered but slightly in chemical composition. In contrast, water that percolates into the ground dissolves large quantities of mineral matter from earth materials above and below the water table. As shown on figure 2, the dissolved-solids content of direct runoff is lower (63 mg/l) than that of ground-water runoff (102 mg/l). Ground water discharging into streams and lakes adds a load of dissolved solids to these water bodies; much of this load eventually reaches Long Island Sound. About one-half of the precipitation falling on the basins is lost by evaporation from streams and lakes and transpiration by plants to complete the cycle.

THE WATER BUDGET

Just as the financial operation of a household or business firm can be expressed by a money budget, so the hydrologic cycle can be expressed by a water budget which lists receipts, disbursements, and water on hand. Fresh water received in the basins consists almost entirely of precipitation falling upon the area. Disbursements consist of total runoff, which is made up of direct runoff and ground-water runoff, and evapotranspiration from surface water, ground water, and soil moisture. Although the amount of water stored within the basins changes continuously throughout the year in response to the changing rates at which water enters and leaves the basins, storage changes are negligible from year to year. The quantities of each major component of the water budget in an average year for the reference period October 1930 - September 1960 are shown schematically on figure 3. Although the quantities vary from year to year, the water budget always balances--the disbursements equal the receipts, taking into account changes in storage.

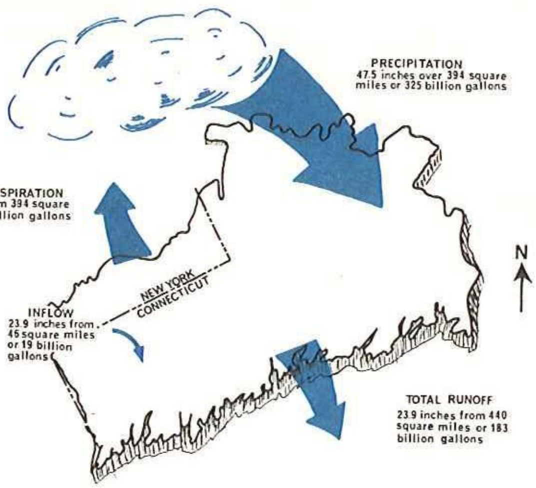


Figure 3.--Mean annual water budget, for the southwestern coastal river basins, 1930-60.

Diversions into and out of the basins and changes in storage from year to year are considered to be negligible, and the amount of water leaving the basins equals the amount entering.

Precipitation has been measured for many years at various points in and near the basins. The mean monthly and the maximum and minimum monthly precipitation falling on the basins during the reference period 1931-60 are shown on figure 4; they were computed from data summarized on tables 24, 25, and 26 in "The Climate of Connecticut" by Joseph J. Brumbach (1965) and from other sources. In computing these values, data from the different precipitation stations in and near the basins were weighted in proportion to the area represented by each station.

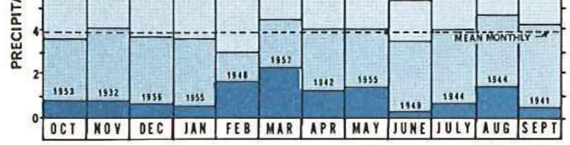


Figure 4.--Monthly precipitation on the basins, water years 1931-60.

Both mean monthly and minimum monthly precipitation were relatively uniform throughout this 30-year period, but maximum monthly precipitation varied widely. Mean annual precipitation for the reference period is 47.5 inches.

The mean annual precipitation on the basins is 47.5 inches. The mean monthly precipitation is evenly distributed throughout the year as shown on figure 4; it ranges from 3.0 inches in February to 4.8 inches in August. Minimum monthly precipitation is similarly distributed but maximum monthly precipitation varies widely, ranging from 0.2 inch in June 1949 to 16.1 inches in October 1955.

Precipitation is the natural source of all fresh water in the streams draining the basins. Ground-water drainage divides are assumed to coincide with topographic drainage divides of the basins, therefore no water enters the basins as underflow from adjoining areas. However, in the west a significant quantity of water enters Connecticut, both on the surface and underground, from the 46 sq mi of the basins that are in New York. The mean annual runoff and underflow entering Connecticut is 19 billion gallons and about 10.5 million gallons, respectively. In 1965, 5,519 million gallons of water were imported into the basins from the Housatonic River basin by the Bridgeport Hydraulic Co. A small but undetermined amount of water is imported into the basins by the Ridgefield Water Supply Co.

Although no satisfactory long-term records of runoff from the basins are available, it is possible to approximate the mean annual runoff from the data on figure 8. The mean monthly runoff, which is shown on figure 5, is estimated from the monthly distribution of mean runoff observed at the long-term gaging station on the Still River near Lanesville, which is located 12 miles north of the basins. The mean annual runoff from the basins for the period October 1930 - September 1960 was determined to be 23.9 inches, and the mean monthly runoff varies from 3.7 inches in March to 1.1 inches in July. Ground-water runoff is estimated from figure 22 to make up about 10.8 inches of the mean annual runoff.

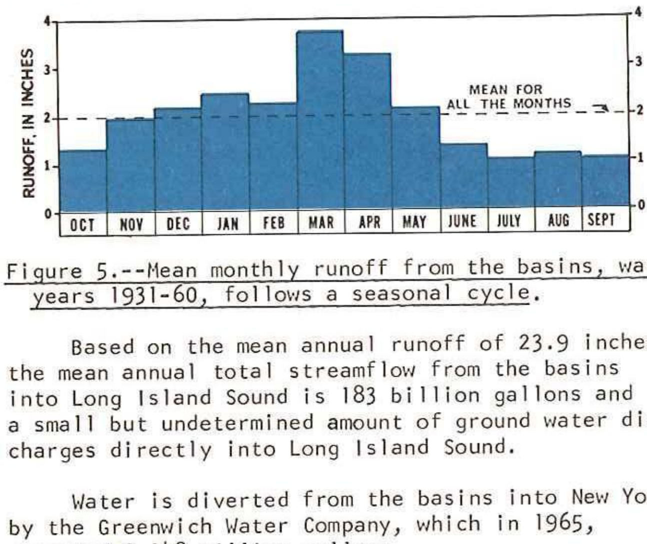


Figure 5.--Mean monthly runoff from the basins, water years 1931-60, follows a seasonal cycle.

Based on the mean annual runoff of 23.9 inches, the mean annual total streamflow from the basins into Long Island Sound is 183 billion gallons and a small but undetermined amount of ground water discharges directly into Long Island Sound.

Water is diverted from the basins into New York by the Greenwich Water Company, which in 1965, exported 2,148 million gallons.

A large part of the water falling on the basins returns to the atmosphere by means of evapotranspiration (evaporation and transpiration). The total amount lost is difficult to measure directly, but may be computed as the remainder after all other gains and losses are measured or estimated. That is, assuming that long-term storage remained substantially unchanged (an assumption supported by records of ground-water levels and natural pond and lake levels), the mean annual evapotranspiration from the basins for the reference period October 1930 - September 1960 is 23.6 inches, about 50 percent of the precipitation, and is equal to the mean annual precipitation of 47.5 inches minus the mean annual runoff of 23.9 inches.

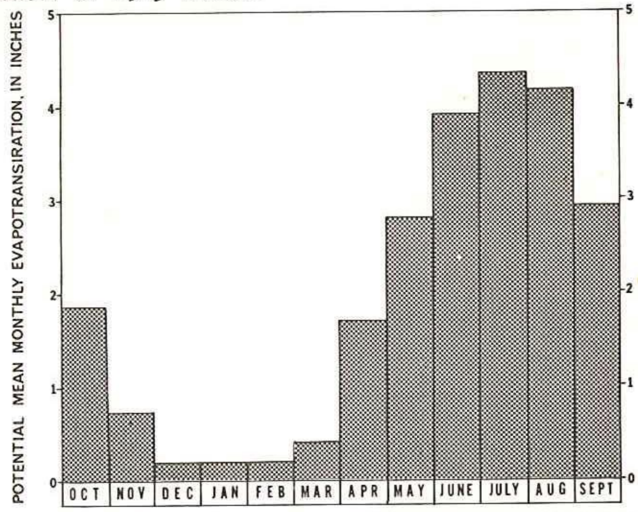


Figure 6.--Potential mean monthly evapotranspiration from the basins, water years 1931-60.

Potential evapotranspiration is greatest during the growing season (April to October) when plants use a large amount of water, temperatures are above freezing, and the days are longest.

The monthly potential evapotranspiration from the basins, which is shown on figure 6, changes throughout the year, and is largely dependent on changes in air temperature and duration of daylight (Thornthwaite, 1952, p. 382). Thus, the potential evapotranspiration is greatest during the growing season, April through October, when air temperatures are above freezing and the days are longest. Annual evapotranspiration and its distribution through the year are relatively constant for a given locality because these major factors repeat themselves with relatively little change year after year.

A mean monthly water budget for the basins for an average year, illustrating the factors previously discussed, is shown on figure 7 and is tabulated on table 1. Precipitation during the late autumn and winter is sufficient to cause abundant runoff and substantial increases in storage. Similar amounts of precipitation in the late spring and summer are not adequate to supply the large evapotranspiration losses, therefore storage is decreased and runoff is reduced. Storage changes may occur either in stream channels and banks, in lakes, ponds, and reservoirs, in swamps, and in the unsaturated zone, and in aquifers, or in any combination of these.

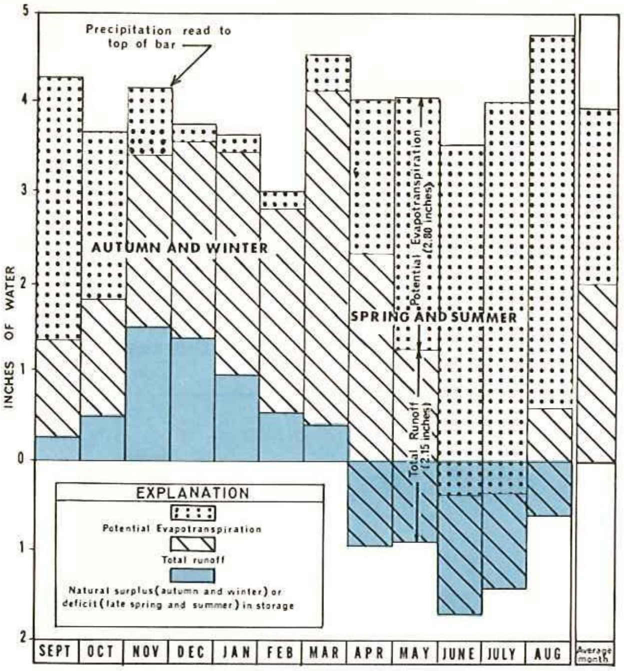


Figure 7.--Mean monthly water budget of the basins, water years 1931-60.

During the non-growing season (autumn and winter) precipitation on the basins produces a substantial increase in water stored and in runoff. During the growing season (spring and summer) similar quantities of precipitation are not sufficient for replacing evapotranspiration losses and sustaining runoff, resulting in substantial withdrawals from storage.

Table 1.--Monthly water budget, in inches of water over the basins. Mean for 1931-60.

Month	Precipitation	Runoff	Evapotranspiration	Change in storage
Oct.	3.7	1.3	1.9	+0.5
Nov.	4.2	1.9	.8	+1.5
Dec.	3.8	2.2	a/ .2	+1.4
Jan.	3.6	2.5	a/ .2	+1.0
Feb.	3.0	2.3	a/ .2	+ .5
Mar.	4.5	3.7	.4	+ .4
Apr.	4.0	3.2	1.7	- .9
May	4.1	2.1	2.8	- .9
June	3.5	1.3	3.9	-1.7
July	4.0	1.1	4.4	-1.4
Aug.	4.8	1.2	4.2	- .6
Sept.	4.3	1.1	2.9	+ .3
Water year	47.5	23.9	23.6	0

a/ Estimated for times when air temperature was above freezing.

SURFACE WATER

WATER IN STREAMS

The basins are drained by more than 20 streams, all of which discharge into Long Island Sound and are less than 20 miles long. The drainage basins of 10 of the streams exceed 10 sq mi (see fig. 1 and pl. A-C); the largest basin, that of the Saugatuck River, is 92.1 sq mi. The complete drainage systems of all the basins are shown in blue on plates A-C.

The amount of streamflow passing any point within the basins varies continuously from day to day, season to season, and year to year. Continuous records of streamflow reflecting this variation have been obtained at nine stream-gaging stations for periods ranging from 18 months to 35 years as shown on table 2. Additional discontinuous or partial records have been obtained at many other sites during the period June 1964 - March 1966. Locations of these gaging stations are shown on plate A. Records may be found either in annual publications entitled "Surface Water Records of Connecticut" for water years 1961-65 or "Water Resources Data for Connecticut" for water year 1966 and in the companion basic-data report. Continuous records through water year 1965 are published in a series of U.S. Geological Survey Water-Supply Papers entitled "Surface Water Supply of the United States."

Variations in runoff within the basins have been regionalized and may be used to estimate amounts of streamflow that might be expected to occur in the future at any selected location. These regionalizations are based upon a 30-year reference period beginning either in April or October 1930 to conform with the practice agreed upon by the World Meteorological Organization (Searcy, 1959) and with previous reports in this series. They are also based upon an approximate statewide mean annual runoff for the 30-year reference period of 1.16 mgd per sq mi (1.80 cfs per sq mi). Variations in mean annual runoff in the southwestern coastal river basins related to the approximate statewide average are shown by isopleths on figure 8.

Regional relationships may be applied to any site on any stream if there is no diversion or regulation upstream. They can also be applied to any site on any stream where the total drainage area has been reduced by practically complete diversion of water from an upstream part of the drainage basin. If any water should bypass a point of diversion and its amount and time-distribution is known, adjustments to the regional relationships can be made to reflect this. Regulation, if known, can also be adjusted for in a similar manner. As an aid in applying the runoff data to a specific site, known sites of surface-water diversion in 1965 are shown on plate C, and the drainage divides of the ten largest basins are shown on plates A-C.

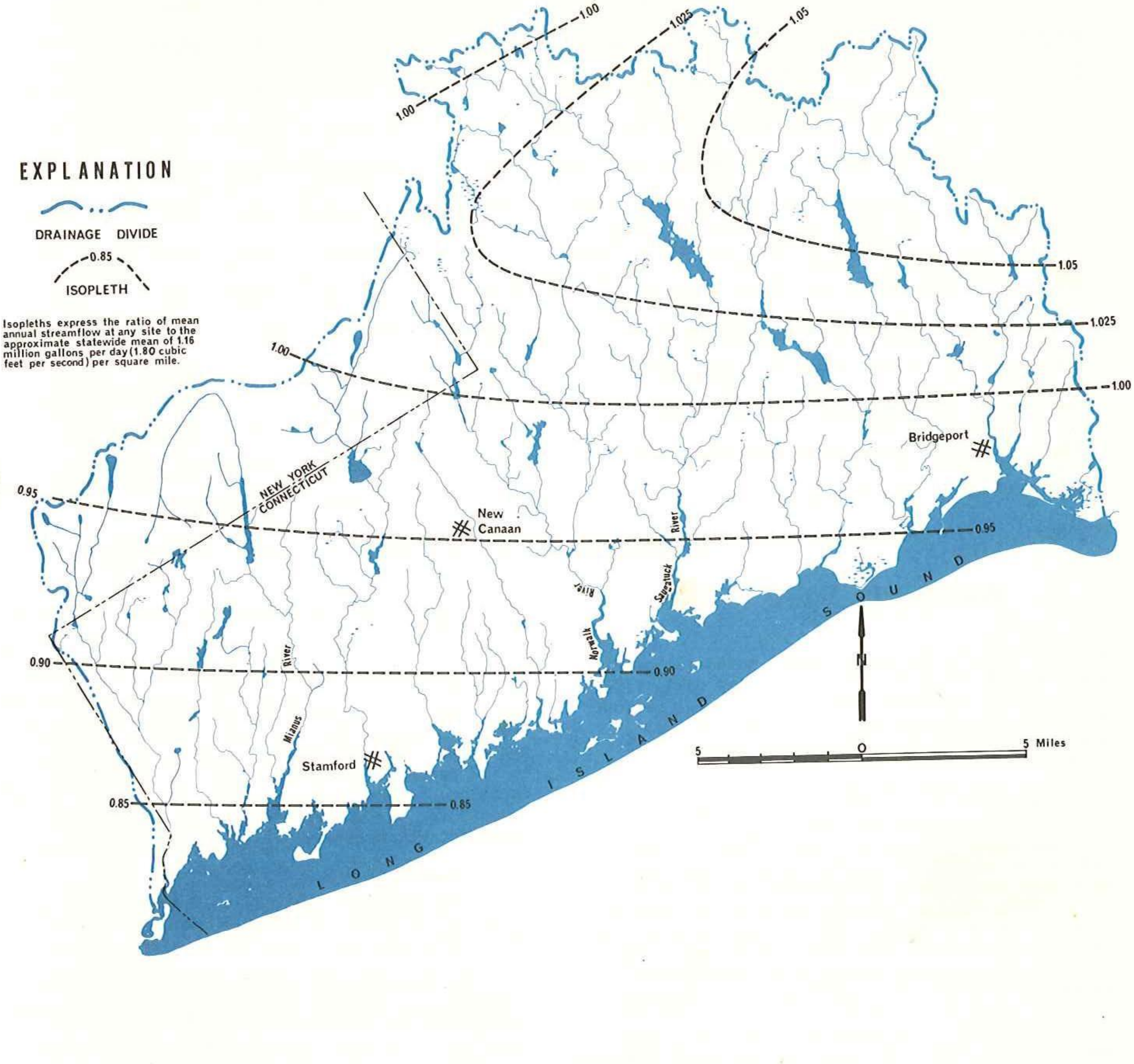


Figure 8.--Areal variations in mean annual streamflow in the southwestern coastal river basins, 1930-60.

Table 2.--Length of continuous streamflow records at gaging stations in the southwestern coastal river basins and vicinity.

(Locations of stations within the basins are shown on plate A)

U.S. Geological Survey Station no.	Stream and location	Drainage area (sq mi)	Length of record
	Gaging stations in the basins		
2088.5	Poquonock River at Trumbull, Conn.	11.4	Oct. 1964 - Sept. 1966
2089.5	Sasco Brook near Southport, Conn.	7.28	Oct. 1964 -
2089.9	Saugatuck River near Redding, Conn.	20.4	Oct. 1964 -
2089.99	Little River at Sanfordtown, Conn.	5.46	Mar. 1965 - Sept. 1968
2095	Saugatuck River near Westport, Conn.	77.5	Sept. 1932 - Sept. 1967
2097	Norwalk River at South Wilton, Conn.	30.6	Aug. 1962 -
2097.85	Noroton River near Stamford, Conn.	7.84	Oct. 1964 - Sept. 1967
2116	Byram River at Riversville, Conn.	11.4	Oct. 1964 - Mar. 1966
2121	East Branch Byram River at Riversville, Conn.	7.64	Oct. 1962 -
	Gaging stations in the vicinity of the basins		
2015	Still River near Lanesville, Conn.	68.5	Oct. 1931 -
2035	Pootatuck River at Sandy Hook, Conn.	24.2	May 1965 -
2048	Copper Mill Brook near Monroe, Conn.	2.50	June 1958 -
3000	Blind Brook at Rye, N.Y.	9.20	Nov. 1943 -
3005	Beaver Swamp Brook near Harrison, N.Y.	4.71	Nov. 1943 -

FLOW DURATION

One index of the water-supply potential of a stream is the percent of time specified daily flows are equaled or exceeded during a particular period. Regional flow-duration curves for eastern and southern Connecticut, including the basins, prepared by M. P. Thomas (1966) are shown on figure 9. The curves show that the amount of runoff from areas underlain by stratified drift is more evenly distributed throughout time than runoff from areas underlain largely by till. These relationships reflect the large infiltration capacity and resultant high proportion of ground-water runoff from stratified drift, and the low infiltration capacity and resultant high proportion of direct runoff from till. Stratified drift absorbs a large proportion of overland runoff and stores it for sustained release to streams during periods of dry weather.

The regional flow-duration curves (fig. 9) were originally based on long-term (30-year) streamflow records at 23 gaging stations in Connecticut and one station on Long Island, New York. Subsequently, records from 11 additional gaging stations in Connecticut were used to confirm the curves. The only long-term gaging station within the basins (on the Saugatuck River near Westport) could not be used in the final regional analysis due to regulation and diversions which could not be accounted for. However, four long-term gaging stations reasonably close to and nearly surrounding the basins were used to define the curves shown. Thus it is believed that the regional curves shown apply to streams in the report area. A statistical analysis of the regional flow-duration data gave standard errors of estimate that range from ±6 percent to ±12 percent for the 1-percent to 80-percent flow duration, respectively, and from ±25 percent to ±36 percent for the 90-percent to 99.9-percent flow duration, respectively.

Flow-duration data at gaging stations in the basins are given on table 3. Maximum and minimum limits of duration in a single year may be estimated from figure 10.

The flow-duration curves on figure 9 and the isopleths on figure 8 may be used to estimate flow duration at any ungaged site in the basins. For example, assume that flow-duration characteristics are needed for a site on the Noroton River at Springdale downstream from Springdale Brook near Stamford where there is no diversion or regulation upstream. On plate B, the total drainage area above this site measures 7.84 sq mi and that portion of the drainage area underlain by stratified drift measures 1.18 sq mi. Thus, with 15.1 percent of the area underlain by stratified drift, the flow-

Table 3.--Duration of daily flow at gaging stations in the southwestern coastal river basins.
(Data are adjusted to the period October 1930-September 1960 on basis of long-term streamflow records)

Index no. (Pl.A)	Stream and place of measurement	Drainage area (sq mi)	Percent of drainage area underlain by stratified drift	Average flow (mgd)	Flow equaled or exceeded for indicated percentages of time (mgd)												
					1	5	10	20	30	40	50	60	70	80	90	95	99
2088.5	Poquonock River at Trumbull a/	11.4	18.3	13.9	79	42	31	21	15	11	8.6	6.4	4.3	2.7	1.7	1.1	0.70
2088.7	Rooster River at Bridgeport	9.16	6.0	10.9	47	27	21	16	12	9.6	7.9	6.7	5.1	4.0	2.9	2.3	1.5
2089	Patterson Brook near Easton	1.20	0	1.5	12	5.0	3.5	2.3	1.6	1.2	.74	.43	.22	.09	.03	.01	0
2089.18	Mill River at Stratfield b/	4.74	12.9	h/ NS	NS	NS	NS	NS	6.2	4.7	3.5	2.6	1.7	1.0	.62	.44	.24
2089.5	Sasco Brook near Southport	7.28	1.7	8.3	55	27	19	12	9.1	6.5	4.6	3.1	1.8	1.0	.44	.23	.09
2089.9	Saugatuck River near Redding	20.4	18.0	24.5	160	80	55	37	28	19	14	9.8	6.1	3.5	1.6	1.0	.55
2089.99	Little River at Sanfordtown	5.46	1.4	6.6	50	22	15	10	7.4	5.1	3.4	2.0	1.1	.48	.14	.05	.01
2090.8	Aspetuck River at Hopewell	3.08	17.6	3.8	26	13	8.6	5.9	4.2	2.9	2.1	1.3	.77	.37	.15	.07	.02
2090.95	Aspetuck River near Easton	13.2	12.0	16.1	110	54	37	25	18	13	8.8	5.7	3.3	1.6	.63	.29	.09
2093	West Branch Saugatuck River at Weston	9.20	6.4	10.9	75	37	26	17	12	8.5	6.0	3.9	2.2	1.0	.42	.20	.06
2095.5	Ridgefield Brook near Ridgefield	3.58	28.2	4.3	28	14	10	6.4	4.7	3.3	2.4	1.6	.97	.47	.21	.13	.05
2095.7	Norwalk River at Georgetown	14.3	16.7	17.2	110	56	39	26	19	13	10	6.7	4.3	2.4	1.1	.73	.39
2096	Comstock Brook at North Wilton	3.44	0	4.1	31	14	9.6	6.2	4.5	3.1	2.0	1.2	.62	.25	.07	.02	0
2097	Norwalk River at South Wilton	29.7	14.3	35.3	220	110	77	53	39	29	22	16	11	6.2	3.6	2.3	1.4
2097.5	Silvermine River at Silvermine c/	7.39	11.4	NS	NS	NS	NS	NS	9.2	6.9	5.1	3.8	2.5	1.6	.89	.65	.35
2097.7	Fivemile River near Norwalk d/	7.74	19.1	NS	NS	NS	NS	NS	9.3	7.1	5.6	4.1	2.9	1.8	1.1	.74	.45
2097.8	Stony Brook at Darien	3.10	14.7	3.3	22	11	7.8	5.0	3.7	2.6	1.8	1.2	.74	.34	.17	.10	.04
2097.85	Noroton River near Stamford	7.84	15.1	8.5	54	28	20	13	9.4	7.0	5.2	3.8	2.5	1.5	.86	.56	.33
2099	Rippowam River at Stamford e/	10.5	17.0	NS	NS	NS	NS	NS	13	9.2	7.2	5.5	3.8	2.5	1.4	1.0	.63
2103	East Branch Mianus River near Long Ridge	3.39	0	3.8	29	13	8.8	5.8	4.2	2.9	1.9	1.1	.58	.23	.06	.02	0
2104.9	Mianus River near Riverbank f/	9.16	4.1	NS	NS	NS	NS	NS	11	7.7	5.5	3.7	2.3	1.0	.49	.30	.13
2111	Greenwich Creek at Cos Cob	4.94	4.0	5.1	37	17	12	7.9	5.7	4.0	2.7	1.8	.99	.45	.15	.06	.01
2116	Byram River at Riversville	11.4	16.8	12.2	71	38	27	18	14	10	7.4	5.0	3.0	1.4	.39	.16	.05
2117	East Branch Byram River at Round Hill	1.67	6.9	1.8	12	6.0	4.2	2.7	2.0	1.4	.97	.63	.38	.18	.08	.04	.01
2121	East Branch Byram River at Riversville g/	7.64	3.0	8.1	54	27	19	12	9.2	6.3	4.4	2.9	1.7	.84	.34	.17	.06

a/ Excludes 3.8 sq mi from which entire flow is diverted into Easton Reservoir.

b/ Excludes area above or flow from Easton Reservoir.

c/ Excludes area above or flow from Grupes and South Norwalk Reservoirs.

d/ Excludes area above or flow from New Canaan Reservoir.

e/ Excludes area above or flow from North Stamford Reservoir.

f/ Excludes area above or flow from Mianus (Bargh) Reservoir.

g/ Excludes 3.56 sq mi from which entire flow is diverted into Putnam Lake.

h/ NS: data not shown because of variable flow from excluded drainage area.

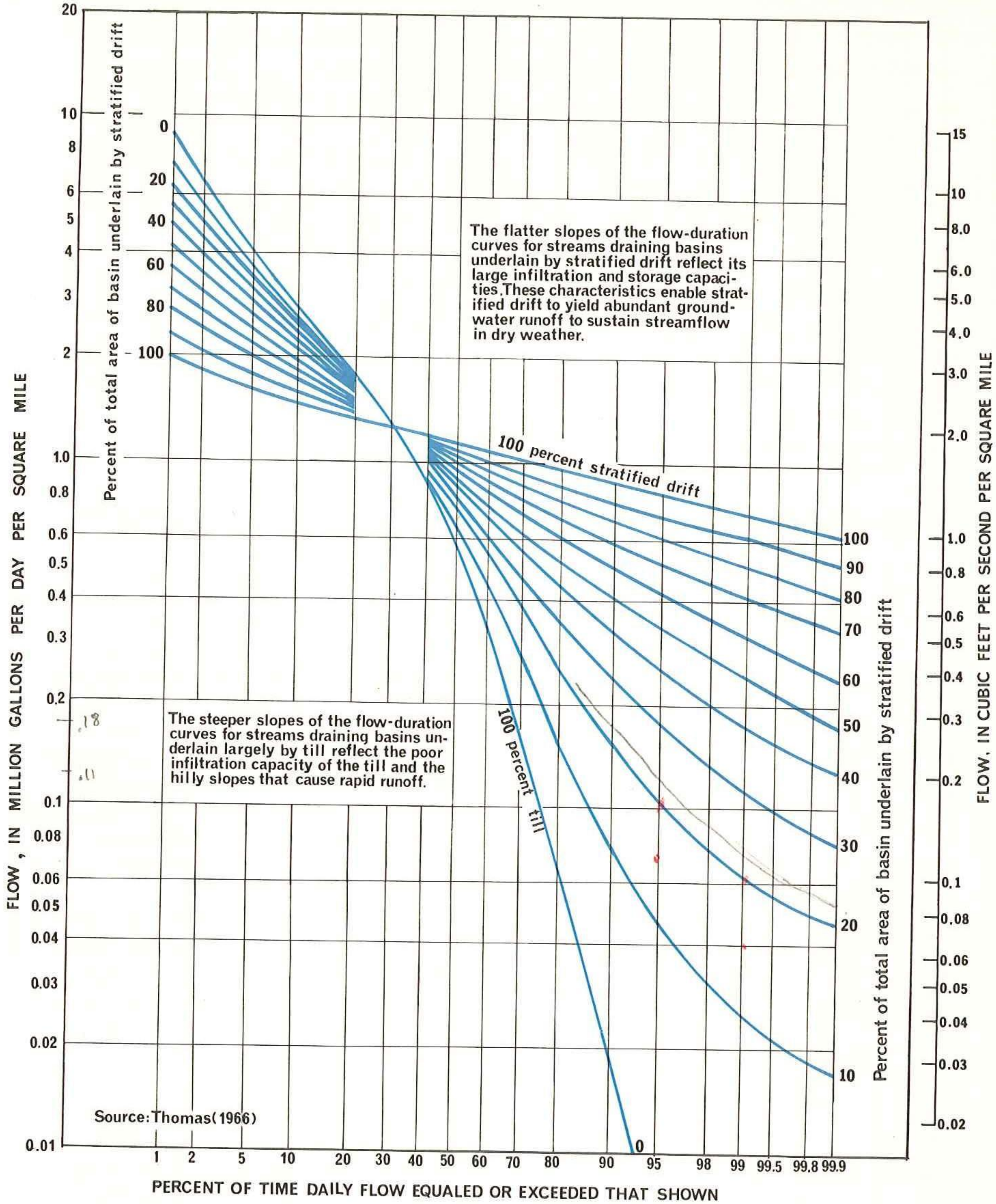


Figure 9.--The relation of the duration of mean daily flow to percent of stratified drift underlying the drainage area.

This relation is the average for water years 1931-60. These curves apply to unregulated streams having a mean annual flow of 1.16 mgd (1.80 cfs) per sq mi.

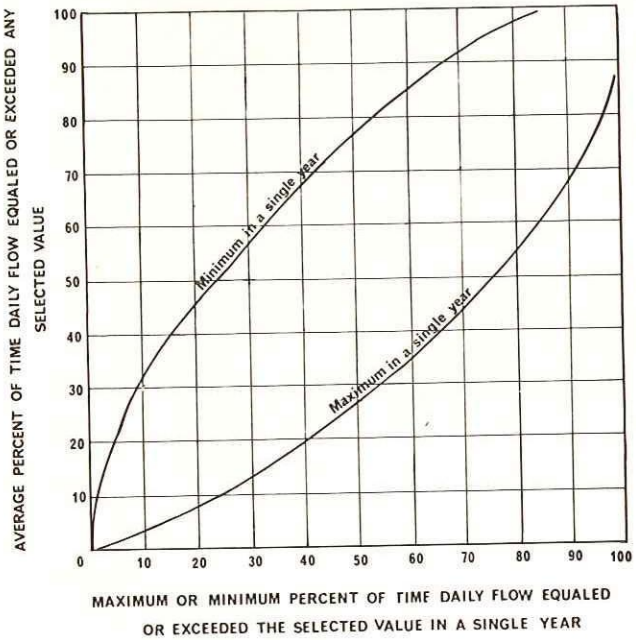


Figure 10.--Range in duration of streamflow in the basins, water years 1931-60.

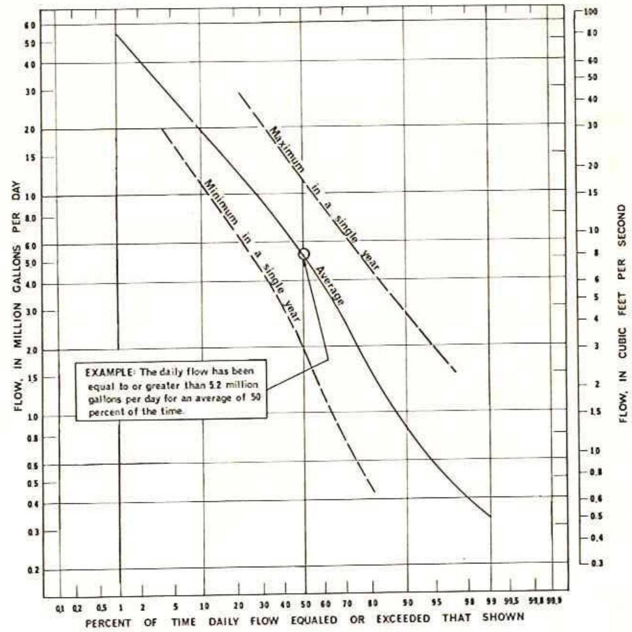


Figure 11.--Duration of daily mean flow of the Noroton River near Stamford computed for the period 1930-60.

duration curve for the stream at this site is the curve interpolated on figure 9 for this percent of stratified drift with all ordinates multiplied by the drainage area of 7.84 sq mi and by a runoff factor of 0.93 from figure 8. This curve for the site for the period October 1930 - September 1960 is shown on figure 11. Supplemental curves on this figure, derived by use of figure 10, show the probable range of this variation in flow in single years. For example, a flow of 5.2 mgd, which is equaled or exceeded 50 percent of the time on an average, also probably was equaled or exceeded 26 percent of the time during the driest year and 76 percent of the time during the wettest year for the period October 1930 - September 1960.

FREQUENCY AND DURATION OF LOW FLOWS

Although flow-duration curves indicate the minimum amounts of daily streamflow available for certain percentages of time, it may also be desirable to know how long specified low streamflows are expected to last. Recurrence intervals of annual lowest mean flows for specified periods can be constructed from the flow-duration data presented for partial-record gaging stations on table 3 or from flow-duration data for ungaged sites, which have been developed by use of figures 8 and 9 by the use of table 4. Table 4 indicates, for example, that the low flow for 30 consecutive days at a particular site, which could be expected to recur on the average every 2 years, is equivalent to the flow equaled or exceeded 90 percent of the time at that site. By selecting other recurrence intervals, a complete low-flow frequency curve for 30 consecutive days may be constructed. Similar frequency curves for other durations may be constructed in a similar manner. Curves showing recurrence intervals of specified low flows for various periods for the previously mentioned site on the Noroton River near Stamford are presented on figure 12. These curves were developed by use of figure 11 and table 4.

Perhaps the most widely used values of low streamflow are the 7-day and 30-day mean flows having a 2-year recurrence interval. Streamflow will diminish below these values every other year, on the average. Accordingly, these values are termed "indices of low-flow frequency." The 7-day and 30-day 2-year mean flows on table 4 are equivalent to flows equaled or exceeded about 95 percent and 90 percent of the time, respectively. Streamflows equaled or exceeded 90 percent of the time are shown on plate B as an index of surface-water availability. These values of streamflow can be considered as a first approximation of the minimum supply available from a low run-of-the-river impoundment dam, for only a small amount of surface storage or supplemental ground-water supply is needed to continuously provide these amounts in most years.

The State Water Resources Commission, based on Public Act 57 of the 1967 Connecticut General Assembly, reporting on criteria for water-quality standards for intrastate and interstate waters, recommended that the streamflow to which their standards apply be the lowest mean daily flow for 7 consecutive days occurring on an average once in ten years. In the basins, this flow is equaled or exceeded about 90 percent of the time.

Analyses of the streamflow records of the Saugatuck River near Westport (site no. 2095) indicate that, for any partial-record or ungaged site, the lowest daily flow not exceeded for periods of 7, 30, 60, and 120 consecutive days may be approximated by multiplying the lowest annual mean flows from table 4 and figure 10 for a 31-year recurrence interval for these respective periods by 1.1, 1.3, 1.6, and 2.0 respectively. For example, at the previously mentioned site on the Noroton River near Stamford, the mean flows during 7, 30, 60, and 120 consecutive days are determined from figure 12 (31-year recurrence interval) to be 1.5, 1.8, 2.3, and 3.3 mgd, respectively. The lowest daily flows not exceeded for these same consecutive day periods

Table 4.--Average duration of lowest mean flows of streams in the southwestern coastal river basins.

Example shows that for any partial record or ungaged site on an unregulated stream, the 30-consecutive day low flow that could be expected to recur on the average every 2 years is equivalent to the flow equaled or exceeded 90 percent of the time.

Period of low flow		Average percent of time during the reference period April 1930 - March 1960 in which streamflow equaled or exceeded the lowest mean flow for indicated recurrence interval in years a/						
Consecutive days	Consecutive months	1.2	2 median year	3	5	10	20	31 driest year
3	--	92	97	98	99.2	99.7	99.8	99.9
7	--	88	95	97	98	99.2	99.6	99.7
30	1	81	90	94	96	98	99	99.3
60	2	74	85	90	94	96	98	98
120	4	61	75	81	87	92	95	96
183	6	49	65	72	77	84	88	91
274	9	35	50	57	63	70	75	78
365	12	25	37	44	50	56	62	65

a/ These percentages are based on long-term records from 25 continuous-record gaging stations throughout Connecticut.

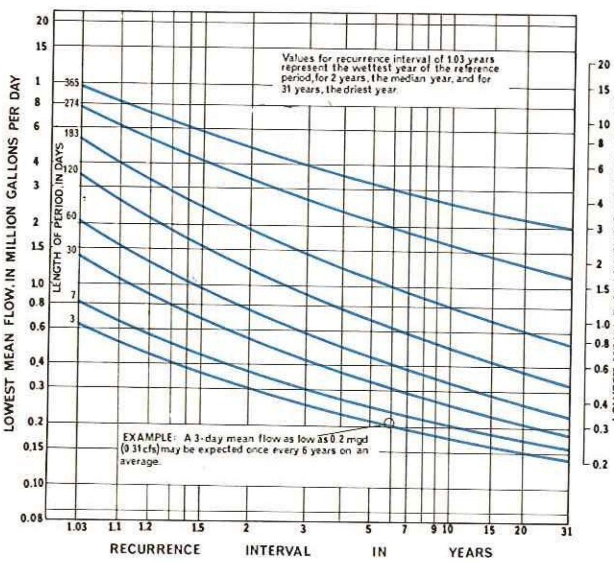


Figure 12.--Recurrence intervals of specified low flows of the Noroton River near Stamford computed for the period 1930-60.

are estimated, therefore, to be 1.65, 2.3, 3.7, and 6.6 mgd, respectively.

The period during which a specified lowest daily flow is not exceeded is determined by multiplying the flows from the low-flow frequency curve for a 31-year recurrence interval for 7, 30, 60, and 120 days by the same appropriate ratios of 1.1, 1.3, 1.6, and 2.0 and constructing a curve of lowest daily flows not exceeded for various periods of time. Application to this curve of the specified lowest daily flow not exceeded will indicate the period during which this flow will not be exceeded.

WATER IN LAKES AND RESERVOIRS

Of the many lakes, ponds, and reservoirs within the basins, the largest is Saugatuck Reservoir, with a surface area of 868 acres when full. Table 5 lists important bodies of surface water with usable storage that may be withdrawn by gravity. The volume of usable storage in existing lakes and ponds is also shown on plate B.

If the minimum flow of a stream is inadequate for projected use, a reservoir can be constructed to supplement the flow. Its cost may be balanced by the loss caused by insufficient supply if the frequency with which different amounts of storage would be required is known. Storage required to maintain various regulated flows at sites on unregulated streams are presented on table 6. These data are for various percentages of drainage area underlain by stratified drift. Storage providing regulated flow as indicated would be replaced each year except for underlined values, which represent storage required to maintain relatively large regulated flow in dry years and hence would not be completely replaced during dry years. The rates of regulated flow and amounts of storage required at a particular site must be adjusted to the mean streamflow at the

Table 5.--Lakes, ponds, and reservoirs in the southwestern coastal river basins. a/

Index no. (Pl.A)	Name and location	Source of data b/	Drainage area (sq mi)	Surface area (acres)	Surface elevation (ft above msl)	Maximum depth (ft)	Average depth (ft)	Total storage (million gallons)	Usable storage (million gallons)	Maximum amount of storage released during 1965 water year (million gallons)	Type of use
2088.54	Bunnells Pond near Bridgeport	FG	24.0	42	34	22	11	147	147	c/ NA	Recreation
2088.55	Lake Forest near Bridgeport	FG	1.51	72	178	22	15	342	342	NA	do
2089.09	Easton Reservoir near Easton	Br	13.2	488	303	130	31	5,848	5,848	1,754	Water supply
2089.19	Hemlock Reservoir near Plattsville	Br	5.26	437	228	90	27	3,801	3,801	1,216	do
2089.2	Samp Mortar Reservoir near Fairfield	FG	29.0	50	68	26	11	177	177	NA	Recreation
2089.95	Putnam Park Pond near Redding	FG	1.05	22	590	8	3.5	25	25	NA	do
2090	Saugatuck Reservoir near Lyons Plain	Br	33.5	868	283	123	42	11,924	11,924	6,439	Water supply
2091	Aspetuck Reservoir near Easton	Br	17.0	61	228	12	3.3	66	66	None	do
2096.1	Streets (Popes) Pond at North Wilton	No-2	2.30	75	368	18	9.8	240	240	90	do
2097.15	Scotts Reservoir near Lewisboro, N.Y.	No-1	1.96	12	522	20	14	54	54	54	do
2097.17	Browns Reservoir near Lewisboro, N.Y.	No-1	7.31	44	432	44	20	290	290	263	do
2097.18	John D. Milne Lake near New Canaan	No-1	9.13	71	371	71	26	610	610	360	do
2097.19	Grupes Reservoir near New Canaan	No-1	10.1	22	294	22	7.8	56	56	8	do
2097.38	Rock Lake near Silvermine	No-2	.91	15	332	37	33	160	160	NA	do
2097.39	South Norwalk Reservoir near Silvermine	No-2	2.31	140	273	30	13	600	600	450	do
2097.6	New Canaan Reservoir near New Canaan	NC	.90	22	449	42	18	132	116	84	do
2097.9	Soscowit Reservoir (Mead Pond) near Pound Ridge, N.Y.	St	3.42	45	446	10	6.0	88	88	88	do
2097.95	Trinity Lake Reservoir near Pound Ridge, N.Y.	St	.62	73	458	30	19	450	450	274	do
2098.1	Laurel Reservoir at High Ridge	St	12.8	265	314	45	26	2,253	2,253	2,048	do
2098.49	North Stamford Reservoir at North Stamford	St	22.0	114	201	21	14	512	512	162	do
2102.79	Mianus (Bargh) Reservoir near Stanwich	Gr	18.0	320	256	64	24	2,450	2,250	1,350	do
2111.4	Rockwood Lake near Round Hill	Gr	.80	96	330	23	16	500	468	183	do
2111.49	Putnam Lake near Round Hill	Gr	3.08	96	303	19	18	572	572	53	do

a/ All lakes, ponds, and reservoirs listed are artificial.

b/ Chiefly from (FG) State Board of Fisheries and Game; (Br) Bridgeport Hydraulic Company; (No-2) 2nd Taxing District, City of Norwalk; (No-1) 1st Taxing District, City of Norwalk; (NC) New Canaan Water Company; (St) Stamford Water Company; (Gr) Greenwich Water Company.

c/ NA: Data not available.

Table 6.--Storage required to maintain indicated regulated flows at sites on unregulated streams in the southwestern coastal river basins.

(Data are adjusted to the reference period April 1930-March 1960 and to an average flow of 1.16 mgd per sq mi. Storage required would be replenished within a year except for figures underlined which would require more than a year. Storage is uncorrected for reservoir seepage, evaporation, and for bias in computation procedure, all of which increase slightly the amount of storage required.)

Percent of area underlain by stratified drift	Recurrence interval of annual lowest mean flow (years) a/	Maximum amount of storage which would be replenished during the year of lowest annual flow (million gallons per sq mi)	Storage required (million gallons per sq mi) to maintain indicated regulated flow (mgd per sq mi)																
			0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.90	1.0
0	1.2	...	1	3	5	7	10	14	18	23	28	33	38	44	50	56	63	76	90
	2	144	3	7	12	17	23	30	37	45	53	61	69	77	86	95	104	124	145
	5	94	8	14	22	30	39	48	57	67	77	87	98	109	120	132	144	170	197
	10	69	11	19	28	37	46	56	66	77	88	100	112	124	137	150	164	192	221
	31	46	15	27	38	50	62	75	89	102	116	130	145	160	175	190	208	...	...
10	1.2	...	..	..	2	3	5	7	10	14	18	22	26	30	34	39	45	58	70
	2	...	..	2	4	7	10	15	20	26	33	40	48	56	64	73	82	100	118
	5	91	2	6	11	17	24	32	40	49	58	68	78	88	98	109	120	142	165
	10	76	5	11	17	24	32	42	52	62	72	82	93	105	117	129	142	168	194
	31	58	6	15	25	35	46	57	69	81	93	105	118	132	146	160	174	204	235
20	1.2	...	..	..	..	..	..	2	4	6	9	12	16	20	24	29	33	44	58
	2	...	..	..	..	2	5	8	12	17	22	29	36	43	50	57	65	81	98
	5	87	..	..	3	7	13	19	26	34	42	51	60	68	76	86	96	117	140
	10	77	..	2	6	11	19	27	35	44	54	64	74	84	94	105	116	140	164
	31	63	..	4	11	20	30	40	50	60	71	82	94	106	118	131	145	172	202
30	1.2	...	..	..	..	..	..	..	1	3	5	8	11	14	18	22	27	37	49
	2	...	..	..	..	..	1	3	6	10	14	19	24	30	37	44	51	68	86
	5	78	..	..	..	1	4	8	14	20	27	34	42	50	59	69	79	99	121
	10	65	..	..	1	4	8	14	20	28	36	44	53	62	71	80	90	112	136
	31	57	..	..	2	8	14	23	32	41	51	61	72	83	94	105	117	142	172
40	1.2	...	..	..	..	..	..	..	..	..	1	3	6	9	12	15	19	29	40
	2	...	..	..	..	..	..	..	2	5	8	11	15	20	25	31	38	53	69
	5	73	..	..	..	..	1	3	6	10	15	21	29	37	45	53	61	80	100
	10	64	..	..	..	..	2	6	11	17	24	32	40	48	57	65	74	94	114
	31	57	..	..	..	1	6	12	19	27	36	45	55	65	75	86	98	123	150
50	1.2	...	..	..	..	..	..	..	..	..	..	..	2	4	6	9	12	22	33
	2	...	..	..	..	..	..	..	..	..	2	4	7	11	16	22	28	43	59
	5	68	..	..	..	..	..	..	1	3	6	11	16	22	29	37	46	67	88
	10	58	..	..	..	..	..	..	3	7	12	27	24	32	40	49	58	77	98
	31	51	..	..	..	..	..	2	7	13	20	29	37	45	54	64	74	98	124
60	1.2	...	..	..	..	..	..	..	..	..	..	..	..	1	2	4	6	13	23
	2	...	..	..	..	..	..	..	..	..	..	1	4	6	9	12	18	32	48
	5	61	..	..	..	..	..	..	..	..	2	5	8	13	19	25	32	50	68
	10	55	..	..	..	..	..	..	..	1	4	9	14	20	27	35	43	61	81
	31	50	..	..	..	..	..	..	1	4	9	15	22	30	38	48	58	78	104
80	1.2	...	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	10
	2	...	..	..	..	..	..	..	..	..	..	..	..	..	..	1	4	12	23
	5	...	..	..	..	..	..	..	..	..	..	..	..	..	2	5	10	22	37
	10	...	..	..	..	..	..	..	..	..	..	..	..	1	4	8	15	30	48
	31	43	..	..	..	..	..	..	..	..	..	..	1	5	10	17	24	41	62
100	1.2	...	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
	2	...	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5
	5	...	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	11
	10	...	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	16
	31	...	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	9	26

Values for recurrence interval of 2 years represent the median year of the reference period, and for 31 years, the driest year of the reference period.

site by multiplying by an appropriate ratio determined from the isopleths on figure 8. Also, the draft rates apply for round-the-clock use; obviously they may be increased if usage is restricted to part of a day.

The storage-required values on table 6 are smaller than those actually needed because they do not include evaporation and seepage losses from the reservoir; also there is a bias of about 10 percent inherent in the statistical method used (the frequency-mass curve). Nevertheless, they are accurate enough for reconnaissance planning and for the preliminary selection of a proposed site.

As an example, what is the amount of storage necessary to maintain a regulated flow of 3 mgd for 24-hour day use at the previously mentioned site on the Noroton River near Stamford? The total area of the drainage basin is 7.8 sq mi and 15 percent of the basin is underlain by stratified drift. Also, the mean streamflow from this basin into the proposed reservoir is 93 percent of the statewide mean streamflow. To use table 6, which is based on a mean inflow of 1.16 mgd per sq mi, the desired regulated flow of 3 mgd, or 0.38 mgd per sq mi, must be increased to $\frac{0.38}{0.39}$ or 0.41 mgd per sq mi. Interpolated amounts of storage required to maintain a regulated flow of 0.41 mgd per sq mi from table 6 for 10 percent and 20 percent of an area underlain by stratified drift are 21 and 12 million gallons per sq mi, respectively. Storage required to maintain this flow for the Noroton River near Stamford where 15 percent of the area is underlain by stratified drift, is then interpolated as 16 million gallons per sq mi or 125 million gallons. This may be increased 10 percent to 138 million gallons to allow for the bias from the frequency-mass curve and for evaporation and seepage losses.

Possible draft rates for impoundments not shown on table 5 may be determined by reversing this procedure. For example, if the available storage in an impoundment at the site on the Noroton River is 125 million gallons, this should be divided first by 1.1 to restore the bias used in constructing table 6, and then by the drainage area of 7.84 sq mi. This adjusted storage available of 16 million gallons per sq mi is then entered on table 6 and a draft rate of 0.41 mgd per sq mi determined for 15 percent of the drainage area underlain by stratified drift. This draft rate of 0.41 mgd per sq mi must be multiplied by the runoff factor of 0.93 to result in an effective draft rate of 0.38 mgd per sq mi.

FLOODS

HISTORY

Floods may occur in any month of the year, although they usually come in the spring. Tropical hurricanes or other storms moving northward along the Atlantic coastline cause some floods in the late summer and fall. Detailed records of the major floods of 1936, 1938, and 1955, for the stream-gaging station on the Saugatuck River near Westport (site no. 2095) are given in Grover (1937) for March 1936, in Paulsen and others (1940) for September 1938, in Water-Supply Paper 966 for January and July 1938, and in Bogart (1960) for August and October 1955. A compilation of all flood peaks above 900 cfs at this location between 1933 and 1960 is given in Green (1964).

Table 7.--Floods on the Saugatuck River, in excess of 2,500 cfs, at stream-gaging station no. 2095.

Date	Elevation (ft above msl)	Flow (cfs)
Sept. 17, 1934	26.95	2,920
Mar. 12, 1936	29.46	5,310
July 24, 1938	26.93	3,120
Sept. 21, 1938	28.44	4,420
Mar. 15, 1940	27.24	3,400
Feb. 8, 1941	27.72	3,830
Mar. 31, 1951	27.06	3,220
Mar. 11, 1952	26.48	2,740
Mar. 13, 1953	28.81	4,710
Aug. 19, 1955	26.20	2,530
Oct. 16, 1955	34.09	14,800
Mar. 13, 1962	26.36	3,660

In the basins, floods of successively increasing magnitude were recorded in 1801, 1807, 1853, 1854, 1875, and 1896. Continuous records of floods have been kept for the Saugatuck River near Westport (site no. 2095) since September 1932 and are summarized on table 7. All except the latest of these floods are believed to have been lower than the flood of 1896. The flood of October 1955, however, was probably at least as high as the 1896 flood and possibly was the highest since the time of first settlement of the basins.

MAGNITUDE AND FREQUENCY OF FLOODS

Knowledge of the magnitude and frequency of floods is essential to the planner and water manager concerned with the location and establishment of flood-plain encroachment lines. The maximum flood of record and mean annual flood at gaging stations in the southwestern coastal river basins are given on table 8. Estimates of the flood flow having any recurrence interval can be made from figures 13 and 14 for all sites within the basins that have a drainage area of at least 1 sq mi. The mean annual flood at any site can be found from figure 13 if the effective drainage area is known. The effective drainage area can be measured on plate B, and is that part of the total drainage area that contributes runoff to the flood peak and does not include drainage areas of large headwater ponds and lakes. Flood flows for recurrence intervals of up to 100 years are determined by multiplying the mean annual flood by the appropriate ratios for any selected recurrence interval taken from figure 14.

Table 8.--Maximum flood of record and mean annual flood at stream-gaging stations in the southwestern coastal river basins.

Index no. (Pl. A)	Stream and place of measurement	Drainage area (sq mi)	Period of continuous record	Date	Flow of maximum flood of record (cfs)	Flow of maximum flood of record (cfs per sq mi)	Flow of maximum flood of record: Ratio to mean annual flood	Flow of mean annual flood (cfs)	Flow of mean annual flood (cfs per sq mi)
2088.45	Poquonock River near Trumbull	14.4	None	Oct. 16, 1955	4,110	285	a/ NC	NC	NC
2088.5	Poquonock River at Trumbull	15.2	1962-65	Mar. 12, 1962	700	46	1.43	490	32
2089	Patterson Brook near Easton	1.20	1960-65	Mar. 12, 1962	61	51	.94	65	54
2089.5	Sasco Brook near Southport	7.28	1960-65	Mar. 12, 1962	280	38	1.17	240	33
2089.9	Saugatuck River near Redding	20.4	1962-65	Mar. 12, 1962	650	32	1.33	490	24
2090.01	Saugatuck River near Lyons Plain	33.5	None	Oct. 16, 1955	7,100	212	NC	NC	NC
2095	Saugatuck River near Westport	77.5	1932-65	Oct. 16, 1955	b/ 14,800	191	7.79	c/ 1,900	25
2095.65	Norwalk River near Branchville	7.54	None	Oct. 16, 1955	3,100	411	NC	NC	NC
2096	Comstock Brook at North Wilton	3.44	1960-65	Sept. 12, 1960	370	110	1.09	165	48
2097	Norwalk River at South Wilton	30.6	1963-65	Mar. 6, 1963	465	15	.74	630	21
2097.68	Fivemile River near New Canaan	5.85	None	Oct. 16, 1955	2,140	366	NC	NC	NC
2097.7	Fivemile River near Norwalk	8.64	1962-65	Mar. 12, 1962	510	59	1.31	390	45
2104.8	Mianus River near Stamford	26.6	None	Oct. 16, 1955	3,780	142	NC	NC	NC
2117	East Branch Byram River at Round Hill	1.67	1960-65	Mar. 12, 1962	200	120	2.67	75	45
2121	East Branch Byram River at Riversville	7.64	1963-65	Nov. 10, 1962	395	52	1.41	280	37

a/ NC: not calculated.

b/ Elevation 34.09 ft above msl.

c/ Elevation 25.32 ft above msl.

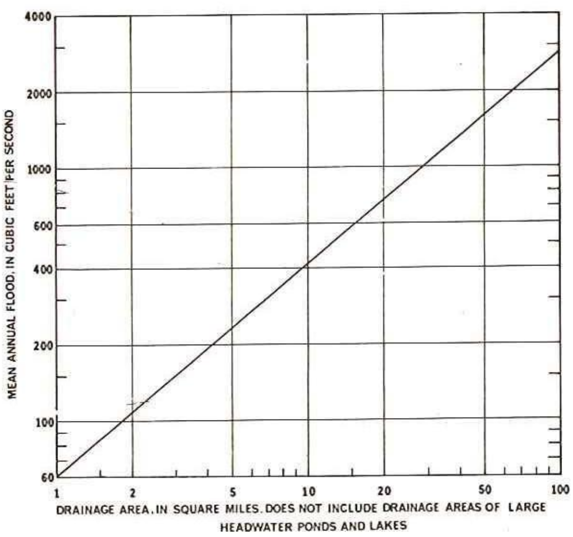


Figure 13.--The mean annual flood varies with effective drainage area.

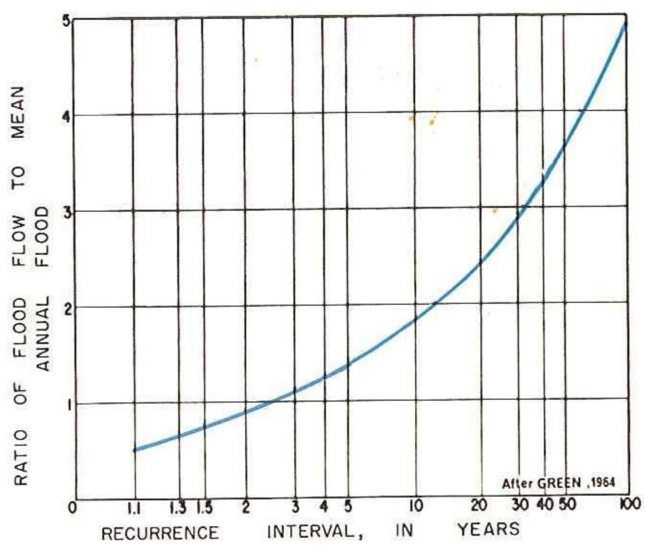


Figure 14.--Magnitude of flood flows varies with average intervals between their recurrence.

Floods several times larger than the mean annual flood occur infrequently. The mean annual flo flow for any particular site obtained from fig 13 may be used with the relation in this figure to estimate the frequency of flood flows as much as 5 times the mean annual flood.

GROUND WATER

The basins are underlain by aquifers that can supply water to meet industrial and water-utility needs at some places, and domestic needs at most places. Individual well yields are primarily dependent upon the water-bearing characteristics and geometry of the aquifer, and secondarily upon the type of well construction. On the other hand, the potential yield of an aquifer is determined by the annual amount of ground water discharging from the aquifer, the storage capacity of the aquifer, and the amount of water in streams and ponds that can be induced to flow into the aquifer.

AQUIFERS

Stratified drift, till, and crystalline bedrock are the water-bearing earth materials or aquifers in the basins. Stratified drift is made up of unconsolidated, interbedded, and sorted deposits of gravel, sand, and silt, and is the only aquifer capable of yielding enough water to supply most industrial and public-supply needs (see section "Large Supplies from the Stratified-Drift Aquifer"). Till and bedrock are relatively impermeable and are minor aquifers in terms of individual well yields. Till is a dense, unconsolidated, poorly sorted mixture of gravel, sand, silt, and clay, that discontinuously mantles the bedrock throughout the basins, and is barely capable of yielding enough water for household uses. Bedrock underlies the entire area and is capable of yielding enough water to support household uses at most places; in some places it can yield enough for small industrial and public-supply uses. The distribution of these three aquifers in the basins is shown on plate B and their subsurface relationships are shown on figure 15.

THE STRATIFIED-DRIFT AQUIFER

Glacial deposits of stratified drift, where saturated, form the stratified-drift aquifer. Stratified drift underlies about 15 percent of the area of the basins, and is chiefly restricted to valleys and lowland areas where it overlies till and bedrock. In most places, a poorly sorted, relatively dense, and poorly stratified layer of pebble to boulder gravel, ranging in thickness from 5 to 25 ft, marks the top of the aquifer. This coarse material is exposed at land surface throughout the basins but it extends only a few feet into the saturated zone and, therefore, forms only a small part of the aquifer. A few shallow wells tap this coarse material, of which one, Wn 12, produced 127 gpm (gallons per minute).

The stratified-drift aquifer is made up of a variety of interbedded materials, as shown on figure 15. At some places it consists of moderately to well sorted coarse to medium sand grading downward into very fine sand and silt and, uncommonly, clay at the bottom. Elsewhere, variable thicknesses of moderately to poorly sorted "dirty" sand and gravel underlie sand and silt, and, at still other places, sand and gravel make up the entire section. The extent of these materials and their degree of sorting may change abruptly in both lateral and vertical directions with corresponding changes in water-yielding characteristics. Graphic logs, interpreted from drillers' logs of 144 wells and 319 test holes, are shown in the companion basic-data report and illustrate the general character of stratified drift.

Transmissibility.--The coefficient of transmissibility describes the ability of an aquifer to transmit water. It is possible to estimate the drawdown in a pumping well and in the aquifer at any distance from the well at any time after pumping begins if the transmissibility, storage coefficient, and boundaries of an aquifer are known. The U.S. Geological Survey favors a new term--transmissivity expressed in cubic feet per day per foot--to replace the coefficient of transmissibility, expressed in gallons per day per foot (gpd per ft). For convenience, transmissibility has been retained for use in this report, and a nomograph is presented on p. 50 that shows the relation between transmissibility and transmissivity.

The areal distribution of the coefficient of transmissibility, T, of most of the stratified-drift aquifer in the basins is shown on plate B; impermeable boundaries of the aquifer are shown by the line of zero transmissibility. This map was prepared by contouring values of transmissibility at 240 sites. The values of transmissibility were determined by using three successively less accurate techniques: 1) analyses of pumping-test data, 2) analyses of specific-capacity data, and 3) analyses of logs of wells and test holes.

Table 9.--Water-bearing characteristics of stratified drift as determined from constant-rate pumping tests.

Well no.	Storage coefficient S	Coefficient of transmissibility T (gpd per ft)	Aquifer thickness m (ft)	Length of test (hrs)
Ff 18	0.16	70,000	48	24
NCn 21	.05	67,000	a/ NA	2
Nw 19	.39	23,000	74	500.5
Nw 21	.024	160,000	81	24.5
Nw 36	.06	125,000	70	11.8
Nw 38	.005	64,000	74	8
Wp 21	.14	96,000	70	25
Wp 29	.09	108,000	70	24

a/ NA: Data not available.

Analyses of pumping-test data provide the most accurate values of transmissibility. Chiefly, pumping tests in the basins have been used to test the yield of wells. The coefficient of transmissibility can be computed from those tests during which the pumping rate was held constant for at least several hours, and drawdown data were collected from nearby wells. The theory and methods of analyses of pumping-test data have been discussed by Ferris and others (1962) and Walton (1962). Values of transmissibility computed from pumping tests on 8 wells in the basins range from 22,600 to 160,000 gpd per ft and are shown

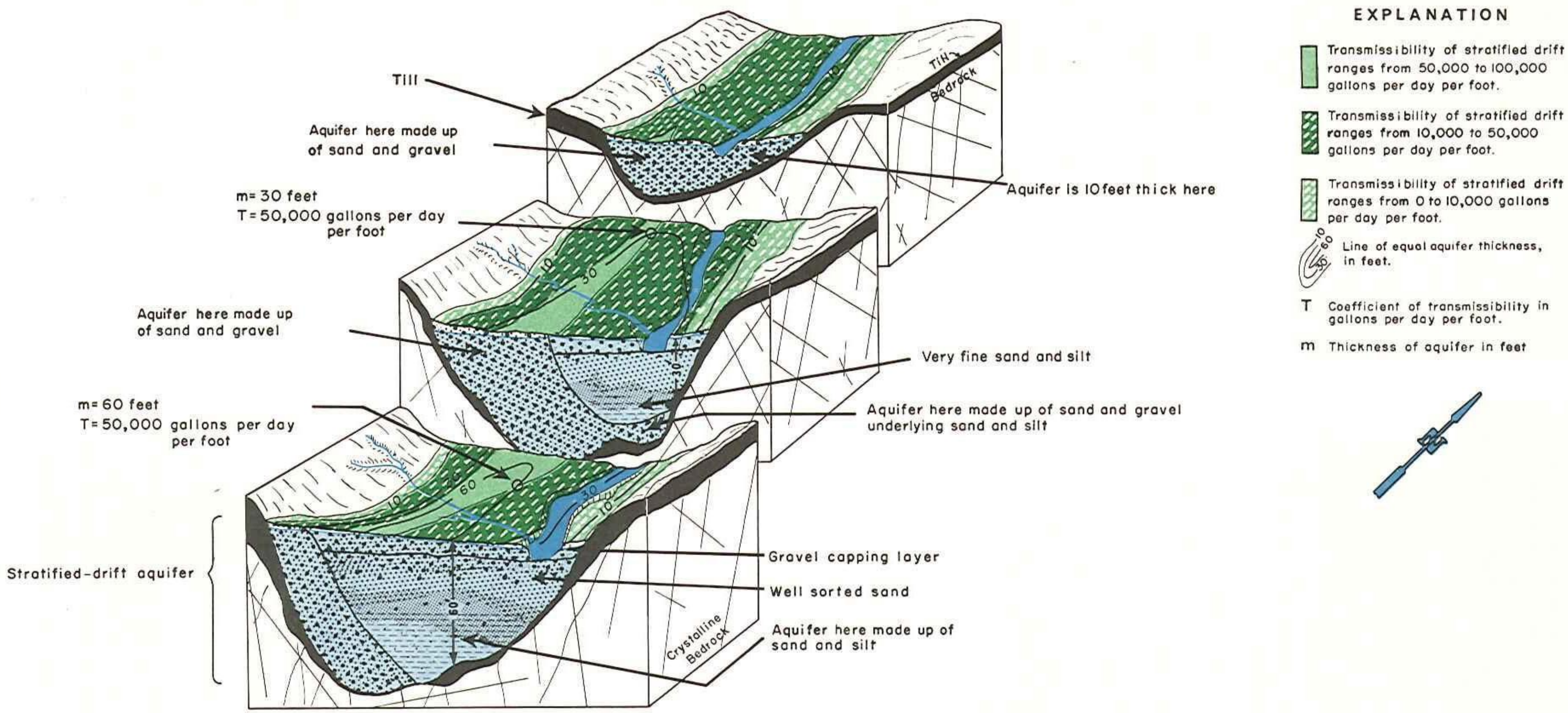


Figure 15.--Schematic block diagrams showing the distribution of the three aquifers in a typical valley in the basins, and the lithology, variability, and distribution of transmissibility, and thickness of the stratified-drift aquifer.

The thickness of the stratified-drift aquifer is measured from the water table down to the top of the underlying till or bedrock. The transmissibility of a thick fine-grained part of the aquifer may be equivalent to that of a thinner coarser-grained part.

on table 9. The table also shows the storage coefficients calculated from the test data. The storage coefficient is discussed in a following section. It can be used with values of transmissibility to calculate by use of curves on figure 23 the amount of drawdown in the stratified-drift aquifer at any distance from a pumping well after a 180-day period of pumping at a constant rate.

Analyses of specific-capacity data provide values of transmissibility that are less accurate than those computed from analyses of pumping tests. Specific-capacity values are obtainable from constant-rate pumping tests where drawdown is measured in the pumping well only. Specific capacity is related to well-construction characteristics as well as to aquifer characteristics (see discussion in section "Development by Wells"). Accordingly, the values of specific capacity for 18 screened wells tapping stratified drift were adjusted for the effects of well construction by a method outlined by Walton (1962). By assuming a storage coefficient of 0.2, values of transmissibility at these 18 sites were estimated by applying the adjusted specific-capacity data to graphs shown on p. 13 of Walton (1962). The resulting values of transmissibility are shown on table 10 and range from 16,000 to 270,000 gpd per ft. These values are probably lower than the true values of transmissibility because the effects of aquifer dewatering and well efficiency on drawdowns were not considered.

Table 10.--Transmissibility of stratified drift determined from specific-capacity data.

Well no.	Specific capacity from pump test (gpm per ft of drawdown)	Specific capacity adjusted for effects of well construction a/ (gpm per ft of drawdown)	Transmissibility determined from adjusted specific capacity b/ T (gpd per ft)	Aquifer thickness m (ft)
Bp 12	6.3	19.2	28,000	40
Bp 15	7.1	17.6	26,000	84
Da 9	20.0	39.0	43,000	38
Dy 16	5.3	15.6	22,000	34
Mo 20	13.0	26.3	38,000	33
Mo 30	4.7	20.7	27,000	86
Nw 16	55.4	161.9	270,000	96
Nw 20	4.8	11.0	16,000	51
R 19	7.0	20.2	30,000	23
Stm 12	18.2	27.8	40,000	57
Stm 15	23.7	57.8	83,000	42
Wp 10	57.7	116.0	180,000	67
Wp 11	118.6	179.0	260,000	66
Wp 12	63.2	134.7	210,000	85
Wp 16	9.6	21.3	33,000	46
Wn 24	16.4	25.8	37,000	45
Wn 28	10.2	32.7	46,000	52
Wn 60	7.6	29.6	45,000	36

a/ Assumes that horizontal permeability of stratified drift is 10 times larger than vertical permeability. Includes adjustment for well diameter and partial penetration but not for aquifer dewatering or well efficiency.

b/ By graphical method in Walton (1962, p. 12, 13).

Transmissibility was estimated at 214 sites from the descriptions of aquifer materials in logs of wells and test holes. These estimates were made by using the relation T=Pm, where T is coefficient of transmissibility in gpd per ft, P is the coefficient of permeability in gpd per sq ft, and m is the thickness of the aquifer in feet. The U.S. Geological Survey favors a new term--hydraulic conductivity, expressed in cubic feet per day per sq ft--to replace the coefficient of permeability, expressed in gpd per sq ft. For convenience, permeability has been retained for use in this report, and a nomograph is presented on p. 50 that shows the relation between permeability and hydraulic conductivity. Values of permeability were assigned to each saturated unit described in the log by use of the relationship shown on figure 16 and data summarized on table 11. Values of transmissibility estimated by this third method are much less accurate than values obtained from pumping tests or estimated from specific capacity.

The relationship on figure 16 was used to estimate transmissibility at sites where median grain size and sorting could be either approximated from the drillers' logs or calculated from laboratory analyses of the grain-size distribution of samples of aquifer material (laboratory grain-size analyses of 39 such samples are given in the companion basic-data report). This relationship synthesizes two kinds of data. The permeability and grain-size distribution of samples of aquifer material were determined in the laboratory, and permeability was plotted versus median grain size making note of the uniformity coefficient, a measure of sorting. Fields of permeability drawn on the plot were guided by permeability values determined from pumping and specific-capacity tests. These fields are directly related to median grain size and uniformity coefficient.

A catalog of representative permeability values for various aquifer materials was used at

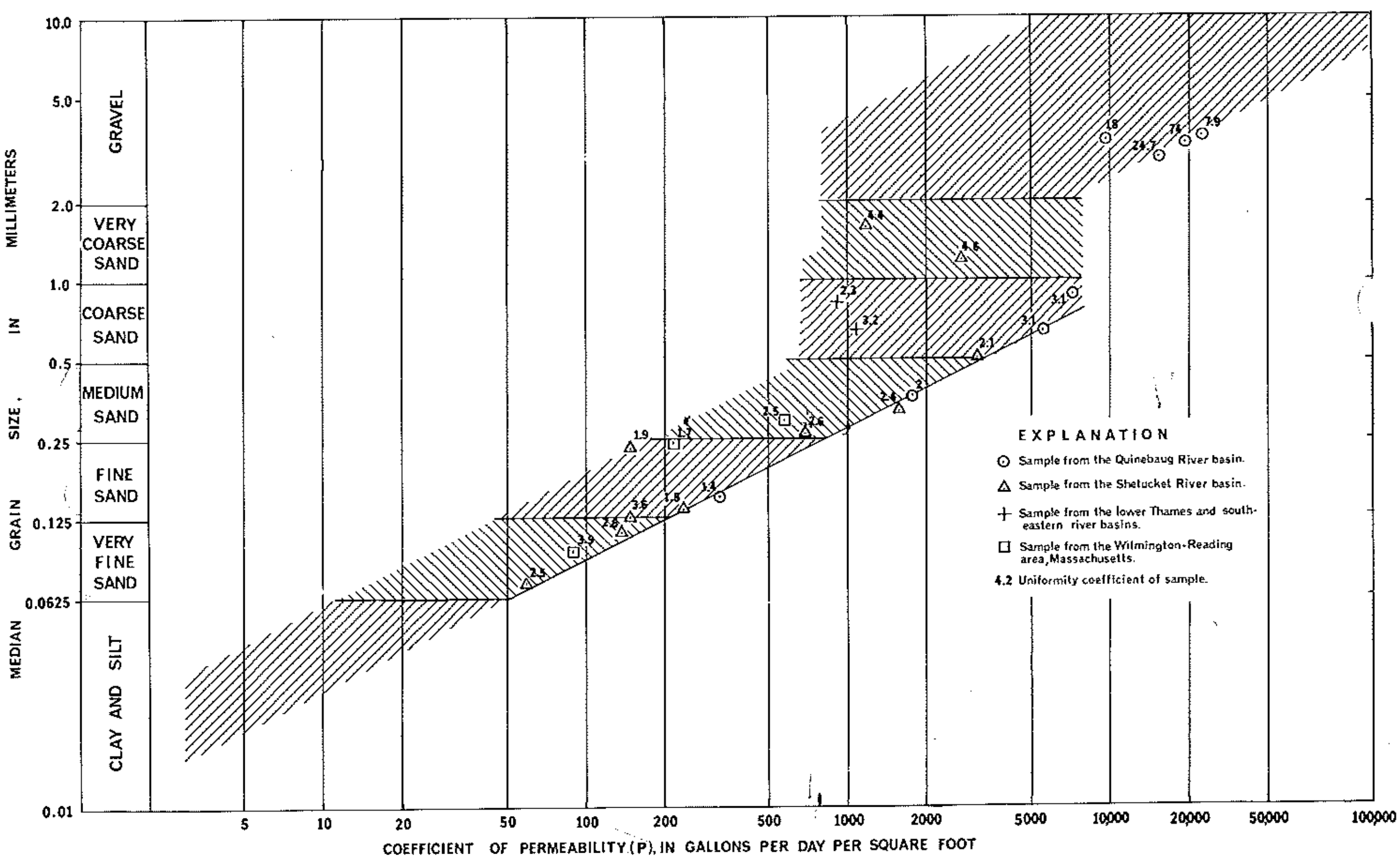


Figure 16.--The relation of permeability of the stratified-drift aquifer to median grain size and differences in sorting.

Values of permeability determined in the laboratory from horizontally oriented undisturbed samples are plotted versus median grain size. Fields of permeability for each grain size class are sketched in based on transmissibility values from pumping tests and estimates of transmissibility from specific-capacity tests. Variabilities in permeability for a given median grain size result from differences in sorting, packing, and probably, grain shape. Sand and gravels, which generally have median grain sizes larger than medium sand, range widely in permeability. In contrast, sands with median grain sizes smaller than coarse sand range narrowly in permeability.

sites where logs were lacking the detail to estimate median grain size and sorting. This catalog is summarized on table 11. It was developed by prorating the values of transmissibility from pumping and specific-capacity tests to the saturated lithologic units described in the logs of the pumping wells.

Table 11.--Representative values used to estimate permeability of stratified drift from drillers' logs.

Description from drillers' logs	Estimated median grain size (millimeters)	Estimated permeability P (gpd per sq ft)
Clay	0.02	5
Very fine sandy silt	.06	45
Fine sand and clay	.07	30
Very fine sand	.08	50
Fine sand	.15	150
Medium to fine sand	.20	200
Sand	.23	300
Fine to medium sand, some medium to coarse gravel	.25	850
Dirty sand	.30	270
Medium to coarse sand with gravel and layers of clay	.40	800
Medium sand	.40	2,000
Coarse sand, trace clay	.45	600
Gravel interbedded with fine sand	.50	1,100
Dirty gravel	.55	700
Coarse sand	.70	750
Medium to coarse sand, very fine gravel	.90	2,400
Medium sand and gravel	1.0	4,000
Medium to coarse sand with grits and gravel	1.0	900
Dirty coarse sand and gravel	1.5	2,600
Coarse sand and fine gravel	1.8	5,500
Very coarse gravel and sand	2.5	5,000

Thickness.--The thickness of the stratified-drift aquifer is measured vertically from the water table down to the underlying till, or bedrock if till is absent. Aquifer thickness is shown on plate B, and ranges from less than 1 ft to over 185 ft and is 30 to 60 ft in many places. Thickness determines the amount of drawdown available for development and together with permeability determines the maximum yields of wells. The lithology of the aquifer at most sites can be estimated by the transmissibility and thickness data on plate B. Variations in thickness produce corresponding variations in transmissibility. If aquifer lithology also varies, transmissibility variations are more complex.

THE TILL AQUIFER

Till, commonly called hardpan, is a dense, poorly sorted, and generally unstratified glacial deposit consisting of clay, silt, sand, gravel, and boulders. It mantles bedrock almost everywhere in the basins, is commonly at the land surface on hilltops and on most hillsides (see pl. B and fig. 15), and is overlain by younger glacial deposits of stratified drift in most valleys. Till deposits range in thickness from a few inches to 145 ft; and logs of wells and test holes indicate that they have an average thickness of about 5 ft where they underlie deposits of stratified drift. Areas where till deposits are known or inferred to be at least 40 ft thick are shown on plate B.

Permeability.--Permeability of the till aquifer is very low because clay- and silt-sized grains are tightly packed in the openings between sand- and gravel-sized grains. Laboratory values of permeability of till sampled in Connecticut, (Randall and others, 1966), Rhode Island (Allen and others, 1966), and Massachusetts (Sammel and others, 1966, and Baker and others, 1964), range from 0.1 to 310 gpd per sq ft. The decline of the water level in well Rd 19 dug in till was analyzed by the type-curve method of Stallman and Papadopulos (1966), to determine the hydraulic diffusivity of till. The permeability of till in the vicinity of the well was calculated to be about 1.5 gpd per sq ft, by assuming a storage coefficient of 0.15 and an average aquifer thickness of 25 ft.

THE BEDROCK AQUIFER

Fractured crystalline bedrock.--Crystalline bedrock, commonly called ledge, is made up of a hard, dense, consolidated, and almost impermeable mass of interlocking mineral grains and crystals. It underlies the basins everywhere, and is mantled by glacial deposits of stratified drift or till except locally, especially on hilltops and hillsides, where it is exposed at land surface.

Two general types of fractured crystalline bedrock occur in the basins. The first type includes schist, gneiss, granite, and diorite. The second type is marble. No significant differences in water-bearing properties of the two rock types were evident in surface exposures nor from a study of records of wells.

Few, if any, intergranular openings in fractured crystalline bedrock are interconnected. Therefore, water moves principally through fractures or cracks. The yield of a well tapping bedrock is directly related to the number and the width of openings along water-bearing fractures intersected during drilling. However, Ellis (1909), Randall and others (1966), and Thomas and others (1967) have shown that the number and width of openings along water-bearing fractures decrease with depth, therefore the chances of increasing the yield obtained at any depth generally decrease as drilling continues.

Table 12.--Types of well construction suggested for supplying yields from aquifers in the southwestern coastal river basins.

Yield	Type of Aquifer: Stratified drift	Till	Crystalline bedrock	Weathered marble
200 gpd (0.14 gpm) or less	DUG: porous casing. DRIVEN: where water table is within 15 ft of land surface and material permits construction	DUG: porous casing at least 3 ft in diameter	DRILLED: open hole	DRILLED: if open hole cannot be developed, drilling should be continued to sound bedrock.
200 gpd to 10 gpm	DUG: porous casing. DRIVEN: see above.	DUG: porous casing at least 5 ft in diameter	DRILLED: open hole	DRILLED: open hole, see above.
10 gpm to 100 gpm	DUG: porous casing or screen; well must tap at least 30 ft of aquifer. DRILLED: open end or, preferably screen.	WNS a/	DRILLED: open hole MS b/	DRILLED: if open hole cannot be developed, a screen should be used in the troublesome section.
100 gpm to 500 gpm	DUG OR DRILLED: screen; see figure 19 for aquifer thickness and transmissibility required.	WNS	WNS	DRILLED: open hole or screen; well must tap at least 100 ft of aquifer; yields of 200 gpm or more are marginal.
About 1 mgd or more	DUG OR DRILLED: screen; see figure 19 for aquifer thickness and transmissibility required.	WNS	WNS	WNS

a/ WNS: At most sites the aquifer Will Not Supply the yield indicated.
b/ MS: At most sites the aquifer will only Marginally Supply the yield indicated.

Weathered crystalline bedrock.--At a few places in the basins, shown on figure 27, fresh fractured marble grades upward into an unconsolidated granular earth material that is believed to be weathered marble. This material is overlain by deposits of stratified drift or till, and is known to be as much as 127 ft thick. It is made up of grains of calcite and quartz in various proportions that range in size from coarse sand to clay. Lateral and vertical variations in degree of weathering and grain size are common as are lateral variations in thickness. Weathered marble generally supports an open hole when drilled and it is commonly described by well drillers as a thoroughly decomposed white rock that drills alternately hard and soft.

An analysis of drawdown data from a pumping test of well R 18, which is open to 127 ft of saturated weathered marble, indicates that the transmissibility is 6,600 gpd per ft and the average permeability is 52 gpd per sq ft. The value of permeability is probably representative of the weathered marble where it is made up of sand-sized grains; lower values of permeability can be expected where clay and silt sizes predominate.

DEVELOPMENT BY WELLS

The types of wells suitable for obtaining various yields from the aquifers in the basins can be determined from table 12. Small yields for most domestic and commercial uses can be obtained from any aquifer with little regard to the type of well construction used, but yields of 1 mgd or more can be obtained only from screened wells tapping the stratified-drift aquifer where it is thick and permeable.

The stratified-drift aquifer.--The stratified-drift aquifer can yield from 100 gpm to more than 2,000 gpm to individual screened wells. The yield of 64 screened wells tapping stratified drift in the basins ranges from 10 to 2,100 gpm and the median is 262 gpm. The specific capacity of 48 of these wells ranges from 0.9 to 118.6 gpm per ft of drawdown, and the median is 9.9 gpm per ft. Many of the large-yielding wells were enclosed by a gravel pack.

By using figures 17 and 18, aquifer thickness and transmissibility data shown on plate B can be

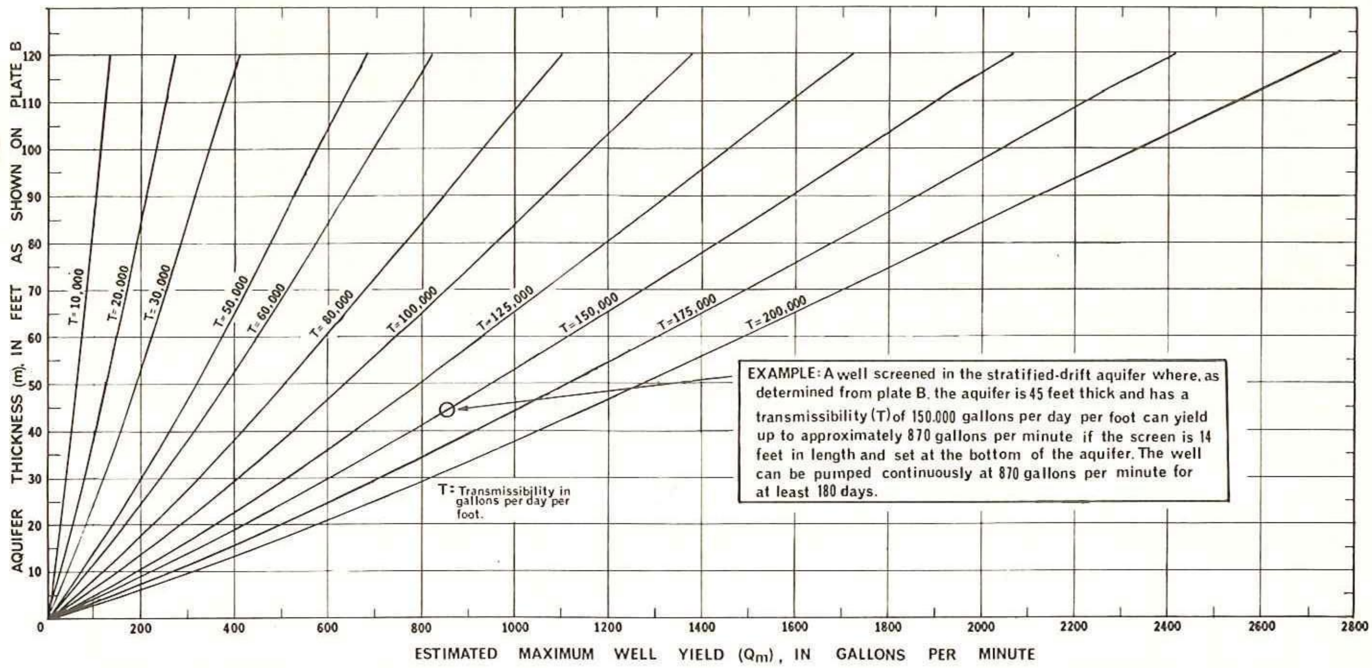


Figure 17.--Estimated maximum yields of wells screened in stratified drift are related to the thickness and transmissibility of the aquifer.

This relation applies strictly to a 90 percent efficient 24-inch diameter well with a screen length equal to 0.3 times the aquifer thickness set at the bottom of an aquifer where the horizontal permeability is 10 times greater than the vertical permeability. The maximum yields of similar wells constructed in stratified drift anywhere in the basins can be estimated by applying data on plate B to these graphs. These estimated yields can be continuously maintained through the 180-day period of no recharge.

used to estimate the yield of a screened well tapping stratified drift. These estimated yields can be continuously maintained at least through the 180-day period of no recharge (see following section entitled "Large Supplies from the Stratified-Drift Aquifer").

Figure 17 relates thickness and transmissibility to the well yield obtained at maximum available drawdown, which, for purposes of this analysis, is assumed to be equivalent to a pumping water level drawn down to within 1 ft of the top of the well screen. Figure 18 relates drawdown to well yield for various values of transmissibility. The relations shown on both figures strictly apply to 90 percent efficient 24-inch diameter wells, gravel pack included, screened in the bottom 30 percent of the aquifer. A further assumption is that the horizontal permeability of the stratified-drift aquifer is ten times greater than the vertical permeability.

The relations on both figures are based on the equation:

$$Q = \frac{Ts}{2,000}$$

where: Q = constant discharge of pumped well, in gallons per minute

T = coefficient of transmissibility, in gallons per day per foot

s = drawdown in the pumped well, in feet, due to Q and the aquifer transmissibility.

This equation is a simplification of the Thiem equation (Ferris and others, 1962, p. 91) and assumes that a 24-inch diameter well has been pumped long enough (approximately 180 days) so that the drawdown in the aquifer is zero at any point approximately 10,000 ft from the well.

The theoretical drawdown, s, in the equation is related to aquifer characteristics and pumping rate only. However, the actual drawdown in a pumping well will be greater than the theoretical figure because of several components. The most important of these are: 1) increased drawdown owing to thinning of the aquifer by dewatering, 2) increased drawdown due to the effects of nearby pumping wells or impermeable boundaries, 3) increased drawdown required to move water from the aquifer into the well, commonly called well loss, and 4) drawdown due to the effects of partial screening or partial penetration of the aquifer by the well. The effects of partial penetration are substantial and may account for more than half the drawdown in some pumping wells. Partial penetration causes flow lines in the aquifer to converge vertically, with a loss of head or energy, toward the part of the well open to the aquifer. Three types of partially penetrating pumping wells and their effect on flow lines in the aquifer are shown on figure 19.

Accordingly, in order to construct the curves on figures 17 and 18 from the above equation, drawdown was corrected by methods shown in Walton (1962) for the effects of: 1) partial penetration of the aquifer, 2) well loss, and 3) thinning of the aquifer owing to dewatering. In addition, it was assumed that drawdown would not be affected by other pumping wells nor by hydrogeologic boundaries.

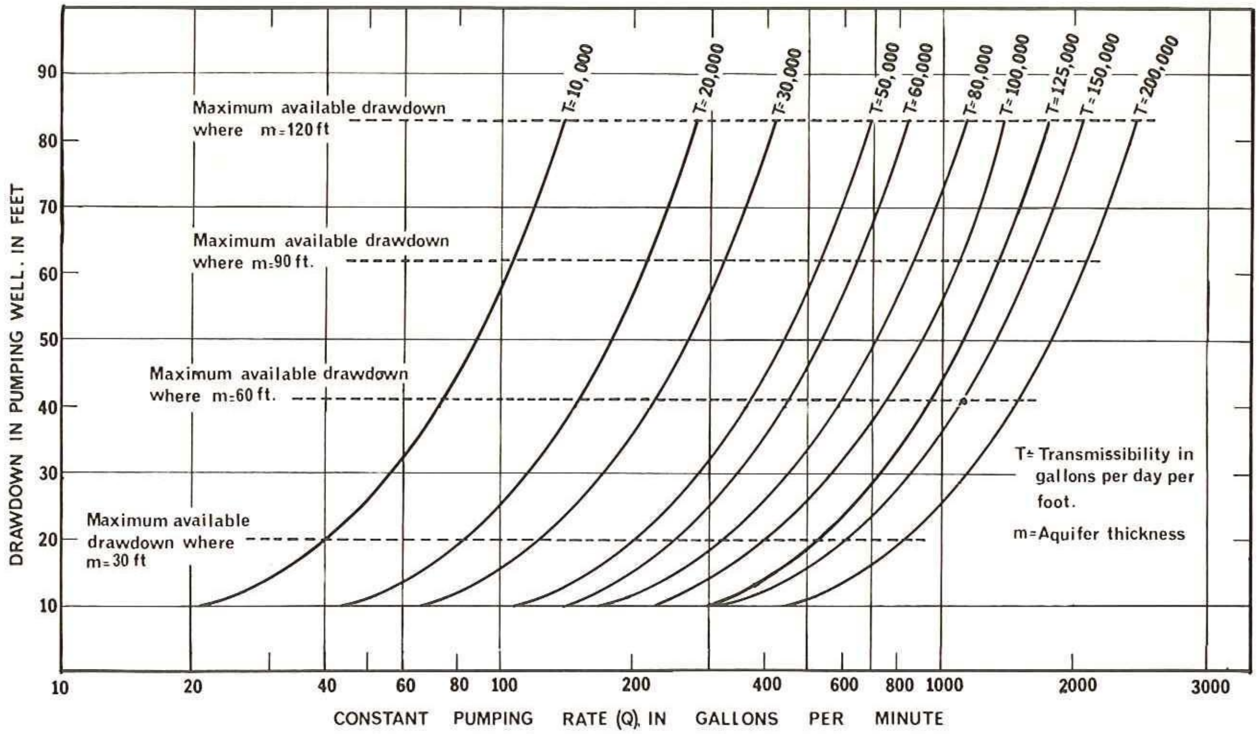


Figure 18.--Drawdown in a well pumping from the stratified-drift aquifer is related to constant pumping rate and transmissibility.

This relation applies strictly to a 90 percent efficient 24-inch diameter well screened in the lower 30 percent of the aquifer where horizontal permeability is 10 times greater than vertical permeability.

Maximum available drawdown is the difference between static water level and a pumping water level 1 ft above the top of the well screen.

Estimated pumping rates can be continuously maintained at least through the 180-day period of no recharge.

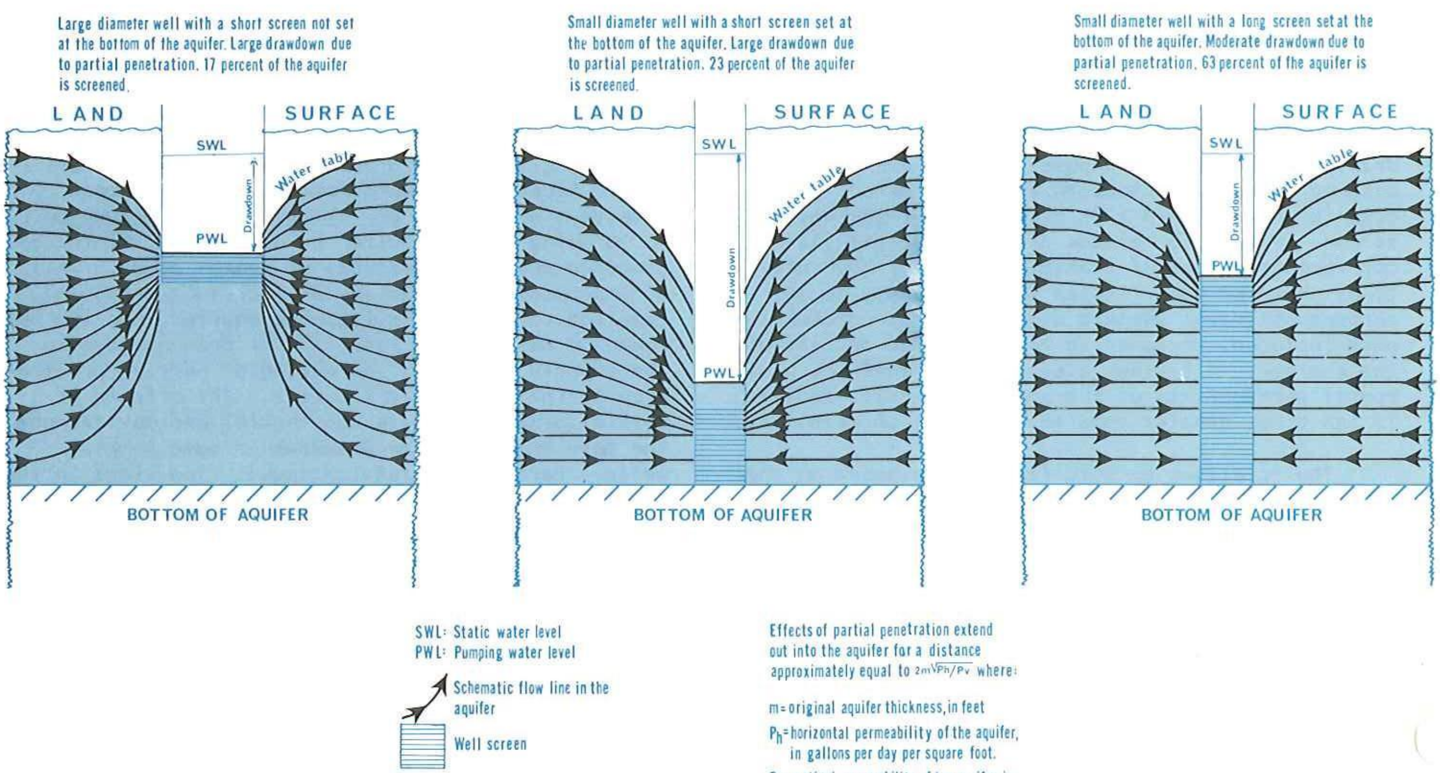


Figure 19.--Drawdown in a pumping well related to the percent of aquifer penetrated.

An estimate of the yield, at maximum available drawdown of a hypothetical 24-inch diameter screened well is shown on figure 20. Well yields represented on figures 17 and 18 probably are lower than will actually be obtained because the underlying assumptions are conservative. The correction for partial penetration was made by assuming that the ratio of vertical permeability to horizontal permeability is 0.1. If the ratio is greater than 0.1, drawdown caused by partial penetration will be less, therefore well yields will be larger than estimated from figures 17 and 18. Also, yields larger than estimated can be expected from wells with longer screens, and from wells located near streams or ponds. On the other hand, larger drawdowns, hence yields smaller than estimated can be expected from smaller diameter wells with shorter screens, and from wells located within tens of feet of impermeable aquifer boundaries or other production wells.

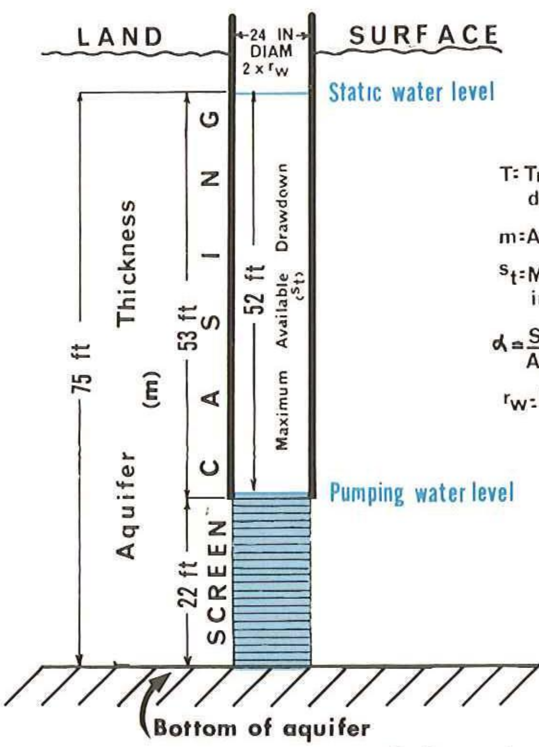
Unscreened open-end wells can be drilled in coarser-grained parts of the stratified-drift aquifer to supply most domestic and commercial water needs. The reported yield of 15 open-end wells in the basins ranges from 5 to 100 gpm and the median is 40 gpm. Characteristically these wells have a low specific capacity because the open-end construction produces very large drawdowns due to the effects of partial penetration.

A well dug in stratified drift can supply most domestic, commercial, and some light industrial needs wherever the aquifer is at least 5 ft thick. For example, well Tr 1, a 36-inch diameter well 13.9 ft deep, supplied approximately 10,000 gpd 5 days a week for industrial cooling in 1963.

Wells yielding adequate water for most domestic and some commercial uses can be constructed by driving a screened "well point" where the water table is within 15 ft of land surface and the aquifer is at least 5 ft thick and is made up of well-sorted, sand-sized material. Well points are commonly 1.25 to 2 inches in diameter and are 2 to 4 ft in length, and are available in a variety of screen-slot sizes. Slot size should be tailored to the grain size of the aquifer material, however, a small slot size prolongs the sand-free life of the well.

The till aquifer.--The till aquifer has low permeability and is generally thin, consequently it can supply only a few gallons per minute to individual wells in the basins. Till is tapped by shallow dug wells at least 3 ft in diameter that are used for small-scale irrigation, stock watering, and emergency purposes. Many till wells in the basins proved to be inadequate for modern domestic water demands and were replaced by drilled bedrock wells.

Theoretical well that partially penetrates the stratified-drift aquifer



EXPLANATION

T: Transmissibility, in gallons per day per foot

m: Aquifer thickness, in feet

S_t: Maximum available drawdown, in feet

$\alpha = \frac{\text{Screen length}}{\text{Aquifer thickness}}$, or amount of partial penatration

r_w: Radius of well

Estimation of the maximum yield (Q_m) of the hypothetical well.

A. Assumptions

T= 90,000 gallons per day per foot

m= 75 feet

α= 0.3

Screen length=0.3(75)= 22 feet

s_t = 75-22-1 = 52 feet

r_w= 1 foot

well is 90 percent efficient

$\frac{\text{Vertical permeability}}{\text{Horzontal permeability}} = 0.1$

B. From figure 17:

for T= 80,000,

Q_m= 725 gallons per minute

for T= 100,000,

Q_m= 910 gallons per minute

Therefore Q_m for T= 90,000 is:

$$\frac{910-725}{100,000-80,000} \times (90,000-80,000) + 725 =$$

$$\frac{185}{2} + 725 = 92 + 725 = 817$$ gallons per minute or

approximately 815 to 820 gallons per minute

Figure 20.--Estimation of the maximum yield of a hypothetical well screened in stratified drift.

The construction characteristics of the hypothetical well shown in this example are those used for the preparation of the graphs on figures 17 and 18.

Example shows that where the stratified-drift aquifer has a transmissibility equal to 90,000 gpd per ft and is 75 ft thick, a 24-inch diameter well with a 22 ft screen (30 percent of the aquifer thickness) set at the bottom of the aquifer can produce up to approximately 815 to 820 gpm.

The large diameter of a dug well provides a large storage capacity that once used is only slowly replenished. Each foot of water in a well 4 ft in diameter is equal to 94 gallons and in a well 3 ft in diameter it is equal to 53 gallons. The important role that storage plays in the practical yield of a till well is illustrated by the following hypothetical example, which assumes that the permeability of till is 5 gpd per sq ft. A well 4 ft in diameter, lined with unmortared stone work, is 20 ft deep and extends to bedrock, and the bottom of the pump intake is 1 ft above the bottom of the well. The static water level is 10 ft below land surface, therefore, the amount of water in usable storage is 9 times 94 or 846 gallons. If 840 gallons are pumped from the well in a day, approximately 53 hours will be required before the water level will return to its static position. More importantly, the water level will recover about 4 ft in 24 hours; at this time approximately 375 gallons are available for pumping, just barely enough to supply the daily water needs of a family of five. In contrast, a 2-foot diameter well in the same situation would not provide an adequate supply.

Fractured crystalline bedrock aquifer.--Fractured crystalline bedrock, tapped by drilled open-hole wells, can support water supplies adequate for most domestic and commercial needs and some small-scale industrial uses.

The depth and yield of a bedrock well cannot be predicted in advance of drilling because its intersection with water-bearing fractures is essentially a chance phenomenon. The yield and depth data reported by drillers from 725 selected bedrock wells in the basins were analyzed statistically to determine the relationship between maximum yield and amount of uncased saturated bedrock penetrated. Maximum yield of a bedrock well is obtained when the pumping level is maintained at the bottom of the well. Maximum yield data were taken from only those wells in which the static water level was above the bottom of the well casing to assure that all fractures penetrated by the well were water bearing.

About 90 percent of the wells selected for analysis were drilled by the air-rotary percussion method, in which yields were measured by the amount of water blown from the well. The remaining 10 per cent of the wells were drilled by the cable-tool method, in which yields were measured by the rate of recovery of the water level after the well had been emptied by bailing. Maximum yields, which are for short periods of pumping, commonly less than 2 hours, range from 0.1 to 100 gpm; the mean is about 11 gpm; the median is about 5 gpm.

The statistical relation between maximum yield and amount of uncased saturated bedrock penetrated is shown by the curves on figure 21. Figure 21 shows that yields of at least 3 gpm may be obtained from bedrock at most places in the basins--90 percent of the wells drilled through 350 ft or less of uncased saturated bedrock yielded 1 gpm or more. Yields of 10 gpm or more may be obtained at a few sites--only 29 percent of the wells drilled through 350 ft or less of uncased saturated bedrock had a yield of 10 gpm or more. To determine the relation of yield probability to total depth at a site where a bedrock well is to be drilled, the thickness of unconsolidated material overlying the bedrock plus the depth to static water level below the bottom of the well casing must be added to the amount of uncased saturated bedrock penetrated shown on figure 21.

The data on figure 21 can be used only to give an indication of the probability of obtaining a specified yield within a specified total amount of uncased saturated bedrock penetrated; they cannot be used to determine the probability of increasing the yield by drilling a given number of feet deeper. However, as a guide during drilling, the data show that productive fractures are uncommon and are restricted to shallow depths of uncased saturated bedrock penetrated, and that even low-yielding fractures decrease in frequency with increases in amount of uncased saturated bedrock penetrated.

Weathered crystalline bedrock aquifer.--Weathered marble can yield as much as 100 to 200 gpm to individual drilled open-hole wells at most sites in the basins. Where maximum well yields are desired, no part of the aquifer should be cased off. If any part of the aquifer will not maintain an open hole a screen can be placed opposite the caving interval.

The maximum practical long-term (greater than 100 days of pumping) yield of a large diameter (1 ft or greater) well tapping weathered marble consisting primarily of sand-sized grains can be estimated within a few tens of gallons per minute by assuming that the well is open to the entire aquifer, that the permeability, P, is 50 gpd per sq ft, and that the pumping level is at the top of the aquifer. For example, a hypothetical 12-inch diameter well penetrates 40 ft of till, 150 ft of

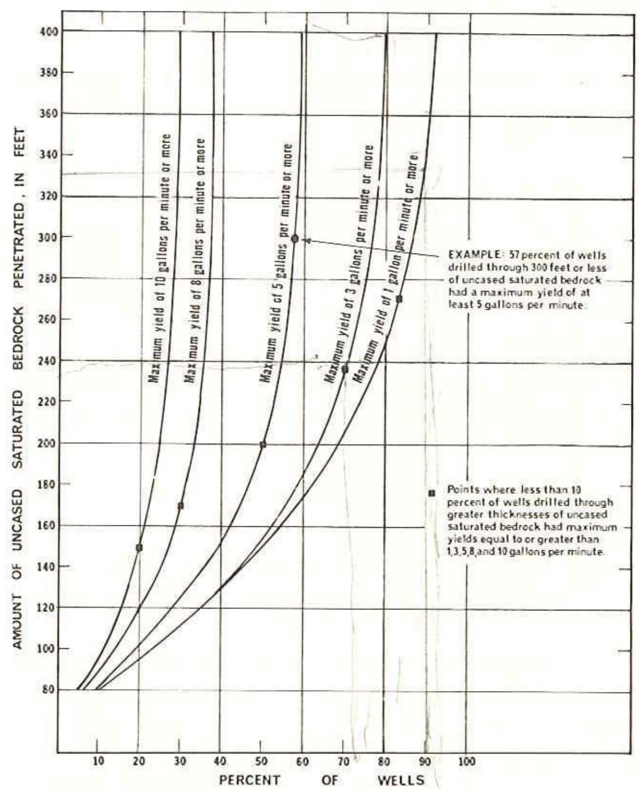


Figure 21.--Maximum yields of bedrock wells are related to the amount of uncased saturated bedrock penetrated.

weathered marble, and 5 ft of dense crystalline marble. The well is cased to the top of the weathered marble, and the static water level is 5 ft below land surface, therefore:

Aquifer thickness, m = 150 ft

Transmissibility of aquifer, T = P x m = 50 x 150 = 7,500 gpd per ft

Drawdown, s = 40-5 = 35 ft

Estimated constant pumping rate, $Q = \frac{Ts}{2,000} = \frac{7,500}{2,000} \times 35 = 130$ gpm, or about 100 gpm.

LARGE SUPPLIES FROM THE STRATIFIED-DRIFT AQUIFER

Only stratified drift can support large-scale long-term development of water supplies. The quantities of water that can be developed by wells from this aquifer are dependent upon 1) aquifer characteristics such as transmissibility, storage, and thickness, which determine the yield, spacing, and construction characteristics of individual wells; 2) the location and relative position of impermeable boundaries, which restrict the drawdown available in individual wells; and 3) the quantities potentially available from ground-water outflow, storage, and induced infiltration of streamflow.

WATER POTENTIALLY AVAILABLE

Ground-water outflow.--Disregarding the amount of water available from induced infiltration of streamflow and from salvage of ground-water evapotranspiration, the long-term amount of ground water annually available for development from a drainage basin in the southwestern coastal river basins is conservatively estimated as being equal to the natural ground-water outflow.

Under natural conditions, annual ground-water outflow is equal to the quantity of infiltrating precipitation that reaches the water table minus the quantity of water withdrawn from the basin by ground-water evapotranspiration plus or minus changes in ground-water storage. The magnitude of ground-water evapotranspiration was not determined in the southwestern coastal river basins, therefore no estimate was made of the quantity of ground water that could be salvaged by lowering the water table below the root zone by development.

Stratified drift, because of its permeability and topographic position, receives more infiltrating precipitation than does till or bedrock. Consequently, the mean annual quantity of ground-water outflow varies directly with the percentage of a drainage area underlain by stratified drift.

To determine the magnitude of annual ground-water outflow, hydrographs of the daily mean discharge of four streams during water year 1966 were separated into direct runoff and ground-water runoff components by use of a method explained by Randall and others (1966), which is based on the relation of ground-water levels to ground-water runoff. Net changes in aquifer storage were negligible during water year 1966, therefore ground-water outflow during the year was the sum of ground-water runoff and the underflow calculated at each stream-gaging site. These one-year ground-water outflow values were then adjusted to the statewide mean annual runoff of 24.4 inches, which is considered to include underflow, for the base period 1931-1960. The base period annual discharge records of Still River at Lanesville, which is located about 12 miles north of the basins, were used to convert the adjusted mean annual ground-water outflow from the 4 basins to 30-year minimum annual outflows and annual outflows exceeded 7 years out of 10. These data were combined with similar data from seven basins in eastern Connecticut (Randall and others, 1966, and Thomas and others, 1967). The percent of stratified drift underlying each of the 11 basins was determined from an analysis of the flow-duration data for each of the gaging stations (in most basins this percent was approximately equal to the percent of stratified drift underlying the basins measured on a map). Data for basins underlain entirely by stratified drift were taken from analyses of hydrographs of streams draining such basins on Long Island, New York made by Pluhowski and Kantrowitz (1964). These analyses indicate that about 95 percent of the annual runoff from 100 percent stratified-drift basins is made up of ground-water runoff. The adjusted mean annual and 30-year minimum annual ground-water outflow, and ground-water outflow exceeded 7 years out of 10 were plotted against the percent stratified-drift aquifer underlying each of the 11 basins. Curves fitted to these data are shown on figure 22. Data from the curve for 7 years out of 10 probably provide the best estimate of the annual amount of ground-water outflow available for development from a drainage basin. To apply these curves to any site in the basins it is necessary to: 1) determine on plate B the drainage area upstream from the site and then the percent of this area underlain by the stratified-drift aquifer, 2) determine the outflow, per square mile, from figure 22, 3) multiply the outflow, per square mile, by the drainage area, and 4) adjust the outflow for areal variations in mean annual runoff by the isopleths on figure 8.

Ground-water outflow is not constant throughout the year, but varies with the amount and timing of ground-water recharge. Yearly hydrographs of ground-water levels in the basins indicate that recharge is primarily during the non-growing season when soil-moisture content is usually at field capacity. Brumbach (1965, p. 42-47) reports that the growing season in the basins averages 183 days and extends from about April 15 to about October 15. During this period, soil moisture is usually less than field capacity; therefore, precipitation percolating downward through the soil only occasionally reaches the water table. Hydrographs of water levels in 12 wells in the basins, during calendar year 1965, indicate that the period of little or no recharge ranged from 312 to 154 consecutive days. Hydrographs from 8 wells, during calendar year 1966, indicate that the period of little or no recharge ranged from 192 to 111 consecutive days. The mean length of the period of little or no recharge for the two calendar years is 172 consecutive days. It is assumed, therefore, that aquifers in the basins receive little or no recharge for approximately 180 consecutive days in an average year.

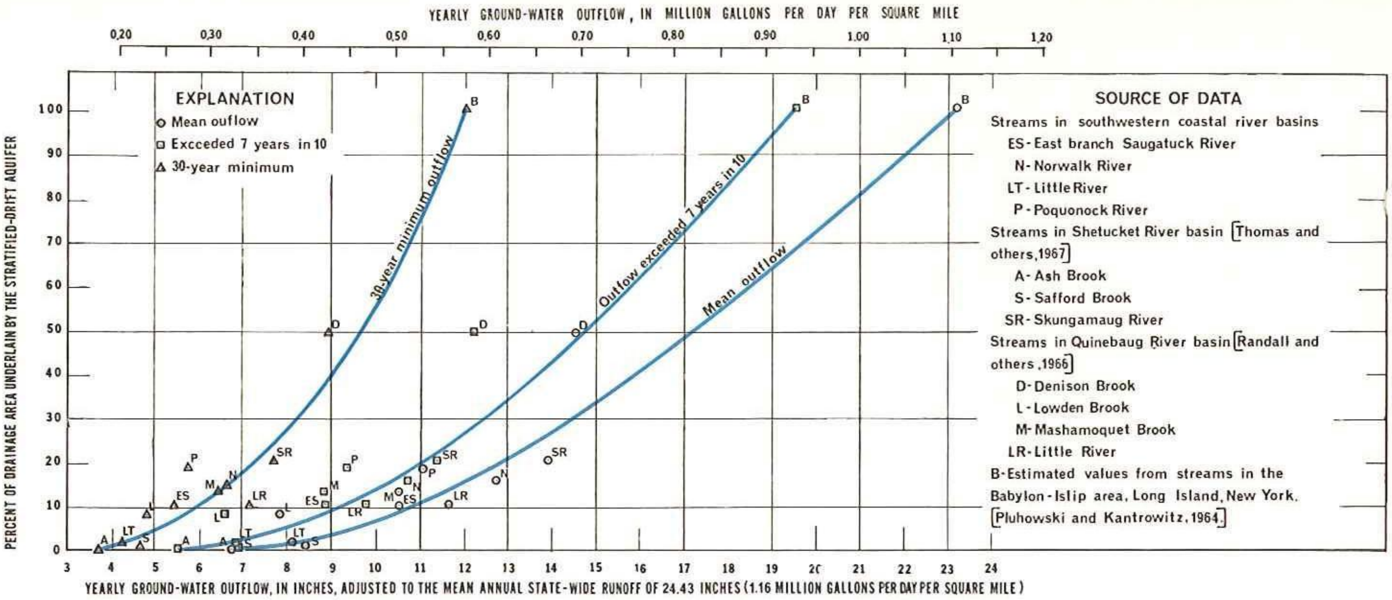


Figure 22.--Yearly ground-water outflow is related to the areal percent of stratified drift underlying a drainage area.

The yearly amount of ground water outflowing from a drainage basin is determined by the area of the basin and the percent of that area underlain by stratified drift. Values of ground-water outflow exceeded 7 years in 10 provide conservative estimates of the amount of ground water available for long-term development.

Water in aquifer storage.--Ground-water outflow is sustained during the period of little or no recharge by the depletion of aquifer storage. The amount of water available from storage in the stratified-drift aquifer is equivalent to the storage coefficient multiplied by the volume of the aquifer unwatered during any period of storage depletion. The storage coefficient of the aquifer was determined at 8 sites in the basins from pumping-test data. These values, which are shown on table 9, ranged from 0.005 in the vicinity of well Nw 38 at the end of an 8-hour test to 0.39 in the vicinity of well Nw 19 at the end of a 21-day test, and three values were greater than 0.10. A storage coefficient of 0.20 was selected from these data and similar data for eastern Connecticut (Randall and others, 1966, Thomas and others, 1967) and Rhode Island (Allen and others, 1966) as an areally applicable and probably conservative value for stratified drift in the basins. The practical significance of a storage coefficient of 0.20 is that 41.7 million gallons of water will be released from storage if, during the 180-day period of little or no recharge, the water table declines 1 ft throughout a 1 sq mi area of the stratified-drift aquifer.

Induced infiltration of streamflow.--Ground-water levels in a stratified-drift aquifer can be depressed beneath nearby streambeds by prolonged pumping from wells. Under these conditions, a hydraulic gradient is established through the streambed material, thereby inducing water in the stream to flow through the streambed and into the aquifer. The dependable amounts of water in streams that can be induced into the aquifer are governed either by the potential rate of infiltration of water in the stream, or by the quantity and duration of the low flow of streams.

Assuming that ground-water levels can be depressed to or below the bottom of a streambed and that the infiltration capacity of a streambed is lower than the vertical permeability of the underlying aquifer, the potential rate of infiltration can be estimated by a modified form of Darcy's equation (Ferris and others, 1962):

$$Q_i = RI$$

Where: Q_i = potential rate of infiltration of water in the stream, in gallons per day per square foot of streambed

R = infiltration capacity of the streambed, in gallons per day per square foot per foot of stream depth at a given temperature

I = stream depth, in feet

Temperature of stream water affects the infiltration capacity of a streambed as water is more viscous at low temperatures than at high temperatures. A 0.6°C (1°F) change in water temperature produces approximately a 1.5 percent change in the infiltration capacity. The temperature record of the Saugatuck River at gaging station 2095 (see fig. 28) indicates that, for a constant stream stage, the infiltration capacity may increase as much as 43 percent and decrease as much as 33 percent relative to the annual mean water temperature of 11°C (52°F). Nevertheless, the effects of viscosity changes during an average year probably can be considered negligible because high stream stages, which increase the rate of infiltration, generally coincide with periods of low water temperatures. Similarly, low stream stages, which decrease the rate of infiltration, generally coincide with periods of high water temperatures.

The infiltration capacity of streambeds in the vicinity of production wells Wp 29 and Wp 30 (see pl. A for location) was measured indirectly on November 17, 1965. At that time the pumpage from the two wells was 2.6 mgd, the temperature of the nearby streams was 10°C (50°F), and the average depth of the streams was slightly less than 1 ft. Measurements opposite the wells and at points 1,000 to 4,300 ft upstream showed a loss in streamflow of 1.95 mgd. At 10°C (50°F) the average infiltration capacity, R, of the streambeds, which consist entirely of sand and gravel, was calculated as 59 gpd per sq ft per ft, assuming that ground-water levels were depressed to or below the streambeds for 1,000 ft upstream from the wells. At the annual

Table 13.--Estimates of long-term daily yields from areas favorable for ground-water development in the southwestern coastal river basins.

Favorable area			Ground-water outflow			Induced infiltration			Pumpage from aquifer storage during period of little or no recharge determined from mathematical model				Estimated long-term yields				
			Ground-water drainage area		Col. ① Ground-water outflow exceeded 7 years out of 10	Col. ② Flow of principal streams entering favorable area equaled or exceeded 90 percent of the time	Col. ③ Maximum number of consecutive days that streamflow of principal streams was less than ②	Col. ④ Mean streamflow during period shown in ③	Col. ⑤ Total pumpage from wells shown in ⑦	Col. ⑥ Individual well yield	Col. ⑦ Well placement		Col. ⑧ During 185-day period of recharge ①+②; if ①>⑤, use: 2×(①-⑤)+②	During 180-day period of little or no recharge			Col. ⑫ Mean daily yield for the year, exceeded 7 years out of 10
														During days of deficient streamflow	During days of sufficient streamflow		
Symbol on Pl. 8	Location	Size (sq mi)	Total area (sq mi)	Percent underlain by stratified drift	(mgd)	(mgd)	(days)	(mgd)	(mgd)	(gpm)	Number of wells	Spacing (ft)	(mgd)	Col. ⑨ ④ + ⑤ (mgd)	Col. ⑩ 180- ③ (days)	Col. ⑪ ② + ⑤ (mgd)	185 × ⑧ + (③×⑨)+(⑩ × ⑪) / 365 (mgd)
A	Mill River north of Mill Plain in town of Fairfield	0.47	3.86	31.1	2.3	1.4	32	1.1	2.3	230	7	1,000	3.7	3.4	148	3.7	3.7
B	Norwalk River south of Merritt Parkway in North Norwalk	.42	2.20	37.3	1.3	4.8	35	3.6	1.3	460	2	2,000	6.1	4.9	145	6.1	6.0
C	Rippowam River in city of Stamford	.30	2.79	26.9	1.4	1.4	30	1.1	a/1.3	150	6	750	2.9	2.4	150	2.7	2.8
D	Noroton River near Springdale in town of Stamford and town of Darien	.47	2.61	42.5	1.6	.9	37	.7	a/1.5	175	6	b/1,000	2.6	2.2	143	2.4	2.5
E	Saugatuck and Aspetuck Rivers																
	1. Near Coleytown	1.26	5.97	57.8	4.3	3.1	30	2.4	2.1	290	5	1,000	7.4	6.7	150	7.4	7.3
	2. Near Westport								2.2	510	3	2,000					

a/ Adjusted downward because aquifer storage cannot provide the theoretical value shown in Col. ①.

b/ 2 groups of 3 wells, 2,100 ft apart.

mean water temperature of 11°C (52°F), this infiltration capacity is 60 gpd per sq ft per ft and this value is probably applicable to many sand and gravel streambeds in the basins. In reaches upstream from small dams, streambeds consist largely of silt, clay, and organic muck. The infiltration capacity of this material is considerably lower than that of sand and gravel, perhaps as low as 0.1 gpd per sq ft per ft.

Daily mean streamflow equaled or exceeded 90 percent of the time during an average year (hereinafter referred to as the 90-percent flow duration) is considered a good estimate of the dependable amounts of streamflow available for induced infiltration. It can be determined for most sites in the basins by interpolation of the data shown on plate B. Where the potential rate of infiltration is greater than the 90-percent flow duration and ground-water levels are lowered at least as far as the bottom of the streambed throughout the year, larger amounts of streamflow, not exceeding the infiltration rate, may be induced into the stratified-drift aquifer. Conversely, where the infiltration rate is less than the 90-percent flow duration, the infiltration rate is considered as the estimate of the amount of induced streamflow available.

Streamflow is generally less than the 90-percent flow duration value, or deficient, for many days during the 180-day period of little or no recharge. The mean daily flow during the maximum number of consecutive days that streamflow can be expected to be deficient or less than the infiltration rate, whichever is smaller, can be computed by the method outlined in the section "Surface Water." The estimated induced streamflow available during the entire period of little or no recharge is the infiltration rate or the weighted daily mean of the deficient and sufficient streamflow, whichever is less.

AREAS FAVORABLE FOR DEVELOPMENT

Five areas within the basins underlain by the stratified-drift aquifer are especially favorable for the development of large supplies. These areas and their estimated long-term yields, which range from 2.5 to 7.3 mgd, are shown on plate B. Areas B and E are near full development and area A is under development in 1967.

These areas are favorable for development because: 1) most of the stratified-drift aquifer has a transmissibility greater than 50,000 gpd per ft and is at least 40 ft thick, 2) a large quantity of streamflow enters the area, and the infiltration rate of most of the streambeds is approximately 60 gpd per sq ft, and 3) the impermeable boundaries of the stratified-drift aquifer, which are shown by the line of zero transmissibility on plate B, are at least 2,000 ft apart. The procedure for estimating the daily yields which is summarized on table 13, makes use of data shown on plate B, figures 8, 9, 18, 22, 23, and table 4.

One basis for the favorable area analysis is to determine if the pumpage of water at the ground-water outflow rate, exceeded 7 years out of 10, can be sustained by water stored in the stratified-drift aquifer, particularly during the period of little or no recharge. Ground-water outflow from each area was estimated by determining from plate B the size and the percent of stratified drift underlying the drainage area contributing ground water to the favorable area and then applying these data to the 7-years-out-of-10 curve on figure 22. These outflow values were then adjusted for variations in runoff by use of the isopleths on figure 8, and are shown on column 1 of table 13.

The coefficients of transmissibility and storage and locations of impermeable boundaries of the stratified-drift aquifer within each favorable area were used to determine if pumpage at the ground-water outflow rate could be supported by ground-water storage for 180 days without lowering water levels below the top of screens in hypothetical pumping wells. The hypothetical wells are 90 percent efficient, 24 inches in diameter, and screened in the bottom 30 percent of the aquifer (see figs. 17, 18, 20). The drawdown in each well due to pumping at a selected constant discharge was determined from figure 18. The additional drawdown in each well caused by impermeable boundaries and interference from other pumping wells was computed by: 1) idealizing the boundaries of the stratified-drift aquifer as parallel and straight surfaces, and 2) using the curves on figure 23, which show the drawdown at any point around a pumping well caused by pumping at any constant rate for 180 days without recharge. An example of this computation is shown on figure 24. The number, spacing, and pumping rates of the hypothetical wells used for analysis in each favorable area are shown in column 6 and 7 of table 13 and on figure 25. Figure 25 shows the amount of water which may be pumped and the idealized shape and average transmissibility of the stratified-drift aquifer underlying each favorable area.

In areas C and D an ideal number of wells with optimum spacing and pumping rates (column 6 and 7 of table 13) will not permit withdrawals from storage at the ground-water outflow rate. Accordingly, the amount of stored water available from these two areas shown in column 5 of table 13 has been adjusted downward to that which can actually be pumped using the ideal well configuration. However, during the 185-day period of recharge, aquifer storage is replenished and pumpage in areas C and D during this period can be increased so that the weighted daily pumpage during the year equals ground-water outflow.

The 90-percent duration streamflow entering the favorable areas (column 2 of table 13) was determined from plate B. This is an index of the amount of water available for induced infiltration if ground-water levels are lowered by the hypothetical pumping wells shown on figure 25 to at least the bottom of all streambeds in each favorable area. The maximum number of consecutive days that streamflow entering the favorable areas would be deficient--less than the 90-percent flow duration--ranged from 30 days for areas C and E to 37 days for area D (column 3 of table 13). The mean streamflow durin this deficient period (column 4 of table 13) was calculated by use of table 4 and a method outlined in the section "Surface Water." The infiltration rates of streambeds in each area were computed for

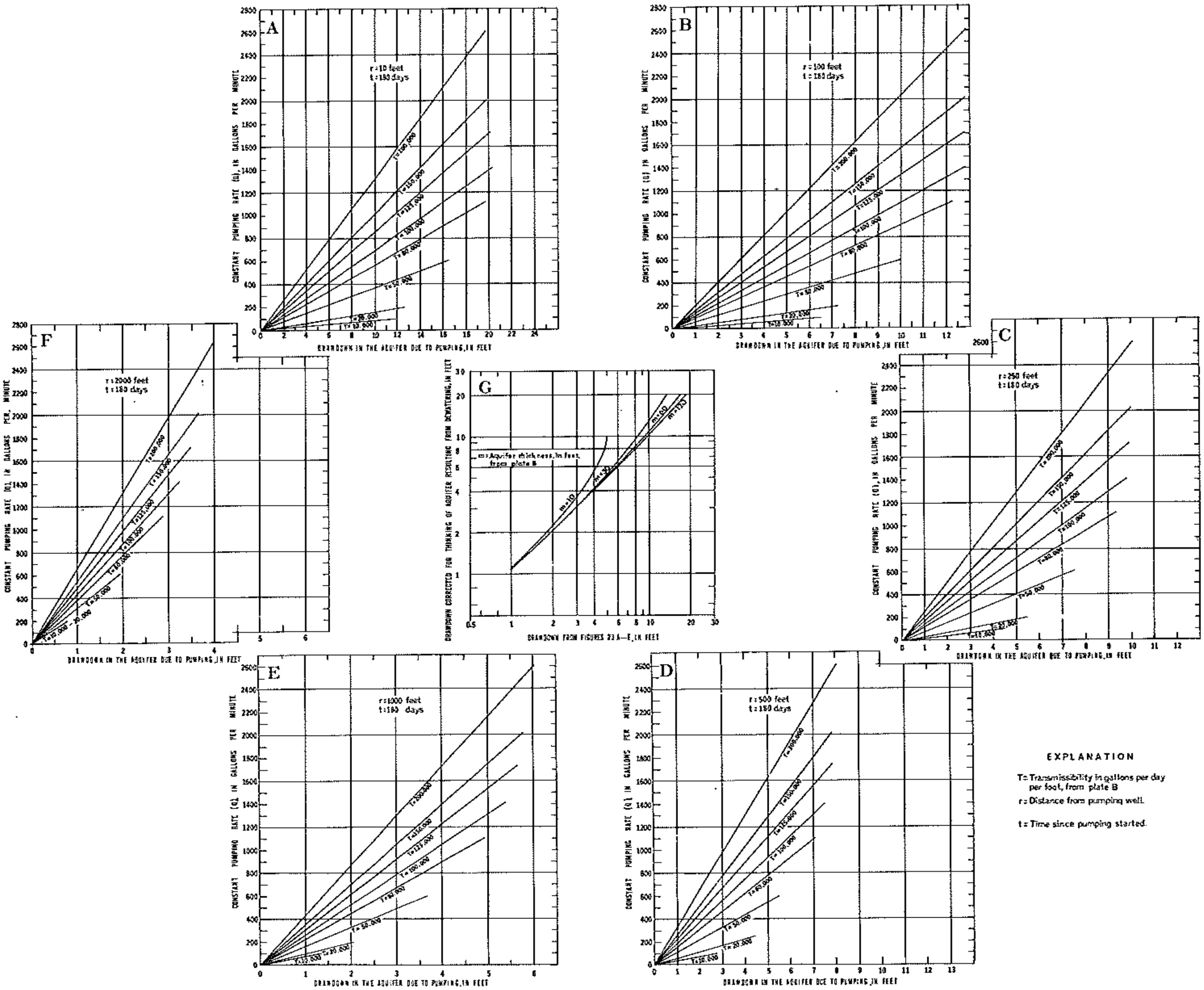
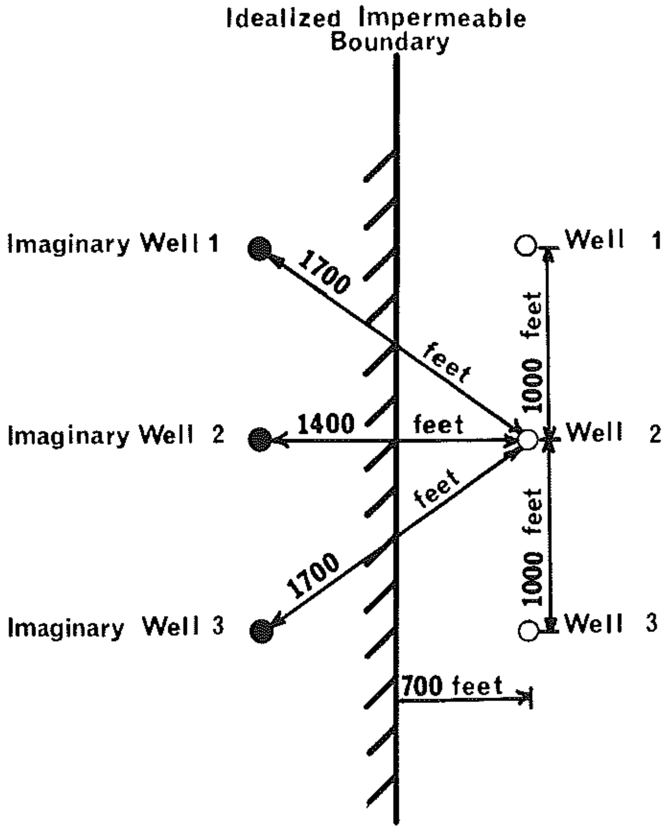


Figure 23.--Curves relating drawdowns in the stratified-drift aquifer at selected radial distances (r) from a well pumped at various constant rates (Q) for the 180-day period of little or no recharge.

These curves, which are based on the Theis non-equilibrium equation (Ferris and others, 1962) with the assumption that the storage coefficient of stratified drift is 0.2, can be used to estimate the distribution of drawdown around a pumping well. They can be used also to estimate the effects of impermeable boundaries and pumping from nearby wells on water levels in and around a pumping well. Boundary effects are estimated by using an r value that is twice the shortest distance from the pumping well to the boundary.

The total drawdown (s) at any radial distance is the drawdown (s_a) from figures 23A-F applied to the curves on figure 23G This adjustment accounts for decreases in aquifer thickness resulting from pumping.



A. Wells 1, 2, and 3 tap a stratified-drift aquifer that is 60 feet thick with an average transmissibility of 50,000 gallons per day per foot. These wells are 24 inches in diameter and have screens 18 feet long set at the bottom of the aquifer. The drawdown at well 2 after 180 days of pumping at a constant rate of 300 gallons per minute is calculated from figure 18 as 33.5 feet.

B. Additional drawdown, s_a, in well 2 caused by pumping of wells 1 and 3 at the same rate for the same time period as well 2, is calculated from figure 23 as 3.66 feet:

s_a from well 1	= 1.83 feet
s_a from well 3	= 1.83 feet
total	= 3.66 feet

C. Additional drawdown, s_a, in well 2 caused by the impermeable boundary, is calculated also from figure 23 as 3.66 feet.

s_a from imaginary well 3	= 1.14 feet
s_a from imaginary well 2	= 1.38 feet
s_a from imaginary well 1	= 1.14 feet
total	= 3.66 feet

D. Total additional drawdown in well 2 is 7.32 feet:

s_a from wells 1 and 3	= 3.66 feet
s_a from impermeable boundary	= 3.66 feet
total	= 7.32 feet

E. Total additional drawdown corrected for thining of the aquifer is 7.83 feet from figure 23 G.

F. Total drawdown in well 2 is 41.33 feet or approximately 42 feet, and is equivalent to a pumping water level that is at the top of the screen.

drawdown due to pumping well 2	= 33.50 feet
additional drawdown	= 7.83 feet
total	= 41.33 feet

Figure 24.--An example of the estimation of total drawdown in a pumping well developed in the stratified-drift aquifer located near two other pumping wells and an impermeable boundary.

a mean stream depth of 1 ft and a mean water temperature of 11°C (52°F) by use of the equation Q = RI. These infiltration rates of the entire streambeds in the favorable areas were at least eight times larger than the rate necessary to permit infiltration of the entering 90-percent duration streamflow. Therefore, the selected parameter of streamflow, not the infiltration rate, is the limiting factor on the amount of water available from induced infiltration.

The total potential daily yield from each favorable area during the period of little or no recharge when streamflow is sufficient is listed in column 11 of table 13 and is the sum of the 90-percent flow duration (column 2) and the pumpage available from storage (column 5). The daily yield during the period of little or no recharge when streamflow is deficient is listed in column 9 of table 13 and is the sum of the mean streamflow (column 4) and the pumpage available from storage (column 5).

The total daily yield during the 185-day period of recharge is listed in column 8 of table 13 and, for areas A, B, and E, is the sum of the 90-percent duration streamflow (column 2) and the ground-water outflow (column 1). The daily pumpage during the period of recharge from areas C and D was adjusted upward from that listed in column 5 of table 13. This was necessary in order to balance the reduced pumpage during the period of little or no recharge.

The annual potential daily yield available from each favorable area, exceeded 7 years out of 10 (column 12 of table 13), is the weighted mean of the daily yields for the periods of recharge and little or no recharge.

These yields are only theoretically available, and are considered to be conservative. Larger values can be computed by selecting a more liberal parameter of streamflow, by using values of mean daily ground-water outflow from figure 22, and by estimating the quantity of ground-water evapotranspiration salvageable when ground-water levels are lowered below the root zone. Also, additional amounts of ground water are available if the cones of depression produced by pumping wells extend beyond the assumed ground-water drainage area

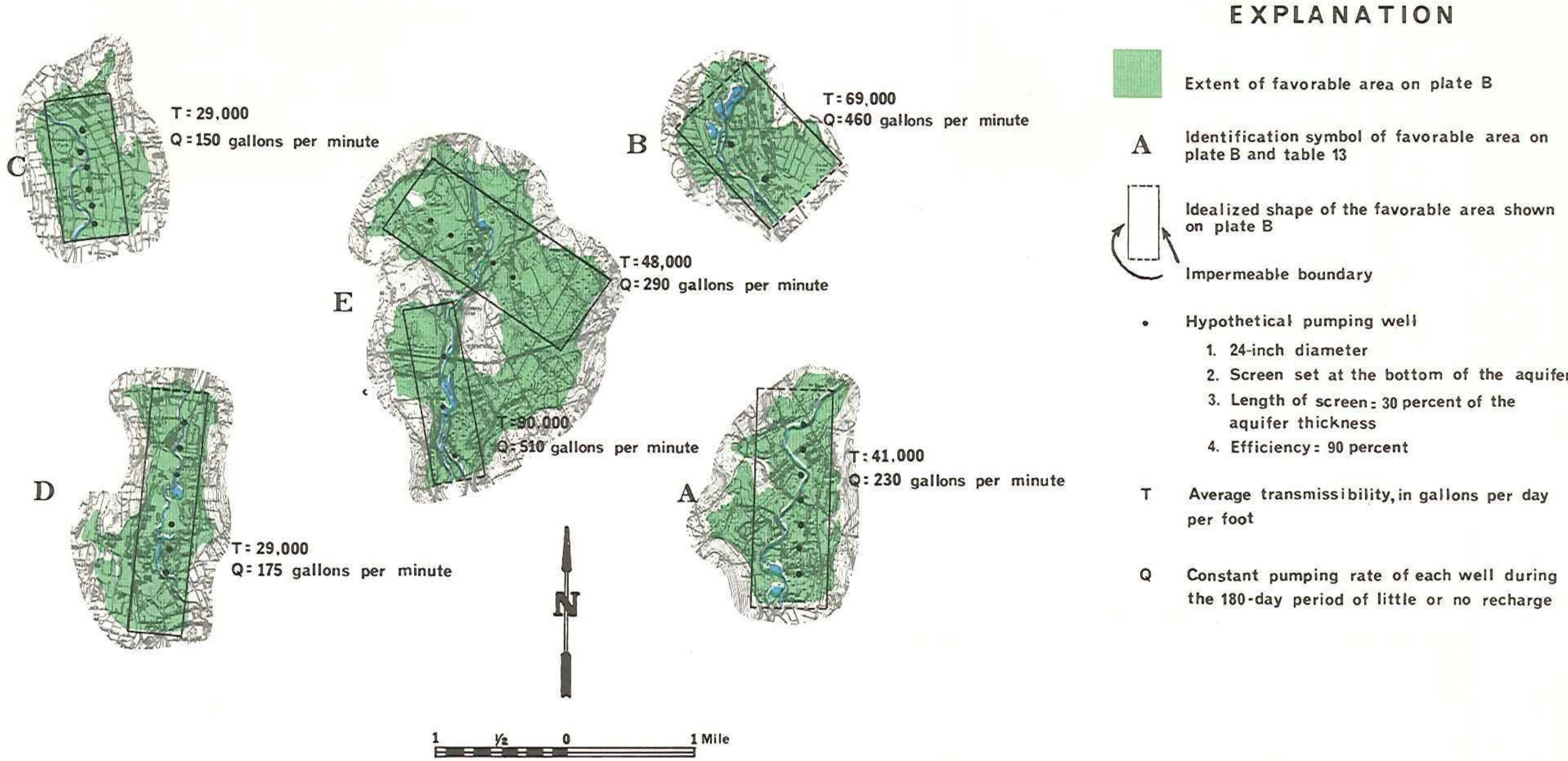


Figure 25.--Areas favorable for large-scale ground-water development.

Idealized shape, average transmissibility, and construction, location, and constant pumping rate of the hypothetical wells used to determine the amount of water available from storage in the stratified-drift aquifer during the 180-day period of little or no recharge.

given on table 13, and the pumped water is returned within the area of development.

The estimated yields listed in column 12 of table 13 are more than adequate for planning the location, type, and degree of development required for optimum management of the ground-water resource even though they are based on techniques of area analysis requiring a number of simplifying assumptions. The amount of water actually obtainable from individual wells can be estimated by the techniques described herein. However, specific site development must be further quantified by test drilling to accurately determine the optimum number, spacing, and construction characteristics of wells, and the geometry and transmissibility of the stratified-drift aquifer. Properly conducted constant-rate pumping tests are necessary for the determination of the coefficients of storage, transmissibility, and vertical permeability of the stratified-drift aquifer within the area of development. Also necessary are data delineating the infiltration capacity of streambeds, the shape of stream channels, and the yearly variability of water temperature and stream depth.

QUALITY OF WATER

The quality of water in the basins differs from place to place and varies from time to time. Some differences depend on whether the water is from precipitation, streams, ponds, swamps, or aquifers. In many parts of the basins, particularly the urbanized southern part, the quality of water not only reflects natural conditions but man-made conditions as well.

Much of the water in the basins is of good to excellent chemical quality as indicated by the chemical analyses of 43 samples of precipitation, 140 samples of water from streams, and 92 samples of water from wells in the basins, which are given in the companion basic-data report. The sampling sites are shown on plate A and the source and significance of the chemical constituents are summarized on table 14 of this report.

QUALITY OF PRECIPITATION

Although water is purified by evaporation, a large amount of mineral matter is brought to the basins by precipitation. From March to December 1965, the mean chloride content of precipitation ranged from 3.7 mg/l at Bridgeport to 1.0 mg/l near Ridgefield (stations 1P and 3P respectively, on fig. 26 and pl. A). Monthly mean concentrations of chloride, sulfate, hardness, and dissolved solids are shown on figure 26, which also shows the mean concentration of these constituents for the period of collection. The mean concentrations shown on figure 26 indicate that each inch of rain on the basins delivers, on the average, a total of 6 lbs (pounds) of dissolved solids to each acre including 2.3 lbs of sulfate.

QUALITY OF SURFACE WATER AND GROUND WATER

Natural Conditions

Samples of surface water and ground water were collected at 100 sites in the basins where the quality of water was considered to reflect natural conditions. The analyses of these samples are summarized on table 15; the chemical quality of this water is good to excellent, as indicated by the low concentrations of dissolved solids. About 70 percent of these solids consist of calcium, magnesium, sodium, bicarbonate, and sulfate.

The dissolved-solids concentration of direct runoff, which is not much higher than that of precipitation, is generally lower than that of ground-water runoff. Therefore, as shown on table 15, the dissolved-solids concentration at high streamflow, which consists chiefly of direct runoff, is lower than that at low streamflow, which consists largely of ground-water runoff. However, the total amount of dissolved solids is greater during high streamflow than during periods of low streamflow.

Ground water differs in chemical quality from place to place, reflecting areal differences in the mineral composition of earth materials in the basins. Analyses of samples from 63 wells, which are diagrammed on figure 27 by a method developed by Stiff (1951), indicate that despite these variations, ground water is generally of the calcium-magnesium bicarbonate type and is soft to moderately hard. Figure 27 also shows that when ground-water runoff predominates in streams, the chemical quality of stream water reflects areal variations in the quality of ground water.

The dissolved-solids concentrations of ground water in most of the basins are low, because stratified drift and bedrock consist chiefly of minerals such as quartz that are only slightly soluble in water. However, a few small areas in the towns of Greenwich, Redding, and Ridgefield, which are shown on figure 27, are underlain by marble, a crystalline rock consisting of soluble calcium and magnesium carbonate and minor amounts of relatively insoluble silica. Water from these areas is higher in dissolved solids, especially calcium, magnesium, and bicarbonate, than elsewhere in the basins. The median dissolved-solids concentration in water from 3 wells tapping marble is 266 mg/l, more than twice the median concentration in water from 55 wells tapping bedrock other than marble. Stratified drift overlying marble or overlying other bedrock types in areas adjacent to marble may be expected to yield water that exceeds the median dissolved-solids concentration on table 15. In these areas, strati-

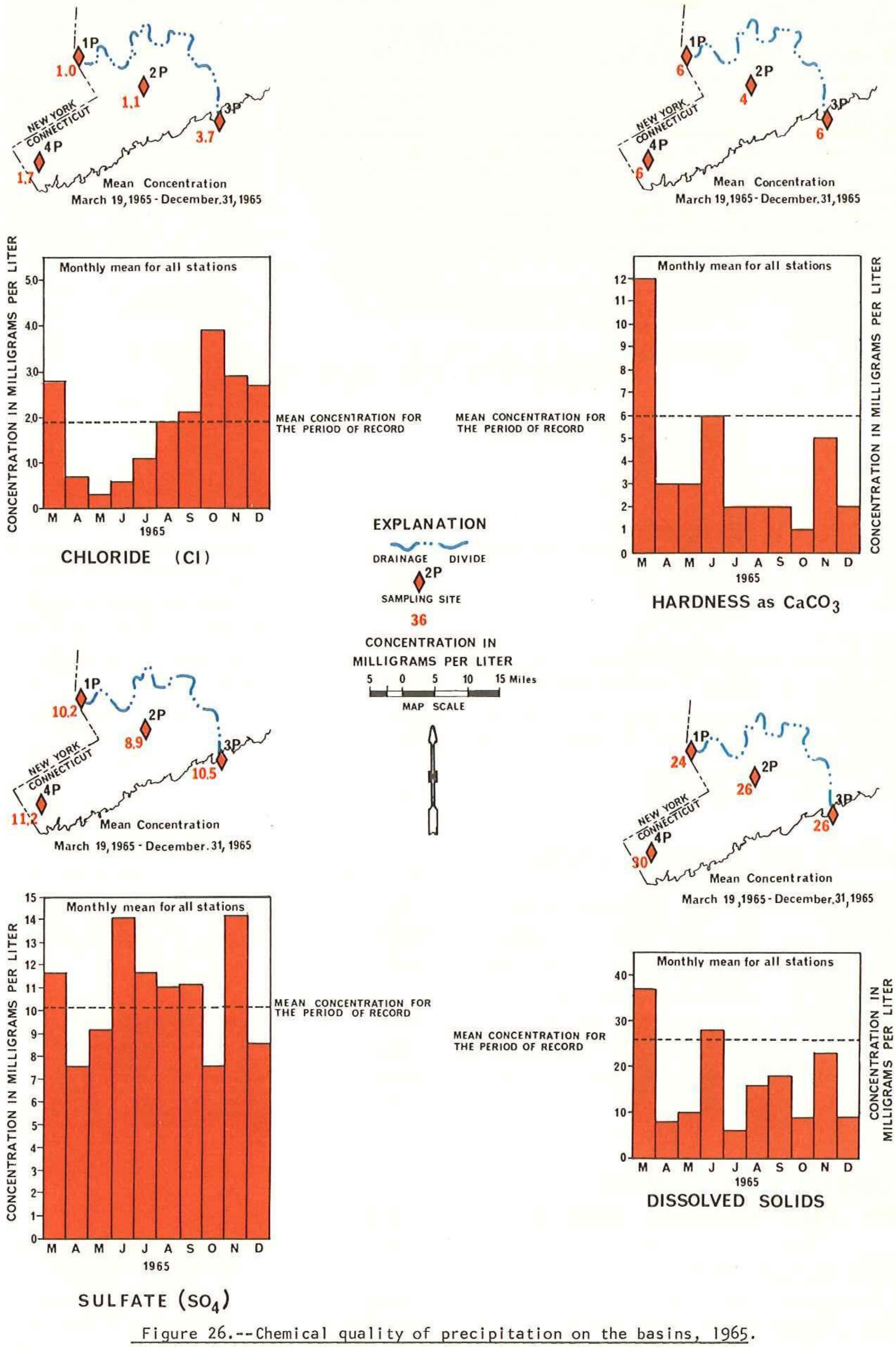


Figure 26.--Chemical quality of precipitation on the basins, 1965.

Table 14.--Source and significance of some of the chemical constituents in and physical properties of water in the southwestern coastal river basins.

Chemical constituent or physical property	Source and concentration	Significance and maximum limit of tolerance
Silica (SiO_2)	Dissolved from practically all rocks and soils. Usually found in the basins in small amounts ranging from 1 to 25 mg/l. Surface water usually has a smaller concentration than does ground water.	Forms hard scale in boilers, water heaters, and pipes. Inhibits deterioration of zeolite-type water softeners. The USPHS (U.S. Public Health Service, 1962) has not recommended a maximum limit for drinking water.
Iron (Fe)	Dissolved from many assorted minerals that contain oxides, sulfides, and carbonates of iron. Decaying vegetation and iron objects in contact with water, sewage, and industrial waste are also major sources. Surface water in the basins in its natural state usually has less than 1.0 mg/l. Ground water generally has higher concentrations than surface water.	On exposure to air, iron in ground water oxidizes to a reddish-brown precipitate. More than about 0.3 mg/l of iron stains laundry and utensils, causes unpleasant odors, and favors growth of iron bacteria. Iron in water is objectionable for food and textile processing. Most iron-bearing waters when treated by aeration and filtration are satisfactory for domestic use. The USPHS recommends a maximum limit of 0.3 mg/l for drinking water.
Manganese (Mn)	Dissolved from many rocks and soils. Often found associated with iron in natural waters but not as common as iron. Surface water in the basins usually has less than 0.1 mg/l. Ground water generally has higher concentrations than surface water.	More than 0.2 mg/l precipitates upon oxidation. Manganese has the same undesirable characteristics as iron but is more difficult to remove. The USPHS recommends a maximum limit of 0.05 mg/l for drinking water.
Calcium (Ca) and magnesium (Mg)	Dissolved from practically all rocks and soils, especially marble, calcium silicate, and clay minerals, and lenses of impure limestone.	Hardness and scale-forming properties of water are caused by dissolved bicarbonates and sulfates of these minerals (see hardness). These are objectionable for electroplating, tanning, dyeing, and textile processing. They also cause scale formation in steam boilers, water heaters and pipes. The USPHS has not recommended a maximum limit for drinking water.
Sodium (Na) and potassium (K)	Dissolved from practically all rocks and soils. Sewage, industrial wastes, road salt, and sea water are also major sources. Most home water softeners replace soluble hardness-producing minerals with sodium.	Since the concentration of potassium is usually low, sodium and potassium are calculated together and reported as sodium. Quantities found in the fresh water of the basins have little effect upon the usefulness of water for most purposes, however, more than 50 mg/l may cause foaming of steam boilers. The USPHS has not recommended a maximum limit for drinking water, however, the Connecticut State Department of Health suggests a maximum limit of 20 mg/l for municipal water supplies.
Carbonate (CO_3) and bicarbonate (HCO_3)	Results from chemical action of carbon dioxide in all natural water on calcium carbonate and calcium silicate minerals. Decaying vegetation, sewage,and industrial wastes are also important sources.	Bicarbonates of calcium and magnesium cause hardness and form a scale in boilers and pipes, and release corrosive carbon dioxide gas (see hardness). Water of low mineral content and low bicarbonate content in proportion to carbon dioxide is acidic and can be corrosive. The USPHS has not recommended a maximum limit for drinking water.
Sulfate (SO_4)	Dissolved from rocks and soils containing sulfur compounds, especially iron sulfide; also from sulfur compounds dissolved in precipitation, and sewage and industrial wastes.	Sulfates of calcium and magnesium form permanent hardness and hard scale in boilers and hot water pipes (see hardness). The USPHS recommends a maximum limit of 250 mg/l for drinking water.
Chloride (Cl)	Small amounts dissolved from soils and metamorphosed sedimentary rocks. Relatively large amounts are derived from animal wastes, sewage, road salt, industrial wastes, and sea water. Chloride concentration of natural fresh water in the basins seldom exceeds 20 mg/l.	Large amounts of chloride in combination with calcium will result in a corrosive solution and in combination with sodium will give a salty taste. The USPHS recommends a maximum limit of 250 mg/l for drinking water.
Fluoride (F)	Dissolved from assorted minerals, such as apatite, fluorite, mica, and scapolite. Ground and surface waters in the basins rarely have more than 0.3 mg/l. Added to water by fluoridation of public water supplies.	About 1.0 mg/l of fluoride is believed to be helpful in reducing the incidence of tooth decay in small children; larger amounts possibly cause mottled enamel on teeth. The USPHS recommends the following maximum limits for drinking water: lower, 0.8 mg/l; optimum, 1.0 mg/l; upper, 1.3 mg/l.
Nitrate (NO_3)	Very small amounts in natural waters from precipitation and decaying organic matter. Sewage, industrial wastes, fertilizers, and decaying vegetation are major sources.	Small amounts of nitrate have no effect on usefulness of water. A concentration greater than 6 mg/l generally indicates pollution. Nitrate encourages growth of algae and other organisms which produce undesirable tastes and odors. The USPHS recommends a maximum limit of 45 mg/l for drinking water which is equivalent to 10 mg/l of nitrate expressed as N in a sanitary analysis. Waters containing more than 45 mg/l have reportedly caused methemoglobinemia which is often fatal to infants and, therefore, such water should not be used in infant feeding.
Dissolved solids and specific conductance	Includes all mineral constituents dissolved in precipitation and from rocks and soils, locally augmented by mineral matter in sewage and industrial wastes. Measured as residue of evaporation at 180°C or calculated as numerical sum of amounts of individual constituents. Specific conductance, or the capacity of water to conduct an electric current, is used as an index of total mineral content. In natural waters in the basins, ground water usually has a larger concentration of dissolved solids than does surface water. Nearly all waters sampled had a dissolved-solids content much below the limit recommended by the USPHS.	Waters containing more than 1,000 mg/l of dissolved solids are unsuitable for many purposes. The USPHS recommends a maximum limit of 500 mg/l for drinking water but will permit up to 1,000 mg/l. A dissolved-solids concentration of 500 mg/l is approximately equivalent to a specific conductance of 850 micromhos at 25°C.
Hardness (as $CaCO_3$)	Hardness is primarily due to presence of calcium and magnesium, and to a lesser extent to iron, manganese, aluminum, barium, and strontium. There are two classes of hardness, carbonate (temporary) hardness and non-carbonate (permanent) hardness. Carbonate hardness refers to the hardness in equivalents with carbonate and bicarbonate; non-carbonate to the remainder of the hardness. In this report hardness, except where noted, refers to calcium-magnesium carbonate hardness. Most waters in the basins are classified as soft, with a hardness of 60 mg/l or less.	Hard water consumes soap before lather will form and deposits soap curds on bathtubs. Water having a hardness of more than 120 mg/l is commonly softened for domestic use. Hardness forms scale in boilers, water heaters, radiators, and pipes causing a decrease in rate of heat transfer and restricted flow of water. In contrast, water having a very low hardness may be corrosive. Carbonate (temporary) hardness can be reduced by water softeners; non-carbonate (permanent) hardness cannot be readily dissolved. The USPHS has not recommended a maximum limit for drinking water. The U.S. Geological Survey classification of hardness appears on p. 38.

Table 14.--Source and significance of some of the chemical constituents in and physical properties of water in the southwestern coastal river basins.--Continued

Chemical constituent or physical property	Source and concentration	Significance and maximum limit of tolerance
pH (Hydrogen ion concentration)	Water with a dominance of acids, acid-generating salts, and free carbon dioxide has a low pH. If carbonates, bicarbonates, hydroxides, phosphates, and silicates are dominant, the pH is high. The pH of most natural waters ranges between 6 and 8.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote alkaline characteristics; values lower than 7.0 indicate acid characteristics. Acid waters and excessively alkaline waters corrode metals. The USPHS has not recommended a maximum limit for drinking water.
Color	Color in water may be of natural, mineral, or vegetable origin such as iron and manganese compounds, algae, weeds, and humus material. May also be caused by inorganic or organic wastes from industry. True color of water is considered to be only that attributable to substances in solution after the suspended material has been removed.	Water from domestic and some industrial uses should be free of perceptible color. Color in water is objectionable in food and beverage processing and many manufacturing processes. Results are usually expressed as units of color and not as mg/l. The USPHS recommends a maximum limit of 15 units for drinking water.
Detergents as MBAS	MBAS is a measure of the concentration of detergents in water. Primary sources of alkyl benzene sulfonate (ABS) and linear alkylate sulfonate (LAS) are synthetic household detergent residues in sewage and waste waters.	High concentrations of ABS cause undesirable taste, foaming, and odors. It often indicates presence of sewage or industrial waste. In mid-year 1965 ABS began to be replaced by LAS. Under similar optimum conditions, LAS is more degradable than ABS. The USPHS recommends for ABS a maximum limit of 0.5 mg/l for drinking water.
Temperature	Temperature fluctuates widely in streams and shallow wells following seasonal climatic changes, but wells at depths of greater than 30 feet remain within 2 or 3 degrees of mean annual air temperature (10°C - 11°C for the basins). Disposal of water used for cooling or industrial processing causes local temperature abnormalities.	Temperature affects the usefulness of water for many purposes. For most uses, especially cooling, water of uniformly low temperatures is desired. A few degrees rise in the temperature of a stream may limit the capacity of a stream to support aquatic life. Warm water will carry less oxygen in solution than water at low temperatures, and a corrosive water will become more corrosive with increased temperatures.
Turbidity	An optical property of water attributed to suspended or colloidal matter which inhibits light penetration. May be caused by microorganisms or algae; suspended mineral substances including iron and manganese compounds, clay or silt, or sawdust, fibers, and other materials. May result from natural processes of erosion or from the addition of domestic sewage or wastes from various industries, such as pulp and paper manufacturing.	Excessive concentrations are harmful or lethal to fish and other aquatic life; also very undesirable in waters used by most industries, especially in process water. Turbidity can modify water temperature. Results are expressed in standard units, not mg/l. The USPHS recommends a maximum limit of 5 units for drinking water.

Table 15.--Chemical quality and physical characteristics of water from representative streams and aquifers in the southwestern coastal river basins.

(Concentration in milligrams per liter)

Constituents or property	Water in streams under natural conditions: During a period of high flow (5 percent flow duration) at 21 sampling sites — Median	Range	During a period of low flow (97 percent flow duration) at 21 sampling sites — Median	Range	Water in aquifers: From 18 to 21 wells tapping stratified drift a/ — Median	Range	From 58 wells tapping bedrock — Median	Range	Upper limit in drinking water b/
Iron (Fe)	0.30	0.07-1.1	0.16	0.05-1.3	0.06	0.01-0.84	0.14	0.01-8.6	0.3
Manganese (Mn)	--	--	--	--	.03	.00- .24	.03	.00- .66	.05
Calcium (Ca)	9.6	6.0-25	12	8.0-60	15	5.5-50	21	7.1-62	--
Magnesium (Mg)	2.6	1.0-8.6	3.4	1.9-16	3.8	1.1-69	4.4	1.2-27	--
Sodium as Sodium (Na) plus Potassium (K)	6.7	2.1-13	6.0	1.6-17	8.8	4.1-14	9.2	3.0-76	--
Bicarbonate (HCO_3)	13	4 - 68	42	17- 230	29	10 -209	62	6 -292	--
Sulfate (SO_4)	22	16 - 35	14	7.6-24	19	12 - 39	20	8.9- 72	250
Chloride (Cl)	10	2.7-24	8.2	5.0-26	12	2.0-37	9.6	2.6-140	250
Nitrate (NO_3)	1.1	.4- 3.3	.7	.1- 4.6	2.2	.0-34	.3	.0- 40	45
Dissolved solids (residue on evaporation at 180°C)	63	38 -158	74	53-268	112	71 -225	124	52 -354	500
Hardness as $CaCO_3$	35	19 - 98	50	28-215	53	21 -188	73	30 -266	--
Specific Conductance (micromhos at 25°C)	108	62 -258	123	90-448	158	104 -396	190	75 -589	--
pH	6.6	5.7-7.0	7.3	6.8-7.7	6.9	6.4-7.7	7.5	5.7- 8.2	--

a/ Excludes wells affected by the encroachment of salty water from Long Island Sound.
b/ Recommended by U.S. Public Health Service (1962).

fied drift contains fragments of marble and may receive water discharged from the marble.

The quality of impounded water in the basins is generally excellent. Analyses of water from 17 impoundments, which are shown on table 16, indicate that 15 contain water with dissolved-solids concentrations of 75 mg/l or less. However, water in 2 reservoirs, Trinity Lake and Laurel Reservoir, which are situated in a valley underlain by marble, has dissolved-solids concentrations of 103 mg/l and 86 mg/l, respectively, presumably reflecting the influence of the underlying marble.

Water from most natural streams in the basins has a dissolved-solids concentration of less than 100 mg/l except in marble areas where it commonly ranges from 100 to 300 mg/l.

Hardness.--Hardness in water is determined largely by the concentration of calcium and magnesium (see table 14) and is expressed as calcium carbonate ($CaCO_3$). In this report, unless otherwise noted, hardness refers to carbonate hardness, commonly referred to as temporary hardness.

"Hard" and "soft" are imprecise terms for water quality; the following ranges are used by the U.S. Geological Survey:

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

a/ Methods of softening water are discussed by Wilke and Hutchinson (1962).

The hardness of naturally occurring water sampled in the basins is summarized on table 15. Stream water throughout the basins is commonly soft except in areas underlain by marble. Ground water is typically harder than surface water; more than 70 percent of 57 well samples were moderately hard to very hard. The hardest water--206 and 266 mg/l--was from two wells tapping marble. Water from stratified drift is commonly softer than water from bedrock although it too may be hard where marble is the underlying

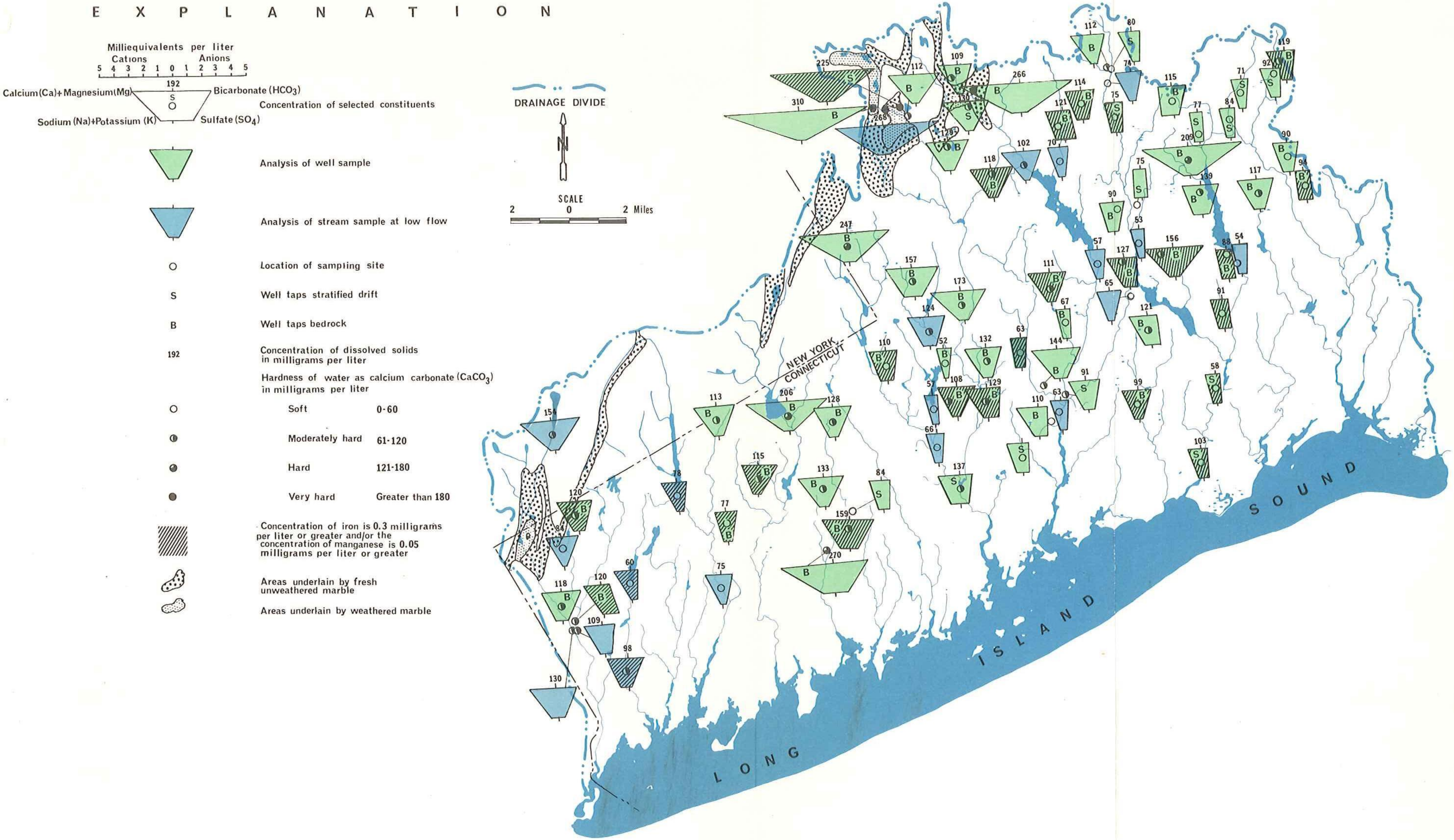


Figure 27.--Quality of ground water and surface water at selected sites in the southwestern coastal river basins.

The quality of stream water during a period of low flow generally reflects the quality of ground water upstream. Moderately hard to very hard ground water can be expected in areas underlain by marble.

Table 16.--Chemical quality and physical characteristics of water from selected public water-supply systems in the southwestern coastal river basins.

(Chemical constituents, in milligrams per liter.
Source: F, finished water; R, raw water. Analyses by the U.S. Geological Survey)

Public water-supply system	Date of collection	Source	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium Magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Detergents as MBAS	Turbidity as mg/l SiO_2	Temperature °C (°F)
U.S. Public Health Service (1962) drinking-water standards recommended upper limits	--	--	--	0.3	0.05	--	--	--	--	--	250	250	1.3a/	45	500	--	--	--	--	15	0.5	5	--
Bridgeport Hydraulic Company	b/ 7-26-51	F Distribution system	3.0	0.21	0.09	8.0	2.2	2.6	0.9	17	12	6.2	0.2	0.3	46	29	15	75	6.8	15	h/ ND	2	ND
	8-11-64	R Aspetuck Reservoir	.9	.28	.04	8.9	2.1	4.4	1.5	24	13	6.5	.2	1.3	55	30	11	98	6.5	12	0.0	1	ND
	6- 1-62	R Easton Reservoir	6.5	.09	.01	7.0	1.1	3.6	1.2	11	13	5.9	.1	.8	51	22	13	73	6.6	9	ND	1	10 (50)
	8-11-64	R Easton Reservoir	5.8	.04	.04	6.6	1.4	4.4	1.3	10	15	6.6	.2	.7	51	22	14	83	6.1	5	.0	1	13 (55)
	c/ 5-15-62	F Easton Reservoir	10	.07	.02	11	.7	3.7	1.3	14	14	9.0	.1	.7	60	31	19	86	6.7	5	ND	2	ND
	d/ 6- 1-62	R Hemlock Reservoir	4.0	.06	.01	6.4	1.6	3.6	1.0	16	13	5.5	.1	.4	47	27	14	78	6.9	6	ND	.2	14 (57)
	6- 1-62	F Hemlock Reservoir	5.0	.07	.01	10	1.4	3.6	1.0	18	13	8.0	.1	.5	57	31	16	88	7.2	4	ND	3	16 (60)
	8-11-64	R Saugatuck Reservoir	3.7	.02	.02	11	2.6	3.3	.9	32	14	5.2	.2	.5	60	38	12	104	7.1	3	.0	2	ND
	6- 1-62	R Trap Falls Reservoir	7.7	.12	.03	7.3	1.6	3.8	1.0	12	14	6.4	.1	1.0	57	25	15	79	6.6	12	ND	2	17 (62)
	8- 4-67	R Trap Falls Reservoir	7.0	.12	.09	13	3.2	6.6	1.6	30	20	12	.1	.5	84	46	21	142	7.0	12	.0	ND	15 (59)
	e/ 5-15-62	F Trap Falls Reservoir	7.7	.19	.02	10	1.5	4.1	1.0	10	16	11	.1	1.2	68	31	23	91	6.7	6	ND	2	ND
	f/ 8- 4-67	F Trap Falls Reservoir	7.5	.13	.17	18	3.4	6.9	1.6	40	20	15	.8	.3	101	59	26	169	7.1	8	.0	ND	ND
	6- 7-66	R Well Ff 18	11	.84	.20	13	4.0	5.6	2.4	22	20	13	ND	3.6	103	49	31	138	6.5	ND	ND	ND	11 (52)
	8-11-64	R Well Mo 20	12	ND	ND	12	1.5	5.3	2.0	22	12	14	.2	1.7	84	36	18	119	7.3	4	.0	ND	10 (50)
	8-11-64	F Well Mo 20	ND	.05	ND	12	ND	5.8	ND	22	ND	15	ND	ND	ND	34	16	132	7.6	2	ND	ND	11 (51)
	8-11-64	R Well Wp 9	10	.10	.02	67	30	g/ 106	ND	27	44	315	.1	9.1	694	290	268	1,190	7.3	3	ND	ND	13 (56)
	8-11-64	R Well Wp 10	9.2	.08	.03	21	4.7	g/ 22	ND	36	18	49	.2	1.8	166	72	42	275	7.4	4	ND	ND	18 (64)
	8-11-64	R Well Wp 11	9.8	.16	.02	18	4.6	g/ 18	ND	38	18	36	.2	2.0	138	64	33	234	7.6	3	ND	ND	19 (66)
	8-11-64	F Wells Wp 9, 10, 11	9.3	ND	ND	25	9.5	32	2.9	56	21	72	.3	3.9	216	102	56	385	7.8	2	.0	ND	18 (64)
	8-11-64	R Well Wp 12	7.2	.22	.05	194	105	483	11	25	124	1,280	.2	1.8	2,430	916	895	4,200	7.0	3	ND	ND	18 (64)
First Taxing District, City of Norwalk, Water Department	8-20-51	F Distribution system	4.0	.21	.04	8.7	2.5	2.8	.6	16	15	6.9	.1	.8	54	32	19	87	6.7	7	ND	2	ND
	11-23-64	R Browns Reservoir	3.2	.49	.10	11	3.4	4.2	.9	28	20	6.8	.2	2.0	67	42	18	118	6.8	3	.0	1	6 (42)
	11-23-64	R Grupes Reservoir	3.2	.17	.03	9.3	2.7	4.0	.7	26	14	7.5	.2	.3	58	34	12	98	7.1	2	.0	.4	6 (43)
	11-23-64	R John D. Milne Lake	3.7	.25	.14	9.1	2.4	3.9	.7	25	14	7.4	.1	.6	57	32	12	97	7.0	3	.0	2	8 (46)
	11-23-64	R Wells Nw 16 and 17	10	.02	.01	21	6.9	11	2.0	50	28	22	.2	4.9	137	81	40	231	6.7	2	.0	0	14 (58)
Greenwich Water Company	11-20-64	R Mianus (Bargh) Reservoir	2.5	.10	.02	14	3.2	4.3	1.7	42	17	7.2	.2	.2	75	48	14	132	7.4	4	.0	2	11 (51)
	11-20-64	R Putnam Lake	1.4	.06	.09	14	3.0	4.4	1.6	37	18	7.2	.2	.5	73	48	17	130	7.0	5	.0	2	9 (48)
	6-24-52	F Putnam Lake	5.2	.11	ND	12	2.0	3.7	1.3	23	21	7.0	.1	.2	76	38	19	110	7.1	2	ND	2	ND
Monroe Consolidated Water Company, Incorporated	5- 9-66	R Well Mo 8	12	.01	.02	14	3.9	5.5	2.0	32	19	11	ND	2.1	92	51	25	142	6.6	1	.0	ND	ND
New Canaan Water Company	8-13-64	R New Canaan (Oenoke) Reservoir	2.0	.06	.02	7.6	1.9	4.4	.7	12	16	6.9	.2	.4	51	27	17	88	6.5	7	.0	1	22 (72)
	8-13-64	R Well NCn 21	11	.04	.01	11	3.5	6.8	1.6	30	19	10	.2	2.2	84	42	18	135	7.0	1	.0	.9	13 (56)
Noroton Water Company	11-20-64	F Well Da 5	14	.44	.01	20	11	13	2.8	36	42	29	.1	12	178	95	66	282	6.2	1	.0	.2	ND
	11-20-64	F Distribution system	4.5	.17	.04	15	2.9	4.6	1.4	37	16	12	.2	1.0	81	50	19	137	7.0	1	.0	.4	17 (62)
Ridgefield Water Supply Company	11-19-64	R Round Pond Reservoir	1.6	.12	.05	5.9	1.4	2.7	1.0	11	13	2.6	.1	1.0	39	20	12	66	6.4	4	.0	1	9 (49)
Second Taxing District, City of Norwalk, Water Department	8- 1951	F Distribution system	4.0	.24	.05	10	2.7	2.8	1.0	27	11	7.1	.1	.6	54	36	14	94	7.6	8	ND	2	ND
	11-24-64	R Rock Lake	3.7	.53	.11	8.7	2.7	4.7	1.0	14	18	12	.2	.6	63	32	21	105	6.9	3	.0	1	5 (41)
	11-24-64	R South Norwalk Reservoir	4.3	.14	.08	8.2	2.5	4.3	1.4	15	17	9.0	.2	1.0	62	30	18	104	6.4	2	.0	1	3 (38)
Stamford Water Company	11-24-64	R Laurel Reservoir	3.3	.49	.20	20	3.0	2.5	1.4	56	17	5.4	.2	.7	86	62	16	146	7.2	6	.0	2	3 (38)
	11-24-64	R North Stamford Reservoir	4.2	.12	.01	14	2.4	4.0	1.3	39	16	7.0	.2	.5	71	45	13	121	7.4	3	.0	1	7 (44)
	11-24-64	F North Stamford Reservoir	3.1	.03	.04	9.2	2.0	3.0	.9	20	12	7.2	.0	.2	56	31	15	88	6.7	2	ND	.8	ND
	11-24-64	R Siscowit Reservoir (Mead Pond)	3.2	.27	.08	9.4	2.3	5.1	1.4	12	24	6.8	.2	1.6	67	33	23	107	6.3	3	.0	1	4 (39)
	11-24-64	R Trinity Lake	3.3	.05	.03	29	2.7	1.5	1.4	87	13	3.3	.1	.8	103	84	12	178	7.7	2	.0	.7	6 (42)

a/ Recommended control limits: lower, 0.8 mg/l; optimum, 1.0 mg/l; upper, 1.3 mg/l.
b/ Aluminum (Al): 0.0 mg/l, Phosphate (PO_4): 0.0 mg/l.
c/ Aluminum (Al): 0.1 mg/l, Phosphate (PO_4): 0.06 mg/l.
d/ Aluminum (Al): 0.1 mg/l, Phosphate (PO_4): 0.01 mg/l.
e/ Aluminum (Al): 0.1 mg/l, Phosphate (PO_4): 0.40 mg/l.
f/ Fluoridated sample.
g/ Calculated as sodium (Na) + potassium (K).
h/ ND: Not determined.

rock. The relation of the hardness of water from streams and aquifers to the distribution of marble in the basins is indicated on figure 27.

Much of the marble contains silica, and where the soluble carbonates have been leached out by weathering processes, a granular semi-consolidated earth material remains. Water from such weathered marble is softer and lower in dissolved solids than water from fresh marble or from overlying stratified drift or till that contains fresh marble fragments. For example, the hardness of water sampled from well R 18, which taps weathered marble, is 94 mg/l. In contrast, the hardness of water sampled from well R 20 is 184 mg/l. Well R 20 is 200 ft from well R 18 and taps the overlying stratified drift that contains fresh marble fragments. Heavy pumping from wells tapping weathered marble, such as R 18, may be expected to produce water of progressively increasing hardness as harder water migrates upward from fresh marble.

Impounded water in the basins is commonly soft. Of 17 impoundments sampled, 15 contain water with less than 60 mg/l of hardness (see table 16). Only 2 impoundments, Trinity Lake in New York and Laurel Reservoir in Connecticut, contain moderately hard water--84 mg/l and 62 mg/l, respectively. As previously indicated, these reservoirs are in a valley underlain by marble.

Iron and manganese.--Iron and manganese are minor dissolved constituents of water, but are troublesome in many parts of the basins. They are derived in part from the solution of iron- and manganese-bearing minerals but some are of organic origin. Iron and manganese in concentrations of 0.3 and 0.05 mg/l or more, respectively, are objectionable for domestic uses (U.S. Public Health Service, 1962). Iron in concentrations as low as 0.2 mg/l in water may produce undesirable effects similar to those listed on table 14 for higher concentrations, particularly if appreciable dissolved manganese is also present. Sixteen of 38 analyses of water from selected public-supply systems shown on table 16 contain excessive iron or manganese.

Color.--Small shallow streams draining swamps are often colored a light to dark amber. Iron contributes some, but not all, of the color to water. Some originates from decaying organic matter, which releases dissolved plant substances such as tannin to water. In the autumn, large accumulations of leaves release colored extracts to water. In addition, diatoms and algae may add color to water. Color measurements in 58 stream samples during high flow range from 2 to 25 color units, the median is 12. Nearly 30 percent of the stream samples exceed the maximum recommended limit of 15 color units (U.S. Public Health Service, 1962).

Temperature.--Temperature is one of the most important characteristics of water; it influences water's chemical, physical, and biological properties. The ability of water to dissolve and precipitate materials, to move rapidly or slowly, and to support aquatic life, depends to a large extent on its temperature. The temperature of surface water and ground water differs from place to place and changes continuously.

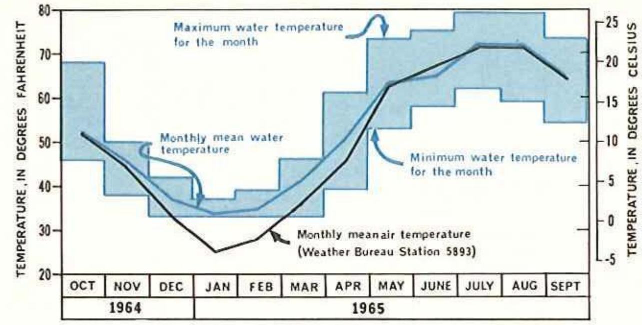


Figure 28.--Monthly variations of temperature of water in the Saugatuck River at gaging station 2095 near Westport compared to that of temperature of the air.

As shown on figure 28, monthly stream temperature fluctuates tens of degrees within a year and follows a seasonal pattern that closely corresponds with monthly air temperature, although variations of stream temperature are less extreme. This pattern is repeated from year to year, although it may be slightly out of phase in some years. The temperature of the Saugatuck River at gaging station 2095 (see pl. A) ranged from 0°C to 26°C (32°F to 79°F) during the period October 1964 - September 1965. The mean water temperature for this period, 11°C (52°F), closely approximates the mean annual air temperature in the basins, which is 11°C (51°F) in the south and 10°C (50°F) in the north (Brumbach, 1965, p. 18). In contrast, the data on table 17 indicate that the temperature of water pumped from wells in the basins fluctuates only about 6°C (10°F) throughout a year.

Table 17.--Temperature of water pumped from wells in the southwestern coastal river basins.

Well no.	Aquifer	Depth interval that well is open to aquifer (ft)	Period of continuous pumping prior to temperature measurement (hrs)	Temperature °C	Temperature (°F)	Date of measurement
R 18	Weathered marble	51-178	3.25	9.4	(49)	12-20-65
Ff 18	Stratified drift	33-44	24	11.1	(51.9)	7- 7-66
Mo 30	do	64-84	5.5	10.6	(51)	4-16-62
Nw 20	do	32-52	24.25	10.3	(50.5)	1-12-65
Nw 21	do	69-84	27.5	11.2	(52)	2- 2-65
Stm 15	do	35-45	705	9.7	(49.5)	5-24-66
Wp 21	do	50-70	25.5	12.0	(53.5)	10-28-64
Wp 29	do	35-60	24	9.7	(49.5)	5-13-65
Wn 24	do	28-48	23.75	10.0	(50)	4-10-65

MAN-MADE CONDITIONS

Man alters the quality of water in all parts of the hydrologic cycle. The extent of his influence in the basins depends largely on agricultural development, population density, urban development, and industrialization. In rural areas, the clearing of forests, the draining of wetlands, and the irrigation of crops increase the load of dissolved and suspended solids in streams. In urban areas, waste water is commonly discharged through sewer systems directly into estuaries or into Long Island Sound, likewise increasing the load of dissolved and suspended solids. Waste water may bypass sewage-

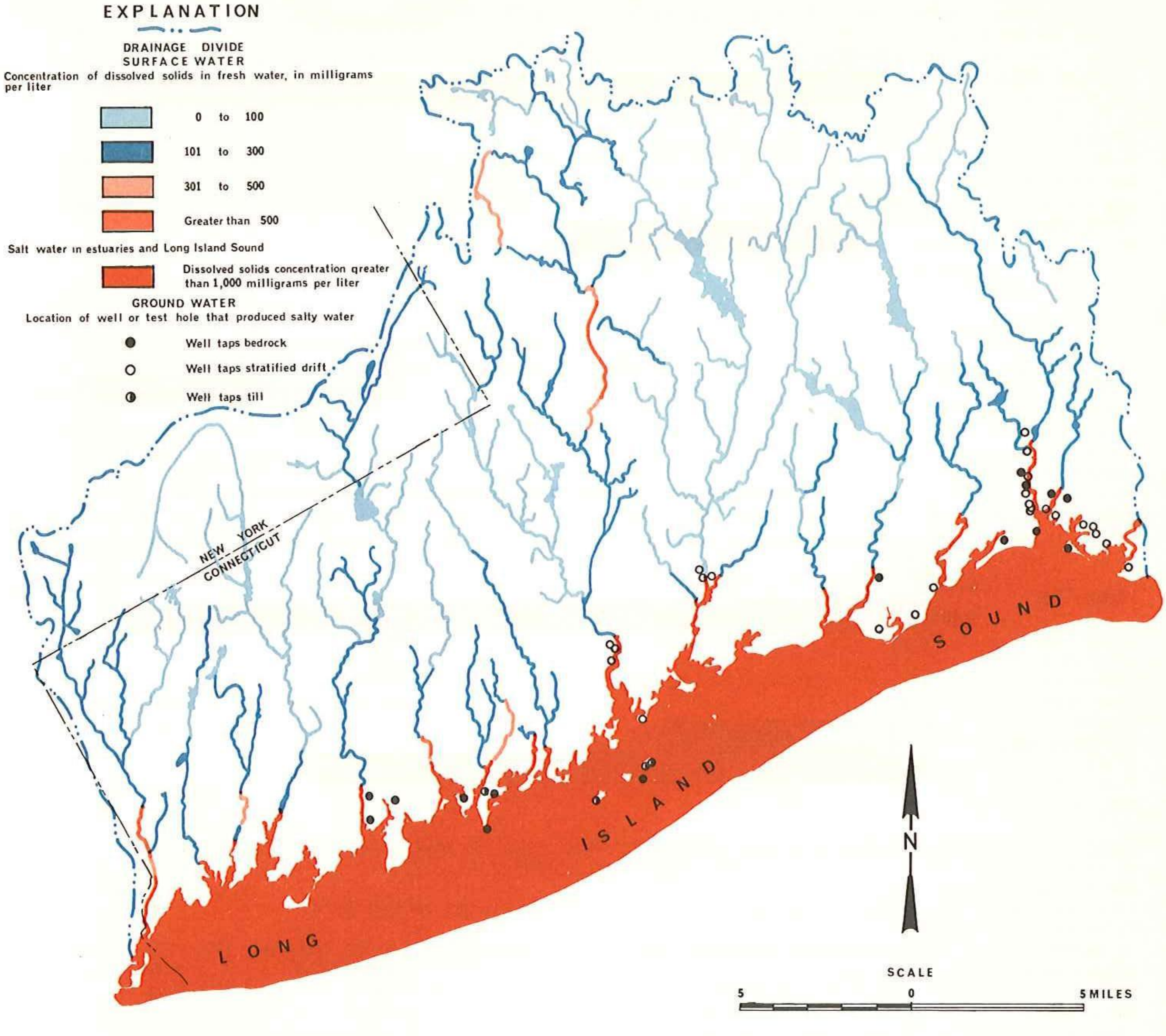


Figure 29.--Dissolved-solids concentration in streams during low flow in 1964 and 1965 and location of wells that have produced salty water since 1900.

Upstream extent of salty water in streams is marked by riffles or by low dams. Salty ground water occurs along estuaries and shore of Long Island Sound.

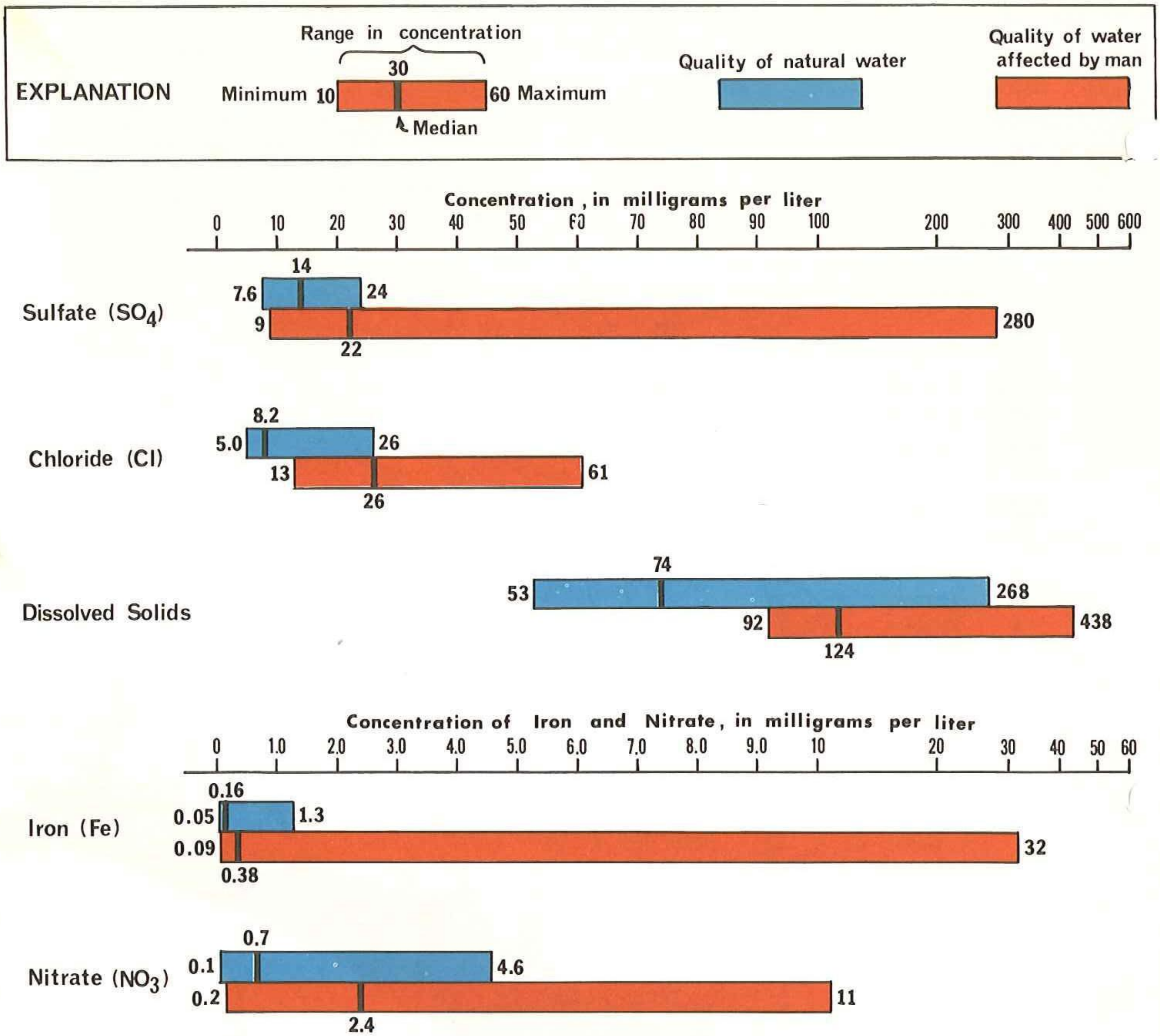


Figure 30.--Contrast in chemical quality of water in natural and man-affected streams during low flow on September 11, 1964.

Samples collected when streamflow was at 99 percent duration.

treatment plants following storms and enter streams untreated. Construction activities also significantly increase the load of suspended solids. Runoff from roads and pavements adds chemical and organic pollutants to the dissolved-solids content of streams. Solutions from salt used on highways in winter and from animal wastes, chemical fertilizers, and pesticides spread on the land are carried into streams or percolate into the ground.

Disposal of industrial and domestic wastes to the ground can contaminate nearby wells and can progressively deteriorate the quality of water throughout an aquifer. The damage may be long lasting, though reparable. Most water withdrawn from streams and wells for industrial use is returned to streams or to the ground with its dissolved-solids content increased and its temperature changed.

Surface water.--The commonest man-made change in the quality of surface water is an increase in dissolved solids. Industries and municipalities discharge a variety of inorganic and organic wastes to streams in the basins. Even small amounts of some dissolved wastes, such as salts of metals and dyes, are objectionable because they may color the water, are toxic to aquatic life, and make surface water unsuitable for use in other ways.

The concentration of dissolved solids in streams throughout the basins is shown on figure 29. The values shown are close to maximums because measurements were made during periods of low streamflow in 1965 and 1966. Specific conductances measured in the field at more than 200 sites were converted to dissolved-solids concentrations by multiplying the measurements by 0.58; a conversion factor derived from laboratory analyses of samples in the basins. The reaches of three streams shown on figure 29 contained water with more than 500 mg/l of dissolved solids; these were: the Norwalk River directly south of Georgetown, the Noroton River below Springdale, and the Byram River at Glenville. In addition, reaches of Goodwives Brook and Greenwich Creek may sometimes contain water with dissolved-solids concentrations of more than 500 mg/l. In the heavily-populated reaches of many streams, the dissolved-solids concentration of water ranges from 300 to 500 mg/l, whereas upstream from these reaches, it is commonly less than 300 mg/l.

The striking changes in quality of surface water in the basins resulting from man's activities are shown graphically on figure 30. This graph contrasts the quality of 21 samples of natural stretches of streams with that of 12 samples of man-affected stretches during a period of low streamflow on September 11, 1964. Only 19 percent of the natural stream water samples contain more than 0.3 mg/l of iron, whereas 75 percent of the man-affected stream samples contain more than 0.3 mg/l of iron. Samples from the natural streams contain chloride with a median value of 8.2 mg/l, whereas every sample from affected streams exceeds this value. The maximum concentration of sulfate in the samples from natural streams is 24 mg/l, in contrast, the maximum concentration in the samples from affected streams is 280 mg/l, more than 10 times as high and substantially above the limits recommended for most industrial uses (McKee and Wolf, 1963, p. 276).

The quality of the Norwalk River in a 0.7 mi reach near Georgetown provides a specific example of man's effect. Within this short reach, the river receives industrial effluent that includes copper, iron, and zinc. Three sites, one upstream and two downstream from the effluent discharge, were sampled on July 17, 1964 when streamflow was equivalent to a daily mean flow equaled or exceeded 72 percent of the time. The marked chemical changes that the effluent imposes on the natural quality of the river are clearly shown on figure 31 by the Stiff (1951) diagrams. The sample collected upstream from the effluent discharge, at site 2095.68, has a dissolved-solids concentration of 135 mg/l; directly downstream from the effluent discharge, at site 2095.69, the concentration is 700 mg/l and 0.7 mile downstream, at site 2096.7 it is 317 mg/l (see fig. 31). Hydrochloric and sulfuric acids are also major constituents of the effluent; at the same three stations, the pH measurements are 7.6, 3.5, and 6.1, respectively. During periods of lower flow at these sites, water in the stream would have a higher dissolved-solids concentration if the quantity and quality of the effluent discharge were to remain constant. Water in the Norwalk River at the site farthest downstream (2095.7 on fig. 31) was sampled on September 11, 1964, when streamflow was at 96 percent duration flow. As shown on figure 31, this sample has a dissolved-solids concentration of 438 mg/l and an extremely low pH of 2.8.

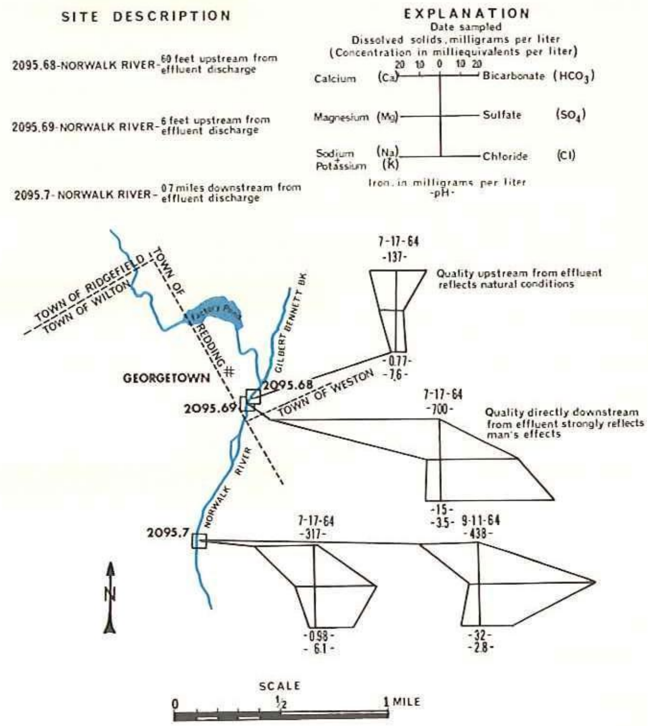


Figure 31.--Industrial pollution of water in the Norwalk River south of Georgetown during low flow in 1964.

Ground Water.--Under natural conditions, ground water in the basins contains only small amounts of chloride and nitrate, and is completely free of detergents. Unusual quantities of any of these constituents reflect the activities of man. A chloride concentration of 20 mg/l or more in water from aquifers unaffected by salt-water encroachment probably indicates a man-made condition. Chloride may be added to ground water by dissolution of road salt, by discharge of domestic sewage through cesspools and septic tanks, and by the backflushing of water softeners.

Ground water has been contaminated by dissolution of road salts in several parts of the basins. Sodium chloride (common salt) usually mixed with calcium chloride and sand is spread on roads to melt snow and ice during the winter. Melt water and rain flush the salt into the roadside soil from where it may move down to the water table. Samples of water from two bedrock wells (Wes 21 and Wn 50) situated within 50 ft of heavily salted roads have chloride concentrations of 104 and 140 mg/l, respectively; more than 10 times greater than the median for all bedrock wells sampled (see table 15). Several other bedrock wells situated about 700 ft from an open-air stockpile of sand mixed with salt adjacent to the Merritt Parkway in the town of New Canaan produced corrosive salty water in 1965. Presumably, precipitation on the stockpile dissolved the salts and carried them down to the water table and along the local hydraulic gradient to the wells.

Unusually high concentrations of nitrate in ground water in the basins, as elsewhere, indicate contamination by human and animal wastes or by nitrate fertilizers. A nitrate concentration of 45 mg/l is the upper limit recommended for drinking water (see table 14) primarily because higher concentrations may cause methemoglobinemia (infant cyanosis or "blue-baby" disease) when ingested by infants. As shown on table 15, the nitrate concentration in water samples from 6 wells is at least 10 mg/l; in 2 of these it is 34 and 40 mg/l. Samples from these 6 wells also have concentrations of chloride higher than the median for the area. High concentrations of both constituents suggest contamination by septic-tank or similar effluents.

The presence of detergents ABS (alkyl benzene sulfonate) and LAS (linear alkylate sulfonate) in ground water results from the introduction of sewage. Even large amounts of detergents are not toxic but esthetic considerations have resulted in the setting of a recommended upper limit of 0.5 mg/l for ABS (see table 14). Samples from 11 wells have measurable detergents, determined as MBAS (methyline blue active substance), indicating that ground water in the vicinity of these wells presumably contained some septic-tank or similar effluent.

The likelihood of ground-water contamination from bacteria in septic-tank effluent can be evaluated by use of a system devised by LeGrand (1964). This method, modified for use in the basins, indicates that contamination of a bedrock well is possible but unlikely if at least 40 ft of till overlie bedrock at the well site. Areas where till is known to be at least 40 ft thick are shown on plate B.

SALT WATER IN STREAMS AND AQUIFERS

Natural water throughout the basins contains less than 20 mg/l of chloride except in the south along the coast. Here, the estuaries, coves, inlets, marshes, and wetlands are exposed to a tidal surge of salt water from Long Island Sound. In estuaries, the zone between fresh water and salt water moves upstream during high tides and downstream during low tides. Changes in the position of the zone between fresh water and salt water may also be seasonal or climatic. In the late summer and fall, low streamflow facilitates the upstream migration of salty water. In the spring and after heavy rains, high streamflow forces salty water downstream. Regardless of season, upstream migration of salty water may be slowed or halted by natural rapids and riffles, or by dams. The maximum extent of salty water in streams in the basins is shown on figure 29.

Sea water generally contains about 35,000 mg/l of dissolved solids, of which about 19,000 mg/l is chloride (Hem, 1959, p. 10). Measurements of specific conductance during low streamflow in 1965 and 1966 indicate that the dissolved-solids concentration of water in estuaries in the basins ranges from 5,000 to 26,000 mg/l compared to the concentration in reaches upstream from estuaries, which ranges from 53 to 268 mg/l. The chloride concentration of water from estuaries ranges from 2,600 to 13,500 mg/l whereas in water from reaches upstream from estuaries, it ranges from 5 to 26 mg/l.

Salty surface water may affect the quality of water in nearby aquifers. Ground water near the coast may be naturally salty, but more commonly it becomes salty as continued pumping causes salt water to encroach upon the naturally occurring fresh water. Salt-water encroachment of aquifers is discussed in detail by Cooper and others (1964). The locations of all wells known to have been affected by salt-water encroachment since 1900 are shown on figure 29. The map shows that almost all of these wells are near bodies of salty water.

From the 1920's to the early 1940's many industries in the town of Bridgeport pumped large quantities of water from wells tapping stratified drift or bedrock near the Poquonock River estuary. Ground-water levels were lowered below sea level and salty water from the estuary intruded the aquifers. Pumpage of hard, corrosive salty water led to the abandonment of most of the wells and also discouraged further development of ground water along estuaries and the coast of Long Island Sound. The affected area was sizable but its present-day extent is not precisely known because many of the wells that produced salty water are destroyed or inaccessible for measurement.

More recently, salty water has intruded stratified drift along the Saugatuck River in the vicinity of 4 closely spaced wells of the Bridgeport Hydraulic Company. The wells, which are shown on figure 29, are directly upstream from a dam that marks the upstream extent of salty water in the estuarine part of the river. Large withdrawals, totaling about 565 million gallons in 1965, lowered ground-water levels around the wells to below sea level and salty water moved upstream and into the wells. The relation between chloride concentration of water samples and distance of each well from the estuary is shown on table 18. These data indicate that salty water can intrude aquifers even upstream from dams. Accordingly, proximity to salty surface water has been used to delimit the downstream extent of three of the five areas considered favorable for large-scale ground-water development shown on plate B and table 13.

Table 18.--The concentrations of chloride in water pumped from wells in the Westport well field, which tap stratified drift, are affected by salt-water encroachment.

Well no.	Approximate distance from salty water in the Saugatuck River estuary a/ (ft)	Concentration of chloride on 8-11-64 (mg/l)
Wp 11	650	36
Wp 10	450	49
Wp 9	150	315
Wp 12 b/	100	1,280

a/ See plate A for exact locations.
b/ Most heavily pumped well.

Three other wells (Nw 33, 34, and 35) known to have been contaminated by salty water are situated on two of the Norwalk Islands, a group of about 10 small islands located 3/4 mi to 1 mi offshore in Long Island Sound (see fig. 29). Although the wells penetrate only 2 to 3 ft of saturated till, the chloride concentration in water from the wells ranged from 350 to 1,700 mg/l in 1966. Withdrawals of water, though small and intermittent, were enough to cause salt-water encroachment. However, it is possible that flooding by water from Long Island Sound during severe storms may have contributed salty water to the wells. It is evident that even small withdrawals of water on the islands and coastal peninsulas may result in encroachment, as most are rocky or veneered with only thin till. Elsewhere in coastal and estuarine areas, even small to moderate pumpage may cause salty water to intrude any aquifer.

DEVELOPMENT OF WATER

SOURCE, USE, AND DISPOSAL OF WATER

The total amount of water used in the basins during calendar year 1965 was about 36.7 billion gallons (about 165 gpd per capita), 87 percent of which was supplied by water utilities almost wholly from surface-water sources. The source, use, and disposal of water in the basins in 1965 are summarized on figure 32; and the locations, amounts, and type of all major withdrawals of water are shown on plate C.

Nine public water-supply systems met the domestic needs of 88 percent of the population of the basins and 80 percent of the water needs of industry in 1965. The source of water, capacity and type of treatment, population served, and other important features of these systems are given on table 19. The areas served by the nine systems, seven of which are contiguous, and the movement of water from sources to the systems are shown on plate C.

Each water-supply system utilizes several reservoirs, which may be in the same drainage basin. Generally, the impounded water is diverted either to the lower part of the basin or to another drainage basin. After diversion and use, much of the water is discharged to estuaries and Long Island Sound rather than to a site near the point of diversion. Water is also imported into and exported from the report area. The Bridgeport Hydraulic Company imported 5,519 million gallons from the Housatonic River basin in 1965, and the water-supply systems serving the towns of Greenwich, Stamford, and Norwalk have some of their reservoir watersheds in New York State. The Ridgefield Water Supply Company supplies an area both in and outside the southwestern coastal river basins. The Greenwich Water Company exported approximately 2,148 million gallons to Port Chester, New York in 1965, and an unknown quantity of water was exported by the Bridgeport Hydraulic Company to a part of the town of Stratford that lies outside the basins.

In general, residents served by the nine water-supply systems listed on table 19 received water of good chemical quality. The analyses of water from these systems are given on table 16 and show that the delivered water was soft to moderately hard--29 to 106 mg/l--and had a low dissolved-solids concentration, ranging from 46 to 216 mg/l. The concentrations of the constituents shown on table 16 are considerably below the maximums suggested by the U.S. Public Health Service (1962), with the exception of a few iron or manganese concentrations.

The areas served by sewer systems in the basins and the points at which used water is returned to streams, estuaries, and to the ground are shown on plate C. Although no sewer system discharges untreated sewage, reports by several State agencies indicate that sewage-treatment facilities are at times overtaxed so that treatment of effluent is incomplete. Pollution abatement planned by the Connecticut Water Resources Commission under Public Act 57 of 1967 is designed to eliminate these adverse conditions.

USE OF WATER IN THE FUTURE

The Connecticut Development Commission (1962 and 1963) reported that the population and water consumption in the basins will continue to increase rapidly in the coming years. Projected trends indicate that population in the basins will increase from approximately 610,000 in 1965 to between 1,113,000 and 1,368,000 in the year 2000. Water use will increase from 36,700 million gallons (about 165 gpd per capita) in 1965 to between 78,000 and 99,900 million gallons (about 200 gpd per capita) in the year 2000.

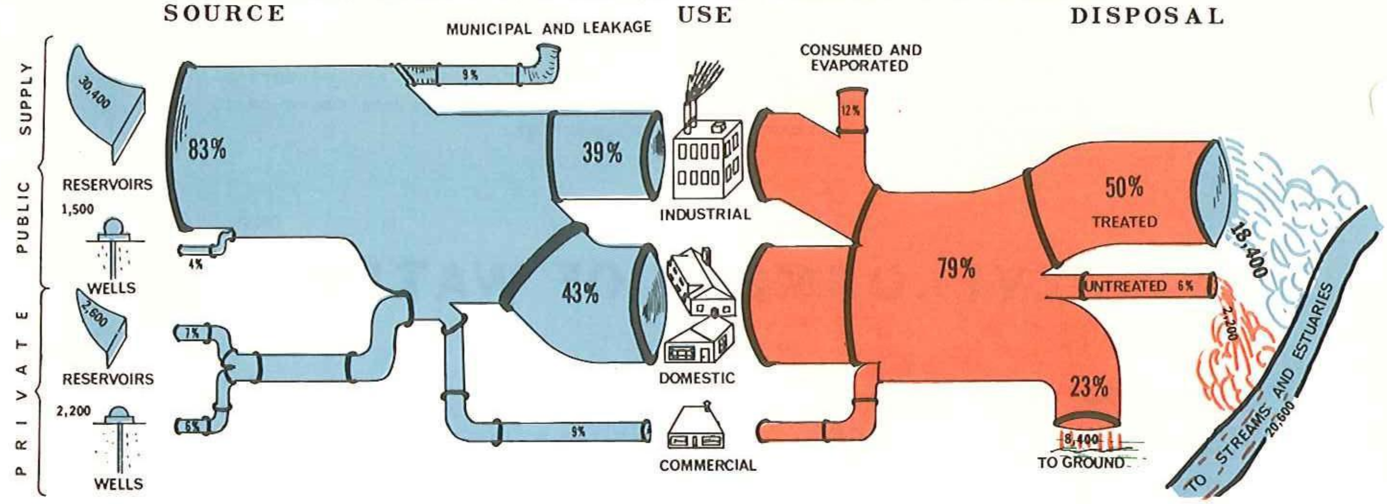
CONSEQUENCES OF DEVELOPMENT

SURFACE WATER

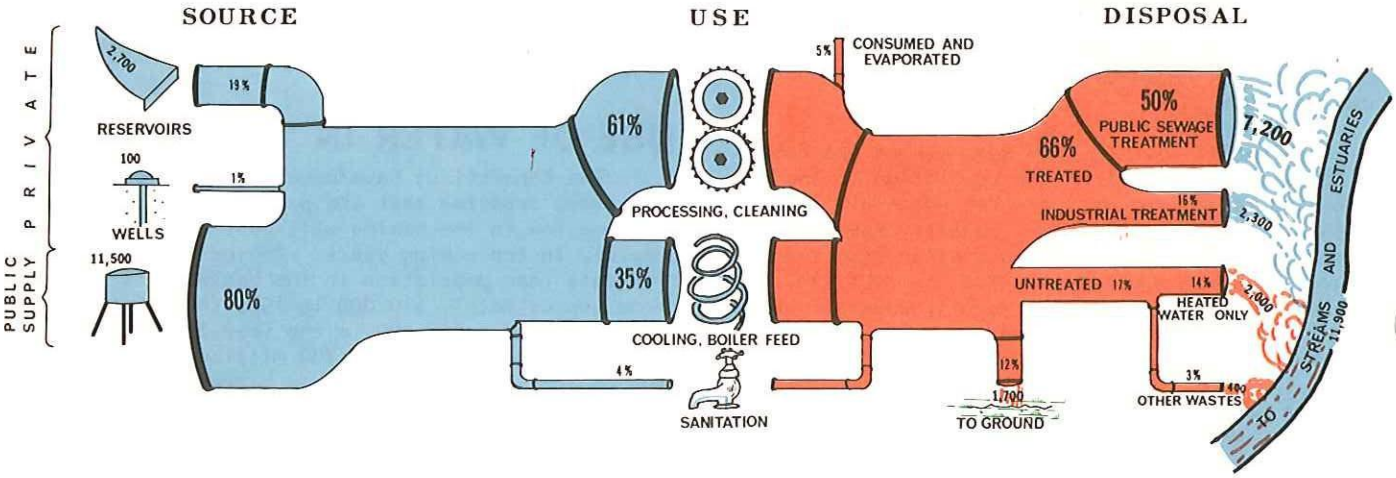
The time-distribution of flows of most of the larger streams in the basins have been drastically altered by storage reservoirs that divert large amounts of water. Some stream channels below these reservoirs are practically dry during most of the year. A few streams in the basins have been developed by a series of reservoirs, leaving very little catchment area available for future development. The major storage reservoirs and large diversions are shown on plate C and are discussed below.

Most of the flow from 3.8 sq mi of the upper part of the Poquonock River basin is diverted into Easton Reservoir, which has a drainage area of 13.2 sq mi in the Mill River basin. Water from 33.5 sq mi of the Saugatuck River basin is diverted from Saugatuck Reservoir through a 0.8 mi long tunnel to the Aspetuck Reservoir, which has a drainage area of 17.0 sq mi in the Aspetuck River basin. The water is then diverted into Hemlock Reservoir in the Mill River basin. Most of the water diverted into the Mill River basin supplies the towns of Bridgeport, Easton, Fairfield, Monroe, Stratford, Trumbull, Weston, and Westport and is then discharged after treatment into estuaries and Long Island Sound.

TOTAL WATER USE 36,697 MILLION GALLONS



INDUSTRIAL WATER USE 14,300 MILLION GALLONS



DOMESTIC AND INSTITUTIONAL WATER USE 19,100 MILLION GALLONS

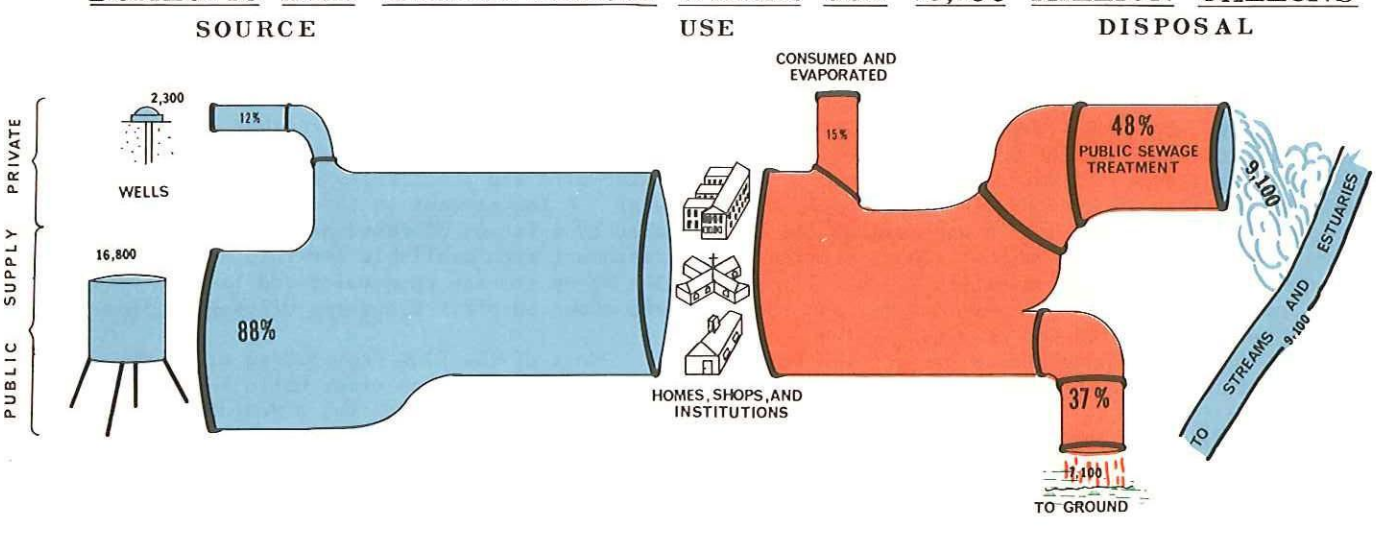


Figure 32.--Source, use, and disposal of water in the southwestern coastal river basins, 1965, in million gallons.

Table 19.--Description of selected public water-supply systems serving the southwestern coastal river basins.
(Based on estimates and records for 1965 from water-utility officials)

Public water-supply system	Town(s) supplied	Total population served	Primary source of water: Name	Primary source of water: Percent of supply	Treatment: Type(s) used in system	Treatment: Name or location of plant	Treatment: Capacity (mgd)	Raw water storage (million gallons)	Finished water storage (million gallons)	Total supplied in 1965 (million gallons)	Use of water (percent): Industrial	Use of water (percent): Commercial	Use of water (percent): Domestic	Use of water (percent): Municipal and leakage	Remarks
Bridgeport Hydraulic Company	Bridgeport Easton Fairfield Monroe Stratford Trumbull Weston Westport	a/ 320,000	Easton Reservoir Hemlock Reservoir Trap Falls Reservoir Westport well field Coleytown well field Blue Ridge and Stepney wells	17.8 49.1 28.9 2.6 .8 .8	Chlorination and corrosion control	Easton Hemlock Trap Falls Westport	32 100 50 9	24,600	4.7	21,950	42.0	11.0	35.8	11.2	Hemlock Reservoir is supplied by Saugatuck Reservoir and Aspetuck Reservoir. Trap Falls Reservoir is located in the Housatonic River basin.
First Taxing District, City of Norwalk, Water Department	Norwalk New Canaan	36,000	Browns Reservoir Grupes Reservoir Milne Reservoir Scotts Reservoir Wells	60.0 (Browns, Grupes, Milne, Scotts Reservoirs) 40.0	Chlorination and filtration; corrosion, taste, and odor control	Reservoir system, Valley Rd., New Canaan At wells	5.5 4.0	1,003	5.7	1,990	33.2	b/ 52.8		14.0	
Greenwich Water Company	Greenwich c/	49,700	Grays Pond (Brush Lake) Mianus (Bargh Reservoir) Putnam Lake Rockwood Lake	.4 69.3 16.2 14.1	Chlorination and filtration; corrosion, taste, and odor control	Mianus Putnam	4 12	3,536	2.1	4,610	4.8	55.6	25.4	14.2	
Monroe Consolidated Water Company, Inc.	Monroe	a/ 1,492	Wells	100	None	None	None	None	None	23	None	5.0	94.0	1.0	Two wells located in the Housatonic River basin.
New Canaan Water Company	New Canaan	7,250	New Canaan (Oeonke) Reservoir Wells	44.5 55.5	Chlorination and use of strainers; corrosion control	New Canaan Reservoir Weed Street Well	.9 .29	116	.45	d/ 277	None	14.0	60.0	26.0	
Noroton Water Company	Darien	18,750	Rewok Well Stamford Water Co.	.5 99.5	Chlorination and use of strainers; corrosion control	None	None	None	.6	569	None	15.9	64.0	20.1	
Ridgefield Water Supply Company	Ridgefield	a/ 6,000	Round Pond Oscaleta Well	80.0 20.0	Chlorination and corrosion control	Round Pond Oscaleta Well	.3 .06	320	.68	133	2.0	2.0	76.2	19.8	Sources located outside of the basins.
Second Taxing District, City of Norwalk, Water Department	Norwalk	25,000	Streets (Pope) Pond Rock Lake South Norwalk Reservoir	100	Chlorination and filtration; corrosion control	At South Norwalk Reservoir	4	1,000	4.0	e/ 1,514	20.0	15.0	53.0	12.0	
Stamford Water Company	Darien Stamford	78,000	Laurel Reservoir Siscowit Reservoir (Mead Pond) North Stamford Reservoir Trinity Lake	68.2 2.7 15.5 13.6	Chlorination and use of strainers; corrosion control	North Stamford	25	3,303	4.0	f/ 4,435	26.6	g/ 25.8	44.7	2.9	

a/ Part of service area located outside of the basins.

b/ Commercial and domestic.

c/ Port Chester Water Works, Inc. in New York uses 47.5 percent.

d/ First Taxing District, City of Norwalk, Water Dept. supplied 5 million gallons.

e/ Bridgeport Hydraulic Company supplied 187 million gallons and the First Taxing District supplied 137 million gallons.

f/ Noroton Water Company purchased 545 million gallons, and Greenwich Water Company purchased 90 million gallons.

g/ Includes water sold to Noroton Water Company.

This means that most of the water from 3.8 sq mi out of the 15.2 sq mi Poquonock River basin, 50.5 sq mi out of the 92.1 sq mi Saugatuck River basin (the Aspetuck River is a major tributary of the Saugatuck River), and 18.5 sq mi out of the 34.6 sq mi Mill River basin is exported. It is not returned and thus is not available for reuse within the basin of origin.

Water is also diverted from 12.4 sq mi out of the 22.9 sq mi Silvermine River basin to supply the town of Norwalk, from 22.0 sq mi of the 39.8 sq mi Rippowam River basin to supply the town of Stamford, and from 18.0 sq mi out of the 34.0 sq mi Mianus River basin, 3.08 sq mi out of the 5.95 sq mi Horseneck Brook basin, and 7.64 sq mi out of the 31.7 sq mi Byram River basin, to supply the town of Greenwich.

Streamflow in the basins is also depleted, particularly at low flows, when water is pumped from streams for irrigation of lawns and golf courses. Many old industrial dams in the area seldom regulate streamflow, but delay and lower flood peaks, as do diversion reservoirs that spill only at times of high streamflow. Artificial storage of water in reservoirs not only increases evaporation but also increases ground-water storage by raising the local water table.

GROUND WATER

Pumping from wells developed in the stratified-drift aquifer during the period of little or no recharge increases drawdowns and expands cones of depression in the aquifer beneath and, in many places, beyond nearby streams. Pumping continued into the period of recharge results in smaller drawdowns, and cones of depression will contract in response to recharge and increases in stream infiltration.

The estimated quantities of ground water available from areas favorable for long-term development include the 90-percent duration streamflow. If the amount of water being pumped is equal to the mean daily yield exceeded 7 years out of 10 (see table 13), streamflow out of the areas will cease at least 10 percent of the time during an average year. Streamflow leaving the areas during the remainder of the year will be reduced by the amount of ground-water runoff diverted to pumping centers, which would discharge to streams under natural conditions, plus the amount of surface water induced into the aquifer by pumping. Under these conditions, downstream water developments, such as water-supply reservoirs or wells that depend on induced infiltration, may be forced to change their pattern of operation. The situation can be significantly improved by returning the used water, properly treated, to the streams directly downstream from the developed areas. However, if the pumped water is transported to and disposed of in another drainage basin, or in estuaries or in Long Island Sound, then reuse of the water in the basin of origin is precluded.

Effect of induced infiltration on quality of ground water.--Water available for development from a stratified-drift aquifer depends partly upon inducing water in nearby streams to infiltrate into the aquifer. During infiltration, stream water mixes with and thereby modifies the chemical quality and temperature of the water naturally occurring in the aquifer. Because the quality of the stream water fluctuates throughout the year, the quality of the pumped water will also fluctuate. The magnitude of these fluctuations is dependent upon the aquifer characteristics, amount and duration of pumping, percent of pumpage derived from induced infiltration, and the differences in the qualities of the two waters. These fluctuations should be expected upon development and indeed are excellent indicators of induced infiltration.

The natural dissolved-solids concentration in stream water generally varies inversely with the quantity of streamflow. Therefore, the dissolved-solids concentration in water pumped from wells, which is derived in part from induced infiltration, can be expected to fluctuate also. The dissolved-solids concentration of such water will probably be greater during the period of little or no recharge, when ground-water runoff makes up most of the streamflow, than during the period of recharge, when direct runoff makes up most of the streamflow. The quality of water pumped from aquifers crossed by streams of impaired quality can be expected to deteriorate with time as the poorer quality stream water infiltrates and pervades the aquifer. Deterioration is a possibility along the Norwalk River between the communities of Georgetown and Cannondale in the town of Wilton, and along the Noroton River between Camp Avenue and Middlesex Road in the towns of Darien and Stamford. However, in most places the earth materials making up streambeds and the stratified-drift aquifer act as natural filters. They can remove most of the turbidity, suspended solids, and most organisms except viruses and some bacteria from the infiltrating stream water, thereby rendering the pumped water usable for most purposes without further treatment.

The temperature of water in streams fluctuates tens of degrees annually, whereas the temperature of ground water, at depths below 30 ft is nearly constant where not affected by induced infiltration of stream water and is approximately equal to the mean annual air temperature. For example, the daily mean temperature of the Saugatuck River during 1965 ranged from 1°C (33°F) in January and February to 24°C (76°F) in August. Such temperature fluctuations produce corresponding fluctuations of ground-water temperature in areas of induced infiltration that will be larger in pumping wells located close to an infiltrating stream than they will be in more distant wells.

The influence of induced infiltration upon the temperature of water pumped from stratified drift is illustrated on figure 33. The data shown on this figure are from the Westport well field of the Bridgeport Hydraulic Company. The field consists of 4 wells, Wp 9, 10, 11, and 12 and is located adjacent to the Saugatuck River (see pl. A). During 1963, the monthly flow of the Saugatuck River at a point about 8,000 ft upstream from the well field at stream-gaging station 2095, ranged from 171 million gallons in September to 5,000 million gallons in March. Monthly pumpage from the well field was equivalent to 0.7 percent of the streamflow during February and to 29 percent during August and September. The pattern of temperature changes of the pumped water throughout the year, shown on figure 33, generally agree with those inferred for the Saugatuck River. However, in October, November, and December the rate of decrease of the temperature of the pumped water was less than that of the river. During these months, pumping from the well field was reduced and the aquifer received increased quantities of recharge. The cones of depression in the well field responded by contracting, thereby decreasing the hydraulic gradient between the well field and the river. Under these changing conditions, the warm river water that had rapidly infiltrated the aquifer in July, August, and September moved more slowly and its arrival at the pumping wells was consequently delayed until October, November, and December.

Similar conditions exist in the well field operated by the 1st Taxing District, City of Norwalk, Water Department. This well field consists of four wells, Nw 16, 17, 21, and 36 (see pl. A for locations), and is located adjacent to the Norwalk River from which it induces much of its pumpage. Well Nw 38, which is located more than 200 ft north of the nearest production well and is within 200 ft of the river, was pumped for seven hours on November 10, 1966, producing water with a temperature of 18.4°C (65.5°F). On the same day, the temperature of water pumped from the rest of the well field was approximately 13°C (55°F) and that of the Norwalk River, opposite well Nw 38, was 10.6°C (51.0°F). Apparently well Nw 38 tapped warm river water that had infiltrated the aquifer during the late summer and early fall and was slowly migrating toward the well field in November.

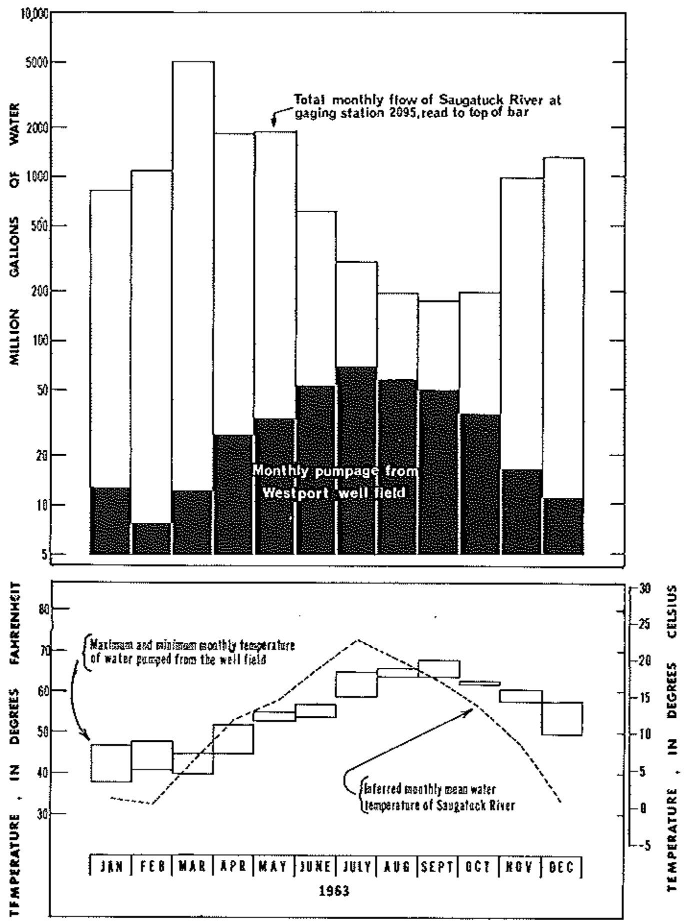


Figure 33.--Variation in temperature of water pumped from the Westport well field (wells Wp 9, 10, 11, and 12) is related to the percent of pumpage derived from induced infiltration and the variation in the temperature of the infiltrating stream water.

Wells Wp 9, 10, 11, and 12 are located along the Saugatuck River. Pumpage in the months of July through October is equivalent to more than 15 percent of the streamflow past the well field. The monthly temperature of the pumped water during this period is generally similar to that of the water in the river and is considerably above normal ground-water temperatures. In contrast, pumpage in the months January through April is equivalent to less than 2 percent of the streamflow. The monthly temperature of the pumped water during this period is more uniform and similar to that of ground water.

ABBREVIATIONS

p.	-	page(s)
pl.	-	plate(s)
°C	-	degree(s) Celsius (Centigrade)
°F	-	degree(s) Fahrenheit
mm	-	millimeter(s)
in	-	inch(es)
ft	-	foot (feet)
mi	-	mile(s)
sq ft	-	square foot (feet)
sq mi	-	square mile(s)
mcf	-	million cubic feet
cfs	-	cubic foot (feet) per second
gpm	-	gallon(s) per minute
gpd	-	gallon(s) per day
mgd	-	million gallons per day
mg/l	-	milligrams per liter
msl	-	mean sea level

EQUIVALENTS

1 cfs = 646,317 gpd = 0.646317 mgd

1 mgd = 694 gpm = 1.547 cfs

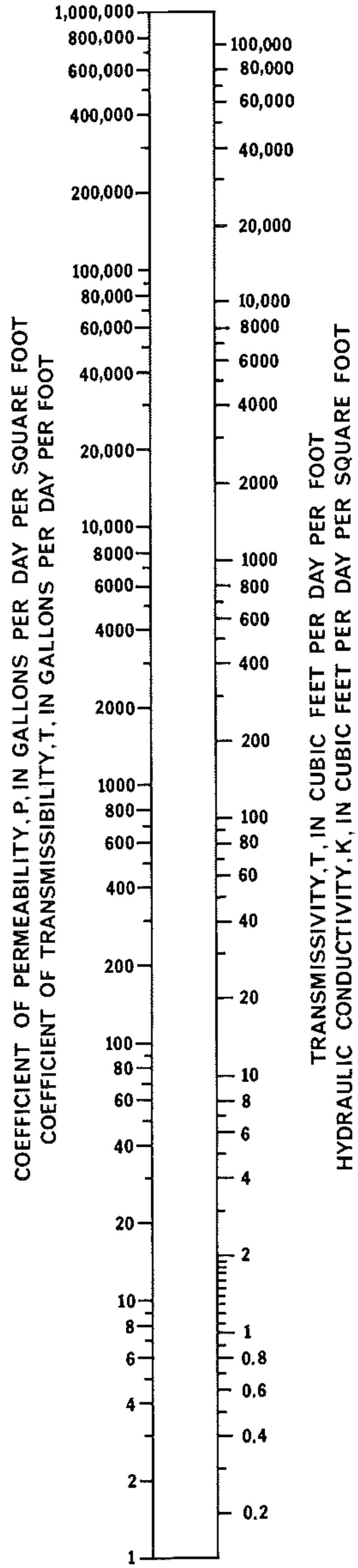
1 cfs per sq mi = 13.57 in of runoff per year

1 mgd per sq mi = 21.0 in of runoff per year

1 in of water upon 1 sq mi = 17.4 million gallons = 2.32 mcf

1 mm = 0.001 meter = 0.04 in

1 mg/l = 1 part per million (ppm)



Logarithmic nomograph used to convert coefficient of transmissibility to transmissivity and coefficient of permeability to hydraulic conductivity.

GLOSSARY

Annual flood: The highest peak discharge in a water year.

Aquifer: A geologic formation or deposit that can yield usable quantities of ground water.

Calcite: A common mineral, calcium carbonate ($CaCO_3$); the principal constituent of limestone and marble.

Casing, of wells: Any construction material, such as steel, concrete, cinderblock, plastic pipe, stone or brick laid dry or with mortar that keeps unconsolidated earth materials from entering and filling up a well.

Clay: Particles of earth material smaller than 0.004 mm in diameter.

Climatic year: A continuous period, April 1 through March 31, during which a complete annual streamflow cycle takes place from high flow to low and back to high flow. It is designated by the calendar year in which it begins.

Coefficient of permeability: The rate of flow of water, in gallons per day, through a cross sectional area of 1 sq ft of a saturated material under a hydraulic gradient of 1 foot per foot at a temperature of 16°C (60°F). The field coefficient of permeability is the same except that it is measured at prevailing water temperatures. The U.S. Geological Survey favors a new term--hydraulic conductivity, expressed in cubic feet per day per square foot--to replace permeability. For convenience, permeability has been retained for use in this report; the relation between coefficient of permeability and hydraulic conductivity is shown by a nomograph on p. 50. Vertical permeability is the coefficient of permeability in a vertical direction.

Coefficient of transmissibility: The rate of flow of water at the prevailing water temperature, in gallons per day, through a vertical strip of an aquifer 1 foot wide extending the full thickness of the aquifer under a hydraulic gradient of 1 foot per foot. It is the product of the field coefficient of permeability and thickness of an aquifer. The U.S. Geological Survey favors a new term--transmissivity, expressed in cubic feet per day per foot--to replace transmissibility. For convenience, transmissibility has been retained for use in this report; the relation between coefficient of transmissibility and transmissivity is shown by a nomograph on p. 50.

Color unit: A standard of color of water. It is the color produced by the platinum-cobalt method of measuring, with the unit being 1 mg/l of platinum in water. Results are conventionally expressed as units of color, and not as mg/l.

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

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

Drawdown: The lowering of the water level or the equivalent reduction in the pressure of the water in a well caused by the withdrawal of water.

Field capacity: The amount of water held in a soil by capillary action after gravitational water has percolated downward and drained away; expressed as the ratio of the weight of water retained to the weight of dry soil.

Flow duration, of a stream: The percent of time during which specified daily flows are equaled or exceeded in a given period. The sequence of daily flows is not chronological.

Fracture: An opening or crack in bedrock.

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

Gravel: Particles of earth material bigger than 2 mm in diameter.

Gravel pack: A lining or envelope of gravel placed around the outside of a well screen to increase well efficiency and yield.

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

Hydraulic diffusivity: The ratio of the coefficient of transmissibility to the storage coefficient.

Hydraulic gradient, of an aquifer: The rate of change of water level per unit distance at a given place and direction in the aquifer. It is generally understood that the direction of maximum rate of change is meant.

Hydrograph: A graph showing stage (height), flow, velocity, or other property of water with respect to time.

Impermeable boundary: The boundary of an aquifer across which ideally no ground water flows.

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

Induced infiltration: Water that infiltrates from a stream or lake into an aquifer because pumping of nearby wells has established a hydraulic gradient from the stream or lake toward the wells.

Isopleth: Line on a map connecting points at which a given variable has a specified constant value.

Mean: The sum of a set of individual values of any quantity, divided by the number of values in the set; popularly called the "average."

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

Median grain size: A measure of average grain size obtained graphically by locating the diameter associated with the midpoint of a particle-size distribution.

Milligrams per liter (mg/l): A unit for expressing the concentration of chemical constituents in solution. Milligrams per liter represents the weight of a constituent per unit volume of water.

Partial penetration: Describes the condition where wells do not completely penetrate an aquifer.

Quartz: A mineral (SiO_2).

Recharge: The process(es) by which water is absorbed and is added to the saturated zone; also, the quantity added.

Recurrence interval: The average interval of time between extremes of streamflow, such as floods or droughts, that will at least equal in severity a particular extreme value over a period of many years. Frequency is the average number of extremes during the same period. The occurrence of a drought or flood of a given magnitude cannot be predicted, but the probable number of such events during a reasonably long period of time may be estimated with reasonable accuracy.

Reference period: A period of time chosen so that comparable data may be collected or computed for that period. Streamflow data in this report are based on climatic years 1930 to 1959 or water years 1931 to 1960.

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

Sand: Particles of earth material between 0.0625 and 2 mm in diameter.

Saturated zone: The subsurface zone in which all open spaces are filled with water under hydrostatic pressure.

Screen, in a well: A cylindrical device fashioned so as to admit water but prevent the passage of most or all of the surrounding earth material into the well. Screen openings are generally called slots.

Siliceous: Containing abundant quartz.

Silt: Particles of earth material between 0.004 and 0.0625 mm in diameter.

Sorting: An expression of the variability of grain sizes in an earth material. Poorly sorted materials have a wide range in grain sizes; well sorted materials have nearly uniform grain sizes.

Specific capacity of a well: The rate of yield per unit of drawdown, commonly expressed as gallons per minute per foot of drawdown.

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

Storage coefficient: The volume of water released from or taken into storage per unit surface area of an aquifer per unit change in the component of head normal to that surface.

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

Streamflow: The discharge that occurs in a natural channel without regard to the effect of diversion or regulation.

Thermal stratification: The vertical temperature layering of water in most deep open-water bodies.

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

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

Unconsolidated: Loose, not firmly cemented or interlocked, describes sand in contrast to sandstone.

Underflow: The downstream flow of ground water through permeable materials underlying a stream.

Uniformity coefficient (C_u): A quantitative expression of sorting of an earth material. It is the quotient of 1) the diameter of a grain that is just too large to pass through a sieve that allows 60 percent of the material, by weight, to pass through, divided by 2) the diameter of a grain that is just too large to pass through a sieve that allows 10 percent of the material, by weight, to pass through. Poorly sorted deposits such as dirty gravel have high uniformity coefficients; well sorted deposits such as uniform sands have low uniformity coefficients.

Unsaturated zone: The zone between the water table and the land surface in which the open spaces are not all filled (except temporarily) with water.

Water table: The upper surface of the saturated zone.

Water year: A continuous period, October 1 through September 30, during which a complete streamflow cycle takes place from low to high flow and back to low flow. A water year is designated by the calendar year in which it ends.

Well interference: The lowering of a water level in a pumping well caused by the pumping of a nearby well or wells.