Geology and Ground-Water Resources of the Town of Southold, Suffolk County New York

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1619-GG

Prepared in cooperation with the Suffolk County Board of Supervisors, the Suffolk County Water Authority, and the New York State Water Resources Commission

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By H. C. CRANDELL

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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GEOLOGY AND GROUND-WATER RESOURCES OF THE TOWN OF SOUTHOLD, SUFFOLK COUNTY, NEW YORK

By H. C. CRANDELL

ABSTRACT

The town of Southold has a total area of about 54 square miles and includes most of the north fork peninsula at the eastern end of Long Island and a chain of small islands extending northeastward from the peninsula. It is underlain by Cretaceous and Pleistocene deposits resting on a southeastward sloping bedrock surface of Precambrian age.

The Harbor Hill end moraine, which follows the northeastward-trending peninsula along the shore of Long Island Sound, and a glacial-outwash plain are the predominant topographic features. The peninsula is naturally divided by salt-water ponds, marshes, and inlets into six distinct islandlike areas. The peninsula's fresh ground water, which is chiefly unconfined, is contained in a series of six lenslike bodies in stratified to semistratified upper Pleistocene glacial deposits. These are probably in dynamic balance with salty ground water in accordance with the Ghyben-Herzberg principle. About 25 to 35 percent of the precipitation, which averages 45 inches per year, is available for recharging the ground-water reservoir. This is ample to balance losses due to natural discharge to the sea and withdrawals from wells at present rates. The draft amounted to about 2½ billion gallons in 1957 and was withdrawn for public supply, for domestic uses, and particularly for irrigation. Several areas were contaminated by salt water between 1948 and 1952. Although sea-water encroachment is still a potential hazard, the situation in 1959 was less critical than in previous years. Recommendations for future study and use of ground water include (1) a water-level and chloride-monitoring program, to be intensified during years of below-normal precipitation and heavy irrigation withdrawal, (2) the periodic collection of water samples for complete chemical analysis and synthetic-detergent determinations, (3) the construction of "outpost" wells to determine the position and possible movement of the zone of diffusion between the fresh and salty ground water, (4) the spacing of most wells at least 1,000 feet from shoreline and 300 feet from each other, (5) the use of field tensiometers to determine water needs of crops before irrigation as a measure of ground-water conservation, and (6) the limitation of withdrawal in the eastern part of the Southold peninsula to that prevailing in 1957–59.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

In 1932 the U.S. Geological Survey began an overall and continuing appraisal of ground-water conditions on Long Island. This report presents the results of an investigation undertaken as a part of that program in cooperation with the Suffolk County Board of Supervisors, the Suffolk County Water Authority, and the New York State Water Resources Commission (formerly the New York State Water Power and Control Commission). Fieldwork by the writer began in September 1957 and ended in December 1959. The present report is based on data available prior to January 1960.

The town of Southold is 1 of 10 major political subdivisions of Suffolk County. In this report the names "town of Southold" and "Southold" are used interchangeably. Because the town of Southold is almost entirely surrounded by salt water and has a relatively small area for recharge to the ground-water reservoir, development and use of fresh ground water must be such as to prevent or keep to a minimum the encroachment of sea water into deposits now containing fresh water. Two public water-supply installations and many domestic and crop-irrigation systems are totally dependent on the continued availability of ground water of good quality. This investigation, therefore, has included study of (1) the areal extent, thickness, and physical properties of the water-bearing deposits; (2) the hydrologic characteristics of the ground-water reservoir; (3) the conditions under which sea-water encroachment may take place; and (4) the establishment of a monitoring program to observe any future sea-water encroachment resulting from depletion of the ground-water supply. The report includes pertinent conculsions from previous investigations of the geology and hydrology of Southold as well as data obtained during this investigation.

LOCATION OF THE AREA

The eastern third of Long Island is made up of two narrow peninsulas separated by Peconic Bay, Gardiners Bay, and contiguous inlets. The town of Southold occupies the eastern 20 miles of the northern peninsula and also includes Robins, Plum, Great Gull, Little Gull, and Fishers Islands (fig. 1). Robins Island is in Peconic Bay, whereas the other islands form a broken chain in Long Island Sound that is a continuation of the northeastward-trending peninsula. Plum Island is about 1 mile from Orient Point, Great Gull and Little Gull Islands are about 7 miles from Orient Point, and Fishers Island is about 13 miles from Orient Point and about 7 miles southeast of New London, Conn. The total area of Southold is about 54 square miles, distributed as shown in the following table:

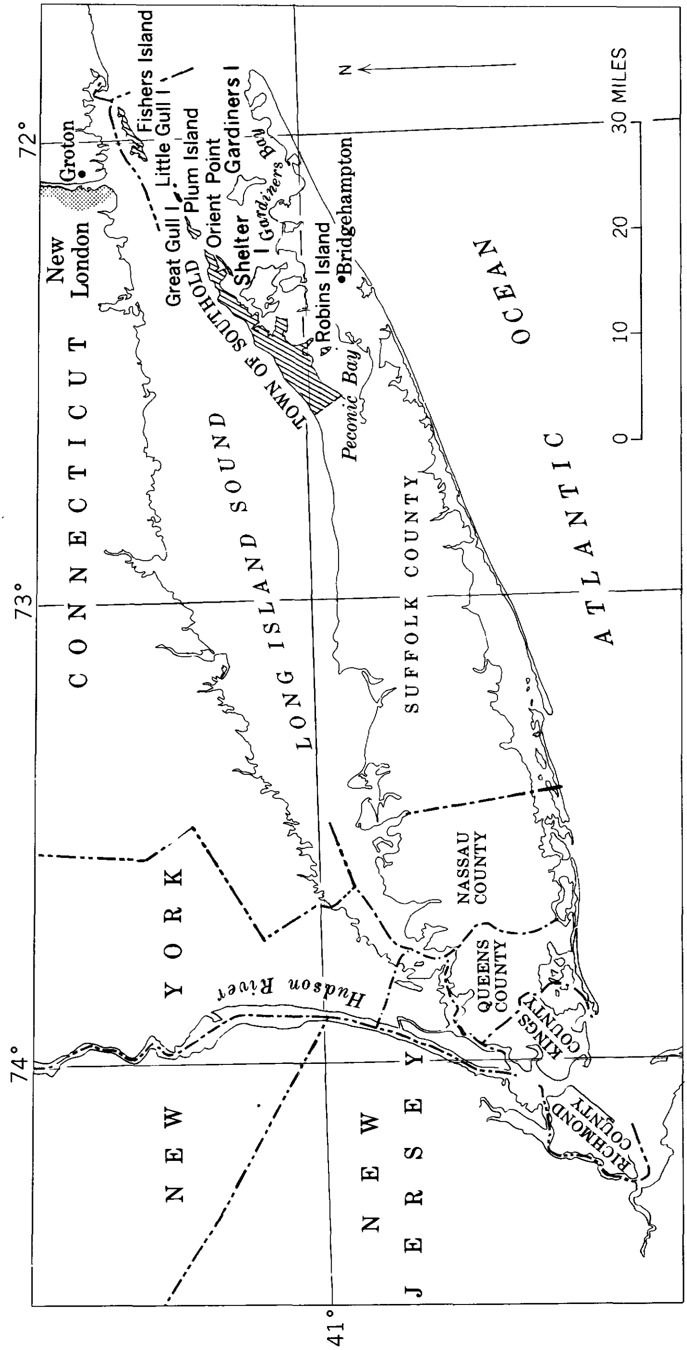

FIGURE 1.—Map showing location of the town of Southold.

	Area (square miles)
Peninsular part	42.90
Robins Island	5.20
Plum Island	1.34
Gull Islands	.03
Fishers Island	4.22

The whole of Southold lies almost entirely between lat 40°57′30″ and 41°17′30″ N. and long 71°55′ and 72°35′ W. This investigation included the peninsular part of the town only.

The following topographic quadrangle maps of the U.S. Geological Survey include all parts of Southold:

Map	State	Scale	Year published
Greenport	New York	1:24,000	1956
Mattituck	New York	1:24,000	1956
Mattituck Hills	New York	1:24,000	1956
Mystic	Conn.-N.Y.-R.I	1:31,680	1951
New London	Conn.-New York	1:31,680	1951
Orient	New York	1:24,000	1956
Plum Island	New York	1:24,000	1954
Southampton	New York	1:24,000	1956
Southold	New York	1:24,000	1956

PREVIOUS INVESTIGATIONS

References to parts of Southold appear frequently in early works on the geology of Long Island. Mather (1843) described in some detail the bluffs and boulder-strewn beaches of the peninsula's north shore, as well as the clay deposits between the villages of Greenport and Southold. These deposits were again discussed by Merrill (1886) and by Ries (1900). Veatch (1906) prepared a detailed report on Long Island's water resources, which included the logs of eight wells in Southold. The most comprehensive report of Long Island geology was prepared by Fuller (1914). This report contains many specific observations made in Southold and evaluates them in their relation to the geologic history of the Long Island area. An earlier paper by Fuller (1905) describes the geology of Fishers Island.

Very little has been written since Fuller's time that mentions Southold. Logs of many wells in Suffolk County, including some in Southold, were compiled by Leggette (1938), Roberts and Brashears (1945), and Johnson (1952). Suter, deLaguna, and Perlmutter (1949) summarized the geology of Long Island and correlated the logs of several deep wells in Southold with logs of wells elsewhere on the island. Data on the temperature and chloride concentration of water from wells in Suffolk County were presented and interpreted by Hoffman and Spiegel (1958).

More recent work on Southold was done by Hoffman (1961), who described the hydrology of the shallow ground-water reservoir, with particular reference to sea-water encroachment, and by Crandell (1962), who investigated the geology and ground-water resources of Plum Island.

METHODS OF INVESTIGATION

In carrying out the purposes of this investigation the author examined outcrops of glacial outwash and till in Southold and prepared a generalized map of the deposits. Thirty-five test holes, ranging in depth from about 50 to 100 feet, were augered to obtain samples of outwash for permeability and specific-yield determinations. Well points and pipe were installed in 32 of the test holes to establish control for a contour map of the water table. Eleven rain gages were established in different parts of the area to compare differences in precipitation. Data on evaporation were obtained from the U.S. Weather Bureau, which operated an evaporation pan at Greenport. Eighty wells were measured monthly to determine the altitude and trend of water levels, and 100 wells and 5 ponds were sampled to determine the chloride content of the water.

WELL-NUMBERING SYSTEM

On Long Island the Geological Survey uses a well-numbering system established by the New York Water Resources Commission. Wells in each county are numbered serially as drilling reports are received by the Commission. The well number is prefixed by the initial letter of the county in which it is located. Thus a well in Suffolk County is designated by the letter "S" followed by the assigned number (for example, S10361).

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of the staff members of the Long Island office of the New York State Water Resources Commission for providing most of the well records used in the preparation of this report. Volunteer rain-gage observers have ably assisted in the compilation of precipitation data, and the author is especially grateful to Mr. Harry Monsell, Superintendent of Public Works, village of Greenport, for generously providing the Geological Survey with additional manpower and equipment to install wells, to measure water levels in wells, and to obtain water samples for chloride determinations.

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GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

Much of Southold, particularly the eastern part, may be considered as virtually a chain of small islands along an axis trending northeastward. Even the peninsular part is naturally subdivided by salt-water ponds, marshes, and inlets into six separate morphologic and hydrologic areas, four of which are designated by the letters A, B, C, and D for purposes of reference in this report (pls. 2 and 3). The other two areas are Little Hog Neck and Great Hog Neck, which jut south from the peninsula but are largely detached from it by salt-water marshes and inlets. Plum, Great Gull, Little Gull, and Fishers Islands are separated by open salt-water passages and lie in a chain extending northeastward from the peninsula. Robins Island lies in Peconic Bay between the northern and southern peninsulas of Long Island.

Area A (about 7 square miles) extends from a short distance west of the western boundary of the town of Southold to Mattituck Creek, is about 3 miles wide, and contains most of the village of Mattituck. Area B (abut 25 square miles) is bounded on the west by Mattituck Creek and on the east by Hashamomuck Pond. This area constitutes the largest part of Southold. It ranges in width from about 1½ to 4 miles. The villages of Cutchogue, Peconic, and Southold are in this area. Area C (about 7 square miles) extends eastward from Hashamomuck Pond to Dam Pond. It is about 1 to 1½ miles wide. Greenport, which is Southold's largest village, and East Marion are in this area. Area D (about 5 square miles) is bounded on the west by Dam Pond and terminates to the east at Orient Point. The area has a width of about 1 to 1½ miles. Little Hog Neck (about 0.75 square mile) and Great Hog Neck (about 2.3 square miles) extend southeastward from the south shore of area B.

The southern shoreline of the peninsula is very irregular as it is marked by numerous salt-water embayments and marshes. Attractive beaches, which are made up of well-sorted clean quartz sand, form the rest of the southern shoreline. In many places they form bayhead beaches and spits. The most prominent spit, Long Beach (pl. 3) extends southwestward almost 4 miles from Orient Point and is occupied by Orient Beach State Park. The combination of pleasant beaches and embayments, which provide good swimming conditions and boat anchorage, has attracted many summer-home builders.

The north shore of peninsular Southold is relatively rugged. A prominent ridge lies near the shore except where inlets and ponds mark the boundaries between areas A, B, C, and D. In the eastern part of area D, however, erosion has removed most of this ridge. The shoreline is generally regular and smooth, but two small headlands in area B, two in area C, and one in area D extend into Long Island Sound. Most parts of the ridge are more than 50 feet above sea level. The ridge has a maximum altitude of slightly more than 160 feet in area A. Erosion by storm waves and high tides has removed much of the ridge material and has left steep bluffs which are from about 20 to more than 50 feet high at the shore, and narrow beaches strewn with cobbles and boulders. Very large boulders are clustered at the headlands and at some places on the southern slope of the ridge. Mather (1843, p. 169) described their size in the following quotation:

> Some of the erratic blocks of Long Island are of great size. One on Mr. Latham's farm at Oysterpond Point (Orient) was mostly blasted to pieces, and made into a stone fence. He stated that the fragments made eighty rods (one-fourth of a mile) of stone fence, four feet high. A portion still remains in the ground. The portion used must have weighed more than nine hundred tons.

A gently rolling outwash plain with numerous shallow depressions extends from the ridge along the north shore to the south shore. The plain slopes southeastward at about 20 to 30 feet per mile.

Great Hog Neck and Little Hog Neck extend southeastward from area B. Little Hog Neck is roughly triangular, about 2 miles long and about half a mile wide at the base, which is joined to area B by a very narrow sand bar. Much of the land surface has an altitude of more than 50 feet and is extremely hilly. Great Hog Neck is almost a rectangle, about 1½ miles wide by 2 miles long. It is joined to area B by a small marshy area about a quarter of a mile wide. Most of the land surface is similar to the gently rolling plain in the central parts of areas A, B, C, and D, although it has somewhat greater relief. Two prominent hills more than 70 feet high lie in the northwestern part of the neck.

Robins Island has very much the same shape and appearance as Little Hog Neck and is only slightly smaller. It is very hilly; the altitude of most of the land surface is more than 50 feet and exceeds 80 feet in the north-central part. Bluffs that rise 20 to 50 feet above sea level mark the island's western shoreline.

Plum Island also has a triangular outline and ranges in width from about 300 feet near the eastern end to almost 1 mile at the southwestern end. The island is about 3 miles long. A lowland in the central part of Plum Island slopes gently to the northeast and thence southeast and separates two low ridges. The northeastern ridge is the more extensive and rises to an altitude of more than 100 feet, whereas the southeastern ridge ranges in altitude from 40 to 75 feet. Both ridges are marked at the shoreline by steep bluffs, and the beaches are strewn with many large boulders.

Great Gull Island is about one-tenth mile wide by about one-half mile long and is only about 30 feet above sea level at its highest point. Little Gull Island is about 400 feet wide by about 800 feet long and is only slightly above sea level.

The outline and topography of Fishers Island are very irregular. The island is almost 7 miles long and ranges in width from 500 feet near the northeastern end to 1½ miles near the southwestern end. The principal ridge of hills, which lies along the south-central shoreline, has a maximum altitude of about 70 feet, which is about the average elevation of the many knoblike hills that cover most of the remaining parts of the island. Some individual knobs however, rise to 100 feet above sea level. Shoreline bluffs are not well formed and are less than 20 feet high in most places. Numerous shallow undrained depressions are scattered over the island, and some of these in the central part contain fresh-water ponds.

Most of peninsular Southold is cropland. Vegatation in the remaining parts of Southold consists mainly of marsh grasses, beach and dune grasses, and wild shrubs and bushes. Stands of mixed deciduous forest and some conifers are in the hilly areas and where land has not been cleared for farming.

None of the islands in Southold have streams, and the peninsula has relatively few. Ground-water discharge into these streams is negligible, and virtually all the streams are ephemeral. Surface runoff during and after heavy storms provides the only observable flow in the stream channels. Generally the streams are no more than a mile long and discharge into the marshes along the south shore.

CLIMATE

Owing to its virtually insular nature, its latitude, and the proximity of the Atlantic Ocean, Southold has a predominantly temperate marine climate. Temperatures are moderate, and precipitation is abundant during the fall, winter, and spring. A brief dry spell commonly occurs during the summer. The following table compiled from information collected by Mordoff (1949) and periodic climatic summaries of the U.S. Weather Bureau sumarizes available temperature and precipitation data. All stations are in Southold except Bridgehampton and New London-Groton (fig. 1).

Mean annual temperature and precipitation at stations in and near the town of Southold

Station	Distance (miles) and direction from the village of Southold	Temperature		Precipitation	
		Period of record (years)	Mean annual (°F)	Period of record (years)	Mean annual (inches)
Bridgehampton, N.Y	12 SE	43	50. 4	43	44. 85
Cutchogue, N.Y	5 SW	54	51. 2	51	44. 93
Greenport, N.Y	4 NW			20	37. 80
New London-Groton, Conn	26 NW	77	50. 4	86	44. 36
Orient Point, N.Y	10 NW			18	41. 47

The amount of catch in the 8-inch rain gages at Cutchogue, Greenport, and Orient differs perceptibly. This difference may be attributed to the local topography, the exposure and location of the gage, and the spotty distribution of local storms. In order to obtain more accurate data on precipitation in the many parts of Southold, additional 3-inch rain-gaging stations were established as follows: East Marion, Greenport North, Mattituck Inlet, Mattituck West, village of Orient, Peconic, Southold (pl. 3), and Plum Island (fig. 1). Data for 1958 and 1959 from these stations together with those for the three earlier long-term stations in Southold and the two nearby long-term stations are compiled in table 1.

HISTORY OF DEVELOPMENT

Southold was founded in the early 17th century. Colonists, probably Englishmen, settled at Yennicott (town of Southold) as early as 1638 (Wood, 1949). Southold was part of a large land grant made by Charles I of England to Sir William Alexander, Earl of Stirling. Fishers Island, however, was discovered in 1614 by Adrian Block and granted in 1640 to John Winthrop, in whose family it remained until 1869.

The first settlement in Southold was just west of Greenport. This was followed by settlements at the village of Southold and then by settlements at other locations; Greenport was the last village to be founded. Some of the early settlers had come from Southwold, England, and the Indian name Yennicott, which had been applied to the area, was soon changed to Southold.

The early inhabitants cleared land and established crops, which were mostly grain, fodder, and pasture. In the early 19th century, shipping and whaling became important aspects of Southold's economy. The need for a fast combined railroad and steamer route from New York to Boston brought about the extension of the Long Island Railroad to Greenport in 1848. Fishing and oyster farming have always been

TABLE 1.—*Precipitation, in inches, during 1958 and 1959 at 11 stations in the town of Southold and at 2 nearby stations*

[All stations except for Plum Island, Bridgehampton, and New London-Groton are shown on pl. 3]

Month and year	Area A stations			Area B stations				Area C stations				Area D stations			Plum Island N.Y.	Nearby stations	
	Mattituck Inlet, N.Y.	Mattituck West, N.Y.	Average	Cutchogue, N.Y.	Peconic, N.Y.	Southold, N.Y.	Average	East Marion, N.Y.	Greenport, N.Y.	Greenport, North, N.Y.	Average	Orient Point, N.Y.	Orient Village, N.Y.	Average		Bridgehampton, N.Y.	New London-Groton, Conn.
1958																	
January	7.02	7.60	7.31	7.28	8.75	7.10	7.71	6.88	7.62		7.25	7.39	7.77	7.58		9.25	9.68
February	1.75	3.37	2.56	3.35	4.49	2.70	3.51	2.33	2.05		2.19	3.25	2.70	2.98		5.48	4.33
March	4.22	4.65	4.44	4.05	5.23	4.61	4.63	4.19	4.46		4.33	4.80	5.13	4.97		7.08	6.29
April	5.72	5.59	5.66	5.08	5.98	6.75	5.94	7.81	5.30		6.55	6.23	7.17	6.70		5.10	7.38
May	5.34	6.04	5.69	5.62	5.61	5.45	5.56	5.36	4.81		5.09	4.22	4.84	4.53		5.54	4.49
June	1.88	1.78	1.83	2.18	1.79	1.43	1.80	1.77	1.61	1.78	1.72	1.46	2.02	1.74		1.97	2.75
July	2.85	3.27	3.06	3.60	2.83	3.58	3.34	4.00	3.50	3.52	3.67	3.93	4.46	4.20		3.00	6.82
August	6.73	6.11	6.42	5.68	5.57	5.45	5.57	6.04	5.60	6.34	5.99	5.53	5.72	5.63		6.15	5.96
September	4.21	3.81	4.01	4.39	4.79	5.73	4.97	5.45	5.06	6.04	5.52	4.39	5.03	4.71		5.39	4.79
October	6.75	6.74	6.75	5.59	3.80	7.08	5.49	5.88	5.73	5.81	5.81	4.88	5.67	5.28	4.28	6.55	5.37
November	2.72	2.61	2.67	2.39	2.63	2.01	2.34	2.20	2.24	2.23	2.22	1.95	2.54	2.25	1.37	2.88	2.84
December	2.06	2.15	2.11	2.26	2.52	1.85	2.21	2.94	2.50	2.52	2.65	2.35	2.54	2.45	2.70	3.59	2.51
Total	51.25	53.72	52.49	51.47	53.99	53.74	53.07	54.85	50.48		52.99	50.38	55.59	52.99		61.98	63.21
1959																	
January	2.18	2.38	2.28	2.19	2.17	1.92	2.09	2.30	2.19	2.20	2.23	2.31	2.26	2.29	2.10	2.27	2.77
February	2.49	2.27	2.38	2.49	2.42	2.44	2.45	2.79	4.27	2.74	3.27	2.88	2.92	2.90	2.68	2.76	3.62
March	6.20			5.80	6.49	5.61	5.97	6.24	6.11	6.32	6.22	5.56	5.91	5.74	6.22	7.83	6.81
April	4.85			4.10	4.26	4.71	4.36	4.43	4.26	4.57	4.42	4.01	4.43	4.22	3.70	4.03	4.23
May	1.34			1.42	1.44	1.47	1.44	1.54	1.66	1.62	1.61	1.35	1.37	1.36	1.03	2.59	1.50
June	4.57			5.02	5.09	5.79	5.30	5.21	4.86	5.40	5.16	5.47			6.24	4.58	6.76
July	7.23			7.48	7.40	7.23	7.37	6.33	5.52	6.37	6.07	5.52	5.77	5.65	5.55	6.85	6.02
August	2.23			2.10	2.72	3.13	2.65	3.00	2.43	3.68	3.04	2.41	2.87	2.64	2.34	3.34	2.32
September	1.23			.78	1.45	1.10	1.11	1.40	1.32	1.34	1.35	1.19	1.46	1.33	1.48	1.21	1.65
October	4.17			3.41	4.32	4.51	4.08	5.19	4.24	4.94	4.79	4.45	4.74	4.60	4.78	3.96	5.68
November	4.67			3.13	3.68	3.51	3.44	3.54	3.73	3.44	3.57	3.82	3.96	2.89	2.95	3.29	4.50
December	4.62			3.47	4.62	4.40	4.16	4.81	3.37	4.74	4.31	3.76	4.17	2.97	3.70	4.17	5.11
Total	45.78			41.39	46.06	45.82	44.42	46.78	43.96	47.36	46.03	42.73			42.77	46.88	50.97

important industries, but agriculture has been the main support of the area's inhabitants.

With the invention of the mechanical potato digger in 1888, potatoes became the most important crop and remain so today. Southold farms also produce cauliflower, brussels sprouts, peas, beans, and other vegetables. In 1948, vegetables were planted in 13,614 acres, and more than three-quarters of this acreage was used for the cultivation of potatoes (U.S. Department of Agriculture, 1948). The area under cultivation has remained relatively constant since 1899 (Hoffman, 1961, p. 5).

The following table shows the population trend in the village of Greenport and the town of Southold:

Population of town of Southold and village of Greenport

Year	Village of Greenport	Town of Southold[1]
1920	3, 122	10, 147
1930	3, 062	11, 669
1940	3, 259	12, 046
1950	3, 028	11, 484
1957	2, 646	12, 608
Jan. 1, 1960[2]	2, 653	13, 388

[1] Includes village of Greenport.
[2] Estimate by Long Island Lighting Co.

GEOLOGY

No geologic formations older than the Pleistocene crop out in Southold; however, older formations are present at depth. A generalized stratigraphic section of the formations in the Southold area, together with their water-bearing characteristics, is shown in table 2. The estimated thickness and lithologic descriptions are based largely on the log of well S189 (Leggette, 1938), drilled in 1935 at Orient Beach State Park, and on the general stratigraphic studies of Long Island by Suter and others (1949). Logs of the following wells collected by Veatch (1906), which penetrate Cretaceous deposits and in places Precambrian(?) bedrock, also were used to compile the stratigraphic section.

Well	*Location*
S490 (892)[1]	Greenport
S507 (909)[1]	Long Beach
S512 (914)[1]	Great Gull Island
S517 (919)[1]	Fishers Island

[1] Well numbers used by Veatch (1906).

TABLE 2.—*Generalized stratigraphic section in the town of Southold*

System	Series	Geologic formation or unit and symbol on plate 1	Estimated thickness (feet)	Lithologic properties	Water-bearing properties
Quaternary	Recent	Shoreline, dune, and marsh deposits (Qsh, Qd, Qs)	0–20±	Beach and dune sand and gravel. Marshy areas contain sand, silt, and clay mixed with plant material.	Beach deposits yield small supplies of fresh water from very shallow depths. Contains salt water in lower part.
	Pleistocene	Upper Pleistocene deposits (Qhm, Qgm, Qo)	200±	Stratified and unstratified sand and gravel. May be mixed with clay or contain thin beds of clay.	Stratified deposits highly permeable. Upper part contains fresh water. Chief source of fresh ground water in Southold. Lower part probably contains salt water.
		—Unconformity?—			
		Gardiners(?) clay (Qg)	0–20±	Gray and grayish-brown clay and sandy clay.	Permeability generally low. Locally may form a confining unit.
		—Unconformity—			
Cretaceous	Upper Cretaceous	Post-Raritan deposits	200±	White, gray, and pink fine to medium sand mixed with silt and clay; some beds of coarse sand and gravel and clay.	Includes several permeable, but salt water-bearing zones.
		—Unconformity—			
		Raritan formation: Clay member	180±	Gray, white, red, and black silt and clay, and some lenses of sand and gravel.	Low permeability; an extensive confining unit.
		Raritan formation: Lloyd sand member	100±	Gray sand and gravel, and some beds of red, white, and gray clay and silt.	Good water-bearing unit, but contains brackish or salty water beneath eastern Southold; may contain some fresh water in western Southold.
		—Unconformity—			
Precambrian(?)		Crystalline rocks	------------	Probably granite and gneiss.	Low permeability; not an aquifer.

The bedrock basement in the Southold area is made up of crystalline rocks of probable Precambrian age. On Long Island the basement surface generally slopes to the southeast at about 80 feet per mile as determined from many well logs. Semiconsolidated and unconsolidated deposits of Cretaceous and Quaternary age rest on this surface. The materials constituting these deposits were probably eroded from the elevated parts of the bedrock surface north of Southold.

The Lloyd sand member of the Raritan formation of Late Cretaceous age was deposited directly on the Precambrian bedrock. It consists of beds of coarse quartz sand and gravel, fine sandy clay, clayey sand, and some very thin layers of clay. In much of western and central Long Island, the Lloyd sand member is an excellent aquifer and in most places yields moderate to large supplies of fresh water to wells. In Southold at well S490 (No. 892 in Veatch, 1906, p. 331–332), however, only a small amount of fresh water was found in the Lloyd; and at well S189 (Leggette, 1938, p. 93–97) on Long Beach (Orient Beach State Park) salty water was found. The Lloyd grades upward into the clay member of the Raritan formation. The clay member contains some sandy layers, but it is predominantly gray clay and silty clay. Its permeability generally is very low; therefore, it commonly acts as a confining bed or aquiclude and retards the movement of water between the Lloyd sand member and the overlying beds.

An unconformity separates the Raritan formation from the overlying post-Raritan beds of Late Cretaceous age. These beds consist of fine sand, silt, layers of clay, and scattered beds of coarse sand and gravel. Beds equivalent in age to the Magothy formation of New Jersey are present in the post-Raritan deposits of Long Island, but their upper and lower boundaries are not distinct in the logs of wells that penetrate these deposits (Perlmutter and Crandell, 1959). Although the post-Raritan beds contain several excellent water-bearing zones that yield large supplies of fresh water to wells in most of Long Island, in Southold they probably contain mostly brackish or salty water.

During Tertiary and possibly during early Quaternary time, the post-Raritan deposits were dissected by streams and possibly by ice into a hilly terrain of moderate relief. Pleistocene glacial deposits, consisting largely of sand and gravel but with local lenses of clay, were then laid down on this irregular surface. Southold's reservoir of fresh ground water is contained in the upper part of these permeable glacial deposits.

Several geologists, including Veatch (1906), Fuller (1905 and 1914), Fleming (1935), MacClintock and Richards (1936), Thompson and others (1937), and Suter and others (1949), have studied the

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complex Pleistocene glacial history of Long Island and vicinity and recognize two or more major glacial advances. This report, however, is concerned with only the most recent, or Wisconsin glaciation of the Pleistocene Epoch. The following discussion is based, in part, on their findings, and, in part, on field observations. Much data have been obtained from logs of wells drilled in Southold and published in Veatch (1906), Leggette (1938), Roberts and Brashears (1945), and Johnson (1952), as well as from unpublished well logs on file in the Mineola, N.Y., office of the U.S. Geological Survey, and the Westbury, N.Y., office of the New York State Water Resources Commission.

The present topographic features and surficial deposits of Long Island are related largely to the advance of a part of the Huron-Ontario lobe of the great Laurentide ice sheet during the Wisconsin glaciation (Flint, 1947). The ice in its southward movement accumulated rock debris from the land over which it passed and shoved additional material ahead of it in the manner of a bulldozer. After passing over most of the northern half of Long Island and the deposits of earlier ice advances, as well as the beds of sand and gravel laid down by its own melt water, the ice was checked by increased melting at its terminus and by decreased nourishment in its region of accumulation. The accumulation of rock debris held in the ice was released by the melting and, together with the material previously pushed ahead, was partly reworked by the melt water to form a ridge of poorly stratified sand and gravel along the ice front. This ridge at the southern terminus of the ice sheet is known on Long Island as the Ronkonkoma terminal moraine. Continued melting and lack of nourishment in the region of ice accumulation caused the ice front to recede northward. The Harbor Hill end moraine, part of which is in Southold, was formed when the ice front readvanced to the position shown by the end-moraine deposits on plate 1. The moraine consists of large coalescing outwash fans of stratified sand and gravel and associated till. The till ranges in thickness from about 5 to almost 50 feet and is characterized by many large boulders (fig. 2). Gaps or depressions in the ridge formed by the Harbor Hill end moraine are probably the sites of large blocks of ice that were wholly or partly buried and then melted after the retreat of the main ice front. These gaps provided passageways across the ridge for melt-water flow, which, in places, partly refilled the gaps with stratified sand and gravel. However, the marked depressions now occupied by Mattituck Creek, Hashamomuck Pond, and Dam Pond, which are tide-water inlets separating areas A, B, C, and D, and Plum Gut, which separates area D from Plum Island, were never completely filled. Fuller (1914, p. 40) considered Mattituck Creek, which is now a tidal embayment leading to the northwest, to be a

FIGURE 2.—North shore of the town of Southold, just west of Duck Pond Point showing stratified drift, thin till cap, and large erratics. Boulder is about 16 feet high.

kettle valley. Reference to plate 3 shows that the creek's tributaries enter it at such an angle as to suggest that its flow was once southeastward. Recent deposition of sand bars and beaches, largely by longshore currents, have closed parts of these gaps and thus tied together areas A, B, C, and D and Little and Great Hog Necks; all except for area A, were once separate islands.

At several points along the north shore of area D discontinuous bodies of gray to grayish-brown clay are exposed (pl. 1) at the shoreline. Because of the appearance and stratigraphic position of this clay, it is tentatively assigned to the Gardiners clay in this report, although no substantiating fossil evidence has been found. The clay occurs in irregular, highly contorted masses and was probably moved to its present position by ice-shove. Clay with similar characteristics is also found on the western shore (pl. 1) of Robins Island and on the southeastern shore of Plum Island. Well logs do not indicate that the clay underlies Southold except at the few localities previously mentioned. Apparently, it occurs only in isolated masses or discontinuous lenses—at least under the main part of the Southold peninsula.

Another clay, probably of late Pleistocene age, occurs in several places along the south shore of peninsular Southold. No exposures have been found, but it lies under several feet of soil and, in some places, under stratified sand and gravel. This clay underlies most of the south shore, where well logs indicate that it ranges in thickness from 5 to 60 feet. (See logs of wells S4677 and S4788 in table 3.) It appears to extend northward for almost a quarter of a mile except in that part of area C west of Greenport, where it extends nearly to the north shore. The clay was once quarried in this area for use in the production of brick.

On Robbins Island, at Little Hog Neck, and at the western end of Great Hog Neck numerous hills that consist of stratified sand and gravel range in altitude from about 30 to 70 feet. The higher hills are capped with till, which is generally about 5 feet thick.

During Recent time wave erosion has removed a considerable part of the moraine along the north shore of the peninsula, as shown by many large lag boulders on the bottom of Long Island Sound as far as a quarter of a mile offshore. Also, thin swamp and marsh deposits have accumulated in kettle ponds and depressions, particularly around drowned kettle valleys on the south shore (pl. 1). Wave action and tidal currents have constructed several bay-head beaches and spits, especially along the south shore of the peninsula. Wind-blown beach sand has also accumulated as dunes on top of the Harbor Hill end moraine in the central part of area B.

The physical properties of the upper Pleistocene outwash and stratified drift are described in logs in table 3, and mechanical analyses of samples from 28 observation wells are given in table 4. These samples are probably representative of the bulk of the upper Pleistocene deposits underlying Southold. The deposits consist mainly of angular to subangular quartz grains and rock particles and of smaller amounts of biotite, feldspar, magnetite, garnet, and hornblende. Particle diameters are commonly greater than 0.25 mm (medium sand) and most are about 0.5 mm (coarse sand).

TABLE 3.—*Logs of selected wells in the town of Southold*

[See pl. 3 for locations. "Grits" is an informal drillers' term for small gravel]

S3697

[East Marion. Village of Greenport, owner. Land surface approximately 43 ft above mean sea level; screen at 63.6 to 79.6 ft. Driller's log]

	Thickness (feet)	Depth (feet)
Loam	2	2
Upper Pleistocene deposits:		
Sand, fine, dirty	2	4
Sand, coarse; few grits; few gravel	3	7
Sand, coarse; few grits	7	14
Upper Pleistocene deposits—Con.		
Sand, coarse; grits; large gravel	26	40
Sand, coarse; few grits	17	57
Sand, very coarse; few grits	17	74
Sand, coarse, grits; layers of gravel	5.5	79.5

TABLE 3.—*Logs of selected wells in the town of Southold*—Continued

S4677

[Southhold. E. C. Smith, owner. Land surface approximately 15 ft above mean sea level; screen at 69 to 71.5 ft. Driller's log]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Recent deposits:			Upper Pleistocene deposits—Cont.		
Sand, fine	4	4	Clay, red, soft	27	62
Upper Pleistocene deposits:			Sand, coarse	9.5	71.5
Clay, black, soft	31	35			

S4788

[Southhold. Reiter's Fishing Station, owner. Land surface approximately 15 ft above mean sea level; screen at 69.5 to 74.5 ft. Driller's log]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Top soil	0.5	0.5	Upper Pleistocene deposits—Cont.		
Upper Pleistocene deposits:			Sand, fine, brown, dirty	1	65
Clay, brown	8.5	9	Sand, fine, light-brown; grits, lumps of clay.	2	67
Sand, coarse, and gravel	7	16	Sand, medium to coarse; grits; gravel.	7.5	74.5
Clay, sandy, light-brown, and grits.	42	58			
Sand, very fine, gray	6	64			

S5277

[Southhold. Eleanor C. Fitch, owner. Land surface approximately 70 ft above mean sea level. Driller's log]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Recent deposits:			Upper Pleistocene deposits—Con.		
Loam, and stones	10	10	Sand, dirty, and gravel	35	75
Upper Pleistocene deposits:			Sand, brown, and gravel	14	89
Clay, and stones	20	30	Sand, clean, and gravel	10	99
Sand, dirty	10	40			

S10091

[Cutchogue. Vincent Bokina, owner. Land surface approximately 60 feet above mean sea level; screen at 81.5 to 103 ft. Driller's log]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Top soil	2	2	Upper Pleistocene deposits—Con.		
Upper Pleistocene deposits:			gravel	50	85
Clay, sandy, gray	2	4	Sand, fine, brown	12	97
Gravel, coarse, brown	31	35	Sand, fine, brown; trace of gravel; grits	6	103
Sand, coarse, brown, and					

S12556

[Mattituck. Paul L. Ballot, owner. Land surface approximately 90 ft above mean sea level; screen at 130 to 135 ft. Driller's log]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Loam	2	2	Upper Pleistocene deposits—Con.		
Upper Pleistocene deposits:			Clay, sandy, brown	5	116
Clay, mixed with gravel	15	17	Sand, fine, brown, muddy	8	124
Sand and gravel	52	69	Sand, coarse, clean, and gravel	11	135
Clay, solid, brown	42	111			

TABLE 4.—*Physical characteristics of upper Pleistocene water-bearing deposits in the town of Southold*

Well	Depth of sample below land surface (feet)	Mechanical analysis (percent by weight)						
		<0.0625 mm	0.0625–0.125 mm	0.125–0.25 mm	0.25–0.5 mm	0.5–1 mm	1–2 mm	>2 mm
S16756	60	1.9	1.2	10.7	49.7	34.0	2.0	0.5
S16757	60	3.4	2.0	10.3	36.9	39.4	6.2	1.8
S16758	30–35	1.1	.9	8.5	51.2	36.0	1.9	.4
S16759	40–45	2.8	2.1	12.0	42.5	34.5	4.3	1.8
S16760	60–70	3.3	2.6	12.7	39.2	33.5	5.5	3.2
S16761	35–40	.7	.9	9.3	38.6	39.0	5.9	5.6
S16762	55–60	1.3	2.3	17.2	43.5	30.8	3.7	1.2
S16763	60–65	1.4	1.6	11.2	36.0	32.4	4.9	12.5
S16764	50–55	1.2	1.2	9.1	30.3	42.9	9.8	5.5
S16765	27–32	----	----	----	----	----	----	----
S16766	67–72	5.0	3.8	12.4	29.5	30.5	6.7	12.1
S16767	27–32	4.0	3.1	7.9	20.8	31.8	14.6	17.8
S16768	87–92	.8	.9	7.0	31.2	42.4	11.4	6.3
S16769	90	6.9	4.6	10.8	32.7	35.6	5.6	3.8
S16770	67–72	1.6	1.4	9.2	31.3	40.4	9.6	6.5
S16771	60–65	1.3	1.3	10.0	26.5	37.3	11.6	12.0
S16772	65–70	1.8	4.2	20.7	37.5	29.1	4.5	2.2
S16773	67–72	2.7	2.6	12.7	34.5	36.3	6.4	4.8
S16774	75–80	----	----	----	----	----	----	----
S16775	70–75	1.2	2.2	18.1	43.0	29.6	3.1	2.8
S16776	35–40	1.4	2.2	15.7	39.1	34.5	4.8	2.3
S16777	65–70	1.3	2.7	17.7	41.8	31.2	4.2	1.1
S16778	30	.7	1.3	9.9	28.0	34.5	15.7	9.9
S16779	55–60	3.2	2.4	10.1	29.9	34.8	9.2	10.4
S16780	55–60	.7	.9	8.4	28.7	44.3	12.7	4.3
S16785	30	1.4	.8	3.5	19.7	31.6	14.3	28.7
S16786	30	2.2	1.1	5.6	21.2	41.7	15.9	12.3
S16787	67–72	2.1	2.8	18.3	34.9	28.9	7.5	5.5

Sections *A–A′* through *E–E′* (pl. 2) show the subsurface geologic relations and the inferred depth to salt water in each of the areas of the Southold peninsula. Section *A–A′* (pl. 2) shows unstratified drift (till) not more than 35 feet thick exposed in the bluff at the northwestern end of the section. The log of well S4081 shows about 8 feet of clay at sea level that may be a local body of ice-shoved or reworked Gardiners(?) clay. The logs of the remaining wells indicate only outwash deposits. Section *B–B′* (pl. 2) is very much the same except for a smaller amount of till exposed in the northwestern bluffs. Section *C–C′* (pl. 2) indicates a till body about 40 feet thick exposed in the bluff above Long Island Sound and a bed of clay of late Pleistocene age about 18 feet thick in well S12151. Section *D–D′* (pl. 2) shows till about 35 feet thick exposed in the bluff, and section *E–E′* (pl. 2) shows about 20 feet of till in the bluff, which, according to the log of well S7171, thickens southeastward to almost 35 feet before thinning out or grading into the outwash deposits. Each of these sections indicates that the amount of unstratified drift is negligible in comparison to the great thickness of stratified and semistratified outwash deposits.

Section *F–F′* (pl. 2) trends approximately along the axis of the peninsula from west to east. Here as in the other sections, considerable thickness of outwash deposits are indicated at most wells. In area C the logs of wells S8608 and S11748 indicate the presence of about 60 feet of clay of late Pleistocene age; and in area D the log of well S7171, also shown in section *E–E′* (pl. 2), indicates the presence of till.

GROUND WATER

HYDROLOGY

The following discussion of ground-water hydrology refers only to the Southold peninsula (areas A, B, C, and D, Little Hog Neck, and Great Hog Neck). Available ground-water data for Robins Island are very meager, but a small body of fresh ground water occurs on the island. Only one family resides on the island at present (1960). Ground-water conditions on Plum Island have been described in some detail by Crandell (1962). The Gull Islands are uninhabited. Ponded fresh water is the principal source for public and domestic supplies on Fishers Island, which was not included in this investigation.

Precipitation, which averages about 45 inches each year, provides the only natural source of replenishment to the ground-water reservoir in Southold. A part of this precipitation flows overland to the surrounding bodies of salt water, a part is returned to the atmosphere by evaporation and by transpiration of plants, and a part seeps into the ground. Some of the seepage into the ground eventually reaches the ground-water reservoir and becomes available for withdrawal by wells.

Because of the low moisture-retention capacity of the prevailing silty-loam soil, the excellent subsoil drainage, the flatness of most of the terrain, and the absence of visible runoff during most storms, Hoffman (1961, p. 17) suggest that possibly as little as 10 percent of the annual precipitation in Southold enters the streams as direct runoff. Hoffman's estimate is accepted for use in this report.

Much of the precipitation is returned to the atmosphere by evaporation and by the transpiration of plants, collectively termed "evapotranspiration." Using a method developed by Meyer (1944, p. 457), Hoffman (1961, p. 16) estimated evaporation in Southold to be 12 inches for the year of least annual precipitation (1908), 17 inches for the year of greatest annual precipitation (1948), and 14 inches for the year in which annual precipitation closely approached the long-term average (1949). Hoffman's estimates were based on the long-term precipitation records of the Cutchogue gage. However, the U.S. Weather Bureau evaporation pan at the Greenport power house recorded about 23 inches of water evaporated in 1959, a year in which precipitation closely approached the long-term average. This evaporation was measured from a free-water surface without plant growth and open to wind from all directions. The author suggests that evaporation may possibly range from Hoffman's low estimate of 12 inches to as much as 20 inches and may average about 17 inches. This suggestion is in close agreement with the observations of Spear (1912). Meyer (1944) suggests that the average annual rate of transpiration for agricultural crops in the North Central States is from 9 to 10 inches. The nature of the crop and natural vegetative cover in Southold would favor an average rate of about 10 inches. Thus, the annual evapotranspiration rate for peninsular Southold probably ranges from 22 to 30 inches (about 16,000 to 22,000 million gallons per year).

Recharge to the ground-water reservoir in Southold is the difference between the amount of precipitation and the sum of direct runoff and evapotranspiration. This sum may range from about 75 percent of the annual precipitation in very dry years to about 65 percent in very wet years. Thus, 25 to 35 percent of the total annual precipitation would be available for recharging the ground-water reservoir. Recharge in the Southold peninsula during a year of average precipitation (assuming 13.5 inches of recharge) would be about 9,400 million gallons. This recharge is summarized for the individual areas as follows:

Area	*Average annual recharge in million gallons*
A	1,500
B	5,300
C	850
D	1,100
Little Hog Neck	160
Great Hog Neck	500
Total	9,410

The effective recharge area of area C was first reduced by about 2 square miles to allow for an area west of Greenport underlain near the surface by clay of late Pleistocene age and Wisconsin till that would inhibit recharge. The remainder of area C was then reduced by 25 percent because of paving, storm and sanitary sewers, and buildings in Greenport and vicinity. All other areas were reduced by 10 percent to allow for local near-surface till and clay deposits, paving, and built-up areas.

Most if not all the fresh ground water available for use in Southold is contained under water-table (unconfined) conditions in upper Pleistocene deposits. The fresh water occurs in a series, or chain, of irregularly shaped lenses that are bounded both laterally and at depth by glacial deposits saturated with salty ground water (pl. 2). Areas A, B, C, and D, Little Hog Neck, and Great Hog Neck are virtually separated from one another by salt-water marshes and by inlets that also are underlain by salty ground water. Consequently, these areas are treated as individual "islands of ground water," as each has a discrete fresh-water lens. Because the specific gravity of the fresh water is less than that of the underlying salt water, the fresh water tends to "float" on the salt water within the boundaries of the island generally according to the Ghyben-Herzberg principle.

Figure 3 shows the contact between fresh water and salt water

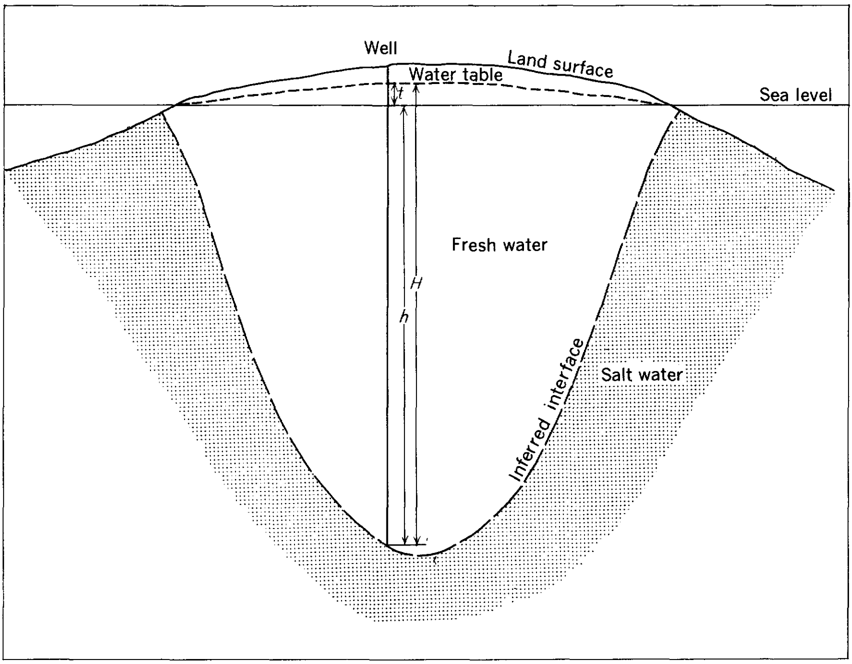

FIGURE 3.—Idealized cross section of an island showing relation of fresh water to salt water according to the Ghyben-Herzberg principle. From Petitt and Winslow (1957, pl. 8).

schematically. Fresh water fills the deposits to the depth at which its head is balanced by the head of the salt water. At equilibrium, the depth of fresh water below sea level at any point on the island is proportional to the fresh-water head above sea level and dependent on the relation of the specific gravities of fresh and salt water. This relationship is summarized in the following equation, which is often referred to as the Ghyben-Herzberg principle:

$$h=\frac{t}{g-1},$$

where

h=depth of fresh water below sea level,
t=height of fresh water above sea level, and
g=specific gravity of salt water as compared to the assumed specific gravity of 1 of fresh water.

The specific gravity of sea water varies somewhat from place to place, but the average of 1.025, if used in this equation, shows that fresh water would extend 40 feet below sea level for each foot it extends above sea level.

The zone of diffusion, or zone of mixed water between normal fresh ground water and salty ground water having the density of sea water, is assumed to be of negligible thickness in the general application of the Ghyben-Herzberg formula. Also, Hubbert (1940) has shown that the Ghyben-Herzberg formula is theoretically correct only under conditions of hydrostatic equilibrium. Although neither of these assumptions are entirely valid for the Southold area, a brief study in Greenport (Hoffman, 1961, p. 23) suggests that the 40:1 ratio may be approximately correct in some parts of the area. Therefore, owing to scantiness of data, the 40:1 relationship is used in this report to define the approximate bottom of the fresh-water lenses (pl. 2) under the Southold peninsula.

The upper surfaces of the fresh-water lenses in Southold are defined by the water table, whose configuration is shown in plate 3 by contour lines referred to mean sea level. The contours are based on water-level measurements made at the end of July 1959 in 89 observation wells.

The upper surfaces of the fresh-water lenses are marked by a chain of ground-water mounds alined along the axis of the Southold peninsula. These mounds are defined by closed contours on the water table (pl. 3). Area B apparently contains only one large and elongated mound, whose crest is at an altitude of 7 to 8 feet, about a mile north of Cutchogue. Little Hog Neck and Great Hog Neck each contains a mound with a crest altitude of slightly more than 1 and 2 feet, respectively. Area C contains three mounds represented by closed 2-foot contours. Also, a shallow cone of depression in the water table is indicated by the 1-foot contour around well S3978 in Greenport. Prior to 1950 substantial withdrawals were made from wells in this vicinity, and the cone of depression was deeper. For example, the water-table contour map of April 1950 (Hoffman, 1961, pl. 1) shows the cone of depression extending below an altitude of 0.5 foot. Since 1950 the rate of pumping has decreased; consequently, by July 1959, the cone of depression had shrunk to a volume of less than one-third that of 1950.

The movement of ground water in each of the areas of the Southold peninsula is radially outward from the crests of the ground-water mounds on the water table. The ground-water divide passes through these crests and, in general, follows the northeast trend of the peninsula. From the vicinity of this divide, ground water moves toward the surrounding salt-water bodies along flow lines whose direction is normal to the water-table contours. The local direction of movement in the horizontal plane is indicated by arrows on the contour lines. Section *B–B′* (pl. 2) shows this movement in the vertical plane also by means of arrows indicating the direction of flow. The direction and rate of flow are largely functions of the permeability of the deposits through which the water moves and of the hydraulic gradient. The net natural ground-water discharge from the peninsula by lateral outflow into the sea, which takes place mostly at or below sea level, and by evapotranspiration in marshy tracts near the shore is unknown. Hoffman (1961, p. 33) estimates that it may range from 2,500 to 6,000 million gallons annually. No data were collected during this investigation to substantiate these estimates.

Saturated upper Pleistocene deposits, whose volume is estimated to total 126,500 million cubic feet, contain the fresh ground water in storage under Southold. The estimates for the individual areas are given as follows:

Area	*Estimated volume of deposits saturated with fresh water (million cubic feet)*
A	28,200
B	82,000
C	6,400
D	6,400
Little Hog Neck	600
Great Hog Neck	2,900
Total	126,500

The estimate for each area has been reduced by 10 percent (25 percent for area C) to allow for the volume of till and clay, which contain little available water. Not all the water filling the interstices of even the coarse-textured deposits is available, however. The volume of available water is roughly equivalent to the specific yield of the deposits. Ten determinations of specific yield made on samples from wells in upper Pleistocene deposits on Plum Island (Crandell, 1962) range from 18 to 28 percent and average about 22 percent. Mechanical analyses of samples of upper Pleistocene deposits from wells on the Southold peninsula (table 4) show that they have virtually the same physical character as those of Plum Island deposits. For this reason a specific yield of 22 percent was applied in estimating the volume of fresh ground water in storage in Southold. This volume in July 1959 was computed to be about 206,500 million gallons. The volume contained in each area is as follows:

Area	*Estimated volume of fresh ground water in storage (in millions of gallons)*
A	46,000
B	134,000
C	10,400
D	10,400
Little Hog Neck	1,000
Great Hog Neck	4,700

Owing to lack of data, the zone of diffusion was considered to be of negligible thickness, and the estimates should be therefore regarded as approximate.

WATER-LEVEL FLUCTUATIONS

Seasonal variations in precipitation, pumpage for irrigation use, and changes in the rate of natural discharge are the main factors affecting fluctuations of the water table in the Southold peninsula. Water levels have been measured periodically in some observation wells in Southold for 10 years or more. The hydrographs of wells in figure 4 illustrate the trend and fluctuations of the water table in Southold from 1949 to 1959. Below-normal precipitation and recharge and concurrent heavy withdrawal for irrigation account for the low stages of the water table in late 1949, early 1950, and the summer and autumn of 1957. Heavy precipitation and recharge and light withdrawal for irrigation resulted in exceptionally high stages of the water table in the springs of 1953 and 1958.

WITHDRAWAL

Withdrawal from Southold's fresh ground-water reservoir in 1957 for public-supply, irrigation, and domestic use was estimated to be 2,400 million gallons. Of the total withdrawal about 7 percent was used for public supply, 79 percent for irrigation, and 14 percent for domestic supply. Withdrawal for public supply decreased somewhat in 1958 and 1959, but the gross withdrawal for all purposes was about the same in these years as in 1957.

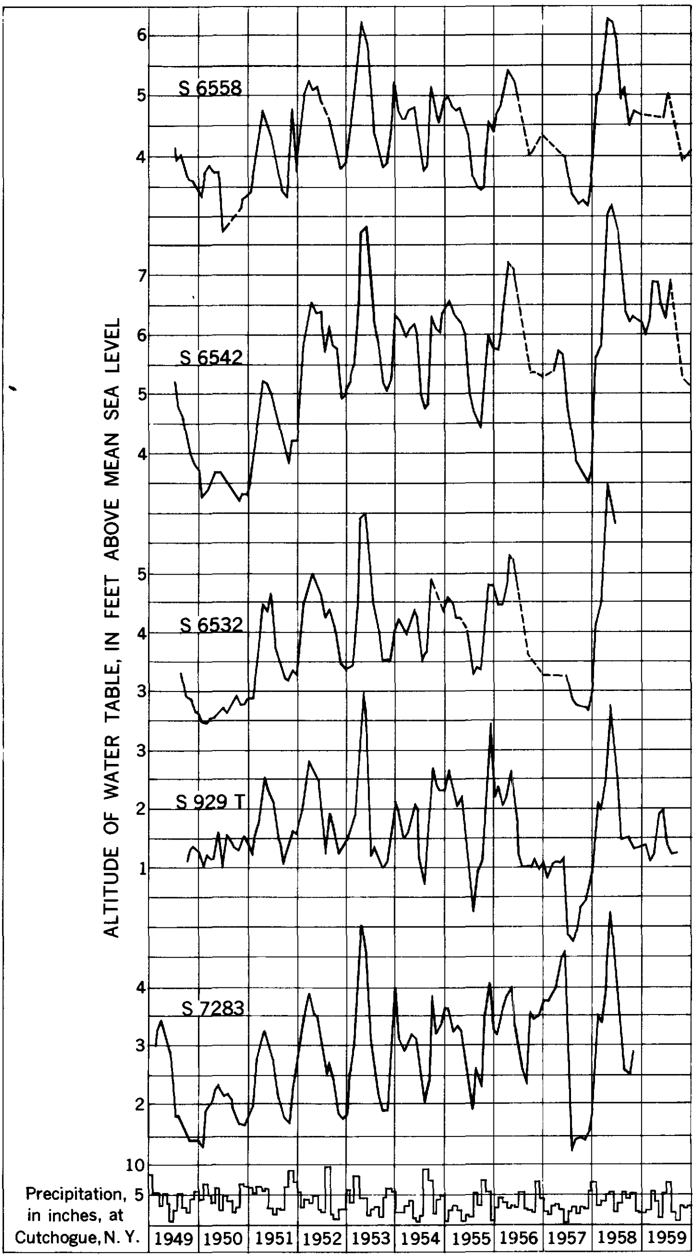

FIGURE 4.—Hydrographs of five representative wells in the town of Southold compared with precipitation records of the Cutchogue gage.

Before 1957 there were two public-supply systems in the town of Southold; the privately owned North Fork Water Co. at the village of Southold and the municipally owned village of Greenport Water Supply. The village of Greenport, however purchased the North Fork Water Co. in 1957 and now operates both systems. In 1959 the Greenport system, which withdrew water from two well fields in Greenport and one in East Marion, served 1,006 consumers. The North Fork system served 281 consumers from a well field in the village of Southold. Both systems supply water for domestic, commercial, and fire-protection needs. The Greenport system also supplied about 5.2 million gallons in 1957 and about 4.6 million gallons in 1958 for irrigation use. Although pumpage from the Greenport system increased somewhat from 1947 to 1959, the annual withdrawal from year to year has varied markedly, owing largely to seasonal demands for irrigation and lawn sprinkling, which are greater in dry than in west summers. Pumpage from the North Fork system increased steadily from 1950 through 1959. Annual withdrawals from the two systems are shown in the following table. The demand on

Year	Pumpage (million gallons)	
	Village of Greenport Water Supply	North Fork Water Co.
1947	113.5	----------
1948	131.3	----------
1949	153.6	----------
1950	114.2	3.3
1951	114.2	4.1
1952	123.6	4.1
1953	148.5	4.6
1954	161.4	4.9
1955	166.1	5.0
1956	133.5	17.0
1957	159.6	20.0
1958	130.0	20.0
1959	122.7	22.8

both systems is greatest during the tourist season—June, July, August, and September. The sewer system of the village of Greenport discharges directly into Long Island Sound, but elsewhere in Southold the water pumped for public supply and from privately owned domestic wells returns to the ground through cesspools and septic tanks.

Sprinkler irrigation of crops, particularly potatoes, accounted for a withdrawal of about 1,900 million gallons of ground water in 1957, or about 79 percent of the total ground-water withdrawal in the town of Southhold for that year. Hoffman (1961, p. 7) estimates that as much as 4,600 million gallons may have been withdrawn in 1949, a year of below-normal precipitation. Some farmers irrigate when the soil no longer cakes on being squeezed or supplement precipitation by an amount that will provide 1 inch of water each week during the growing season. Others adjust irrigation to the limitations of equipment and manpower. Correspondingly, the amount of water used and the frequency of application varies widely. Most irrigation water is withdrawn from wells, 4 to 12 inches in diameter. However, in areas with shallow water tables—nearshore in areas A, B, and C, and in most of area D—water is pumped from gangs of 4 to 10 shallow small-diameter wells or from artificially excavated ponds. Most oscillating springler heads in use in Southold distribute about 15 gpm (gallons per minute), although a few larger ones may distribute as much as 250 gpm. A substantial part of the water distributed by sprinkling systems is transpired by plants or is evaporated, and this represents a net loss from the ground-water reservoir.

Between 9,000 and 10,000 persons are not served by public-supply systems and use privately owned domestic wells. Withdrawals from these wells totaled about 325 million gallons in 1957.

Ground-water withdrawal in Southold is mostly from driven and drilled wells, which range from 1¼ to 12 inches in diameter. The smaller diameter driven wells are used mainly for domestic supply, whereas the larger diameter drilled wells are used for irrigation and public supply. The following table summarizes well-screen data for

Area	Number of wells observed	Approximate depth of bottom of screen below mean sea level		Length of screen	
		Range (feet)	Median (feet)	Range (feet)	Median (feet)
A	30	2–121	35	4–26	15
B	140	0–163	32	2–25	15
C	36	0–52	23	3–20	3
D	22	0–32	12	3–15	3
Little Hog Neck	7	0–15	10	3–10	10
Great Hog Neck	8	10–39	18	3–15	15

243 wells. Most large-diameter irrigation and public-supply wells are equipped with deep-well turbine or submersible pumps, whereas the smaller diameter domestic wells are equipped with jet pumps. Where the depth to water does not exceed suction lift, gasoline, diesel, or electrically operated centrifugal pumps are used. Dug wells no longer are constructed in Southold, but many old ones remain in use. Some artifically excavated ponds are used in area D to supply water for irrigation. These are usually constructed where the water table is less than 8 feet below the land surface.

In an ideal hydrologic system discharge equals recharge plus or minus changes in ground-water storage. The system is unbalanced when natural discharge is augmented by artificial discharge from wells. Balance is reestablished when recharge replaces the water artificially withdrawn from storage. Recharge to the ground-water reservoir in Southold during a year of average precipitation totals about 9,400 million gallons and averages about 26 mgd (million gallons per day). Ideally, pumpage could be allowed to approach this amount. For practical purposes, however, withdrawal must be kept well below this amount to minimize demand on storage and thus prevent sea-water encroachment. If recharge in 1959 (a year of average precipitation) was about 9,400 million gallons and pumpage was approximately 2,400 million gallons, then pumpage amounted to about 25 percent of the recharge on the Southold peninsula. On the basis of known geologic and hydrologic conditions, withdrawal generally should not exceed 30 percent of the annual recharge. Larger withdrawals could be made probably in areas A and B, at least intermittently, where points of withdrawal are widely spaced and the volume of fresh ground-water storage is relatively large. In areas C and D, however, where the total recharge and the volume of fresh-water storage are relatively small and present (1959) heavy withdrawals are concentrated at a few points, continuous pumping in excess of present rates may induce sea-water encroachment.

SEA-WATER ENCROACHMENT

The fresh ground-water supply of the Southold peninsula is potentially subject to sea-water encroachment because the fresh-water lenses that underlie the peninsula are bounded laterally and below by a zone of diffusion and an underlying body of salt water. The fresh water generally has a chloride concentration of less than 40 ppm (parts per million). The chloride concentration of water in the zone of diffusion increases from about 40 ppm on the fresh water side to about 18,000 ppm on the salt water side. The thickness of the zone of diffusion varies widely, depending on such factors as lithology, changes in fresh-water head, pattern of movement of fresh water, and tidal fluctuations, which affect heads in the fresh and salt water. No data on the thickness of the zone of diffusion in Southold were collected for this report. For the sake of simplicity of analysis and representation, the zone of diffusion was assumed to be of negligible thickness on plate 2. The underlying body of salty ground water probably has a choloride content of 16,000–18,000 ppm, as in sea water. Encroachment may occur where wells that are screened close to the boundary between fresh and salt water are pumped heavily and cause an upward or landward migration of the salty water. Where the land surface is low and relatively unprotected, as along the south shore, salt water from high tides or storm waves also may inundate the vicinity of wells and contaminate the fresh ground water by direct downward seepage. Figure 5 illustrates schematically the manner

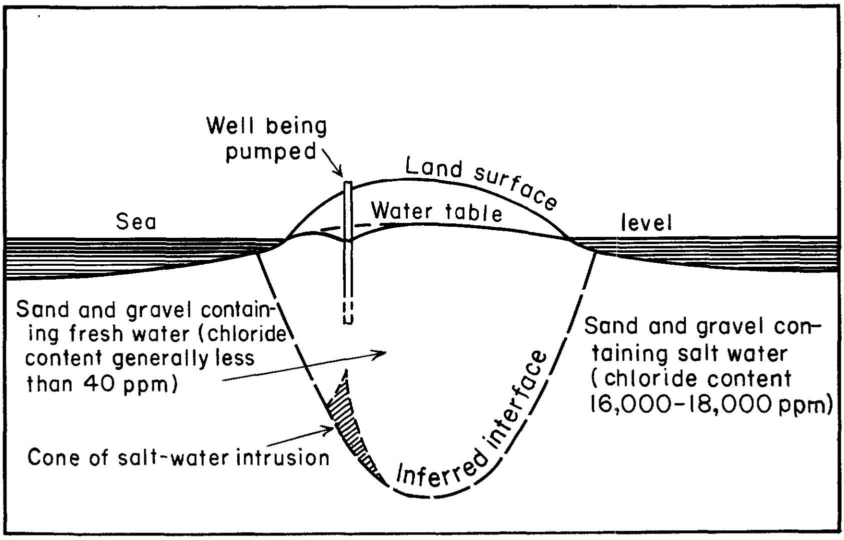

FIGURE 5.—Schematic section showing vertical movement of salty ground water toward a pumping well (zone of diffusion assumed to be of negligible thickness).

in which a cone of salt water may be drawn up toward a pumping well. Figure 6 shows how it may migrate laterally and vertically toward a pumping well, where the cone of depression has extended to the shoreline.

Available data indicate that clay and other deposits of low permeability underlie some parts of the Southold peninsula. If these deposits were extensive, they would provide some degree of protection against the migration of salt water toward pumping wells. Data from well logs, however, suggest that these deposits are probably local and discontinous and, therefore, would have little if any effect in retarding sea-water encroachment.

Hoffman and Spiegel (1958) recorded several instances of salt-water contamination of the fresh ground water of Southold. In area B (pl. 3) and on Little Hog Neck, four wells (S4091, S6059, S5475, and S5476) yielded water having chloride concentrations ranging from 103 to 1,600 ppm between 1950 and 1952. Each well was drilled within about 500 feet of the south shore and probably penetrated the zone of diffusion or was contaminated by lateral migration of the zone of diffusion.

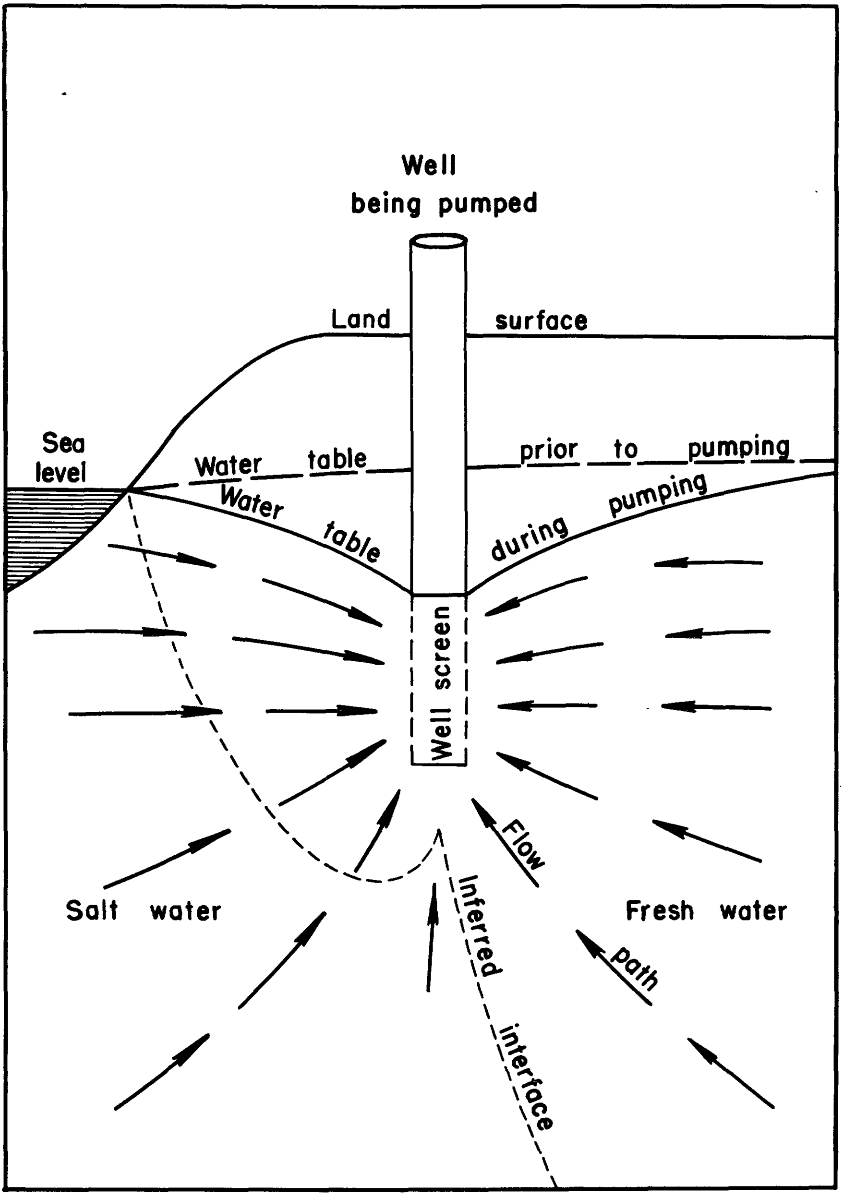

FIGURE 6.—Schematic section showing lateral and vertical movement of salty ground water toward a pumping well (zone of diffusion assumed to be of negligible thickness).

In area C (pl. 3) several wells (S1673–S1678, S1668, and S1669) in the village of Greenport yielded water having chloride concentrations ranging from 76 to 424 ppm between 1949 and 1951. As these wells are 0.5 mile from any shoreline, contamination probably took place by migration of the zone of diffusion.

In area D (pl. 3) two wells (S7176 and S14597) yielded water having chloride concentrations ranging from 296 to 1,000 ppm, and two irrigation ponds near the south shore had water ranging from 100 to 5,810 ppm of chloride. The determinations of chloride concentrations were made between 1948 and 1952, which was a period when precipitation was generally less than normal, the water table was at below normal stage, and withdrawal of water for irrigation was above normal. Lateral migration of the zone of diffusion probably caused the high chloride concentration.

In recent years chloride determinations made on water from some of these wells and ponds indicate a substantial decrease in chloride concentration. For example, in area C, wells S1673–S1678 had chloride concentrations averaging about 70 ppm in the summer of 1959 as compared with about 125 ppm in May 1952 (table 4). Also chloride concentrations in artificial ponds in area D ranged from 15 to 450 ppm in September 1957 but ranged from 100 to 5,810 ppm in 1948–52.

CHEMICAL QUALITY

The natural chemical quality of most of the fresh ground water of Southold is good to excellent (table 5), except in a few places where sea-water contamination has caused some increase in chloride content (p. GG28–GG31). The fresh water generally meets U.S. Public Health Service limits, which were suggested for interstate carriers in 1946 as follows:

	Concentration (ppm)
Iron (Fe) and manganese (Mn) combined	0.3
Magnesium (Mg)	125
Chloride (Cl)	250
Sulfate (SO_4)	250
Total solids (desirable)	500
Total solids (permitted)	1,000

Hardness of water from wells of the North Fork Water Co. and from the village of Greenport system (table 4) ranges from 44 to 200 ppm. Although no official classification for hardness of water is available, Lamar (1942) cites the following classification as being generally acceptable:

Range of hardness (parts per million)	*Description*
1–60	Soft
61–120	Moderately hard
121–200	Hard
$\geqq$ 201	Hard to very hard

TABLE 5.—*Chemical analyses, in parts per million, of water from public-supply wells in the villages of Greenport and Southold*

Well	Date of collection	Source of analysis	Total iron (Fe)	Total manganese (Mn)	Calcium (Ca)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total hardness as $CaCO_3$	pH
North Fork Water Co. (village of Southold)												
S169	Nov. 13, 1933	U.S. Geol. Survey						28				
S169, S170, S3045, and S4163 combined.	Mar. 6, 1956	New York State Health Dept	1.5	<0.01				37		71	176	6.4
Do	Dec. 11, 1956	do	.10					43		44		7.5
Do	Aug. 7, 1947	do	.50					26	0.1	31	104	6.8
Village of Greenport												
S178	Oct. 11, 1932	U.S. Geol. Survey	0.22		11	25	18	45		10		
S1668	Nov. 29, 1949	New York State Health Dept	.10	0.50				84	<0.05	18	96	5.5
S1668	May 30, 1952	S. C. McLendon	.15	.40				60			162	6.5
S1669	do	do	.05	.05				92			200	6.5
S3697	do	do	.10	.05				35			115	5.9
S3698	do	do	.05	.05				30			87	6.1
S1668, S1669, S3973 through S3977 combined.	Nov. 28, 1950	New York State Health Dept						270	.1	.17	76	6.9
S1670, S1671, S1672, S3978 combined.	May 30, 1952	S. C. McLendon	.05	.05				38			44	
S1673 through S1678 combined	do	do	.15	.20				127			112	5.9

Thus, most of the water sampled can be classed as moderately hard or hard. The iron content of the water is less than 0.3 ppm for all samples, except two that contain 0.5 ppm and 1.5 ppm. The pH of water sampled ranges from 5.5 to 7.5, but most of the water is acidic (pH less than 7.0).

The chloride content of water from public-supply wells, which were uncontaminated or moderately contaminated by sea water, ranged from 26 to 270 ppm. In other wells—used for domestic, irrigation, or fire-protection purposes—the chloride content of the water ranged as follows:

Chloride concentration of water in private wells screened in upper Pleistocene deposits, Southold, N.Y., 1958–1959

Area (pl. 3)	Number of wells observed	Range (ppm)	Median (ppm)
Area A	12	8–38	14
Area B	43	8–48	16
Area C	4	28–36	34
Area D	12	14–54	26

CONCLUSIONS

Water-bearing deposits of Late Cretaceous and late Pleistocene age underlie the Southold peninsula. The known fresh ground-water supply, however, is contained only in the upper Pleistocene deposits under water-table conditions. The peninsula is naturally divided into six islandlike areas, each having a fresh ground-water lens that is in dynamic balance laterally and at depth with salty ground water in probable accordance with the Ghyben-Herzberg principle. The deposits containing fresh ground-water have relatively uniform hydraulic characteristics and are moderately to highly permeable. Deposits of low permeability occur only locally. Fresh water can be drawn from wells or ponds almost everywhere on the peninsula provided that (1) they are not too close to the shoreline, (2) the screens of wells are not set too deeply below the water table, or (3) heavy withdrawals are not concentrated in small areas. Sea-water encroachment is likely where these conditions are not fulfilled.

Fresh ground water in storage probably exceeds 207,000 million gallons, and average recharge is sufficient to balance losses due to withdrawals from wells and to natural discharge to the sea.

Hoffman and Spiegel (1958) reported some salt-water contamination of wells and ponds during the period 1948–52, when precipitation was below normal and withdrawals for irrigation and public supply were high. The current (1960) degree of contamination is not critical.

With the exception of locally high concentrations of iron and manganese, the chemical quality of the fresh ground water is good and is satisfactory for most uses.

A water-level and chloride-monitoring program, which would be intensified during periods of below-normal precipitation and increased withdrawal, should be maintained on a continuing basis in Southold. Definite evidence of sea-water encroachment or overdevelopment of the ground-water reservoir can be established only by the accumulation of such data over a considerable period of time.

Chemical analyses of water from representative wells should be made at periodic intervals to determine changes in iron content, hardness, and other constituents important to consumers. Also, water samples from wells in relatively densely populated areas should be analyzed periodically for synthetic-detergent content.

The contact between fresh and salt water shown on plate 2 is theoretical and assumes a sharp boundary that does not exist in nature. For simplicity of analysis, the zone of diffusion is assumed to be of negligible thickness. In each of the hydrologic areas of Southold, the depth and thickness of the zone of diffusion and movement of the salty water need to be determined with much more precision than available data allow. The construction of "outpost" wells in the central part of each area and at selected points on the periphery would give the required data. The wells should terminate in or near the top of the zone of diffusion between fresh water and salt water. Periodic determinations of the chloride concentration of the water from the wells and measurement of water levels would indicate whether salty water is moving upward or inland. "Outpost" wells drilled to a depth of 250–300 feet below the land surface in the central part of areas A and B and 100–200 feet below the land surface in the central part of areas C and D would provide the required information.

In general, new production wells probably should not be located within 1,000 feet of salty surface water or within 300 feet of each other. These spacings may be adjusted somewhat for shallow small-diameter wells that are pumped by suction lift and that have a low rate of withdrawal, but large-diameter wells used for large withdrawal would require greater spacing. The hazard of salt-water contamination can be markedly reduced by appropriate well spacing and construction. Greater use of field tensiometers to measure soil moisture should prove helpful in conserving water pumped for irrigation.

The amount of available ground water in Southold is comparatively small, and all reasonable measures should be taken to conserve the supply and to control withdrawal, especially during periods of below-normal precipitation. A small increase in withdrawal over the amount withdrawn in 1957–59 probably is permissible in areas A and B, provided that withdrawal is not concentrated locally or centered too closely to salt-water bodies. Hydrologic data indicate that the available ground-water supply in areas C and D (pl. 3) has almost reached full development; consequently, sustained withdrawal substantially exceeding that prevailing in 1957–59 would probably induce sea-water encroachment in these areas.

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STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

CONTENTS

[The letters in parentheses preceding the titles designate separately published chapters]