Geology and Ground-Water Conditions in Southern Nassau and Southeastern Queens Counties Long Island, N.Y.

By N. M. PERLMUTTER *and* J. J. GERAGHTY

RELATION OF SALT WATER TO FRESH GROUND WATER

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1613-A

Prepared in cooperation with the New York State Water Resources Commission and the Nassau County Department of Public Works

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1963

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

CONTENTS

ILLUSTRATIONS

[All plates in pocket]

TABLES

GEOLOGY AND GROUND-WATER CONDITIONS IN SOUTHERN NASSAU AND SOUTHEASTERN QUEENS COUNTIES, LONG ISLAND, N.Y.

By N. M. Perlmutter and J. J. Geraghty

ABSTRACT

Test drilling, electrical logging, and water sampling of "outpost" and other wells have revealed the existence of a deep confined body of salt water in the Magothy(?) formation beneath southwestern Nassau and southeastern Queens Counties, Long Island, N.Y. In connection with a test-drilling program, cooperatively sponsored by the U.S. Geological Survey, the Nassau County Department of Public Works, and the New York State Water Resources Commission (formerly Water Power and Control Commission), 13 wells ranging in depth from about 130 to 800 feet were drilled during 1952 and 1953 and screened at various depths in the Magothy(?) formation and Jameco gravel. On the basis of the preliminary geologic, hydrologic, and chemical data from these wells, a detailed investigation of ground-water conditions from the water table to the bedrock was begun in a 200-square-mile area in southern Nassau and southeastern Queens Counties. The main purposes of the investigation were to delineate the bodies of fresh and salty ground water in the project area, to relate their occurrence and movement to geologic and hydrologic conditions, to estimate the rate of encroachment, if any, of the salty water, and to evaluate the effectiveness of the existing network of outpost wells as detectors of salt-water encroachment.

About a million people in the report area, residing mainly in southern Nassau County, are completely dependent on ground water as a source of supply. Fortunately, precipitation averages about 44 inches per year, of which approximately half is estimated to percolate into the ground-water reservoir.

The ground water is contained in and moves through eight differentiated geologic units composed of unconsolidated gravel, sand, and clay, of Late Cretaceous, Pleistocene, and Recent age, having a maximum total thickness of about 1,700 feet. The underlying metamorphic and igneous crystalline basement rocks are of Precambrian age and are not water bearing.

The water-yielding units from the surface down are (1) the upper Pleistocene deposits, (2) the principal artesian aquifer, composed of the Jameco gravel and Magothy(?) formation, and (3) the Lloyd sand member of the Raritan formation. The confining units are the "20-foot" clay, the Gardiners clay, and the clay member of the Raritan formation. The upper Pleistocene deposits contain an extensive unconfined body of fresh water. Fresh water under artesian conditions is contained in the principal artesian aquifer and the Lloyd sand member. The piezometric surface of the principal artesian aquifer is similar in shape to the south-

ward-sloping water table; it ranges in altitude from about sea level to 55 feet above.

The chemical quality of the fresh ground water in most of the area in all aquifers is good to excellent, and concentrations of dissolved solids and of chloride generally are below 100 ppm (parts per million) and 10 ppm, respectively. Analyses of water samples from selected wells show no progressive increase in concentration of chloride in most of the area. The data on quality of water have been used to delineate one major and several minor bodies of salty ground water. The wedge-shaped main confined salt-water body, in which the concentration of chloride reaches about 17,000 ppm, is in the Magothy(?) formation and Jameco gravel in extreme southwestern Nassau County and southeastern Queens County. The base of the salt-water wedge is about at the top of the clay member of the Raritan formation. Beneath the barrier beach in south-central and southeastern Nassau County a shallow extension of the main confined salt-water body contains as much as 4,000 ppm of chloride and is separated from the lower main salt-water body by fresh ground water. Shallow, thin bodies of unconfined salty ground water are common in the upper Pleistocene and Recent deposits adjacent to salty surface water in tidal creeks, bays, and the Atlantic Ocean.

Water-level records for the western part of the area indicate that the water table declined as much as 20 feet and that the piezometric surface of the principal aquifer declined as much as 7 feet from about 1895 to 1955. In the eastern part of the area there apparently has been no permanent decline of water levels since at least 1903. Hydrographs of selected wells show the relation between recharge and discharge of ground water and the hydraulic interconnection between water in the Jameco gravel and that in the Magothy(?) formation. Relatively good hydraulic separation of the Lloyd sand member from the other units is indicated by hydrographs and chemical data.

In 1954 about 163 mgd (million gallons per day) of fresh water was pumped, mainly for public supply, in southern Nassau and southeastern Queens Counties. Most of this water was pumped from wells within the project area. About 47 percent of the pumpage came from the upper Pleistocene deposits, about 46 percent from the principal aquifer, and about 7 percent from the Lloyd sand member. Part of the water was returned to the ground through cesspools and septic tanks; part was lost to the sea through sewers; and part was exported from the area by New York City.

The deep artesian aquifers are recharged by downward leakage from the overlying unconfined water in the northern part of the area and by underflow from the area north of the project limits. Discharge takes place by upward leakage near and beyond the shoreline. Fresh water in the principal aquifer discharges above the main confined salt-water body in southwestern Nassau County.

Salty ground water in the principal aquifer is believed to be encroaching very slowly, at rates of less than 100 feet per year at most places. Locally, near centers of pumping, the rate may be higher. Landward gradients in the main confined salt-water body are due to the influences of local pumping near the contact of the fresh and salt waters and of regional pumping accompanied by general lowering of water levels, and perhaps also the influence of a slow postglacial rise in sea level. The presence of a landward gradient is indicated by observed negative heads in the main confined salt-water body in southwestern Nassau County and by deficiencies of head in the confined fresh water in southeastern Nassau County. Hydrostatic heads and densities of water in additional wells tapping the salt-water body are needed to determine the rates and directions of movement and the landward limit of the salt water more accurately.

Calculations based on the Ghyben-Herzberg formula yield erroneous values for depths to the fresh-salt water contact in the confined aquifers in the report area. A formula in a report by M. K. Hubbert gives more accurate depths and explains the hydraulic interrelation between positive heads in the fresh water and negative heads in the salty water.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

This report is concerned primarily with sea-water encroachment in southern Nassau and southeastern Queens Counties, in the western part of Long Island, N.Y. (fig. 1). More than a million people

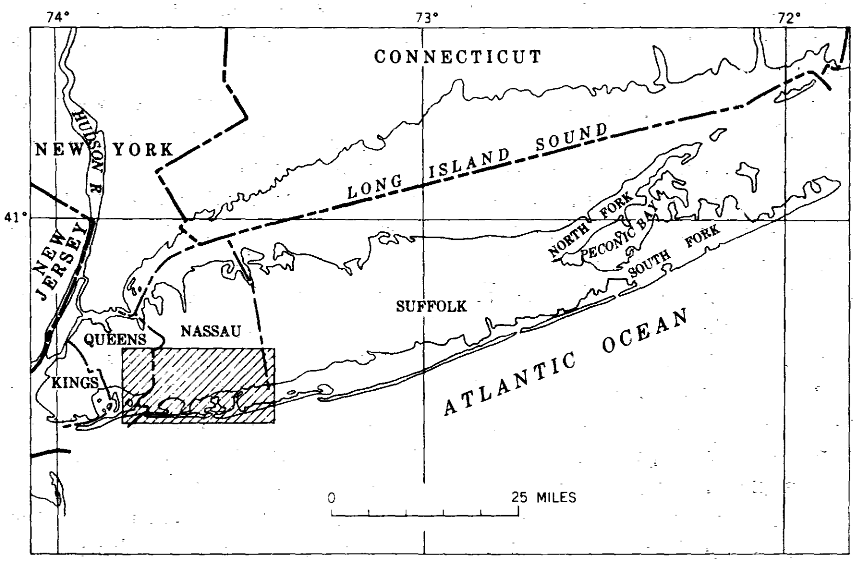


FIGURE 1.—Map of Long Island, N.Y., showing area of investigation.

residing in this area are completely dependent on ground water as a source of supply.

Precipitation on Long Island averages about 44 inches per year and is the only source of natural replenishment of the ground-water reservoirs, which extend for some distance beneath the Atlantic Ocean and Long Island Sound. The reservoirs contain salt water in hydraulic continuity with fresh water in some inland areas; consequently, maximum development of fresh ground water involves a knowledge of the effect of pumpage on landward movement of the adjacent salty ground water.

As a result of rapid growth in population and the accompanying increase in water use in Nassau County, especially since 1945, the U.S. Geological Survey, Nassau County agencies, the New York

State Water Resources Commission, and other organizations became increasingly concerned with the danger to public and private water supplies through landward movement of salty ground water. Accordingly, in 1952 a cooperative investigation of the problem of salt-water encroachment was undertaken in the southern part of Nassau County and the adjoining area of southeastern Queens County.

The purposes of the investigation were to determine the geologic and hydrologic conditions that bear on the occurrence and movement of fresh and salty ground water in the area; to delineate the vertical and horizontal extent of major bodies of salty ground water; to determine the reasons for the presence of salt water; to relate current withdrawals to the rate of movement of salt water; and to establish a network of monitoring or "outpost" wells and to evaluate its effectiveness.

Initially, the program involved the drilling of outpost wells at critical places in southern Nassau County between existing public-supply wells and areas known or suspected to be underlain by salt water. Between February 1952 and November 1953, 8 deep outpost wells were drilled by the rotary method, 1 each in the following communities: Cedarhurst (N3861), Lawrence (N3862), Woodmere (N3864), Oceanside (N3865), Hewlett Bay Park (N3866), Green Acres (N3867), Merrick (N4149), and Freeport (N4150). Wells on Long Island are designated by a letter and a number assigned by the New York State Resources Commission. The letter is the first initial of the name of the county in which the well is located. Numbers are assigned consecutively beginning with No. 1 in each county. These localities and wells are shown on Plate 1. The wells were drilled to depths ranging from about 400 to 800 feet and were screened at various depths in permeable beds of the Magothy(?) formation of Late Cretaceous age.

At each of the 8 deep wells, cores of the deposits were taken at intervals ranging from 5 to 20 feet, and an electric log was run. Drawdown and recovery of water levels during and after pumping were measured in each well, and estimates of aquifer characteristics were made from these data. In an attempt to inhibit or prevent corrosion of the casings of two of the wells (N4149 and N4150) where they passed through shallow deposits containing salty ground water, the following measures were taken: (1) The upper 100 feet of casing was wrapped with plastic tape; (2) the taped part was painted with bitumastic paint, a waterproofing compound; and (3) the annular space between the drilled hole and casing was grouted with a mixture of clay and cement.

In addition to the deep outpost-wells, 5 relatively shallow outposts wells ranging in depth from about 130 to 300 feet were drilled by the

Nassau County Department of Public Works. Four of these, drilled by the cable-tool method, were screened in the Jameco gravel. The fifth well was never completed. Samples of water and of the material penetrated were obtained in each of the shallow wells. A sixth well screened in the Jameco gravel, formerly used as a supply well at the Mill Road Station of the Long Island Water Corp. in Woodmere, also has provided useful data on water levels. Four of the six shallow wells (N1379, N3932, N4062, and N4213) are within 10 to 30 feet of the deep outpost wells in Woodmere, Cedarhurst, Lawrence, and Green Acres, respectively. One shallow well is at the town dock in Hewlett Neck (N4026), and one, which is incomplete, is at Atlantic Beach (N3863). In 1949 a deep observation well (N2790) was constructed to tap the Magothy(?) at Bay Park. The location and depth of this well make it suitable for use as an outpost well. The outpost wells are listed as follows:

Well	Locality	Depth to bottom of screen (feet)	Geologic formation
N2790	Bay Park	560	Magothy(?) formation.
N3861	Cedarhurst	533	Do.
N3862	Lawrence	306	Do.
N3863	Atlantic Beach	(1)	
N3864	Woodmere	470	Do.
N3865	Oceanside	565	Do.
N3866	Hewlett Bay Park	411	Do.
N3867	Green Acres	517	Do.
N3932	Cedarhurst	176	Jameco gravel.
N4026	Hewlett Neck	153	Do.
N4062	Lawrence	142	Do.
N4149	Merrick	562	Magothy(?) formation.
N4150	Freeport	745	Do.
N4213	Green Acres	134	Jameco gravel.

[1] Incomplete. Drilled to 217 ft. Destroyed in 1959.

A chemical analysis of a sample of the water from each outpost well, except for N2790 and N3863, was made at the time of drilling, and periodic determinations of the chloride content of the water from all wells have been made subsequently. For two of the deep wells which penetrate salty water (N3861 and N3862), additional complete chemical analyses were made in 1953 and 1956. Water-stage recorders installed at each of the deep outpost wells and at the shallow companion wells provided nearly continuous records of water-level fluctuations for several years after completion of drilling.

Data regarding many deep public-supply and private wells were obtained in the field when the wells were drilled, or later from drillers. Supplementary information on pumpage, water levels, and water quality was obtained from records of private water companies, the New York State Water Resources Commission, and the Nassau County Department of Public Works. Water-stage recorders were operated for short periods on unused private wells and on some newly constructed public-supply wells.

The data and conclusions presented in this report are based on information available through the spring of 1957. A summary of the data pertinent to the fresh-salt water relation has been published (Perlmutter and others, 1959). In 1958 and 1959 additional test wells were drilled to explore further the main salt-water body delineated in this report. (N. J. Lusczynski and W. V. Swarzenski, 1960).

The work is part of the overall investigation of the ground-water resources of Long Island that has been in progress since 1932 by the U.S. Geological Survey in cooperation with the New York State Water Resources Commission, the Nassau County Department of Public Works, the Suffolk County Board of Supervisors, and the Suffolk County Water Authority.

PREVIOUS INVESTIGATIONS AND ACKNOWLEDGMENTS

The geology in relation to the water supplies of Long Island has been described in early reports by Burr and others (1904), Veatch and others (1906), Spear (1912), and Fuller (1914). These reports provided geologic information and records of water levels and water quality dating back more than 50 years. More recent works containing data directly applicable to this investigation include reports on the altitude of the water table by Jacob (1945a) and by Lusczynski and Johnson (1951), on pumpage for public supplies by Johnson and Waterman (1952), and on a modern treatment of the subsurface geology by Suter and others (1949). A large amount of unpublished data in the files of the Geological Survey and of the New York State Water Resources Commission were examined and used in this report.

The authors acknowledge with appreciation the cooperation of the agencies and individuals interested in this report, particularly the New York State Water Resources Commission and the Nassau County Department of Public Works. The Long Island Water Corp. made available pumpage and chemical data and several water-level observation wells. The Bureau of Water Supply of the New York City Department of Water Supply, Gas, and Electricity and many water districts and water companies also generously contributed information on wells, pumpage, chemical quality, and water levels. Well-drilling firms, especially C. W. Lauman and Co., Inc., Layne-New York Co., Inc., and Mathies Well and Pump Co. supplied logs of wells, drill cuttings, and cores.

The construction of the outpost wells was planned and begun under the supervision of M. L. Brashears, Jr., district geologist prior to April 1952; the drilling in 1952 was largely completed under the supervision of N. J. Lusczynski, acting district geologist from May to October 1952, who also made helpful suggestions relating to the hydrologic and hydraulic conditions in the area. The remainder of the investigation and the preparation of the report was under the direction of J. E. Upson, district geologist from October 1952 to May 1957, who gave considerable guidance and assistance to the authors in the interpretation and presentation of the data. The final review was completed under the supervision of G. C. Taylor, Jr., former district geologist for the Mineola district.

LOCATION AND DESCRIPTION OF THE AREA

The area considered in this report is in southwestern Long Island, N.Y., approximately between 73°24′ and 73°48′ west longitude and between 40°35′ and 40°44′ north latitude. It occupies roughly the southern third of Nassau County and the southeastern quarter of Queens County, a part of New York City (fig. 1 and pl. 1). The area contains about 200 square miles, including bays, lagoons, islands, and barrier beaches.

The project area lies entirely within the glaciated part of the Atlantic Coastal Plain physiographic province. Most of the land surface in the area is a gently rolling slightly dissected southward-sloping plain. This plain has an average grade of about 20 feet per mile from an altitude of some 80 feet at the north to sea level at the south. The relatively even surface is cut by very shallow valleys that contain streams or lakes. Most of the lakes are reaches of the streams that have been ponded artificially for purposes of water supply or recreation. The plain is bordered on the south by tidal marshes, mud flats, and partly interconnected shallow bays, which occupy an area of about 40 square miles, or 20 percent of the total area. The bays are generally less than 10 feet deep, but locally channels have been dredged to depths of as much as 40 feet. This area of bays and marshes is nearly continuous across the width of Nassau County but is separated from Jamaica Bay in Queens County by the Rockaway Peninsula.

The bays and marshes are separated from the open ocean by barrier beaches. These beaches rise from sea level to as much as 20 feet above and are a few tenths of a mile to a mile wide. They are broken by artificially deepened inlets at Atlantic Beach and Jones Beach, and in a few places their natural configuration has been modified by artificial fill. The beaches are separated by open water from adjacent marshes or from Long Island proper, except at Rockaway Peninsula.

The plain that occupies most of the project area continues beyond the north boundary except where it terminates against the irregular hills that form the Harbor Hill moraine in the northwest corner in Queens County (pl. 1). These hills rise 100 feet or more above the plain and reach an altitude of as much as 200 feet.

Two more topographic features deserve mention. One is the Rockaway Peninsula in southwestern Nassau County. This peninsula is a low northeastward-trending ridge that separates Jamaica Bay from other bays to the east and connects the main part of Long Island with the barrier beach. The ridge rises about 30 feet above the adjacent marshy lowlands and about 25 feet above the southernmost part of the sloping plain to the north. The origin of the ridge is unknown. There are no similar ridges elsewhere along the south shore. Core samples and logs of several wells drilled on the peninsula show that the deposits beneath the ridge are similar to glacial outwash deposits beneath other parts of the plain.

The other feature warranting mention is the area of the New York International (Idlewild) Airport, which was a tidal swamp but has been made into land by artificial fill.

The project area is drained chiefly by 13 streams which flow into the marshes and bays in southern Nassau County. A few minor creeks drain small parts of southern Nassau and southeastern Queens Counties. These streams are characteristically dry in their headwater reaches, but where the stream beds intersect the water table the flow is perennial and consists almost entirely of ground-water discharge.

Gaging stations were operated by the U.S. Geological Survey in 1956 on Watts Creek, Wantagh Stream, Massapequa Creek, East Meadow Brook, and Pine Brook, the five largest streams in southern Nassau County. These stations are upstream from the Sunrise Highway and are 1 to 2 miles above the tidal inlets into which the streams flow (pl. 1). Continuous records for the past 19 years have been obtained on all except the Watts Creek station, which was established in 1954. The total average discharge of these streams is about 51 cfs (cubic feet per second), or about 33 mgd. Some miscellaneous measurements of discharge were made on eight other streams in southern Nassau County. These indicate an average discharge of about 42 cfs or 27 mgd. The total discharge of the streams for which there are measurements is about 93 cfs or 60 mgd. As the measured and estimated discharge represents approximately 80 percent of the total discharge (oral communication, R. M. Sawyer, U.S. Geol. Survey, 1956), an average of about 75 mgd probably is discharged by streams in southern Nassau County.

There are no gaging stations in Queens County, and no recent estimates of discharge have been made for streams in that area. Comparison of recent topographic maps with those made more than 50 years ago shows that several of the tributaries of streams in southeastern Queens have ceased flowing and that the perennial reaches of the main streams themselves have been reduced considerably in length, because the water table has been lowered by pumping.

PRECIPITATION

Average precipitation on the project area is between 42 and 45 inches annually and is fairly evenly distributed throughout the year. In southern Nassau County, 11 precipitation stations were in operation in 1955; the period of record is 76 years at stations maintained by New York City in south-central Nassau County, but it is less than 1 year at a recently installed gage at Massapequa Park. A rain gage at Mitchell Field Air Force Base, in central Nassau County near the northern boundary of the project area, has been operated continuously since 1920; a gage at the Mill Road Station of the Long Island Water Corp., in Woodmere, has been in operation continuously since 1927; gages at Mineola and Freeport have been maintained by the Nassau County Department of Public Works since 1937 and 1946, respectively. Figure 2 is a composite graph which shows average annual precipitation from 1879 to 1954 at stations operated by New York City in the Baldwin-Rockville Centre area of southern Nassau County. From 1879 to 1910, the station was at Hempstead Lake; from 1911 to the middle of 1916, it was in Rockville Centre; and from mid-1916 to

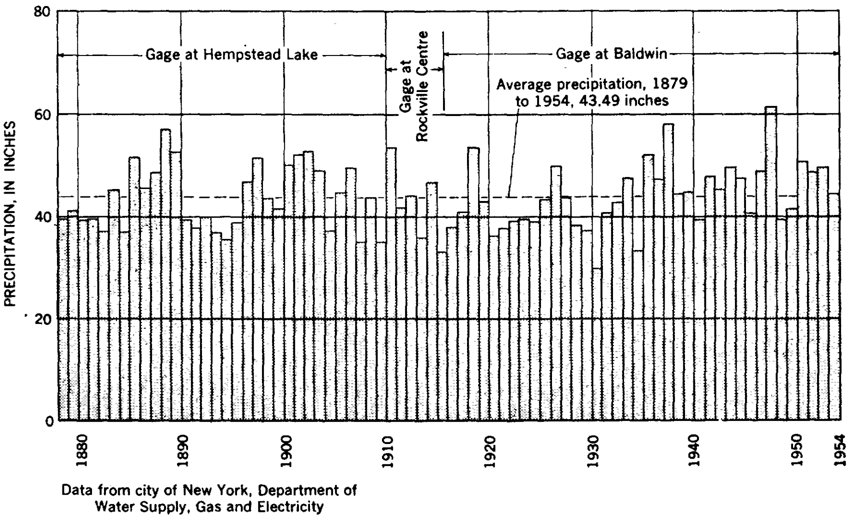


FIGURE 2.—Annual precipitation in south-central Nassau County, 1879–1954.

1954, it was in Baldwin, near well N62 at the Milburn Pumping Station.

Figure 2 shows that there have been few long periods of deficient or excessive rainfall from 1879 to 1954, although there is a record at the Milburn station of almost 12 inches of precipitation in a single month (September 1938), and a record of no precipitation at all in June 1949. The highest annual precipitation reported from this station was 60.54 inches in 1948; the lowest was 29.87 inches in 1931. Average precipitation for the entire 76-year period was 43.49 inches.

Comparison of ground-water levels and precipitation on Long Island shows a correlation between these elements. Further discussion of this relation appears in the section "Fluctuations of water levels."

DEFINITIONS OF SPECIAL TERMS

The definitions that follow are of terms commonly used in reports of the Geological Survey. A few, particularly those pertaining to salt-water encroachment, are defined with reference to their special usage in this report.

Anion.—A negatively charged ion in a solution of an electrolyte.

Aquiclude.—A formation, part of a formation, or a group of formations which although porous and capable of absorbing water slowly, will not transmit it fast enough to furnish an appreciable supply for a well or spring (Tolman, 1937).

Aquifer.—A formation, part of a formation, or a group of formations that is water bearing (Meinzer, 1923b).

Artesian pressure.—Mainly the same as hydrostatic pressure. (See "Head.")

Cation.—A positively charged ion in a solution of an electrolyte.

Confined ground water.—Ground water that is under sufficient pressure to rise above the level at which it is found in a well, but which does not necessarily rise above the surface of the ground (Sayre, 1936).

Confining layer.—Same as aquiclude.

Electric log.—The log of a well or bore hole obtained by lowering electrodes in an uncased hole and measuring the electrical properties of the formation traversed. The log consists of a self-potential (spontaneous-potential) curve and one or more resistivity curves.

Flow section.—Vertical section showing directions of flow by means of arrows, and head relations by means of isopotential lines.

Head (pressure head).—Hydrostatic pressure expressed as the height of a column of water that can be supported by the pressure (Meinzer, 1923b). In this report the head is expressed in feet above or below mean sea level (Sandy Hook datum, adjustment of 1929).

Hydraulic gradient.—As applied to an aquifer it is the rate of change of pressure head per unit of distance of flow at a given point and in a given direction (after Meinzer, 1923b).

Hydrostatic pressure.—(See "Head.")

Isochlor.—Line along which the concentration of chloride in water is equal.

Isopotential line.—Line of equal potential or head in a vertical flow section.

Permeability.—Ability of a water-bearing material to transmit water. The coefficient of permeability is the rate of flow of water, in gallons per day, through a cross section of 1 square foot under a unit hydraulic gradient at a temperature of 60°F. The field coefficient is not corrected for temperature and describes the flow at the prevailing water temperature (after Stearns, 1928).

Piezometric surface.—An imaginary surface that everywhere coincides with the static level of the water in the aquifer. It is the surface to which the water from a given aquifer will rise under its full head (after Meinzer, 1923b).

Porosity.—The ratio of the aggregate volume of interstices in a rock or soil to its total volume. Usually stated as a percentage (after Meinzer, 1923b).

Salinity.—The concentration of dissolved solids in parts per million. Sometimes used qualitatively to express saltiness.

Salt-water bodies.—Water having a relatively high concentration of chloride, generally in the form of wedges, lobes, or tongues in an aquifer.

Wedge.—A body of salt water of broad extent, having a linear landward boundary in plan view and thickening seaward from a featheredge in vertical section.

Lobe.—A body of salt water having the form, in plan, of a broadly rounded protrustion from a major body of salt water; it is wedge shaped in vertical section.

Tongue.—A body of salt water having sharply converging sides, in plan view, pointing toward a center of pumping; it is wedge shaped in vertical section.

Salt-water encroachment.—Movement of a body of salty water so as to displace, either permanently or temporarily, fresh ground water in an aquifer.

Specific capacity.—The rate of yield of a well per unit of drawdown, generally gallons per minute per foot of drawdown (after Wenzel, 1942).

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

654861—62——2

Transmissibility coefficient.—The rate of flow of water, in gallons per day at the prevailing temperature, through each vertical strip of the aquifer 1 foot wide having a height equal to the thickness of the aquifer and under a unit hydraulic gradient (after Theis, 1938). The coefficient of transmissibility equals the field coefficient of permeability times the height of aquifer, in feet.

Unconfined ground water.—Water in an aquifer that has a water table.

Uniformity coefficient.—An expression of the variety of sizes of grains that constitute a granular material. It may be defined as 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 (after Meinzer, 1923b).

Water table.—Upper surface of the zone of saturation except where that surface is formed by an impermeable body (Meinzer, 1923b).

Water-table contour.—A line on a map depicting the water table and along which all points have the same altitude with reference to mean sea level.

Zone of diffusion.—Intermediate zone of "mixed" water in an aquifer, grading from fresh water at one extreme to salt water at the other.

Zone of saturation.—Zone in which the functional rock interstices are filled with water under hydrostatic pressure (after Meinzer, 1923b).

GEOLOGY

STRATIGRAPHIC SUMMARY

The formations within the project area have been described in general terms in previous reports dealing with the entire island, the most recent being that of deLaguna and Perlmutter (Suter and others, 1949). In the present report the formations are described and delineated on the basis of detailed information obtained from test drilling and from other sources.

Eight units of unconsolidated deposits and the underlying bedrock are delineated in this report. The unconsolidated deposits are Late Cretaceous, Pleistocene, and Recent in age. Four of the units of unconsolidated deposits underlie the entire area; the other four occur only in the southern part. The total thickess of the unconsolidated deposits ranges from about 750 to 1,700 feet; the maximum is in the southeast. The stratigraphic units are given in table 1, with summaries of their lithologic characteristics and water-bearing properties. The structure of the units is shown in figure 3, a generalized section from north to south in central Nassau County. Their detailed lithologic characteristics are shown in the geologic sections (pl. 2) and are described in the well logs (table 12). The areal distribution of the exposed units is shown on plate 1.

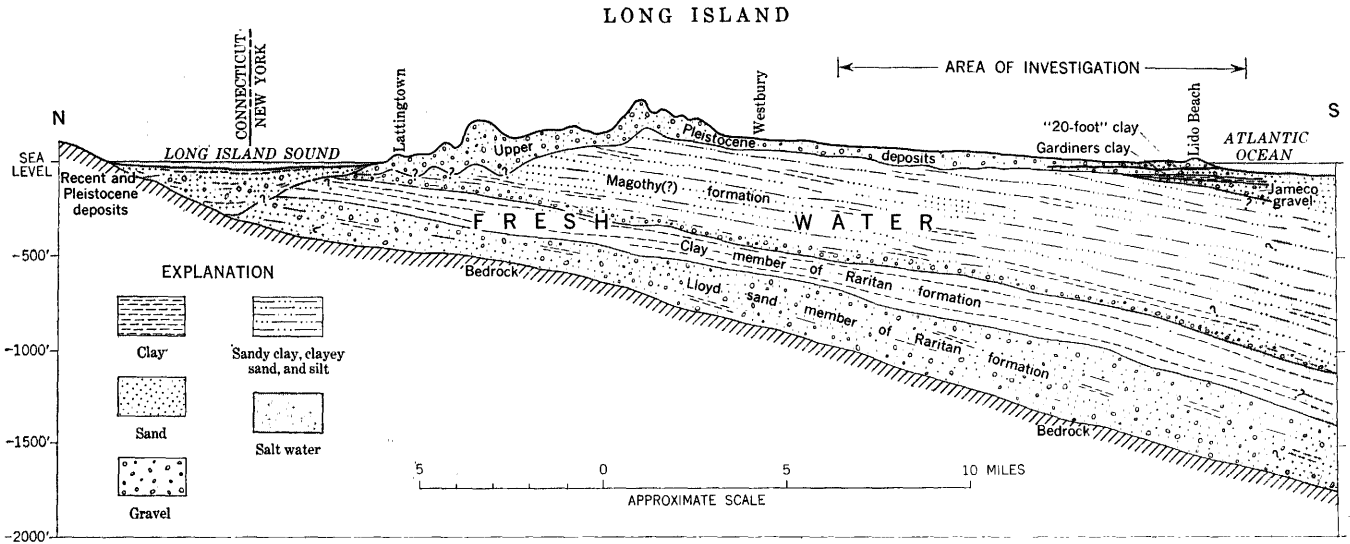


FIGURE 3.—Generalized section showing stratigraphic units in central Nassau County, N.Y.

TABLE 1.—*Summary of the stratigraphy and water-bearing properties of the deposits underlying southern Nassau and southeastern Queens Counties, N.Y.*

System	Series	Geologic unit	Approximate thickness (feet)	Depth from land surface to top (feet)	Character of deposits	Water-bearing properties
Quaternary	Recent	Recent deposits Artificial fill, salt-marsh deposits, and shore deposits.	0–40	0	Sand, gravel, clay, silt, organic mud, peat, loam, and shells. Colors are gray and brown.	Permeable sandy beds beneath barrier beaches yield fresh or salty water at shallow depths. Clay and silt beneath bays retard salt-water encroachment and confine underlying aquifers.
	Pleistocene	Upper Pleistocene deposits: Till and outwash	30–300	0–40	Till, composed of clay, sand, and boulders in form of terminal moraine in northwestern part of area. Outwash consists mainly of brown fine to coarse sand and gravel, stratified. In southern part interbedded with "20-foot" clay.	Till is relatively impermeable but unimportant hydrologically owing to limited distribution. Sand and gravel part of outwash highly permeable; yields as much as 1,700 gpm per well reported. Specific capacities of wells as much as 109 gpm per ft of drawdown. Water generally unconfined except beneath shallow clays in southern part of area. Water fresh except near shoreline.
		Upper Pleistocene deposits: "20-foot" clay	0–40	25–80	Clay and silt, gray and grayish green; some lenses of sand and gravel. Contains shells, Foraminifera, and peat. Altitude of top about 20 ft below mean sea level. Interbedded with outwash in southern part of area.	Relatively impermeable confining unit. Retards salt-water encroachment in shallow deposits.
		- - Unconformity? - -				
		Gardiners Clay	0–140	55–160	Clay and silt, grayish-green; some lenses of sand and gravel. Contains lignitic material, shells, glauconite, Foraminifera, and diatoms. Interglacial deposit. Altitude of surface about 50 ft or more below mean sea level.	Relatively impermeable confining layer above Jameco gravel. Lenses and perhaps channel fillings of sand provide paths for movement of water locally.
		- - Unconformity? - -				
		Jameco gravel	0–150	70–250	Sand, fine to coarse, dark-gray and brown; gravel. Contains some thin beds of silt and clay. Thought to be early glacial outwash.	Highly permeable. Yields as much as 1,300 gpm to individual wells. Specific capacities as much as 135. Contains water under artesian pressure. Water generally has high iron content and is salty near shoreline.

		Unconformity				
Cretaceous	Upper Cretaceous	Magothy(?) formation	30–1,000	40–350	Sand, fine to medium, gray; interfingered with lenses of coarse sand, sandy clay, silt, and solid clay. Generally contains gravel in lower 50 to 100 ft. Some sandy zones and beds of clay may be extensive. Lignite and pyrite abundant.	Moderately to highly permeable. Principal source for public supply. Yields large quantities of water from several zones. Individual wells yield as much as 2,200 gpm. Specific capacities as much as 80. Water contained under artesian pressure; some wells in southern part of area flow. Water generally is of excellent quality except where contaminated by salty water in southwestern part of area.
		Unconformity				
		Raritan formation: Clay member	100–300	400–1,100	Clay, gray, white, and some red and purple: in solid silty and rarely sandy lenses. Some lenses of sand and gravel. Lignite and pyrite abundant.	Relatively impermeable confining unit between the Magothy(?) formation and the Lloyd sand member. Lenses and layers of sand and gravel locally permit more rapid movement of water. Retards but does not prevent movement of water.
		Raritan formation: Lloyd sand member.	150–300	600–1,500	Sand, fine to coarse, gray and white, and gravel; some lenses of solid and sandy clay, and clayey sand. Thin beds of lignite locally.	Moderately permeable. Yields as much as 2,000 gpm to individual wells. Specific capacities as much as 44. Water contained under artesian pressure; some wells flow. Water of good quality except for high iron content.
		Unconformity				
Precambrian		Bedrock	----------	750–1,700	Crystalline metamorphic and igneous rocks; schist, gneiss, and granite. Soft, clayey weathered zone at top, as much as 50 ft thick.	Relatively impermeable. Contains some water in joints and fault zones, but impracticable to develop.

The bedrock consists of crystalline rocks—schist, gneiss, and granite—and lies at depths of about 750 to 1,700 feet below the land surface. Its surface is fairly even and slopes about 80 feet per mile to the southeast. The most recent contour map of the bedrock surface is that given by Suter and others (1949).

Immediately above the bedrock is the Raritan formation, which consists of the Lloyd sand member and the overlying clay member. The name of the formation is derived from the type locality of the beds, which crop out along the Raritan River in New Jersey. On the basis of similar lithology and plant fossils, the Raritan formation was identified in Long Island by early investigators whose works were summarized by Veatch (1906, p. 22–23) and Fuller (1914, p. 77). The name Lloyd sand member was first assigned by Veatch (1906, p. 19) to the coarse-textured beds in the lower part of the Raritan formation which were penetrated by a well at Lloyd Neck, Suffolk County. He showed that the Lloyd was an extensive unit on Long Island and also continued into New Jersey to the southwest. The clay member of the Raritan formation on Long Island has not been assigned a formal name.

Above the clay member of the Raritan formation is a thick sequence of sand, silt, clay, and some gravel which has been tentatively assigned to the Magothy(?) formation. The question mark is used after the name to indicate the uncertainty regarding the designation. A brief summary of the origin of the name Magothy(?) is necessary to understand its use in this and other reports on Long Island. The type locality of the formation is along the Magothy River in Maryland. The name was first applied to the Long Island deposits by W. O. Crosby in an unpublished report (Nov. 12, 1910) to the Chief Engineer of the Board of Water Supply, City of New York, which states (p. 42–43) that the Magothy formation is probably not less than 500 feet and may be as much as 1,000 feet thick. Crosby thought also that the Raritan and Magothy formations formed the bulk of the deposits on Long Island and that beds of the Matawan and Monmouth group which normally overlie the Magothy in New Jersey were probably missing from most of Long Island, owing to erosion. Crosby's stratigraphic correlations apparently were based mainly on the fact that the Magothy formation immediately overlies the Raritan formation in New Jersey and also on an assumed thickening of the Magothy formation from a maximum of about 200 feet in New Jersey to about 1,000 feet in Long Island. Fuller (114, p. 77) suggested that beds equivalent to the Magothy formation and to the younger Matawan, Monmouth, and Rancocas groups of New Jersey are probably present in Long Island, but he gave neither paleontologic nor other criteria for identifying these units, which differ from the formations in New Jersey in the lack of thick fossiliferous greensand units. Thompson and others (1937, p. 451–457), in a paper on the geology of Long Island, accepted Crosby's interpretation that the lower part of the Cretaceous deposits of Long Island consisted largely of the Raritan formation and the upper part mostly of the Magothy(?) formation. DeLaguna and Perlmutter (Suter and others, 1949, p. 8, 36) also used the name Magothy(?) but indicated that the correlation of the formation was uncertain, and that the unusual thickness could be attributed either to a thickening of the deposits from New Jersey to Long Island or to the inclusion of unidentified younger formations in the unit.

Paleontologic evidence of the occurrence of post-Raritan Cretaceous formations younger than the Magothy formation was given by Perlmutter and Crandell (1959) in an article which described a Late Cretaceous marine greensand unit in extreme southern Suffolk County. This greensand unit is considered to be equivalent in age to the Monmouth group of New Jersey. It is the uppermost deposit of Cretaceous age in southern Suffolk County and is underlain by nonmarine beds which are lithologically similar to those assigned to the Magothy(?) formation in the project area. The greensand unit is not known to be present either in Nassau or Queens Counties. Laboratory studies of pollen and spores have been started to correlate the post-Raritan deposits of Cretaceous age. Pending completion of these studies, use of the name Magothy(?) formation is continued in this report.

Overlying the Magothy(?) formation are several units of Pleistocene age which, from oldest to youngest, are the Jameco gravel, the Gardiners clay, and the upper Pleistocene deposits. The first two are discrete formations. The unit referred to as upper Pleistocene deposits embraces all the deposits of Late Pleistocene age that are younger than the Gardiners clay. The unit includes several sequences of glacial outwash differentiated by earlier investigators (Veatch, 1906; Fuller, 1914) but not separated in the present study, a body of till (that of the Harbor Hill moraine), and a shallow-water marine clay to which the name "20-foot" clay is assigned in this report. Discontinous deposits of Recent age overlie the upper Pleistocene deposits.

DESCRIPTION AND WATER-BEARING CHARACTERISTICS OF THE STRATIGRAPHIC UNITS

UPPER CRETACEOUS SERIES

RARITAN FORMATION

The Raritan formation of Late Cretaceous age is the lowest formation of unconsolidated deposits in the report area. It rests directly on the crystalline bedrock and is overlain by the Magothy(?) formation. It occurs beneath the entire area but does not crop out. The thickness ranges from about 300 to 600 feet. On the basis of lithology the formation is divided into a lower unit named the Lloyd sand member and an upper clay member that has no specific name.

LLOYD SAND MEMBER

The name Lloyd sand member is applied to the deposits between the clay member of the Raritan formation and bedrock. These deposits are composed chiefly of beds of gray and white sand and gravel, which are fine to coarse in texture and which generally contain some interstitial clay. Interbedded with the coarser sediments are lenses of sandy clay and nearly pure clay neither thick enough nor extensive enough to justify consideration of the Lloyd sand member as other than a single hydrologic unit. Lithologic characteristics of the unit are shown by well logs (see N3687, N5227, and N4405 in table 12) and electrical logs in the geologic section *C–C'* on plate 2. The occurrence of marine beds in the Raritan formation in New Jersey provides a basis for assuming that the Lloyd grades into marine beds, perhaps of lower permeability, at some distance offshore. The depth to the top of the Lloyd sand member ranges from about 600 to 1,500 feet below the land surface. The altitude of the top of the Lloyd in the project area and adjoining areas is shown by Suter and others (1949, pl. 11). The thickness of the Lloyd increases from about 150 to 300 feet toward the southeast.

Water in the Lloyd sand member is confined, and in some places, wells tapping the unit flow. Static water levels in most wells in the southern part of the project area are about 10 to 16 feet above mean sea level. In the northeastern part of the project area, in Nassau County, water levels were as high as 25 feet above mean sea level in 1956. In central Queens County, water levels in the Lloyd are commonly below sea level owing to heavy pumping, but on the barrier beach to the south they are about 10 feet above sea level. Interference effects have been detected at wells as much as 7 miles from centers of pumping (Leggette, 1937, p. 490–494).

Estimates of the hydraulic properties of the Lloyd sand member have been made at a few places. Jacob (1941, p. 783–787) made an aquifer test of several days' duration in the Lloyd sand member at Rockaway Park in southern Queens County. He determined that the coefficient of transmissibility of the aquifer is about 190,000 gpd per ft, the coefficient of permeability is about 900 gpd per sq ft, and the coefficient of storage is about 0.0003. These data are introduced here mainly for comparison, as the lithologic and water-bearing characteristics of the Lloyd sand closely resemble those of the gravelly zone at the bottom of the Magothy(?) formation.

Most of the supply wells that tap the Lloyd are in barrier-beach communities in southern Nassau County, but a few are in central and eastern Queens County. These wells range in depth from about 600 to 1,200 feet; some have yielded as much as 2,000 gpm.

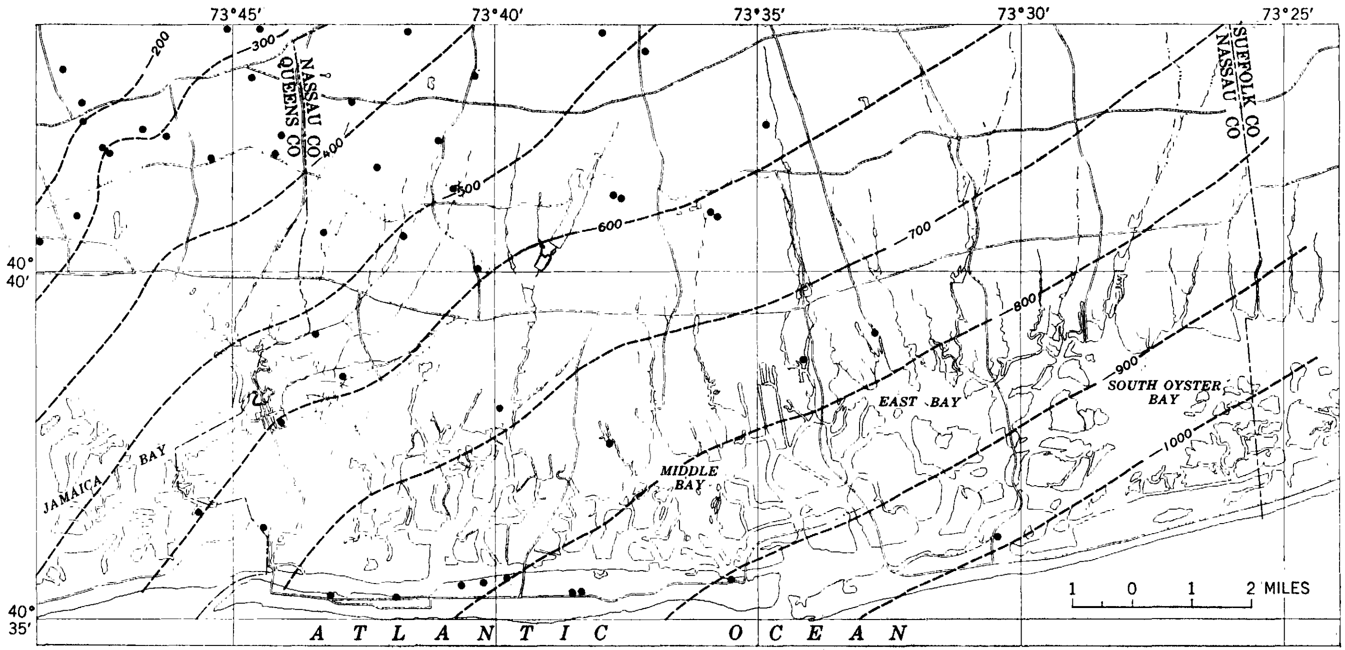
CLAY MEMBER

The clay member of the Raritan formation is an extensive and thick unit which forms approximately the upper half of the formation. It overlies the Lloyd sand member throughout the project area and is in turn directly overlain by the Magothy(?) formation (pl. 2). The clay member consists chiefly of beds of silt and clay and some lenses of sand, sandy clay, and sand and gravel. Laminae of silt and clay alternate commonly with beds of pure clay. The predominantly clayey and silty composition is confirmed by the low resistivity shown on electric logs (pl. 2). The clay is described in many well logs as tough and plastic. The upper and lower contacts of the clay member in most places are sharply defined by changes from clay or sandy clay to sand or gravel.

The beds of clay and silt are light and dark gray, red, white, and variegated. The beds of sand are light gray and white. Lignite occurs in thin layers interbedded with clay and silt or as disseminated particles. Pyrite and marcasite are commonly associated with the lignite. The fine-grained texture, abundance of lignite, and the lack of marine fossils indicate that the clay member was deposited in near-shore fresh-water swamps and lakes and on broad flood plains of sluggish streams.

The thickness of the clay member ranges from about 100 to 300 feet, increasing toward the southeast. Figure 4 shows contours on the surface of the clay member. The surface has a general southeastward slope and ranges in depth from about 400 to nearly 1,100 feet below the land surface. In parts of Queens and Kings Counties, where the clay member is thinner and its top is at a higher altitude, there is evidence from well logs of considerable dissection of the member, and in some places, valleys have been cut completely through it. However, such deep valleys were delineated within the project area.

Although completely saturated with water, the clay member is not a source of water, owing to its low permeability. It functions mainly as a confining unit (aquiclude), transmitting water at very low rates. Its effectiveness as an aquiclude is indicated by the differences in hydrostatic head and quality of water in the aquifers above and below it. For example, on the barrier beaches in the southern part of the area, the hydrostatic head in the Lloyd sand member is as much as 10 feet higher than that in the lower part of



EXPLANATION

● Well penetrating clay member of Raritan formation

– – – 200 – – – Structure contour
Drawn on surface of clay member of the Raritan formation. Contour interval is 100 feet; datum is mean sea level

FIGURE 4.—Configuration and altitude of the top of the clay member of the Raritan formation.

the Magothy(?) formation; farther inland the reverse is true and hydrostatic heads in the Lloyd are as much as 30 feet lower than those in the Magothy(?) formation. The clay member also retards the movement of salt water from the overlying Magothy(?) formation into the underlying fresh water in the Lloyd sand member in the southwestern part of the project area.

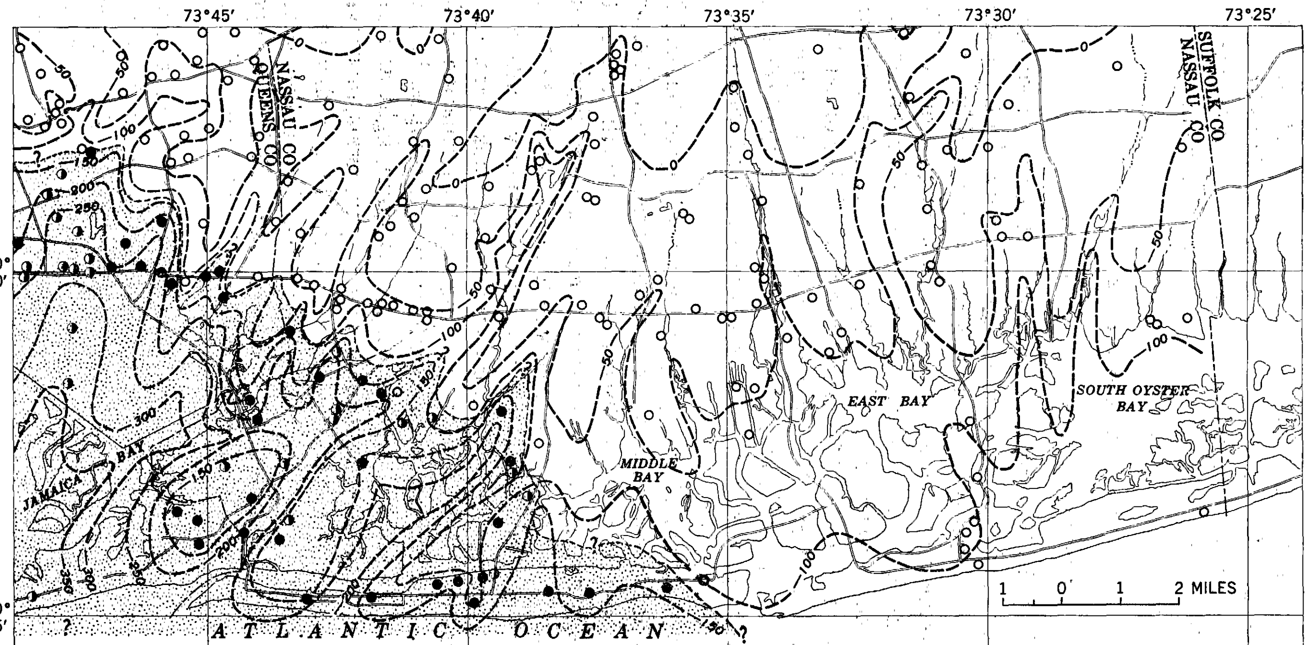
MAGOTHY (?) FORMATION

GENERAL FEATURES AND LITHOLOGY

The name Magothy(?) formation is given to the thick sequence of nonmarine deposits of Late Cretaceous age which overlie the Raritan formation. The Magothy(?) is overlain unconformably at some places by the Jameco gravel and at others by younger units of Pleistocene age. The bottom contact, which is probably an erosional unconformity, can be recognized in most logs by a change from gravelly beds of the lower part of the Magothy(?) to beds of clay or sandy clay in the Raritan formation. The upper contact can be recognized by differences in color, texture, and composition between the beds of the Magothy(?) formation and the Jameco gravel, Gardiners clay, or upper Pleistocene deposits.

Most of the sand of the Magothy(?) formation is gray or tan and fine to medium grained in contrast to the generally brown coarse-textured Jameco gravel and upper Pleistocene deposits. Furthermore, the sand of the Magothy(?) consists mostly of quartz, some lignite, muscovite, and about 2 to 3 percent of heavy minerals, whereas the sand of the Jameco and upper Pleistocene deposits commonly contains an abundance of biotite, feldspar, hornblende, and rock particles in addition to quartz. The clay of the Magothy(?) formation differs from the clay of Pleistocene age in color, mineralogic composition, and fossil content. The clay of the Magothy(?) is white, light and dark gray, yellow, tan, or black and is composed of clay minerals, muscovite, and quartz. No marine fossils have been found in the clay of the Magothy(?) formation within the project area, but pollen grains, spores, and lignite are common. In contrast, clay of Pleistocene age is commonly grayish green and contains biotite, chlorite, some glauconite, and marine fossils.

The Magothy(?) occurs throughout the entire project area, where its thickness ranges from about 30 to 1,000 feet and its top ranges from about 10 feet above to about 350 feet below sea level. The contours shown on figure 5 indicate that the surface is a gently sloping plain that was moderately to highly dissected by streams flowing



EXPLANATION

Extent of Jameco gravel

○ Well penetrating Magothy(?) formation

◑ Well penetrating Jameco gravel

● Well penetrating Jameco gravel and Magothy(?) formation

—300— Structure contour
Drawn on top of the Magothy(?) formation. Contour interval is 50 feet; datum is mean sea level

FIGURE 5.—Configuration and altitude of the top of the Magothy(?) formation and the extent of the Jameco gravel.

south and southwest. These streams cut valleys to depths of 100 to 200 feet below the general level of the plain and possibly more than 350 feet below present sea level in southeastern Queens County. The streams were part of a pre-Jameco drainage system which joined a master stream, problably the ancestor of the present Hudson River, southwest of the project area. Some of the valleys of these ancient streams contain highly permeable deposits of the Jameco gravel.

The materials of the Magothy(?) formation occur in a complex alternation of beds and lenses of clay, silt, sand, and some gravel, as well as some mixtures of these basic types. Individual layers range from a fraction of an inch to a few tens of feet in thickness, and all seem to be discontinuous laterally. Gravelly beds as much as 50 feet thick, commonly containing an abundance of interstitial clay and silt, are extensive in the lower part of the formation. In a few places, as at well N3862 (fig. 12), the gravelly beds are missing. The beds of clay or of silt are thin laminae in some places and as much as 50 feet thick in others, but most are less than 20 feet thick. The thickest clays generally occur immediately above the lower gravelly beds. The nonmarine beds of the Magothy(?) formation probably grade seaward into more clayey marine beds.

As a means of making an approximate statistical analysis to show the varied lithology of the Magothy(?) formation and to distinguish materials of high, intermediate, and low permeability, the sediments described in well logs were grouped into three classes: (1) Sand and gravel; (2) sand, silt, and clay mixtures; and (3) clay and silt. The three classes generally are distinguishable on the basis of descriptions and mechanical analyses of core samples (table 2), descriptions given in drillers' and geologists' logs, and studies of electrical logs.

Class 1 includes beds of sand, sand and gravel, and gravel, estimated to contain not more than about 10 percent of clay and silt. Material in this class is usually described as "clean" by well drillers and is regarded as excellent material in which to finish wells. The phrase "trace of clay or silt" as used in geologists' or drillers' logs in this report is interpreted to mean that the material contains 10 percent or less of clay or silt. Class 2 includes deposits described as sand and clay, sand with some clay, sandy clay, clayey sand, silty sand, and "dirty" sand. The clay or silt content may range from slightly more than 10 to about 80 percent. Class 3 includes sediments described as clay and silt and contains not more than 20 percent of very fine to fine sand. Identification of materials of class 3 was based mainly on megascopic examination of core samples and descriptions given in logs. No mechanical analyses were made of cores composed entirely of silt and of clay.

TABLE 2.—*Mechanical analyses of selected core samples*

[All analyses made by C. W. Lauman and Co., Inc. Grain-size classification used by U.S. Geol. Survey: granules, 2.0–4.0 mm; very coarse sand, 1.0–2.0 mm; coarse sand, 0.5–1.0 mm; medium sand, 0.25–0.50 mm; very fine sand, 0.062–0.125 mm; silt and clay, < 0.062 mm]

Well	Depth range (feet)	Cumulative percent retained by weight (size of grain, in mm)										Percent passed through sieve size, in mm		Uniformity coefficient
		Granules			Very coarse sand		Coarse sand		Medium sand	Fine sand		0.210	0.149	
		4	2.8	2.00	1.68	1.19	0.840	0.590	0.420	0.210	0.149			
N3861	55.63	0	0	0	0	1.3	3.4	8.8	21.6	67.0	87.7	----------	12.3	2.1
	147–149	(*)	(*)	(*)	10.0	20.0	42.4	76.0	91.8	96.3	96.8	----------	3.2	2.1
	428–430	(*)	5.6	9.3	(*)	17.6	25.7	35.3	46.6	80.7	(*)	19.3	----------	5.0
	437–538	(*)	1.0	1.5	(*)	3.0	5.0	9.5	18.5	61.0	(*)	39.0	----------	----------
	457–458	0	.5	1.0	(*)	3.0	5.5	14.0	34.5	90.0	(*)	10.0	----------	2.0
	467–469	(*)	8.0	13.5	(*)	19.5	24.5	30.5	43.0	84.0	(*)	16.0	----------	2.6
	499–501	(*)	5.0	9.0	(*)	19.5	33.5	50.0	65.5	86.5	(*)	13.5	----------	4.8
	509–510	0	0	0	(*)	1.0	3.0	11.5	22.5	84.5	(*)	15.5	----------	2.5
	520–521	0	0	0	(*)	2.0	7.5	21.5	49.0	90.5	(*)	9.5	----------	2.2
	531–533	(*)	2.0	3.5	(*)	8.0	14.0	26.5	54.0	90.5	(*)	9.5	----------	2.5
N3862	291–292	0	0	0	(*)	0	0	.5	26.0	89.0	(*)	11.0	----------	2.0
	302–304	0	0	0	(*)	.25	.5	6.0	64.5	92.0	(*)	8.0	----------	2.2
	312–314	0	0	0	(*)	0	0	1.5	10.5	74.5	(*)	25.5	----------	2.1
	390–392	0	0	0	(*)	0	.25	1.0	2.0	39.0	(*)	61.0	----------	----------
	399–401	0	0	0	(*)	0	.5	1.7	7.0	57.0	(*)	43.0	----------	3.2
	409–411	0	0	0	(*)	0	.25	.75	4.5	84.5	(*)	15.5	----------	1.6
	418–420	0	0	0	(*)	0	0	.5	3.5	68.5	(*)	31.5	----------	2.0
	427–428	0	0	0	(*)	0	0	1.5	7.0	78.0	(*)	22.0	----------	1.9
	437–438	0	0	0	(*)	.25	1.0	7.5	42.5	87.0	(*)	13.0	----------	2.1
	448–450	0	0	0	(*)	0	0	1.6	13.3	82.3	(*)	17.7	----------	1.6
	459–461	0	.25	.75	(*)	3.5	5.0	6.25	10.0	33.5	(*)	66.5	----------	----------
	502–504	0	0	.5	(*)	.75	1.0	2.0	11.0	69.0	(*)	31.0	----------	2.4
N3864	342–343	0	1.9	3.16	(*)	4.42	6.32	22.8	67.6	89.2	(*)	10.8	----------	2.6
	442–443	0	0	.75	(*)	1.50	3.00	8.27	27.8	84.2	(*)	15.8	----------	2.1
	462–463	0	0	0	(*)	.35	1.05	2.8	11.2	72.8	(*)	27.2	----------	2.2
N3865	230–231	0	0	0	(*)	0	1.0	1.5	3.5	70.0	91.0	----------	9.0	2.0
	279–280	0	0	0	(*)	0	0	.5	5.5	86.0	91.5	----------	8.5	2.1
	289–290	0	0	0	(*)	0	0	1.0	15.0	91.5	94.0	----------	6.0	1.7
	392–393	0	0	0	(*)	.5	1.0	2.0	22.0	84.0	89.5	----------	10.5	2.8
	402–403	0	0	1.5	(*)	3.0	3.5	6.0	28.0	74.0	81.0	----------	19.0	4.7
	412–413	0	0	2.0	(*)	2.5	3.0	8.0	32.0	78.5	86.0	----------	14.0	3.7
	422–423	0	0	0	(*)	.5	1.0	2.0	12.5	82.0	88.0	----------	12.0	3.2
	432–433	0	0	0	(*)	0	.5	1.5	9.0	80.0	90.0	----------	10.0	2.2
	542–543	0	0	.5	(*)	3.0	6.0	14.0	43.0	84.0	90.0	----------	10.0	2.8
	551–552	0	0	.5	(*)	4.0	9.0	19.0	39.0	81.0	90.0	----------	10.0	2.2

	561–562	0	0	.5	(*)	1.0	1.5	3.0	25.0	85.0	92.0	----------	8.0	2.3
	572–573	0	0	.5	(*)	1.0	2.0	4.0	13.0	66.0	82.0	----------	18.0	2.5
	622–623	0	0	.0	(*)	0	.5	2.0	21.0	83.0	91.0	----------	9.0	2.3
	633–634	0	0	.5	(*)	5.0	19.5	42.0	65.0	85.0	91.0	----------	9.0	4.0
	764–765	0	0	0	(*)	.5	1.0	1.5	2.0	58.0	90.5	----------	9.5	3.2
	773–774	0	0	0	(*)	.5	1.0	1.5	7.0	79.0	88.0	----------	12.0	2.2
N3866	275–276	0	0	0	(*)	0	1.0	2.5	21.0	70.5	86.0	----------	14.0	3.5
	285–287	0	0	.25	(*)	.50	.75	4.5	28.0	78.5	85.0	----------	15.0	3.8
	296–297	0	0	.5	(*)	1.0	1.5	6.0	28.0	86.0	92.0	----------	8.0	2.1
	387–388	0	0	1.5	(*)	1.7	2.5	9.0	43.0	80.0	89.5	----------	10.5	3.4
	392–393	0	0	.5	(*)	1.0	1.5	4.0	22.0	83.0	88.0	----------	12.0	3.5
	397–398	0	0	.5	(*)	3.0	4.0	6.0	11.0	69.0	82.0	----------	18.0	3.0
	402–403	0	0	.5	(*)	1.0	1.5	5.0	21.5	84.0	90.0	----------	10.0	2.3
	407–409	0	0	0	(*)	1.0	5.0	19.0	40.0	85.0	90.0	----------	10.0	3.4
N3867	247–248	0	(*)	6.0	(*)	0	6.5	7.5	12.0	85.0	90.0	----------	10.0	2.2
	432–434	(*)	(*)	5.5	(*)	9.25	13.3	23.1	42.7	75.7	87.3	----------	12.7	3.4
	504–505	0	(*)	2.2	(*)	2.78	4.45	7.21	23.35	80.0	86.7	----------	13.3	3.5
	509–510	(*)	(*)	42.5	(*)	49.0	52.0	55.0	60.0	77.0	83.0	----------	17.0	----------
	514–515	(*)	(*)	50.5	(*)	64.3	69.0	73.4	76.2	86.7	90.5	----------	9.5	----------
	519–520	0	0	.99	(*)	0	0	1.5	3.48	66.2	82.1	----------	17.9	3.0
N4149	545–546	0	0	0	0	.91	1.83	13.8	45.0	92.7	96.4	----------	3.6	2.5
	565–566	0	0	0	(*)	(*)	1.19	2.38	26.2	89.3	92.9	----------	7.1	1.7
	585–586	0	0	0	(*)	1.34	2.67	9.34	36.0	86.7	92.0	----------	8.0	2.3
	626–627	0	0	0	.72	2.17	5.0	8.0	18.8	79.9	85.5	----------	14.5	3.2
	647–648	0	0	0	.6	1.21	2.42	5.45	12.7	82.0	87.3	----------	12.7	4.3
	689–690	0	0	0	0	0	.53	1.06	4.2	64.1	78.8	----------	21.2	3.7
	718–719	(*)	(*)	0	3.2	4.0	6.4	12.8	37.6	80.9	87.2	----------	12.8	4.0
	759–760	5.2	9.6	16.7	20.2	29.3	39.5	51.7	68.4	87.0	91.3	----------	8.7	5.3
	786–787	0	0	0	0	0	0	1.2	12.2	78.0	84.0	----------	16.0	3.2
	795–796	0	0	0	0	.63	1.27	12.7	55.7	83.5	88.6	----------	11.4	4.7
N4150	635–636	(*)	(*)	(*)	2.08	4.68	9.37	20.8	45.2	83.8	88.5	----------	11.5	4.5
	655–656	0	0	0	0	.68	1.36	4.08	39.4	77.5	83.0	----------	17.0	5.3
	705–706	0	0	(*)	1.3	2.6	3.25	3.9	14.6	76.7	84.4	----------	15.6	4.3
	715–716	0	0	(*)	1.17	3.52	10.6	41.2	67.1	82.3	87.0	----------	13.0	5.7
	726–727	(*)	4.16	6.95	8.35	12.5	18.1	29.2	48.6	82.0	87.5	----------	12.5	----------
	745–746	(*)	12.2	18.3	20.8	24.4	28.1	34.1	42.6	70.7	79.3	----------	20.7	----------
N4756	88– 89	0	0	0	.5	.7	2.4	17.1	48.3	91.0	91.2	----------	8.8	2.2
	98– 99	0	0	0	0	.2	.8	5.4	28.8	82.0	86.0	----------	14.0	3.5
	114–115	0	0	0	0	0	.1	.4	7.2	90.4	90.6	----------	9.4	1.4
	180–181	0	0	0	.3	.4	.5	.9	7.7	78.2	86.0	----------	14.0	2.4
	200–202	0	0	0	.5	.6	.8	1.2	3.0	69.5	84.0	----------	16.0	2.5
	215–216	0	0	0	0	.1	.4	.9	5.7	74.7	75.0	----------	25.0	----------
	225–226	0	0	0	0	0	.4	1.4	10.0	81.5	82.5	----------	17.5	----------
	236–237	0	0	0	0	.1	.6	4.3	21.9	85.6	91.4	----------	8.6	2.0
	246–247	0	0	0	0	0	.6	2.5	9.7	90.0	93.4	----------	6.6	1.4
	271–272	0	0	0	0	.5	4.1	10.0	29.8	94.0	96.5	----------	3.5	1.9
	286–287	0	0	0	.3	.5	.9	1.5	9.5	90.5	90.6	----------	9.4	1.6
	296–297	0	0	0	.2	.4	.8	6.0	45.2	87.9	91.8	----------	8.2	2.8
	301–302	0	0	0	0	0	.4	2.1	23.3	91.4	93.5	----------	6.5	1.7
	316–318	0	0	0	0	0	0	.2	1.1	40.3	54.7	----------	45.3	----------
	342–343	0	0	0	0	.2	.6	3.0	16.0	91.0	94.6	----------	5.4	1.7

*Indicated sieve size not used.

TABLE 2.—*Mechanical analyses of selected core samples*—Continued

All analyses made by C. W. Lauman and Co., Inc. Grain-size classification used by U.S. Geol. Survey: granules, 2.0–4.0 mm; very coarse sand, 1.0–2.0 mm; coarse sand, 0.5–1.0 mm; medium sand, 0.25–0.50 mm; very fine sand, 0.062–0.125 mm; silt and clay, < 0.062 mm]

Well	Depth range (feet)	Cumulative percent retained by weight (size of grain, in mm)										Percent passed through sieve size, in mm		Uniformity coefficient
		Granules			Very coarse sand		Coarse sand		Medium sand	Fine sand		0.210	0.149	
		4	2.8	2.00	1.68	1.19	0.840	0.590	0.420	0.210	0.149			
N4756	347–348	0	0	0	1.9	2.9	8.0	21.3	57.0	88.8	93.0	----------	7.0	2.5
	367–368	0	0	0	0	0	.5	1.6	8.2	89.6	93.6	----------	6.4	1.6
	383–384	0	0	0	0	.2	2.5	11.8	35.4	81.3	90.4	----------	9.6	2.5
	394–395	0	0	0	0	.1	.8	2.6	11.6	80.0	81.2	----------	18.8	----------
	404–405	0	0	0	0	.4	1.7	14.5	68.6	95.8	96.1	----------	3.9	2.2
	419–420	0	0	0	.5	.7	1.6	3.2	9.8	85.2	91.4	----------	8.6	2.1
	429–430	0	0	0	0	.2	.8	3.7	17.8	99.0	97.3	----------	2.7	1.7
	441–442	0	0	0	0	.5	3.0	14.9	51.0	93.7	96.8	----------	3.2	2.5
	453–454	0	0	0	1.2	3.0	8.8	27.9	59.2	91.9	92.0	----------	8.0	2.5
	468–469	0	0	0	.6	.8	1.6	3.3	19.5	70.0	70.6	----------	29.4	----------
	478–479	0	0	0	0	.4	1.6	10.7	48.3	92.3	92.5	----------	7.5	2.2
	503–504	0	0	0	0	.2	.3	.8	21.3	91.6	94.6	----------	5.4	1.7
	529–530	0	0	0	0	0	.4	.5	1.4	28.5	76.3	----------	23.7	2.7
	549–550	0	0	(*)	1.2	2.5	7.3	19.5	38.5	69.2	81.3	----------	18.7	4.0
	564–565	(*)	(*)	(*)	54.9	60.3	64.7	68.4	72.3	85.3	90.2	----------	9.8	----------
	613–614	(*)	(*)	(*)	16.4	22.8	32.7	46.5	64.1	89.8	93.0	----------	7.0	----------
	628–629	(*)	(*)	(*)	7.0	8.9	11.5	18.7	41.5	87.9	92.3	----------	7.7	2.3
	663–664	0	0	0	.2	.5	1.5	3.0	4.5	24.3	56.5	----------	43.5	----------
	680–681	0	0	0	.2	.3	2.0	7.1	17.0	65.0	76.1	----------	23.9	4.0
	748–749	0	0	0	.3	.5	.7	1.0	2.7	42.5	69.7	----------	30.3	2.3

*Indicated sieve size not used.

This method of lithologic classification was applied to data for 9 outpost wells and 1 public-supply well in which core samples had been taken at intervals ranging from 5 to 20 feet. The results of the mechanical analyses of some of the cores from the wells are given in table 2. Most of these analyses are of the more permeable parts of the deposits and were made by the well driller to assist in selecting the proper slot sizes for the well screens. For this reason, they are most representative of lithologic class 1 described above. However, analyses for well N4756 were made for many types of sediments and are more representative of the Magothy(?) formation. According to the mechanical analyses (table 2) and the well logs (table 12), the sand of class 1 is mainly fine to medium in texture. Most of the sand layers contain some clay or silt also. The low uniformity coefficients, which average about 2.8 (table 2), indicate that the sandy beds are fairly well sorted. The uniformity coefficients for the beds of coarse sand and gravel are slightly higher than those of the beds of fine to medium sand and suggest somewhat poorer sorting during deposition.

Although mechanical analyses were made for only a part of the core samples, enough were made of different types of material in wells in all parts of the area to give some basis for an overall classification of the sediments of the Magothy(?) formation. On the basis of these mechanical analyses and from a study of the electric logs and of drillers' and geologists' logs, it appears that of the approximately 5,200 feet of deposits penetrated in the 10 selected wells, about 40 percent is in lithologic class 1 (sand and gravel); about 45 percent is in class 2 (sand, silt, and clay); and the remainder, about 15 percent, is in class 3 (clay and silt). The percentage of each of the three classes of material is given in table 3 and plotted on the trilinear

TABLE 3.—*Relative percentage of different types of sediments of the Magothy(?) formation penetrated in selected wells in southern Nassau County*

Well	Locality	Thickness of Magothy(?) formation (feet)	Class 1	Class 2	Class 3
			Sand and gravel (percent)	Sand, silt, and clay (percent)	Clay and silt (percent)
N2790	Bay Park	609	28	50	22
N3861	Cedarhurst	401	85	12	3
N3862	Lawrence	493	34	47	19
N3864	Woodmere	364	21	58	21
N3865	Oceanside	688	42	36	22
N3866	Hewlett	266	24	50	26
N3867	Green Acres	369	35	55	10
N4149	Merrick	720	43	44	13
N4150	Freeport	701	50	36	14
N4756	Uniondale	579	47	42	11
Total		5, 190			
Average percent			41	43	16

graph (fig. 6). These show that the deposits of the Magothy(?) have about the same average lithology in all the wells, except well N3861 (Cedarhurst) which penetrated an unusually thick sequence of sand and gravel. The high percentage of coarse material (85 percent by volume) is unusual for sediments of the Magothy(?) formation, and nothing comparable to it is known in other logs. The texture of the material suggests that it may be a channel-filling deposit and that it may include beds that are younger than the Magothy(?) formation.

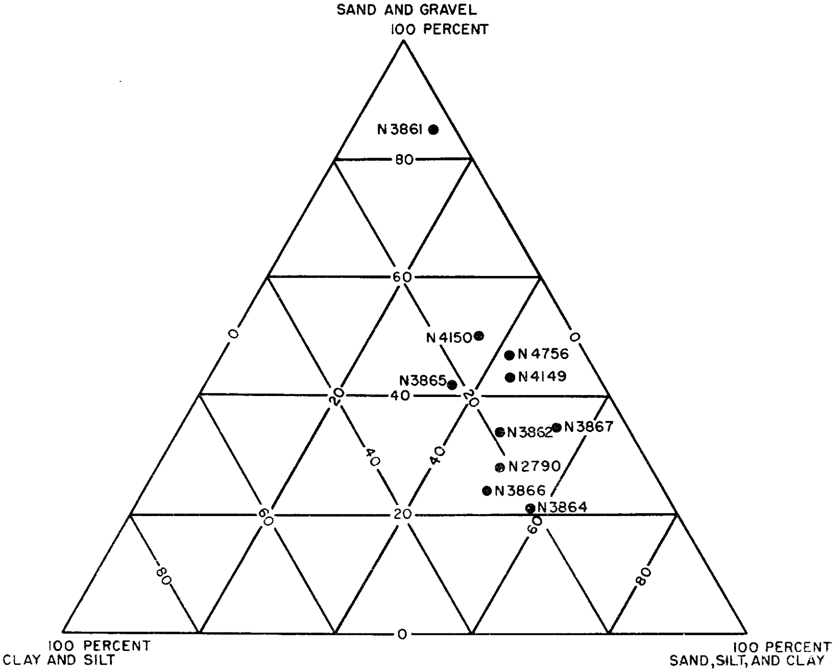


FIGURE 6.—Plot of textures of sediments of Magothy(?) formation penetrated by selected wells.

WATER-BEARING PROPERTIES

Slightly less than half the material of the Magothy(?) formation has good water-yielding characteristics. Nevertheless, large quantities of water are pumped from wells screened in the upper, middle, and lower permeable parts of the formation, from beds of fine sand as well as from zones of coarse sand and gravel. Large-diameter wells, having screens as much as 60 feet in length, individually yield as much as 2,200 gpm. Specific capacities of many such wells are on the order of 30 to 40 gpm per ft of drawdown and have been reported to be as high as 80 gpm per ft. The ability of the Magothy(?) formation to yield substantial quantities of water year after year generally can be attributed to the large thickness of saturated material. The water occurs under artesian pressure.

The amount of water stored in a formation and the rates at which it can move through or be withdrawn from a formation are partly determined by the porosity and permeability of the material. Some estimates of these characteristics have been made for the Magothy(?) formation and are used in subsequent parts of the present report to calculate the approximate rates of movement of salty ground water.

The porosity of unconsolidated deposits depends chiefly on the shape and arrangement of the grains and the degree of compaction and sorting. The degree of sorting is the most important factor and can be expressed quantitatively by uniformity coefficients computed from mechanical analyses. Perfect sorting and relatively high porosity are indicated by a uniformity coefficient of 1; imperfect sorting and less porosity are indicated by larger figures. By use of Hazen's graph (Meinzer, 1923b, p. 8) showing the relation between uniformity coefficient and porosity of selected sand samples, rough estimates of porosity were made for sand beds of the Magothy(?) formation (table 2). These estimates range from about 35 to 45 percent. However, the mechanical analyses were made of the cleanest and coarsest water-bearing sands; no analyses were made of predominantly fine-grained materials. Furthermore, Hazen's relation was developed from experiments on well-graded filter sands and is not strictly applicable to the less well sorted deposits of the Magothy(?) formation. The average porosity of the whole formation, therefore, is somewhat lower than 35 percent.

Laboratory determinations of the porosity of six samples of sand from wells drilled into the Magothy(?) formation in the village of Hempstead were made in 1938 by the hydrologic laboratory of the U.S. Geological Survey in Washington, D.C. These porosities ranged from 32 to 41 percent and averaged about 38 percent. Other tests on samples from the Magothy(?) formation at Creedmoor State Hospital in central Queens and Kings Park State Hospital in northwestern Suffolk County indicated a range in porosity from 28 to 31 percent. These tests were made on disturbed samples and on some washed samples, and the porosities determined are doubtless slightly higher than the true values for the deposits. On the basis of available data, the average porosity of the Magothy(?) formation is estimated to be 25 percent.

Owing to interbedding of coarse- and fine-grained materials, the permeability of the Magothy(?) formation is greatest in a direction parallel to the bedding and least perpendicular to it. Horizontal and vertical permeability may be determined in the laboratory from permeameter tests on cores. Aquifer tests based on measurements of drawdown and recovery of water levels in wells also give a measure of the permeability, mainly in directions parallel to the bedding. The permeability in directions parallel to the bedding has the most direct bearing on the rate of movement of water in the project area.

Laboratory determinations of permeability were made by the Hydrologic Laboratory of the U.S. Geological Survey on the same set of sand samples for which the values of porosity were determined (p. A29). The permeability values ranged from 500 to 1,450 gpd per sq ft and averaged about 950 gpd per sq ft. These tests were made on disturbed and washed samples, and hence the values may be higher than those of the material in place. Permeability of some beds of gravel and sand in the Magothy(?) formation may be more than 1,450 gpd per sq ft, and that of solid silty and sandy clay beds is very much lower than 500 gpd per sq ft. For example, a laboratory determination for a sample (not from Long Island) having 95 percent silt- and clay-size particles gave a permeability of only 0.2 gpd per sq ft (Wenzel 1942, p. 13). Pure clay may have a still lower permeability. Clayey and silty beds of low permeability constitute approximately 16 percent of the Magothy(?) formation (table 3).

During this investigation, attempts were made to determine the coefficients of permeability and transmissibility of beds of the Magothy (?) formation from aquifer tests at eight outpost wells. The procedure consisted of pumping each well at a constant rate and measuring the decline and recovery of water levels in the pumped wells at frequent intervals. Each well was equipped with a screen 10 or 15 feet long placed in what appeared to be the most permeable zone in the middle or lower part of the formation, except well N3862 which was screened in the upper part. The wells were pumped for periods ranging from about 1 to 26 hours, and at pumping rates ranging from about 80 to 300 gpm. Because no observation wells were available, water levels were measured only in the pumped wells. The drawdowns and recoveries were affected by changes in tides, barometric pressures, and rates of pumping in nearby wells. The wide range in specific capacity (from about 1 to 21 gpm per ft) of the pumped wells suggests that the wells may not have been equally developed.

Computations of the aquifer-test data made by N. J. Lusczynski by means of the modified Theis nonequilibrium formula (Theis, 1935; Jacob, 1946) gave a range in transmissibility from about 50,000 to 250,000 gpd per ft. However, because of the lenticularity of the Magothy(?) formation, the thickness of the beds to which these computations apply is uncertain. Tentative values of permeability, based upon an estimated thickness of the beds tested, seem to be similar in magnitude to the laboratory determinations.

PLEISTOCENE AND RECENT SERIES

JAMECO GRAVEL

The Jameco gravel is an irregular body of predominantly coarse sand and gravel deposited on the eroded surface of the Magothy(?) formation. It is overlain in most of its extent by the Gardiners clay (pl. 2). The Jameco gravel is thought to have been deposited as outwash by glacial melt-water streams and is considered to be of pre-Wisconsin age.

The geologic sections (pl. 2) show that the surface of the Jameco gravel is irregular and has 50 to 75 feet of relief. This irregularity suggests that the Jameco was eroded before the Gardiners clay was deposited. At a few places in southeastern Queens County, the formation is directly overlain by sand and gravel of the upper Pleistocene deposits. In those places the Gardiners clay may have been removed by erosion, or perhaps was never deposited.

The Jameco gravel underlies about 75 square miles of the project area in southeastern Queens and southwestern Nassau Counties. Its approximate landward limit is shown on figure 5 by the irregular dashed line that extends generally southeastward from central Queens to southeastern Nassau County. Appreciable thicknesses of Jameco gravel have been identified in some wells drilled on the barrier beaches, and the formation doubtless extends some distance seaward of the present shoreline. West of the area shown on figure 5, the Jameco gravel extends into Queens and Kings Counties (Suter and others, 1949, pl. 20).

The Jameco gravel is thickest, perhaps as much as 180 feet, in the deepest parts of the valleys cut into the surface of the Magothy(?) formation. It is generally no more than a few tens of feet thick over the divides, and thins to a featheredge along its landward limit.

The formation is among the most permeable of the water-bearing deposits of Long Island. Records show a yield of as much as 1,300 gpm and a specific capacity of as much as 135 gpm per ft for large-diameter wells screened in the formation. The quality of the water in the Jameco is generally good; but in most of the southern part of the area, the water is salty.

Water in the Jameco gravel is under artesian pressure, owing to confinement by the overlying Gardiners clay. Widespread interference effects were observed in the Jameco during pumping tests made in southern Queens County by the city of New York in the early 1900's (Veatch, 1906, p. 205) and later by the U.S. Geological Survey (J. G. Ferris, written communication, 1942). These data show that influence of pumping extended several miles from the centers of pumping.

As no extensive impermeable beds separate the Jameco gravel and the Magothy(?) formation, both formations constitute a single aquifer. Thus, the Jameco gravel, although a distinct geologic unit, is hydrologically a permeable zone in the upper part of an aquifer consisting in large part of beds of the Magothy(?) formation. Where there are paths by which ground water can escape from the Jameco, the formation provides a means for discharge of water from the underlying Magothy(?) formation.

GARDINERS CLAY

The Gardiners clay consists chiefly of gray and greenish-gray clay and silt and locally contains lenses of sand and gravel and sandy clay. It was deposited in shallow bays and estuaries in the southern half of the project area (fig. 7) during an interglacial stage. The Gardiners is overlain by the upper Pleistocene deposits and underlain at some places by the Jameco gravel and at others by the Magothy(?) formation. The upper and lower contacts in much of the southwestern part of the area are marked by a sharp change from clay or silty and sandy clay to beds of sand and gravel of the adjacent Pleistocene deposits. Where the Gardiners clay rests on the Magothy(?) formation, as it does in most of the southeastern part of the area, samples of the Gardiners clay are distinguished from clay of the Magothy(?) by the presence of biotite, chlorite, hornblende, glauconite, shell fragments, foraminifers, diatoms, brown partly carbonized plant material, and distinctive pollen grains and spores, which are usually found in the Gardiners clay. The Gardiners was considered by Fuller (1914, p. 106) to be Yarmouth in age. Later investigators, in part on the basis of studies of diatoms and foraminifers (Lohman, 1939; Weiss, 1954) and in part on the basis of further studies of the Pleistocene stratigraphy, have suggested a Sangamon age for the Gardiners.

The logs of cored wells N3861, N3862, N3864, and N3867 (table 12) describe variations in the lithologic character of the clay in southwestern Nassau County. These variations are illustrated also in the sections (pl. 2). As reported by drillers and as cored, much of the clay is tough and compact. In a few places (wells Q311, N3867, fig. 2, and N3862, fig. 12), the formation is reported to consist mainly of sandy clay or fine sand and silt. Foraminifera found in the Gardiners clay in the project area are similar to those identified in the Gardiners clay in western Long Island (Shupack, 1934) and in central Suffolk County (Weiss, 1954). *Elphidium, Rotalia,* and *Nonion* are the most common genera.

The top of the Gardiners clay ranges from about 50 to 120 feet below sea level; the depths are greatest in southern Queens County. The large range in depth presumably is partly a result of post-Gardiners

EXPLANATION

Extent of Pleistocene marine clay	Well penetrating Gardiners clay	Well penetrating "20-foot" clay	Well penetrating "20-foot" clay and Gardiners clay	Approximate extent of "20-foot" clay	Approximate extent of Gardiners clay

Figure 7.—Map showing the extent of Pleistocene marine clay.

erosion and partly a result of deposition on an irregular sea bottom. The thickest deposits penetrated by wells are in southern Queens County north of Jamaica Bay. At well Q683 (pl. 2) in southeastern Queens County, the clay is about 140 feet thick. The maximum known thickness of the Gardiners clay in Nassau County is 65 feet at well N3864 (pl. 2) in Valley Stream.

The Gardiners clay thins to zero along an irregular line crossing southeastern Queens and southern Nassau Counties (fig. 7). The line shown on the map is approximate and may be changed considerably as more data become available. The data on southeastern Nassau County are particularly scanty, and it is entirely possible that in some places beds interpreted as representing the "20-foot" clay may actually be part of the Gardiners clay. Such an interpretation would place the northern limit of the Gardiners in Nassau County near the limit of the "20-foot" clay shown on figure 7. The Gardiners clay is fairly continuous in Nassau County from its northern limit to the south shore.

In Queens County the Gardiners clay seems to be nearly continuous from the northern part of Jamaica Bay northward to the Jamaica area. Its presence beneath New York International (Idlewild) Airport is inferred from data on wells Q675 and Q676 (Veatch, 1906). Beneath the part of Jamaica Bay south of Idlewild Airport and beneath Rockaway Beach, where data are few, the formation either may be missing because of erosion or may consist mostly of sandy and silty beds that are difficult to distinguish from the overlying outwash. The logs of wells Q671 and Q1630 at Rockaway Beach (pl. 2) show predominantly sandy material in the depth interval where clay would be expected.

Although the Gardiners clay doubtless can transmit water slowly, generally it has a very low permeability and serves as a confining unit in most of the southern half of the area. The low permeability is indicated by the large difference in head, as much as 13 feet in places, between the water contained in the aquifers above and below the Gardiners. Further evidence of the low permeability of the Gardiners clay is furnished by large differences in concentration of chloride, as much as 500 ppm, between the water in the deposits above and below the Gardiners clay in southern Queens County. Observations in certain well fields in southern Queens County also showed that aquifers above or below the Gardiners clay were individually contaminated by salt water during heavy pumping, but in no places were both aquifers contaminated simultaneously from a common source (Burr and others, 1904, p. 410–423).

Where the Gardiners clay is missing or is sandy beneath the extreme southwestern part of the area, the movement of fresh water out of the Jameco is not appreciably retarded, nor is movement of sea water into it retarded. Thus, the extent of the major body of salt water described in a later section is partly related to the presence or absence of the Gardiners clay.

UPPER PLEISTOCENE AND RECENT DEPOSITS

The upper Pleistocene and Recent deposits, having a maximum total thickness of about 180 feet, comprise all the deposits from the top of the Gardiners clay to the land surface. These consist of the following units: (1) A body of glacial till which is part of the deposits forming the Harbor Hill terminal moraine; (2) an extensive body of stratified sand and gravel deposited as glacial outwash; (3) a thin deposit of marine clay, called the "20-foot" clay, which occurs in the southern part of the area and in some places is interbedded with the outwash; and (4) discontinuous bodies of peat, silt, clay, sand, gravel, and artificial fill of Recent age which underlie the bays, marshes, beaches, and stream valleys. The till, outwash, shore deposits, salt-marsh deposits, and some areas of artificial fill are shown on plate 1. Recent alluvium along the streams is not differentiated from the outwash deposits on the map.

The till occurs only in the northwestern part of the area, where it composes a terrane of relatively high relief and altitude. It is not water bearing except for small local bodies of perched water. The till does not bear on the problem of salt-water encroachment and is not further described in this report. In the following paragraphs the other three subdivisions of the upper Pleistocene and Recent deposits are discussed.

OUTWASH

The outwash constitutes the bulk of the upper Pleistocene deposits. It is exposed at or near the surface in about 80 percent of the area shown on plate 1. The outwash underlies the till in the northwestern part of the area, and the deposits of Recent age. It rests unconformably upon the Gardiners clay and upon the Magothy(?) formation where the Gardiners clay and Jameco gravel are missing; in a few places it rests directly upon the Jameco. Logs of some wells in the southern part of the area show the outwash to be divided into upper and lower portions by the "20-foot" clay. The sections (pl. 2) show these stratigraphic relations, and the general lithologic character of the deposits.

The outwash ranges in thickness from about 30 to 120 feet, thickening toward the north in the direction of the Harbor Hill moraine. The deposits consist mainly of stratified beds of fine to coarse sand and of sand and gravel. In some well logs thin beds of silt and clay are reported interbedded with the coarse-grained material. The outwash is yellow and brown but in some places is gray. The sand and gravel consist mainly of iron-stained quartz but include particles of biotite, chlorite, and hornblende and of igneous and metamorphic rocks.

The outwash deposits are highly permeable and contain large quantities of water. Individual wells are reported to yield as much as 1,700 gpm and have a specific capacity as high as 109 gpm per ft. The water in the outwash occurs mainly under water-table conditions. In the southern part of Nassau County the water in the outwash deposits beneath the "20-foot" clay is under artesian pressure.

The outwash deposits are the most permeable beds of wide extent in the project area. Because the deposits are mainly coarse grained and well sorted, they are relatively high in both porosity and permeability. These properties may be inferred also from the fact that even after extensive rains there is little overland runoff into streams. Virtually all the rainfall that is not evaporated from the soil or transpired by plants percolates quickly into the deposits.

The results of laboratory tests (Veatch and others, 1906, p. 354–360) on several hundred samples of outwash from southern Long Island, including many from the project area, showed that the porosity of most of the samples ranged from 30 to 40 percent. No laboratory determinations of the permeability of the outwash deposits were available. According to an aquifer test made by the Geological Survey at Brookhaven National Laboratory in Suffolk County, the average permeability and storage coefficient of the outwash deposits were 1,300 gpd per sq ft and 0.24 (written communication, M. A. Warren and N. J. Lusczynski, 1958). These values are probably applicable to much of the outwash in southern Nassau and Queens Counties, as the deposits are lithologically similar to those at Brookhaven.

"20-FOOT" CLAY

The name "20-foot" clay is assigned to relatively thin beds of marine clay that occur at altitudes of about 20 to 35 feet below sea level in the southern part of Nassau County. The clay is lithologically similar to the Gardiners clay. However, because undisturbed Gardiners clay is thought to occur at altitudes of about 50 feet or more below sea level and is separated from the "20-foot" clay by outwash deposits in a number of places, the authors regard the shallower clay as a separate unit.

The "20-foot" clay is overlain by the outwash described in the foregoing section. In most of southwestern Nassau County, outwash also underlies the clay and separates it from the deeper Gardiners clay, whereas in southeastern Nassau County the clay, if correctly identified, lies directly on the Magothy(?) formation. The "20-foot" clay ranges in thickness from 0 to about 40 feet.

Figure 7 shows the approximate northern limit of the "20-foot" clay and the locations of the wells that are thought to have penetrated the unit. Most of the wells are in southwestern Nassau County, south of Sunrise Highway, but logs of a few wells suggest that the clay may have been deposited in several narrow embayments north of Sunrise Highway. As the altitude of most of the wells shown on figure 7 was not determined by precise leveling and as relatively few well cuttings were available, it is conceivable that in some places the clay identified as the "20-foot" clay may actually be the upper part of the Gardiners clay or clay of the Magothy(?) formation. The clay is missing in a number of places in southeastern Nassau County, and its southern limit in a large part of the area is uncertain; therefore no attempt is made to map this limit on figure 7. The "20-foot" clay has not been recognized in most of southeastern Queens County, but there are large parts of that area that remain unexplored.

The "20-foot" clay typically consists of layers of fossiliferous gray and grayish-green silt and clay. At some places thin layers of sand or sand and gravel are interbedded with the clay. Shells, foraminifers, diatoms, and relatively fresh plant material are generally abundant but are not present everywhere.

The faunal and floral content of the "20-foot" clay and the position of the clay between deposits of glacial outwash characterize the clay as a shallow marine and brackish-water lagoonal deposit, conceivably interglacial or interstadial, and possibly of Wisconsin age. Fuller (1914, p. 157–158), on the basis of several well records in which shells, wood, peat, and silt were reported at shallow depths above the Gardiners clay, suggested the occurrence of an interglacial formation younger than the Gardiners clay which he called the Vineyard formation. The "20-foot" clay of this report closely resembles the Vineyard formation of Fuller and perhaps the two are the same unit. On the other hand, a detailed study of the flora and fauna may show that the Gardiners clay and "20-foot" clay are closely related.

Few data are available regarding the permeability of the "20-foot" clay, although its character as reported in well logs suggests that it probably transmits water very slowly and that it acts as a confining layer. Locally the "20-foot" clay separates unconfined salty water above the clay from confined fresh water below (fig. 10).

RECENT DEPOSITS

The Recent deposits, exclusive of soil and artificial fill, occur beneath the bays, in marshlands, on barrier beaches, and in stream valleys (pl. 1). Stratigraphically, the Recent deposits are the uppermost materials. They are immediately underlain by outwash, though in a few places, such as in artificially deepened channels in bays and inlets they may be underlain by the "20-foot" clay. The Recent deposits reach a maximum thickness of about 40 feet and are too thin to be shown on the geologic cross sections, but are differentiated in some of the well logs in table 12.

The bay-bottom deposits consist mainly of dark organic shell-bearing mud and silt and some sand. The marsh deposits consist of dark-brown peaty material lying beneath the islands in the bays and fringing the shorelines. At places the marshes extend inland more than a mile and generally are farthest inland in the valleys of the small streams that flow to the southshore bays.

The Recent deposits in the stream valleys and along the shores consist largely of reworked outwash. The deposits on the barrier beaches and on islands in the bays consist of wind and wave-deposited sand, which is fine to coarse and contains some shell fragments and pebbles. The main constituent of the sand is quartz, there is also some felspar, garnet, magnetite, ilmenite, biotite, and miscellaneous heavy minerals (Colony, 1932, p. 150–159).

The fine-grained bay-bottom and marsh deposits doubtless have low permeability, and may contribute to the confinement of water in the aquifers beneath the southern part of the project area. The highly permeable deposits of the barrier beaches contain unconfined water, but the quality of the water is commonly poor, and the deposits are tapped by a few wells. The water table on the barrier beaches is rarely more than several feet above sea level.

CHEMICAL QUALITY OF THE GROUND WATER AND SURFACE WATER

The chemical composition of ground water is affected by complicated reactions between the water and the minerals in the rocks through which it passes. These processes involve chiefly solution, precipitation, and ion exchange. Physical factors such as the amount and rate of movement of water, admixture of other waters, and changes in pressure and temperature affect the chemical processes significantly. A summary of the chemical characteristics of water and techniques for plotting and interpreting water analyses is given by Hem (1959).

Fresh water in most parts of the project area is of good to excellent quality (table 4); the concentration of dissolved constituents generally is well within the standards established by the U.S. Public Health Service. The content of dissolved solids is commonly less than 100 ppm, and the hardness is less than 40 ppm—except in parts of Queens County where the content of dissolved solids is as much as 311 ppm and the hardness is as much as 200 ppm in the unconfined aquifer. The water is acidic in most places. Locally, high concentration of iron, sulfate, nitrate, and other constituents are present in the fresh water, partly due to natural causes and partly due to agricultural, industrial, and other activities of man. The natural temperature of the ground water (table 11) ranges from about 51°F in the upper Pleistocene deposits to 71°F in the Lloyd sand member. The mean of 75 measurements from all aquifers is 56°F.

The salty ground water has a wide range in concentration of dissolved constituents. In some places it has nearly the same composition as sea water. It has a variable composition in the zone of diffusion (p. A63), because of dilution with fresh water.

The principal basis for differentiating fresh water from salty water is the concentration of chloride. Most of the fresh ground water of Long Island has a chloride content of less than 10 ppm. In some places the concentration ranges between 10 and 30 ppm, which may represent mild contamination from human wastes, inorganic fertilizers, or small amounts of sea water or salt spray. In this report a chloride concentration of 40 ppm or more is taken to signify definite contamination by sea water.

Miscellaneous determinations of chloride are given in table 11. Periodic determinations for the outpost wells screened in the Magothy(?) formation and in the Jameco gravel are given in table 13. This table also contains determinations of chloride made on water samples from shallow drive-point wells situated near the outpost wells and from a small number of other shallow and deep wells in Queens County. In addition to the current data, a small number of records (table 7) show chloride concentrations in the Magothy(?) formation and Jameco gravel from about 1893 to 1929.

A map (pl. 5) shows the chloride concentrations in water from wells screened in the principal confined body of water. The concentrations of chloride plotted are those given in table 11 and selected ones from table 13. The section (fig. 11) gives representative chloride concentrations at various depths along the line *W–W′* (pl. 5). This line extends along the length of the Rockaway Peninsula approximately on the line of section *X–X′* (pl. 7). The section shows the relation of fresh and salty water in the zone extending upward from the bedrock surface to the upper Pleistocene deposits. Another section (fig. 10) on a line extending southward from Wantagh in southeastern Nassau County shows chloride concentrations in the upper Pleistocene deposits and the uppermost part of the Magothy(?) formation. Chloride concentrations at selected depths are shown also on the geologic sections (pl. 2).

TABLE 4.—*Chemical analyses, in parts per million, of ground water in southern Nassau and southeastern Queens Counties*

[Analyses by U.S. Geol. Survey unless indicated otherwise. Water-yielding unit: L, Lloyd sand member of the Raritan formation; M, Magothy(?) formation; J, Jameco gravel; uP, upper Pleistocene deposits]

Well	Map coordinates	Depth below land surface (feet)	Water yielding unit	Date of collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH
Nassau County																			
																			.6
N46 [1]	6B, 0.6N, 0.4W	1,260	L	May 17, 1950	--	3	--	--	--	--	12	3	--	--	40	4	5	--	5.4
N48	6B, 5.0N, 3.8W	509	M	Jan. 15, 1952	7.1	.24	--	--	3.6	4	3	3	--	0.2	--	3	--	29.2	5.0
N67 [1]		1,052	L	July 25, 1950	--	1.5	--	--	--	--	8.1	4.8	--	--	43	8	6	--	4.
N68	6B, 5.1N, 0.5W	500	M	Jan. 16, 1952	7.8	.29	--	--	1.7	2	2	2	--	.2	--	3	--	26.5	5.1
N72	6C, 1.2N, 2.3W	604	M	15, 1952	9.1	.08	--	--	2.6	4	1	3	--	.2	--	3	--	28	5.5
N76 [1]	6C, 1.9N, 3.2W	192	M	Mar. 24, 1947	--	.70	--	--	--	--	--	6.8	<.05	.3	--	10	5	--	5.1
N76 [1]	6C, 1.9N, 3.2W	192	M	Oct. 21, 1959	--	1.8	--	--	--	--	--	7.2	--	.04	49	18	3	--	6.0
N79	6C, 3.3N, 1.9W	418	M	Feb. 26, 1935	5.9	.48	1.4	0.8	4.2	2	8.7	3.9	.0	.0	27	7	--	--	--
				26, 1952	7.6	.17	--	--	2.4	3	4	4	--	.0	--	7	--	40.2	5.2
N129	7B, 1.6N, 0.2W	951	M	26, 1935	7.5	2.7	.4	.6	29	37	25	5.8	.0	.05	86	3	--	--	--
N129	7B, 1.6N, 0.2W	951	M	Nov. 10, 1953	7.6	.24	.5	.2	31	37	29	4.7	.0	.3	96	2	--	137	6.2
N131	7B, 5.7N, 3.8W	533	M	Feb. 26, 1935	6.2	.32	.5	.3	3.9	2	4.4	3.4	.0	.0	19	2.5	--	--	--
N134	7B, 5.5N, 3.8W	517	M	Jan. 16, 1952	13	.24	--	--	1.6	3	1	2	--	.2	--	3	--	23.7	5.3
N180 [1]	8C, 0.6N, 4.2W	762	M	Oct. 7, 1953	--	1.5	--	--	--	--	3.7	4.6	--	--	35	8	1	--	4.5
N634 [1]	7C, 0.1N, 3.1W	40	uP	Feb. 24, 1947	--	.07	--	--	--	--	--	10	<.05	22	--	40	8	--	5.3
N693 [2]	5C, 2.5N, 2.4W	93	uP	1958	--	.03	--	--	--	--	--	16	.1	70	221	87	17	282	6.1
N1379	5B, 3.2N, 2.3W	196	J	Sept. 16, 1953	13	3.6	1.7	1.0	4.2	10	8.6	1.4	.0	.1	35	8	--	41	5.8
N1601 [3]	6C, 0.9N, 0.7W	580	M	14, 1950	--	.35	--	--	--	--	--	4.8	--	.0	37	12	3	--	5.2
N1602 [1]	6C, 0.5N, 4.1W	495	M	Aug. 12, 1947	--	.35	--	--	--	--	--	3.4	--	.2	--	10	9	--	5.3
N1602 [3]	6C, 0.5N, 4.1W	495	M	June 10, 1959	--	.5	--	--	--	--	--	7	--	1.8	--	8	8	--	5.5
N2413 [2]	5C, 1.7N, 1.9W	508	M	1958	--	.30	--	--	--	--	--	3.4	--	.44	--	11	8	40	5.8
N2414 [2]	5C, 1.7N, 1.9W	89	uP	1958	--	.0	--	--	--	--	--	12	.0	40	167	66	11	202	5.9
N2578 [3]	5C, 0.7N, 2.8W	88	uP	Aug. 5, 1958	--	.8	--	--	--	--	--	37	--	20	--	--	58	--	5.6
N2613 [3]	6B, 5.7N, 1.2W	500	M	June 10, 1959	--	.6	--	--	--	--	--	7	--	1.2	--	8	4	--	5.2
N2790 [1,3]	6B, 3.5N, 4.3W	560	M	Sept. 9, 1953	--	2.5	--	--	--	--	2.9	3.6	--	--	32	10	7	--	5.2
N3448 [1]	5B, 0.3N, 1.7W	1,234	L	May 17, 1950	--	4.5	--	--	--	--	17	10	--	--	89	14	--	--	3.7
N3493 [4]	8B, 1.8N, 0.6W	338	M	Nov. 13, 1958	--	3.2	--	--	--	--	--	10	--	.4	--	8	16	--	6.2
N3861 [5]	5B, 3.3N, 3.5W	533	M	Oct. 10, 1952	6.3	84	381	1,040	8,790	0	2,080	15,600	.1	2.9	28,000	5,230	--	34,800	4.4
N3861 [5]	5B, 3.3N, 3.5W	533	M	Sept. 8, 1953	7.9	65	379	1,010	8,670	3	2,080	15,700	.0	.0	30,500	5,200	--	36,800	4.8
N3861 [5]	5B, 3.3N, 3.5W	533	M	Apr. 17, 1956	10	78	365	1,090	8,960	16	2,010	15,800	.0	2.1	28,300	5,510	--	43,000	5.2
N3862 [5,6]	5B, 1.5N, 3.7W	306	M	Oct. 31, 1952	3.2	144	215	149	798	0	131	1,920	.1	5.7	3,350	1,150	--	5,730	2.4
N3862 [6]	5B, 1.5N, 3.7W	306	M	Sept. 18, 1953	6.0	135	250	147	540	0	126	1,860	.0	.8	3,340	1,420	--	6,060	2.8
N3862 [6]	5B, 1.5N, 3.7W	306	M	Apr. 17, 1956	19	146	280	174	595	0	139	1,890	.0	2.8	3,170	1,600	--	5,930	3.4
N3864	5B, 4.0N, 2.3W	470	M	Oct. 24, 1952	9.0	.40	.2	.8	7.5	12	5.2	3.0	.0	.3	32	4	--	35.6	6.3
N3865	6B, 2.9N, 2.5W	565	M	21, 1952	9.4	1.2	.2	.3	4.5	5	2.2	3.0	.0	.3	31	2	--	25.7	6.0

N3866	5B, 3.7N, 1.5W	412	M	Oct. 14, 1952	9.8	2.9	1.5	0.4	4.4	6	5.0	3.5	0.0	0.3	29	5	-------	31.4	6.0
N3867	5B, 4.6N, 2.7W	517	M	Dec. 11, 1952	10	.51	1.3	.9	8.1	12	7.8	3.5	.5	.5	39	7	-------	75.1	6.1
N3932	5B, 3.3N, 3.5W	176	J	Sept. 16, 1953	11	5.7	1.6	.8	7.6	10	12	4.0	.0	.1	42	7	-------	49.3	6.6
N4026	5B, 2.6N, 1.8W	153	J	9, 1953	8.6	7.8	6.1	.9	5.6	13	13	6.4	.0	.1	47	19	-------	75.9	6.5
				Apr. 17, 1956	12	1.4	7	2.9	22	15	18	32	.0	.1	106	30	-------	191	6.1
N4042 [7]	8C, 3.3N, 2.2W	154	M	May 18, 1959		0	-------	-------	-------	-------	-------	.3	-------	.0	52	6	0	-------	5.2
N4062	5B, 1.5N, 3.7W	142	J	Apr. 17, 1954	17	.61	28	16	58	30	28	145	.0	.6	336	137	-------	590	6.2
N4149	7B, 4.7N, 2.5W	562	M	Sept. 30, 1953	6.5	.61	.5	.1	2.7	2.6	1.6	2.5	.0	.1	15	2	-------	22.4	5.8
N4150	7B, 4.3N, 3.6W	745	M	Feb. 2, 1954	7.7	.25	.6	.2	5.5	3.6	6.6	4.2	.0	.1	28	4	-------	40	5.6
N4405	5B, 0.3N, 2.8W	1,075	L	Sept. 15, 1954	8.2	7.9	2.0	.7	13	6.4	15	10	.1	.1	53	8	-------	90.6	6.8
N4602 [8]	8C, 2.1N, 1.1W	450	M	Feb. 9, 1959	-------	.96	-------	-------	-------	-------	-------	4	-------	.2	-------	14	1	-------	6.4
Queens County																			
Q111 [1]	4B, 1.8N, 0.6W	1,016	L	May 22, 1950	-------	6.0	-------	-------	-------	-------	17	20	-------	-------	77	14	9	-------	5.6
Q305 [2]	4C, 3.3N, 0.6W	87	uP	1958	-------	.14	-------	-------	-------	-------	-------	13	.05	35	249	136	39	338	5.8
Q310 [9]	4C, 1.9N, 3.7W	101	uP	June 2, 1958	-------	.00	-------	-------	-------	-------	-------	12	-------	-------	-------	102	19	-------	6.0
Q311 [2]	4C, 1.3N, 2.7W	260	J	1958	-------	.33	-------	-------	-------	-------	-------	5.1	0	.44	126	89	92	207	7.6
Q312 [2]	4C, 0.9N, 0.8W	276	J	1950	-------	.80	-------	-------	-------	-------	-------	9.2	-------	.44	100	42	19	-------	6.5
Q314 [2]	4C, 1.0N, 2.6W	304	J	1958	-------	.25	-------	-------	-------	-------	-------	19	.05	.35	175	103	90	267	7.8
Q559 [2]	4C, 0.6N, 3.2W	214	J	1950	-------	1.5	-------	-------	-------	-------	-------	136	-------	.0	437	252	93	-------	7.6
Q562 [1]	4C, 2.0N, 2.0W	603	L	Feb. 2, 1949	-------	2.7	-------	-------	-------	-------	14	7	-------	-------	62	12	11	-------	6.2
Q567 [2]	4C, 3.3N, 2.8W	621	L	1958	-------	1.0	-------	-------	-------	-------	-------	5.7	-------	.22	75	36	7	128	6.6
Q1230 [2]	4B, 0.8N, 1.2W	161	J	July 20, 1942	-------	4.8	-------	-------	-------	-------	-------	12,600	-------	.0	-------	530	156	-------	-------
Q1839 [9]	4C, 2.0N, 2.0W	85	uP	June 17, 1957	-------	.31	-------	-------	-------	-------	-------	25	-------	-------	-------	162	65	-------	6.3
Q1957 [9]	4C, 3.3N, 0.6W	282	M	30, 1958	-------	.02	-------	-------	-------	-------	-------	8.4	-------	-------	-------	27	8	-------	6.0
Q1958 [9]	5C, 1.9N, 3.7W	432	M	30, 1958	-------	.20	-------	-------	-------	-------	-------	5	-------	-------	-------	22	12	-------	5.9
Q2026 [2]	5C, 0.9N, 3.2W	431	M	1958	-------	.03	-------	-------	-------	-------	-------	4.3	-------	.13	39	13	10	48	6.0

[1] Analysis by New York State Dept. of Health.
[2] Analysis by New York City Dept. of Water Supply, Gas, and Electricity; average analysis for year indicated.
[3] Analysis by Long Island Water Corp.
[4] Analysis by C. W. Lauman & Co., Inc.
[5] Density at 20°C, 1.018 on Oct. 10, 1952, 1.019 on Sept. 8, 1953, and 1.016 on Apr. 17, 1956.
[6] Density at 20°C, 1.000 on Sept. 18, 1953, and 0.999 on Apr. 17, 1956.
[7] Analysis by Water Testing Laboratory.
[8] Analysis by Eastern Biochemical Laboratories.
[9] Analysis by Jamaica Water Supply Co.

These data indicate that most of the ground water has a low chloride concentration but that locally there is salty water in all the aquifers except the Lloyd sand member.

UPPER PLEISTOCENE DEPOSITS

Seven representative partial analyses of water from the upper Pleistocene deposits are given in table 4. The analyses show that most of the water is fresh and of relatively good quality, except in the southern part of the area near and beneath the barrier beaches and bays, where the water is commonly salty.

In general, the fresh water in the upper Pleistocene deposits in Nassau County is soft to moderately hard; in 3 wells the hardness of the water ranges from 40 to 87 ppm. In Queens County the hardness of the water is greater and in 3 wells ranges from 102 to 162 ppm. The average content of dissolved solids in 14 wells in Queens County is 275 ppm and in 3 wells in Nassau County, the average is 185 ppm. The pH of the water ranges from 5.6 to 6.3; and the iron content, with few exceptions, is less than 0.3 ppm.

The chloride concentration in water from the upper Pleistocene deposits is less than 25 ppm in most of the project area, but it is much higher near the shoreline. This is illustrated on figure 11, which shows chloride concentration at several shallow wells along a line from about Hewlett Bay Park to Rockaway. Many wells near the shore are in or immediately adjacent to salt marshes, or on filled land overlying former marshes, or near salty tidal creeks (pl. 1). Such wells, if they terminate in deposits above clay layers and are within a few hundred feet of salty water, ordinarily yield water having a high chloride concentration. For example, a shallow well, 18 feet deep, drilled in 1950 within 6 feet of outpost well N2790 at Bay Park yielded water containing 500 ppm of chloride. In the vicinity of outpost well N3865 at Oceanside in southern Nassau County, the water from a well, about 10 feet deep, had 700 ppm of chloride in July 1952. The well is within 25 feet of a salty tidal creek. Water in well N1283, in the marsh south of Wantagh in southeastern Nassau County and screened in upper Pleistocene deposits at a depth of 39 feet, had 6,600 ppm of chloride in April 1954 (fig. 10).

In contrast, wells in similar shoreline locations which obtain water from below layers of clay generally have much lower concentrations of chloride. For example, near well N2790 at Bay Park, a well 39 feet deep which was terminated below a clay layer yielded water containing 40 ppm of chloride, in contrast to the 500 ppm in water above the clay. Similar conditions are illustrated on figure 10 which shows unconfined fresh water about 0.8 mile inland from East Bay flowing over a shallow body of unconfined salty water above a clay. The salty water contains as much as 6,800 ppm of chloride. Below the clay, at a depth of 60 to 70 feet below sea level, the water in the Magothy(?) formation has a maximum chloride content of 8 ppm.

Unconfined bodies of fresh and salty water probably occur in shallow deposits bordering all the marshes, bays, and inlets of the south shore. Some wells screened in these deposits have yielded fresh water at times and salty water at other times. For example, water from observation well N3708 (table 13) screened at a depth of 18 feet near a tidal marsh along Mott Creek in southwestern Nassau County had 12 ppm of chloride on March 2, 1951, 138 ppm on March 31, 1951, 20 ppm on July 30, 1951, and 124 ppm on November 9, 1953. Water tapped by well N3709 (about 19 ft deep), situated in a marsh to the southwest, had an increase in chloride concentration from 6 ppm on March 2, 1951, to 4,200 ppm on November 9, 1953. Several factors influence the fluctuations. These include variations in rainfall, tidal action, local pumping, and contamination changes in the altitude of the water table, and differences in distance from a source of salty or fresh water. For example, these wells had 124 and 4,200 ppm of chloride, respectively when sampled on November 9, 1953, shortly after the area was inundated by salty water which moved in during a prolonged period of high tide accompanying a severe storm.

There is also confined salty water in the lower part of the upper Pleistocene deposits beneath the barrier beach in Nassau County (pl. 2).

In Far Rockaway and farther west along the Rockaway Peninsula, salty water in the upper Pleistocene deposits may be nearly continuous downward into the Jameco gravel and Magothy(?) formation (fig. 11). This is suggested in part by data from wells Q129 and Q131, which tap the upper Pleistocene deposits at depths of 120 and 118 feet, respectively, and from well Q1383 which taps the Magothy(?) formation at 250 feet near the same site. In September 1953, water from well Q129 (table 13 and fig. 11) had 1,500 ppm of chloride; in September 1944, water from well Q131 had 360 ppm of chloride; and in September 1953, water from well Q1383 had 7,500 ppm.

JAMECO GRAVEL

Chemical analyses for 9 wells that tap the Jameco gravel, 4 in southwestern Nassau County and 5 in Queens County, are given in table 4. The analyses made during 1953 of waters from 3 of the wells in Nassau County show a content of dissolved solids ranging between 35 and 47 ppm. The water from 2 of these wells has a hardness of 7 and 8 ppm, but that of 1, N4026 (Hewlett Neck), had a hardness of 19 ppm. The higher hardness of water from N4026 is attributable to its higher concentration of calcium. It is not accompanied by a proportional increase in bicarbonate, but the sulfate concentration, 13 ppm, is higher than that found in the fresh water from other wells that tap the Jameco or the Magothy(?). Available analyses show that both the calcium and the sulfate concentrations in the Jameco are higher in the southern part of the area. This largely explains the deviation of N4026 from the general plotted position of other wells shown in figure 8, the water-quality diagram. A second analysis of water from N4026 collected in April 1956 differs from the earlier analysis by its somewhat higher concentration of chloride and dissolved solids. The increase in concentration may be due to local contamination resulting from dewatering operations in the vicinity of the well.

In southeastern Queens County the range in hardness of fresh water in 3 wells screened in the Jameco gravel is 42 to 103 ppm. In the wells tapping salty water the hardness is 252 and 530 ppm. The chloride concentration in fresh water in the Jameco gravel is generally less than 10 ppm (tables 11 and 13). However, in several wells in southern Queens the chloride concentration is much higher. For example, in well Q1237, near the Belt Parkway in South Ozone Park, the chloride concentration was 140 ppm in March 1954. In well Q559, about a mile northwest of Q1237, the chloride concentration was 160 ppm in September 1951 when the well was abandoned. In well Q1230, on the barrier beach in Far Rockaway, the concentration of chloride in water from a depth of 161 feet in the Jameco gravel (fig. 11) was 12,200 ppm in May 1955; and in well Q1630, nearly 2 miles farther west, the concentration of chloride in water from the Jameco at 175 feet was 16,200 ppm in April 1955 and 17,400 ppm in June 1956. The latter concentration is about the same as that of Atlantic Ocean water near Long Island (tables 5 and 6).

In southwestern Nassau County the concentration of chloride in water from well N4062, screened at a depth of 142 feet in the Jameco gravel, has ranged from about 25 to 1,200 ppm since the start of the record. These relatively high chloride concentrations may be indicative of the quality of the water in the upper part of the zone of diffusion of the main confined body of salty water (figs. 11 and 12), beneath the Lawrence area. The reliability of the data are questionable, however, as there is some evidence that the well casing leaks, intermittently. At well N3863 in Atlantic Beach, the Jameco gravel yielded water containing 4,300 ppm of chloride in 1954. Electrical logs (pl. 2) of wells at Long Beach show that the water in the Jameco gravel beneath that area also is salty, but about 1 mile north, at well N2921 in Island Park, the chloride content of the water in the Jameco gravel is about 10 ppm.

MAGOTHY(?) FORMATION

The quality of the fresh water in the Magothy(?) formation is indicated by the chemical analyses of water from outpost and other wells given in table 4. The quality of the salty water in the Magothy(?) formation is indicated by the analyses for wells N3861 and N3862. The water from these wells is very salty and contains high concentrations of dissolved constituents. In the fresh waters the concentration of dissolved solids ranges from 15 to 96 ppm, and the hardness as $CaCO_3$ from 2 to 26 ppm. Other constituents are present in correspondingly relatively small amounts, except for iron which ranges in concentration from 0.2 to 5.7 ppm. As indicated by the data plotted on plate 5 the fresh water in the Magothy(?) formation in most of southern Nassau County ordinarily contains between 4 and 8 ppm of chloride. Of particular significance in the present study of salt-water encroachment is the high chloride concentration in water from wells N3861 in Cedarhurst, N3862 in Lawrence, Q1383 in Far Rockaway, and several other wells in the southern part of the area (pl. 5).

The analyses of water from outpost and other selected wells are plotted on the trilinear diagram in figure 8. The diagram is a means for comparing the general chemical characteristics of one water with those of another, regardless of the total concentration of dissolved solids. To make this plot, the concentrations in parts per million of the principal cations (calcium, magnesium, sodium, potassium) and of the principal anions (chloride, sulfate, bicarbonate, and carbonate) are converted to equivalents per million. The equivalents per million are computed by dividing the concentration in parts per million of each chemical constituent by its chemical combining weight. Then the percentage equivalents per million of each cation in relation to the total equivalents of all cations is calculated; the same is done for the anions. These percentages, or percentage reacting values, are plotted on the triangular- and diamond-shaped fields of the diagram.

Except for the analyses of highly salty ground water (Nos. 2 and 3, fig. 8), the analyses of all the water from the outpost wells screened in the Magothy(?) formation (Nos. 4–9) plot in about the same general area of the diamond-shaped field, which indicates that they all represent about the same kind of water chemically. The water from well N3932 (No. 11) which is from the Jameco gravel also is about the same.

Well N129 (No. 1) at Jones Beach is screened in the lower part of the Magothy(?) formation. The analysis of water from this well plots below all the others in the diamond-shaped field of figure 8. This water has a higher content of dissolved solids, sulfate, bicarbonate, and sodium than any of the other waters from the Magothy(?)

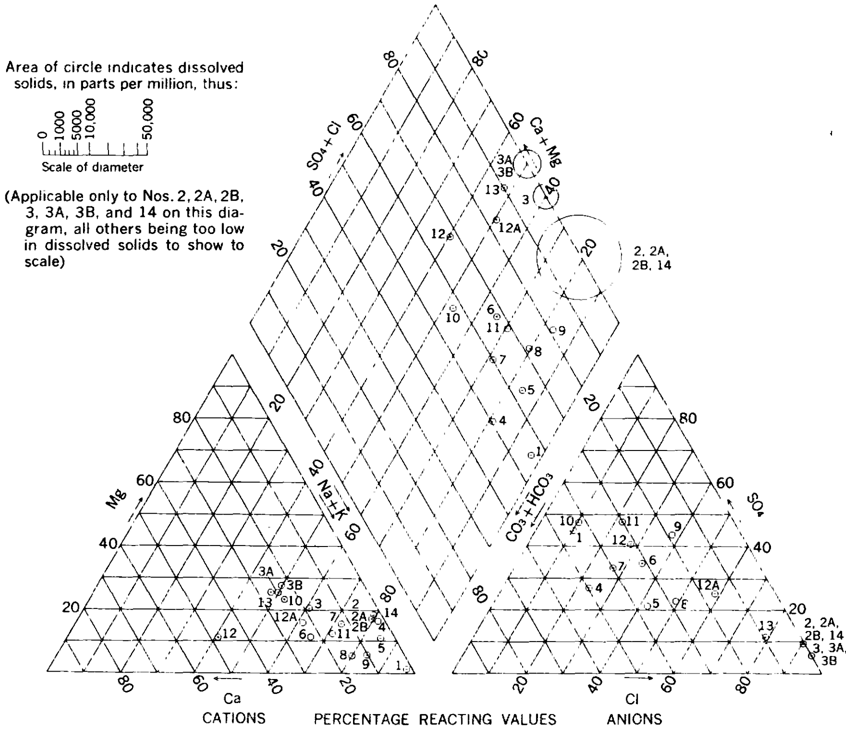


FIGURE 8.—Water-quality diagram for selected wells that penetrate the Jameco gravel and Magothy(?) formation.

and is relatively low in calcium and magnesium. The relatively low content of calcium and magnesium and relatively high content of sodium suggest a natural softening through base exchange. (See Piper, 1953, p. 11.) The flow pattern on plate 7 indicates that water in the lower part of the Magothy(?) formation at Jones Beach is derived from the Lloyd sand member of the Raritan formation by upward leakage through the clay member of the Raritan formation. Minerals in the clay doubtless aid in the process of base exchange. This suggestion is supported by the fact that the concentration of sulfate (29 ppm) and the dissolved solids (96 ppm) in water from well N129 are about the same as those in water from wells that tap the Lloyd (N3448, table 4).

The analyses of water from wells N3861 (Cedarhurst) and N3862 (Lawrence) represent the presence of at least 1, and perhaps 2, distinctly different waters. The analysis of water from well N3861 (No. 2, fig. 8) plots about in the same place as Atlantic Ocean water (No. 14). No appreciable change in overall chemical quality was noted for water from well N3861 in the analyses of October 1952, September 1953, and April 1956. The chloride concentration is high and has ranged from about 15,500 to 17,000 ppm in samples at different times (table 13). Atlantic Ocean water in this area contains 17,000 to 17,500 ppm of chloride. The ratio of calcium to magnesium in the water from N3861 averages about 1:3.5. This compares closely with the ratio of about 1:3 for Atlantic Ocean water and about 1:3.2 for average sea water (Sverdrup and others, 1942). Thus the water from well N3861 has nearly the composition of sea water; however, it differs from sea water in its excessive concentration of iron and manganese (78 ppm and 1.3 ppm, respectively) and low pH (about 5.2). In contrast, a sample of Atlantic Ocean water (table 5) contained no measurable concentration of iron or manganese and had a pH of 7.6.

The water from well N3862 also has a high chloride content. The range has been from 1,800 to 2,300 ppm (tables 4 and 13). This is equivalent to a content of about 10 percent of sea water. However, if this water were entirely a mixture of sea water and the typical fresh water of the Magothy(?) or the Jameco, the analysis should plot in figure 8 approximately on a line between the position of the analysis for Atlantic Ocean water and the other anlyses of fresh water from the Magothy(?). Instead it plots in the direction of increasing concentrations of calcium plus magnesium and sulfate plus chloride. Results from analyses of water collected from well N3862 in three different years are plotted in figure 8. The analysis of October 1952 (No. 3) plots slightly closer to that of Atlantic Ocean water (No. 14) than do those of September 1953 and April 1956 (Nos. 3A and 3B). The difference in the analyses may represent slight changes in chemical composition of the water in the zone of diffusion resulting from the mixing of fresh and salty water. The water is very hard. It also has unusual acidity (pH 2.8 to 3.4) and is extremely high in iron (146 ppm). Also, the ratio of calcium to magnesium is about 4:3 which differs from the ratio for normal sea water and for a mixture of sea water and normal water from the Magothy(?). These data suggest that the water from well N3862 is a mixture of sea water and of fresh ground water which is unusually high in calcium. The calcium content of water from wells N4026 (Hewlett Neck) and N4062 (Lawrence), which are screened in the Jameco gravel, is noticeably higher than that of water from the Magothy(?).

The high iron concentration and acidity of the water from N3861 and N3862 cannot be attributed to local contamination at the well sites, nor has the high concentration of iron any specific relation to the fact that the wells are screened in salty water. The iron may be derived from the limonitic coating on quartz grains or from concretions composed of iron oxide, iron sulfide (marcasite and pyrite), and iron carbonate (siderite).

The reasons for the apparent deviations from sea-water composition of the water from wells N3861 and N3862 are not fully understood, and the chemistry of these waters has been a subject for much speculation. J. D. Hem (written communication, February 1957) of the U.S. Geological Survey speculates on the problem as follows:

One could perhaps safely assume that leaching of the Magothy(?) and overlying material would be extensive. The low solids and low pH of most water in this area indicate that calcareous matter has largely been removed. The humid climate also would favor the growth of vegetation and production of acid soil. The hydrogen ions thus produced might be expected to be carried some distance into the underlying rock and to occupy some of the exchange positions on those mineral particles in the Magothy(?) which had cation-exchange capacity. In time, a considerable amount of hydrogen ions might be so adsorbed, although the solutions containing them would be dilute. Under these conditions also, especially in the presence of organic materials, ferrous iron could be carried in solution and adsorbed on some of the exchange positions. A relatively low pH and reducing conditions would have to be maintained to keep the iron from precipitating as hydroxide.

The sudden introduction of saline water into this aquifer as a result of landward movement of sea water would be expected to cause some types of adsorbed cations to be released from the solid phase. The saline front would thus contain water that had been considerably enriched in certain other cations such as calcium, or magnesium, at the expense of the sodium in the original sea water. This effect is not uncommon and was noted by Piper, Garret and others in the Los Angeles area. Here in Long Island, however, the effect seems to be to release relatively large proportions of adsorbed hydrogen and iron, along with calcium and magnesium. These ions are carried landward as the saline front advances, in a sort of chromatographic effect. Some support for the above interpretation might be gained by examination of the analysis of samples from well N3862. The well water has 1,890 ppm of chloride, equivalent to sea water in a tenfold dilution. Normal sea water diluted in this way would contain some 1,050 ppm or 45 epm of sodium. The well water has some 20 epm less of sodium than diluted sea water would have. The increased amount of calcium and magnesium in the well water accounts for about 13 epm and the remaining 7 epm of sodium could be accounted for as having replaced some 5 epm of ferrous iron and enough H+ to convert all HCO_3 in the sea water to H_2CO_3 and leave a surplus that gives the strongly acid pH of the well water.

LLOYD SAND MEMBER OF THE RARITAN FORMATION

Analyses of water samples from 3 wells screened in the Lloyd sand member beneath the barrier beach in Nassau County and from 3 wells in Queens County are given in table 4. These data show that water from the Lloyd is very soft, averaging about 15 ppm in hardness and is only slightly acidic except for water from well N3448 at Long Beach which is highly acidic (pH 3.7). The iron concentration is markedly high, ranging from about 3 to 7.0 ppm, and may be related to the relative abundance of pyrite and marcasite in the Raritan formation. The water is clear when drawn but a precipitate of brown ferric hydroxide is formed after the sample has been exposed to the air for a short time. The concentrations of sulfate and dissolved solids, which average 15 and 66 ppm, respectively, are slightly higher than those of water in the Magothy(?) formation.

Although the hydrostatic head of water in the Lloyd beneath the barrier beaches theoretically is too low to keep out salty water, natural chloride concentrations exceeding about 20 ppm have not been recorded for the aquifer in the project area, and extensive deterioration in quality due to salt-water encroachment has not been observed. However, the change in chloride content of the water from wells Q111 and Q1929 at Far Rockaway in southeastern Queens County from 7 ppm in 1932 to 18 ppm in 1956 may be indicative of mild contamination and bears further investigation. Significantly, there have been reports of abnormally high chloride concentration in water from wells tapping the Lloyd in Rockaway Park, Queens County, about 1 mile west of the project area. For example, above-normal chloride concentrations of 64 ppm and 46 ppm, respectively, were reported from wells Q1030 and Q1071 shortly after they were drilled in 1939. This may indicate some encroachment of salt water from above or from salt water in the aquifer offshore, but the interpretation of these records is uncertain, and some salty water may have been transmitted from shallower formations through leaky casings.

In water from several wells in Long Beach, Nassau County, that are screened in the Lloyd, high concentrations of chloride have been reported from time to time. Without exception, the high concentrations were due to leaks in well casings and joints, which permitted salty water from the shallower Magothy(?) formation to enter the wells when they were pumped. When liners were installed in the leaky casings or the wells were replaced entirely, the chloride concentration in the water from the repaired and replacement wells was found to be less than 10 ppm.

SALTY SURFACE WATER

Salty surface water occurs extensively in the southern third of the project area in bays, creeks, canals, and channels connected with Jamaica Bay and the Atlantic Ocean. The proximity of these bodies of salty water influences the quality of the adjacent ground water, as the salty water either has already invaded or can invade the ground-water reservoirs, both deep and shallow. Accordingly, a knowledge of the chemical quality, particularly chloride concentration, is important in determining the extent of any encroachment.

The concentrations of the principal constituents in a sample of Atlantic Ocean water near Atlantic Beach are given in table 5, and the comparison with fresh and salty ground water in southern Nassau County is shown in the water-analysis diagram (fig. 8). The order of magnitude of these concentrations is about the same as that for average ocean water (Sverdrup and others, 1942), except that average ocean water contains about 35,000 ppm of dissolved solids of which about 19,000 ppm is chloride. Coastal waters in the latitude of Long Island generally contain 30,000 to 33,000 ppm of dissolved solids, with the content being lowest nearer the coast. The sample of Atlantic Ocean water taken near Atlantic Beach contained 31,000 ppm of dissolved solids and 17,200 ppm of chloride. Chloride concentrations for other samples of Atlantic Ocean water are given in table 6. In the bays, tidal creeks, and canals, there are seasonal and annual variations in chloride concentration depending on the amount of precipitation, ground-water discharge, and inflow from fresh-water streams.

TABLE 5.—*Chemical analyses of water* [1] *from the Atlantic Ocean and Brosewere Bay, southwestern Nassau County*

[Analyses are by the U.S. Geol. Survey. Concentrations are in ppm except for pH, specific conductance, and density]

	Atlantic Ocean	Brosewere Bay		Atlantic Ocean	Brosewere Bay
Silica	1.2	2.1	Bicarbonate	129	133
Iron (total)	1.3	.38	Carbonate	0	0
Manganese	.0	.0	Sulfate	2,290	2,070
Copper	.0	----------	Chloride	17,200	15,500
Lithium	.0	----------	Nitrate	1.1	3.3
Calcium	351	330	Dissolved solids	[2] 31,000	[2] 28,100
Magnesium	1,190	1,080	Hardness	5,770	5,260
Sodium	9,520	8,690	Specific conductance (micromhos at 25°C)	47,100	42,700
Potassium	373	346	pH	7.6	7.8
Zinc	.0	----------	Density at 20°C	1.019	1.017

[1] Samples collected on Apr. 18, 1956.
[2] Calculated values.

The density of average sea water is about 1.025. Data collected by the U.S. Coast and Geodetic Survey (1953) at tide stations on the east coast show that the density of ocean water has a seasonal range and also may vary from year to year. The density of ocean water at Atlantic City, N.J., for example, fluctuated between 1.0197 and 1.026 and averaged 1.023 during the period of record from 1912 to 1952. The density of a sample of ocean water collected near Atlantic Beach, Long Island, was 1.019 at 20°C on April 18, 1956 (table 5).

The water in the bays has a wide seasonal range in composition depending on the character of the water contributed from different sources. In many places the bay water is very similar to the ocean water described above. Elsewhere it is similar to slightly contaminated fresh water. An analysis of a water sample from Brosewere Bay near well N4026 at Hewlett Neck in southwestern Nassau County is given in table 5. The concentrations of dissolved solids and chloride are slightly lower than those in ocean water and the concentration of nitrate is about three times higher. The density was 1.017 in April 1956.

The chloride content of the water at selected sampling points in the creeks and bays (pl. 5) is given in table 6. In general the chloride increases from north to south toward the ocean and inlets in the barrier beaches. In the samples collected, it ranged from 200 ppm near the headwaters of Mott Creek at Valley Stream to 16,900 in the bay near Lawrence in southwestern Nassau. Most of the bay samples have about 16,000 ppm of chloride, indicating fairly good circulation of ocean water through the inlets in the barrier beaches. The range in chloride concentration represents chiefly the effects of the following factors: Location of the sampling point with respect to discharge areas of fresh surface and ground water, proximity of sampling point to inlets in the barrier beaches, tidal fluctuations, and the amount of rainfall.

From time to time during exceptionally high tides, the salty water from the creeks and bays inundates the adjacent land areas and contaminates shallow deposits. Under present hydrologic conditions fresh ground water is being discharged into a large part of the area occupied by bays. If heads in the aquifers were lowered below sea level for an extended period of time by heavy pumping, salty bay water could enter the aquifers by downward and lateral percolation and contaminate the fresh-water supplies.

TABLE 6.—*Chloride content of water in creeks, bays, and Atlantic Ocean in southern Nassau and southeastern Queens Counties*

[All analyses by U.S. Geol. Survey]

Sampling point	Location	Date sampled	Chloride (ppm)
	Nassau County		
1	Mott Creek at Rockaway Blvd., Cedarhurst	Apr. 2, 1952	4,600
2	Mott Creek, Valley Stream	1953	200
3	Tidal creek about 1,000 ft northeast of well N3861, Cedarhurst.	Mar. 27, 1956	5,300
4	Watts Creek, near well N3867, Green Acres	June 6, 1953	1,400
5	Brosewere Bay, foot of town dock, Hewlett Neck.	Aug. 13, 1953	14,600
5	do	Apr. 18, 1956	15,600
6	Reynolds Channel near well N3448, Long Beach.	Sept. 11, 1952	15,500
7	Reynolds Channel near well N2597, Long Beach.	Aug. 25, 1947	16,000
7	do	Apr. 17, 1956	15,900
8	Atlantic Ocean, foot of Laurelton Blvd., Long Beach.	Aug. 25, 1947	17,000
8	do	Apr. 17, 1956	16,250
9	Atlantic Ocean, foot of Albany Blvd., Atlantic Beach.	Mar. 29, 1956	17,500
9	do	Apr. 18, 1956	17,200

TABLE 6.—*Chloride content of water in creeks, bays, and Atlantic Ocean in southern Nassau and southeastern Queens Counties*—Continued

Sampling point	Location	Date sampled	Chloride (ppm)
Nassau County—Continued			
10	Reynolds Channel and Atlantic Beach Bridge, Atlantic Beach.	Apr. 20, 1956	16, 600
11	Foot of Barrett Road, and channel, Lawrence.	Mar. 29, 1956	16, 900
12	Meadow Causeway, near bridge, Lawrence	do	12, 300
13	Barnum Creek at Long Beach Road, Oceanside.	Apr. 17, 1956	16, 600
14	Channel, at south end of Lido Causeway, Lido Beach.	Apr. 19, 1956	16, 600
15	Merrick River, foot of Albany Ave., Freeport.	Aug. 21, 1953	400
16	Tidal Creek at town dock, Merrick	May 13, 1953	6, 300
17	Channel, at south end of Meadow Brook Causeway, Jones Beach.	Apr. 19, 1956	16, 500
18	East Bay, near Wantagh Parkway, bridge to Green Island.	do	16, 350
Queens County			
19	Jamaica Bay, foot of Beach 72d St., Belle Harbor.	Aug. 11, 1953	14, 500
20	Atlantic Ocean, jetty off Beach 81st St., Hammels.	June 12, 1956	17, 400

CHLORIDE DATA AS RELATED TO SALT-WATER ENCROACHMENT

Table 13 gives data on periodic determinations of chloride concentrations in wells within the project area. For the outpost wells and other nearby wells periodic determinations have been made since about September 1952, and for well N2790, since 1949. For other wells a few determinations were made in earlier years. The chloride content of the water from the outpost wells has fluctuated somewhat, but it has not increased progressively since the start of the determinations. Most of the fluctuations observed, especially those in wells N3861 and N3862, probably are within the possible errors inherent in the methods of collection and analysis, although some changes may be due to natural variations in the composition of the water in the zone of diffusion.

The chloride concentrations in water from well N4213 (Green Acres) in July and August 1954, however, are somewhat higher than at other times, and also coincide with the period of lowest water level. Possibly some movement of salty water from nearby Watts Creek or from overlying deposits into the aquifer was induced at that time. The well is probably too far from the main body of salt water to have been contaminated from that source.

The high concentration of chloride (table 13) in water from well N2790 at Bay Park in December 1949 and early 1950 is unusual. The first water sample, taken on December 15, 1949, after development of the well, contained about 608 ppm of chloride. It was suspected that the formation was contaminated locally during drilling operations or that there was a leak in the casing opposite salty water at shallow depth. The well was then pumped for 24 hours at a rate of 120 gpm, but no chloride samples were taken. A week later, on December 22, 1949, the well was pumped for 5 hours at a rate of 35 gpm. The first sample taken immediately after the start of pumping contained about 56 ppm of chloride, and then the concentration decreased steadily to about 36 ppm at the end of the 5-hour period of pumping. From that time to April 16, 1950, the well was sampled monthly, and the chloride concentrations were about the same, from 26 to 36 ppm. From April 6, 1950, to April 27, 1951, the chloride decreased from 36 to 10 ppm. Since then the concentration has fluctuated between 4 and 12 ppm.

Several factors are involved in explaining the unusual range in chloride concentration at Bay Park. First, the well is in marshland and less than a mile from salty tidewater in creeks and bays. Second, the drilling site was inundated by salty water at least once and perhaps several times during the drilling operations. The existence at shallow depth of water containing 500 ppm of chloride was confirmed by a test well 18 feet deep, drilled near N2790 in 1950. Third, a preliminary well was drilled to a depth of 870 feet about 25 feet from N2790. This well was abandoned owing to drilling difficulties. It was backfilled with miscellaneous materials including about 12 cubic yards of sand and gravel. A few months later settling was observed and more sand and gravel were placed in the hole. Fourth, the well was drilled by the rotary method, and the mud pit probably was dug in brackish-water-bearing sand. Brackish water may have been used in preparing some of the drilling mud and also perhaps in the initial development of the well after the screen was set. Fifth, the fall of 1949 and the spring of 1950 were periods of low rainfall, heavy pumping, and correspondingly low water levels. The initial static water level measured in the well in December 1949 was about at the land surface, some 3 feet above mean sea level. After that time the water level rose more or less steadily and in 1955 ranged from about 4 to 5 feet above sea level, except during a few months in the summer when the levels were as low as about 3 feet.

The conditions described above suggest that the initial high chloride content of the water in 1949 was not representative of the normal water. A small quantity of salty water may have been introduced into the Magothy(?) formation either during the drilling operations

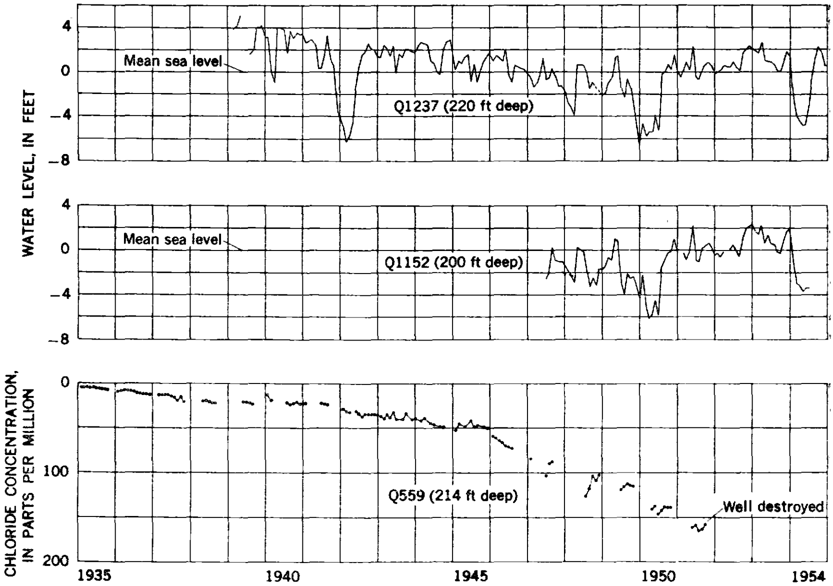


FIGURE 9.—Comparison of water levels and chloride concentrations of water from the Jameco gravel in southeastern Queens County, N.Y., 1935–54.

or inadvertently through the nearby abandoned well. On the other hand, as the well was drilled during a period of deficient rainfall, heavy pumping, and correspondingly low water levels, it is possible that the fresh-salt-water interface in the Magothy(?) was much closer to the well than its present estimated position.

Whereas most records are not long enough to show any progressive change in chloride concentration, the record for well Q559, which is in southeastern Queens County and is screened in the Jameco gravel, showed a progressive increase from 4 ppm in 1932, when the well was first drilled, to about 165 ppm in 1951, when the well was abandoned. The chloride determinations (table 13) were made by the Jamaica Water Supply Co., which formerly operated the well for public supply. The part of the record from 1935 to 1951 is plotted in figure 9, along with fluctuations of water levels in two nearby observation wells (Q1152 and Q1237) tapping the same confined body of water in the Jameco gravel. No accurate water-level records were available from the pumped well, Q559.

The chloride concentration in Q559 was less than 25 ppm and therefore was not considered significant up to about 1941. However, as the graph shows, the concentration increased slowly but steadily. From 1939 to 1950, water-level measurements made in well Q1237 about 0.85 mile southeast of Q559 show a progressive decline. This decline was largely the result of increased pumping from public-supply wells mainly in the area to the north. The chloride concentration in water from Q559 continued to increase even after 1950, when pumping decreased slightly and there was some recovery of water level in wells Q1152 and Q1237 (fig. 9). However, regional water levels were still too low to prevent additional encroachment and thus, when the well was abandoned in September 1951, the chloride concentration had increased to 159 ppm. A sample collected from well Q1237 on March 3, 1954, contained 140 ppm. At well Q1152 about half a mile south of Q559 and about half a mile west of Q1237, the chloride concentration in water in the Jameco gravel increased from 4 ppm in 1897 to 347 ppm in 1941. An analysis in 1954 showed a concentration of 140 ppm. The screens of these wells presumably are now in the zone of diffusion between fresh ground water and salty ground water extending northward from the area of Jamaica Bay.

About three-quarters of a mile northeast of Q559, the slow but progressive increase in chloride concentration in water from well Q314 suggests continued encroachment of salt water. The well is screened in the Jameco gravel and is pumped for public supply. It is on the southern perimeter of an area of heavy withdrawals near Jamaica in central Queens County. In 1938 the chloride concentration averaged about 5.4 ppm; in 1946, 11 ppm; in 1950, 15 ppm; and in 1953, 18 ppm. On June 2, 1958, the chloride content was 21 ppm, according to records of the Jamaica Water Supply Co.

In addition to these recent records, historic data on wells indicate something of the distribution of confined salty water in early years. Table 7 presents chloride data from early records. These data indicate that salty water was present at appreciable depths in Lawrence (near outpost well N3862) and Long Beach in southwestern Nassau County and on the Rockaway Peninsula in southeastern Queens County. About 1903, at well N319 in Long Beach, salty water was reported in the upper Pleistocene deposits, Jameco gravel, and Magothy(?) formation to a depth of about 270 feet (pl. 2). In the same area, at well N42, the chloride concentration at a depth of 550 to 608 feet in the Magothy(?) formation was reported to be 70 ppm in the spring of 1929, when the well was first drilled. Within 2 years the chloride is reported to have risen to about 280 ppm. The well was deepened, cased off in the Magothy(?), and screened in fresh water in the Lloyd sand member of the Raritan formation in 1939. In another well, N320 (Island Park), water from a depth of 380 feet was reported as "not good" prior to 1895, and the well was abandoned. Whereas the report probably did not refer to salinity, it is interesting to note that well N320 was less than 1 mile north of N42, which yielded slightly salty water from the lower part of the Magothy(?) in 1929 and in the early 1930's.

TABLE 7.—*Chloride content of water in the Jameco gravel and Magothy(?) formation from early records*

Well	Veatch No. [1]	Map coordinates	Date sampled	Depth sampled (feet)	Stratigraphic unit [2]	Quality of water and other data
N42		6B 0.7N 4.2W	1929	550–608	M	70 ppm of chloride when drilled. Chloride rose to about 280 ppm during next 2 yr. In 1939 upper screen blocked off, well deepened, and screened in Lloyd sand from 1,144 to 1,184 ft.
N223	V263	5B 1.9N 3.6W	Prior to 1903	416	M	"Exceedingly salty."
N232	V273	5B 4.5N 2.2W	do	190	J	Fresh. Used for public supply.
N319	V373	6B 0.2N 4.3W	1903	?–196	uP and J	"Salty."
				270	M	"Brackish." 159 ppm of chloride.
				383–386	M	29 ppm of chloride.
N320	V374	6B 1.6N 3.9W	Prior to 1895	123	J	"Fresh."
				380	M	Reported as "not good." Well abandoned.
N4714	V272	5B 3.5N 4.1W	Prior to 1905	228	J	"Fresh." Well flowed.
Q671	V188	4B 0.8N 0.2W	Prior to 1896	65–180	uP and J	"Brackish."
				180–190	M	Salty, well abandoned.
Q674	V191	4B 1.6N 0.2W	Prior to 1893	200	J	"Brackish." Well abandoned.
Q676	V193	4B 4.8N 2.3W	Prior to 1905	?–140	uP	"Brackish."
				202–203	J	Probably fresh. Well flowed.
Q681	V202	4B 5.8N 2.0W	Prior to 1895	156	J	5.5 ppm of chloride.
Q682	V203	4B 5.8N 1.6W	do	239	J	7 ppm of chloride.
Q1305	V196	4B 5.6N 0.6W	1897	0–207	J	Fresh.
Q1306	V200	4C 0.0N 2.4W	1894	170	J	38 ppm of chloride.
Q1307	V201	4C 0.2N 2.0W	1894	160	J	4.5 ppm of chloride.

[1] Well number used in U.S. Geol. Survey Prof. Paper 44 (Veatch and others, 1906).
[2] M, Magothy(?) formation; J, Jameco gravel; uP, upper Pleistocene deposits.

A number of occurrences of salty water, in both shallow and deep aquifers, are described in the report by the Commission on Additional Water Supply for the City of New York (Burr and others, 1904, p. 406–423). For example, in 1898, after prolonged pumping at the rate of several million gallons per day from shallow and deep wells, the chloride concentration in water from several individual shallow wells at the Jameco pumping station of the New York City Department of Water Supply, Gas, and Electricity (well Q366) increased from 8 to 670 ppm. The contamination was traced to a nearby salty tidal creek. In the deeper wells at the same station, screened in the Jameco gravel, the chloride concentration remained at about 5 ppm during the pumping. Similarly, the concentration of chloride in water from shallow wells at the former Baisley pumping station of the New York City Department of Water Supply, Gas, and Electricity, near well Q1237, averaged 150 ppm in 1897 and was as high as 2,950 ppm at individual wells. In 1911 this station was abandoned, presumably because of the saltiness of the water. The high concentration of chloride in the water may have resulted from the downward leakage of salty water from marshes as well as lateral encroachment from nearby estuaries and Jamaica Bay.

Increase in chloride content of water from the Jameco gravel at the former Shetucket pumping station of the New York City Department of Water Supply, Gas, and Electricity (not shown on pl. 1 but about a mile west of Q1152) also suggests the proximity of salty water as early as 1898. When the wells were first sampled in October 1897, the chloride concentration was 4.3 ppm. The concentration remained at this low level through March 1898 in spite of a pumping rate of almost 4 mgd. After the pumping rate was increased to 6 mgd in March 1898, the chloride concentration began to rise steadily, and by the end of the year it had increased to 74 ppm although the pumping rate had been reduced to about 3 mgd. At the end of 1899 the concentration was 222 ppm. In 1901 and 1902, although the pumping rate averaged only 1 mgd, the chloride concentration continued to rise, and in December 1902 it was 462 ppm. In order to determine whether the salty water was coming from the shallow deposits, a test well was sunk to a depth of 125 feet, terminating above the Gardiners clay. Samples of water were taken at various depths as the well was driven; chloride in these ranged from 4 to 20 ppm. This fact suggests that the salty water moved into the well field laterally beneath the Gardiners clay and probably from the direction of Jamaica Bay about a mile to the south. Whether the pumping induced salty water from the bay to enter the Jameco through permeable channel-fill deposits in the Gardiners clay or whether the salty water was in the aquifer at some distance south of the well field before pumping began and subsequently was drawn toward the pumping wells is unknown.

In either event, salty water apparently was present at some depth near these wells as early as 1898. In addition, the presence of salty water at wells Q671, Q674, and N223 suggests that, in the early 1900's, salty water was in the Jameco gravel and the Magothy(?) formation beneath part of the Rockaway Peninsula and the southern part of Jamaica Bay. Thus, its landward edge may not have been more than 1 or 2 miles seaward of the present estimated position (pl. 5).

GROUND WATER

DELINEATION OF BODIES OF FRESH AND SALT WATER

Ground water, both unconfined and confined, occurs in the unconsolidated deposits in the project area, at altitudes ranging from about 60 feet above to 1,700 feet below sea level. The deposits are saturated with ground water from the water table to bedrock, but owing to differences in porosity and permeability, some of the major geologic units yield and transmit water much more readily than others. Four geologic units constitute three main water-yielding units (aquifers): The upper Pleistocene deposits, the Jameco gravel and Magothy(?) formation (principal aquifer), and the Lloyd sand member of the Raritan formation. The confining beds (aquicludes) include the "20-foot" clay, the Gardiners clay, and the clay member of the Raritan formation.

All aquifers in the area, regardless of their location, depth, or chemical quality of the water, are interconnected to a greater or lesser degree and overall constitute a unified hydraulic system. However, for simplicity in presentation and because confining beds greatly retard movement, the water in each aquifer is treated as a separate body. The water is further classified as unconfined and confined and as fresh and salty.

BODIES OF FRESH WATER

There are three major bodies and several minor bodies of fresh water in the deposits underlying the report area. The shallowest of the major water bodies is unconfined water in the upper Pleistocene and Recent deposits. The main part of this water body underlies the entire area north of the lagoons and bays, but a small elongate extension occurs beneath the Rockaway Peninsula in southwestern Nassau County. Second is confined water (principal confined water body) in the Jameco gravel and Magothy(?) formation. Third is confined water in the Lloyd sand member of the Raritan formation. In addition, several minor unconfined bodies of fresh water occur separately in the upper Pleistocene and Recent deposits in the islands and barrier beaches along the south shore. Water in small areas of the upper Pleistocene deposits is confined between the "20-foot" clay and the Gardiners clay.

UNCONFINED AND CONFINED FRESH WATER IN UPPER PLEISTOCENE AND RECENT DEPOSITS

Most of the unconfined water in the upper Pleistocene and Recent deposits occurs north of the lagoons and bays, but some extends to the southwest beneath the Rockaway Peninsula. The water is contained almost entirely within the outwash deposits, although, along the fringes of the bays, it extends into beach and marsh deposits of Recent age. Its upper limit is the water table, or top of the zone of saturation. Its lower limit is generally at the top of the Gardiners clay in the southern part of the area (fig. 7) and at the top of the Magothy(?) formation elsewhere. Locally, where lenticular beds of clay or clayey sand occur in the outwash immediately above or within the zone of saturation, parts of the water may be confined under slight pressure. Where the "20-foot" clay or the Gardiners clay is present, the unconfined water is in only restricted hydraulic continuity with water in the underlying aquifers. Beyond the areas in which these clays are present and where the upper Pleistocene deposits rest on the Magothy(?), there is closer hydraulic connection, and the water may move from one unit to the other, depending on the relative hydrostatic heads.

The water is generally of good quality and is poor only where it is mixed with salt water locally in the shoreline areas. At most places the depth to the water table is less than 50 feet, although at some points on the Harbor Hill moraine in Queens County the depth to water is as much as 150 feet. Plate 3 shows contours on the water table in April 1954. The contours were prepared from measurements made in 145 observation wells by the U.S. Geological Survey and the Nassau County Department of Public Works.

The map shows that the water table slopes gently seaward and has an average gradient of about 10 feet per mile from the ground-water divide, which at most places lies several miles north of the project area. Near the ground-water divide and in the meadowlands fringing the bays, the slope of the water table is somewhat less than in the intermediate area. Where the water table is intersected by stream channels, the contours are deflected upstream in characteristic "cusps," such as those shown along Massapequa Creek and East Meadow Brook in southeastern Nassau County. These deflections indicate that ground water is discharging into the streams. A departure from the general southward slope of the water table is found in the elongated ground-water mound beneath the Rockaway Peninsula in southwestern Nassau County. The crest of the mound is marked by the closure of the 10-foot contour. The land surface in the highest parts of this peninsula is about 30 feet above sea level. As indicated by the configuration of the water table, the water flows radially outward from the center of the peninsula in contrast to the generally southward movement of most of the water.

In addition to the major unconfined water body in the upper Pleistocene deposits, there are numerous small discontinuous bodies of unconfined water beneath the barrier beaches and the many small islands in the bays. These are small in area and thickness and are tapped at relatively few places. The water table of these local water bodies is ordinarily less than 5 feet above sea level and is not shown on plate 3. Records of wells that have been drilled to these small unconfined bodies indicate that the water is salty at some places.

Confined ground water occurs in beds of the upper Pleistocene deposits that lie between the "20-foot" clay and the Gardiners clay. This confined water is restricted to the southern part of the area, mainly in Nassau County, and is only a few tens of feet thick at most. The water is fresh in some places and salty in others. The head of fresh water is slightly higher than the water table, except beneath the ground water mound in the Rockaway Peninsula where the reverse is true. This confined water body is not an important source of supply.

CONFINED FRESH WATER IN JAMECO GRAVEL AND MAGOTHY(?) FORMATION

The confined fresh water in the Jameco gravel and Magothy(?) formation is the principal water body in southern Nassau and southeastern Queens Counties. Within the areal limits of the Gardiners clay and the "20-foot" clay (fig. 7), the top of this body is at the base of these units. Elsewhere the confined water is in restricted hydraulic continuity with the unconfined water in the upper Pleistocene deposits, and its upper limit is not well defined. In the area north of the "20-foot" clay and Gardiners clay, the altitudes and fluctuations of the water levels in both the unconfined and the upper part of the principal confined water body are similar. Nevertheless, water levels in some wells tapping the upper part of the confined body of water reflect "leaky" or semiartesian conditions, whereas water levels in deep wells have distinctly artesian characteristics. Therefore, for simplicity of presentation, in the area where the confining clays are missing, the contact between the glacial outwash deposits and the Magothy(?) formation is considered to be the top of the principal artesian aquifer. The lower limit is at the top of the clay member of the Raritan formation.

Within a large part of the project area, the upper and lower limits of the principal body of confined water are coincident with the boundaries of the Magothy(?) formation. In southern Queens and southwestern Nassau Counties, however, the upper part of the principal water body is in the Jameco gravel (fig. 5). The thickness of the principal confined body of water is greatest, about 1,000 feet, at Jones Beach in southeastern Nassau County. It is least, about 200 feet, in central Queens County.

Plate 4 shows contours on the piezometric surface of the principal artesian aquifer. These are, for the most part, based on measurements made in April 1954 of static levels in unused or new wells, and of water levels in production wells measured during shutdown periods. Water levels measured in the outpost wells, at wells N128, N4545, and N4547 in the Jones Beach area, and at observation well N180 in Seaford, provided the basic control for the contours in about the southern half of the map. In the northern half, contours were drawn largely on the basis of reported water levels in public-supply and industrial wells. Plate 4 also shows in southeastern Queens County a small segment of a 10-foot piezometric contour reconstructed for the year 1896, from the reported water levels in a few wells (Veatch, 1906).

Water levels for both deep and relatively shallow artesian wells were used in the preparation of the piezometric contour map. Inasmuch as there are some differences in head between the top and bottom of the unit in places, contours were drawn, insofar as possible, to represent heads at intermediate depths in the confined water body. In the extreme northern part of the area, head differences from top to bottom of the water body are as much as 5 feet. In that area, ground water is moving downward from the shallow to the deep deposits, and there is a gradual decrease in head from top to bottom of the aquifer. In the southwestern part there are differences in head of about 1 foot between the top and bottom of the unit, and in the southeastern part there are differences of as much as 3 feet. In the southern part of the area, confined water moves generally upward, and there is a gradual loss in head in that direction. Many wells in the southern part of the area flow, especially where the land surface is only a few feet above sea level. Details of the pattern of flow are discussed in the section "Movement of ground water."

The piezometric surface of the principal artesian aquifer slopes gently seaward from the main ground-water divide, which lies several miles north of the project area. In broad aspect, contours on this surface are approximately parallel to those of the water table in the northern and central parts of the area. The gradient and the southward slope are nearly uniform in all but the western and southern parts. The contours from the 50-foot to the 10-foot altitudes are almost equally spaced. Also, from about long 73°40′ eastward, these contours are alined mainly east-west, indicating a general southward flow. West of long 73°40′ the contours bend northwestward, indicating that the flow changes to a southwesterly direction toward the area underlain by the Jameco gravel (fig. 5). Although the data are insufficient for contouring, spot water levels show that heavy pumping has created a cone of depression near Jamaica, Queens County and has been responsible for some lowering of water levels and changes in the natural direction of flow in the southwestern part of the project area. However, the segment of the 10-foot contour of about 1896 is nearly parallel to the 10-foot contour of 1954 (pl. 4), although they are offset about a mile.

Comparison of plate 4 with figure 5 shows that the 10-foot contour, and also the 5-, 4-, and 3-foot contours, are approximately parallel to the landward limit of the Jameco gravel. This alinement suggests that ground water moving southwestward in the principal confined water body passes into and through the Jameco gravel which, owing to its high permeability, facilitates ground-water movement toward areas of natural discharge in the vicinity of Jamaica Bay.

Beginning about at the 10-foot contour, along a line which approximately corresponds with the edge of the Pleistocene marine clays (fig. 7), the piezometric surface abruptly flattens. This flattening occurs in the area where the water which has been moving horizontally begins to move upward. The gradient indicated by the contours in this area represents only the horizontal component of the true hydraulic gradient, which is much steeper (pl. 7). In the vicinity of the Mill Road well field of the Long Island Water Corp., at

Woodmere, there is a depression in the piezometric surface caused by pumping from the Jameco gravel and the upper Pleistocene deposits. The dimensions of this depression (figs. 18 and 20) vary seasonally with changes in the rate of pumping.

CONFINED FRESH WATER IN LLOYD SAND MEMBER OF THE RARITAN FORMATION

The confined water in the Lloyd sand member of the Raritan formation is the lowermost body of fresh water. This body occurs directly above the bedrock and is 200 to 300 feet thick. It is separated from the principal body of confined water by the clay member of the Raritan formation (section *C–C′*, pl. 2). The water is fresh throughout the project area.

Hydraulically, the Lloyd sand member is a more nearly ideal artesian aquifer than any other water-bearing unit on Long Island, as it is bounded at the bottom by crystalline bedrock and at the top by the relatively impermeable clay member of the Raritan formation. The degree of confinement in this aquifer is best indicated by the large distances over which interference effects from pumping are felt. These effects have been observed as much as 7 miles away from centers of pumping (Leggette, 1937); by contrast, declines of water levels in the principal confined water body are generally observed only within a mile or two of pumped wells.

The complex pattern of movement of water in the Lloyd is not known in detail. Recharge doubtless takes place mainly by downward movement of water from the overlying formations near the middle of Long Island, for the most part north of the project area. Beneath the southeastern part of Nassau County some of the water in the Lloyd probably passes upward into the Magothy(?) by slow leakage through the clay member of the Raritan formation, and in the southwestern part some of the water moves laterally to zones of natural discharge near the south shore and toward centers of heavy pumping in central Queens County.

A generalized contour map of the piezometric surface of the Lloyd (Lusczynski, 1950) shows that the head in the area of the present report was highest, 25 to 30 feet above mean sea level, in east-central Nassau County, and lowest, about 15 feet below sea level, in the area of heavy pumping in central Queens County.

BODIES OF SALT WATER

Several bodies of salty ground water are in the project area. First are various bodies of unconfined salty water which consist of lenses, some of them extensive, at relatively shallow depths in the upper Pleistocene and Recent deposits along the shore. Second are bodies of confined salty water in the principal aquifer. The bulk of this confined salty water occurs in the Jameco gravel and Magothy(?)

formation in the southwestern part of the project area and is termed "the main confined salt-water body." An extension of this body lies at relatively shallow depth in the Jameco gravel and Magothy(?) formation from Atlantic Beach to Lido Beach. A relatively minor body of confined salty water occurs in the beds of sand and gravel between the "20-foot" clay and the Gardiners clay, but little is known of its extent.

The various salt-water bodies are in hydraulic contact with fresh water in the same aquifers. The boundary between the fresh and salt water is usually not a sharp surface of separation such as that found between immiscible liquids. Instead, a zone of water of mixed chemical composition, referred to as the "zone of diffusion," occurs between the fresh water and the water of maximum saltiness. Probably molecular diffusion and mixing resulting from small fluctuations in the position of the boundary produce this zone. Chloride concentrations in the zone of diffusion range from about 10 to 40 ppm on the fresh-water side to about 18,000 ppm (the chloride content of average sea water) on the salt-water side.

Unconfined salty ground water in the shallow deposits probably is connected rather freely with salt water in the open bays and ocean, whereas salty confined water in the deeper deposits is connected rather poorly through overlying beds of silt and clay. Water levels in wells that tap the main confined body of salt water are affected by nearby pumping of fresh water in the same aquifer and also respond to changes in tidal loading and in barometric pressure.

UNCONFINED SALT WATER IN UPPER PLEISTOCENE AND RECENT DEPOSITS

Unconfined salt water is present at shallow depths in the upper Pleistocene and Recent deposits beneath the beaches and marshes of the south shore. In general, it does not occur inland more than a few hundred yards from the shorelines of tidal creeks and other open bodies of salty water, and is not found at depths greater than about 100 feet below sea level. At its landward edge it is in direct hydraulic contact with unconfined fresh water. Information regarding the exact extent of this salty water along the shore is scanty, as only a few wells tap it. A line marking the inland limit of unconfined salty water would be highly irregular, extending northward in lobes wherever tidal creeks or bays indent the shoreline, but in general it would probably be close to the inland limit of the area mapped as marsh and artificial fill on plate 1. No attempt has been made here to map the unconfined body of salt water, but some occurrences of the salt water are described.

In the Rockaway Peninsula, unconfined salty ground water occurs in the shoreline deposits and beneath the tidal marshes. At several of the outpost-well sites, and at a few other scattered locations, wells driven to depths of 10 or 20 feet below sea level yield water having a chloride concentration as high as 4,200 ppm (table 13).

Chloride concentrations in the unconfined salt water are influenced by changes in tides, discharge from streams, and precipitation. For example, after the abnormally high tides of November 1953 there were pronounced increases in chloride in water from shallow wells tapping nonartesian aquifers along the shore. Some of these increases were due to salt-water encroachment in the aquifer resulting from a temporary landward hydraulic gradient, and others to downward percolation of salty floodwaters after the well sites had been temporarily inundated.

Aside from changes produced by such sporadic events, the inland extent of unconfined salty ground water is determined mainly by the distribution of heads in adjacent bodies of fresh water. Figure 10 shows the relation in the vertical dimension between fresh and salt water at shallow depths near the shore of East Bay, Wantagh. In this area, and extending to about 35 feet below mean sea level, ground water having a chloride concentration up to about 6,800 ppm occurs adjacent to and beneath the unconfined fresh water. A clay, thought to be the "20-foot" clay, separates them both from the

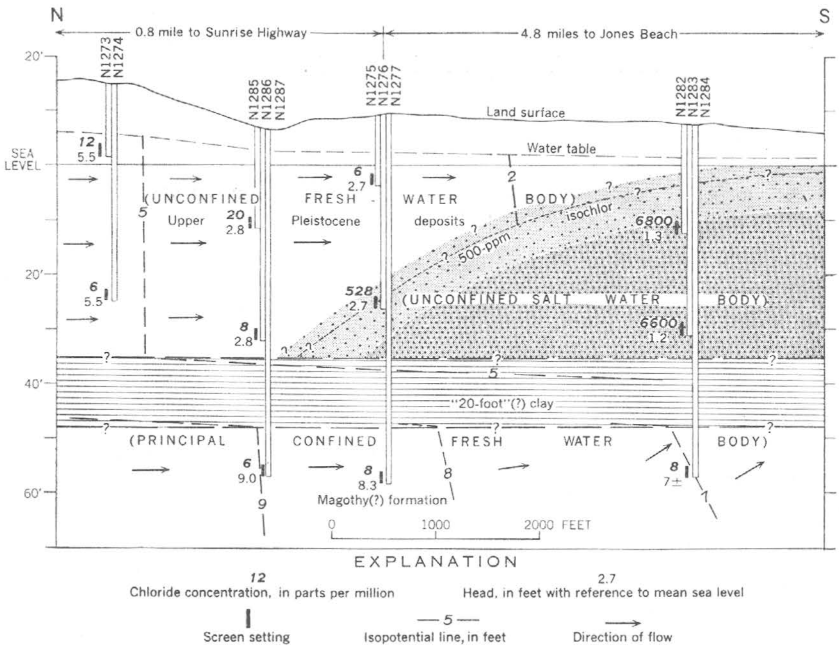


FIGURE 10.—Section showing relation between fresh and salt water at shallow depth south of Wantagh, Nassau County, N.Y.

underlying principal confined fresh-water body in the Magothy(?) formation. The relation shown in figure 10 probably is typical of the occurrence of unconfined salty ground water at many places along the south shore of Nassau County. The general hydraulic relation between unconfined fresh water and salt water is discussed in a later section "Sea-water encroachment."

CONFINED SALT WATER IN JAMECO GRAVEL AND MAGOTHY(?) FORMATION, MAIN CONFINED SALT-WATER BODY

The largest and most significant body of salty ground water with respect to sea-water encroachment occurs as a wedge in the Jameco gravel and Magothy(?) formation in the southwestern part of the project area. Plate 5 shows the areal extent of the main confined salt-water body and the concentration of chloride in water from selected wells. Figure 11 shows a detailed section through the salt-water body in southwestern Nassau County. Other sections are shown on plates 2 and 7.

In southeastern Queens County, salty water is probably in the Jameco gravel and Magothy(?) formation beneath Idlewild Airport and most of the area south and southwest of Rockaway Boulevard. Beneath Jamaica Bay and Rockaway Beach this body apparently is continuous with salt water in the upper Pleistocene deposits. Beneath the villages of Cedarhurst, Inwood, Lawrence, Woodmere, and Hewlett Neck in Nassau County the salt water extends inland mainly in the middle and lower parts of the Magothy(?) formation. Southeastward, beneath Atlantic Beach, Long Beach, and part of Lido Beach, salty water occurs both in the lower and upper parts of the Magothy(?) formation and is also in the Jameco gravel (sec. *C–C′*, pl. 2). At Jones Beach the deep salt-water body is entirely south of the shoreline.

The base of the main confined salt-water body is marked by a relatively thin zone of diffusion at or slightly below the upper surface of the clay member of the Raritan formation. The top is marked by a relatively thick zone of diffusion whose limits are known partly from determinations of chloride concentrations and partly from electric logs.

The depth and thickness of salty water are indicated approximately by the low resistivity recorded on the electric logs opposite sandy zones, which normally show high resistivity where they contain fresh water. For example, the electric log of well N3862 at Lawrence (fig. 12) indicates that the water becomes increasingly salty below a depth of about −125 feet (125 ft below sea level). At a depth of about −288 to −298 feet, where the well is screened, the chloride content of the water (table 4) has ranged from 1,720 to 2,300 ppm.

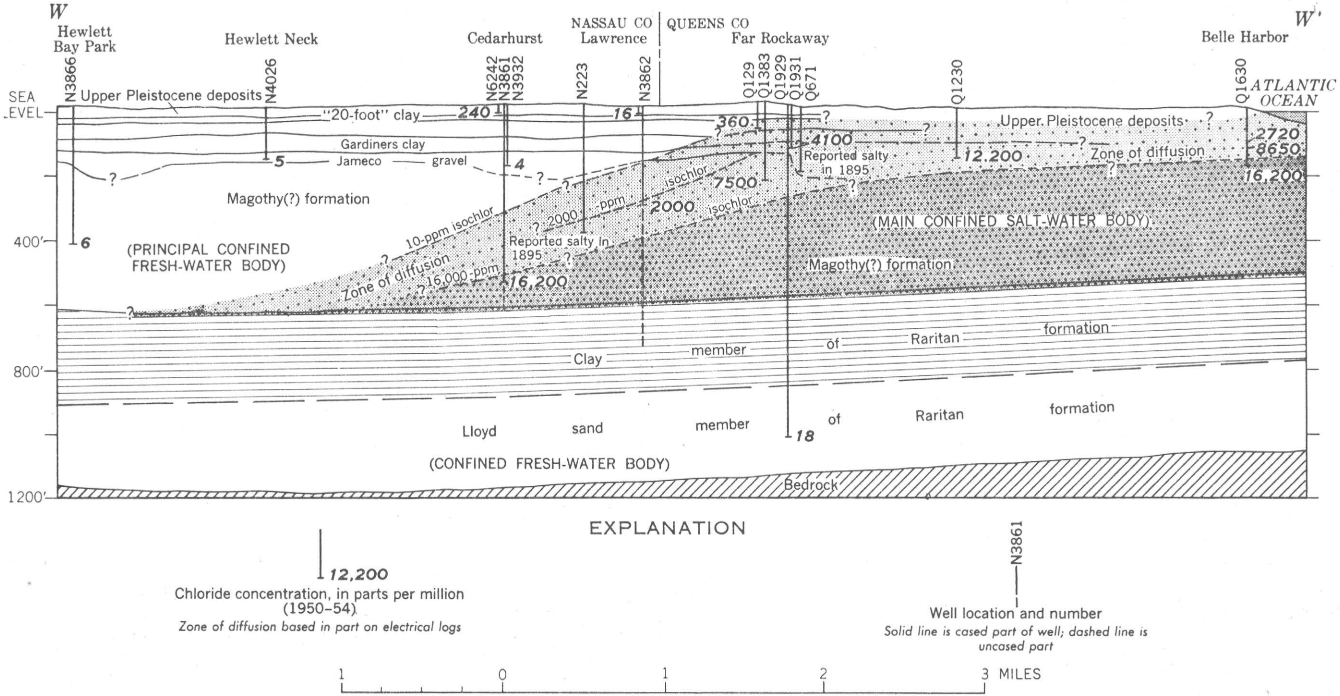


FIGURE 11.—Section showing chloride concentrations and extent of main confined salt-water body along line *W–W'* on plate 5.

The resistivity curve suggests that salty water extends a short distance below the top of the clay member of the Raritan formation and that the water in the clay becomes increasingly fresh below a depth of about —670 feet.

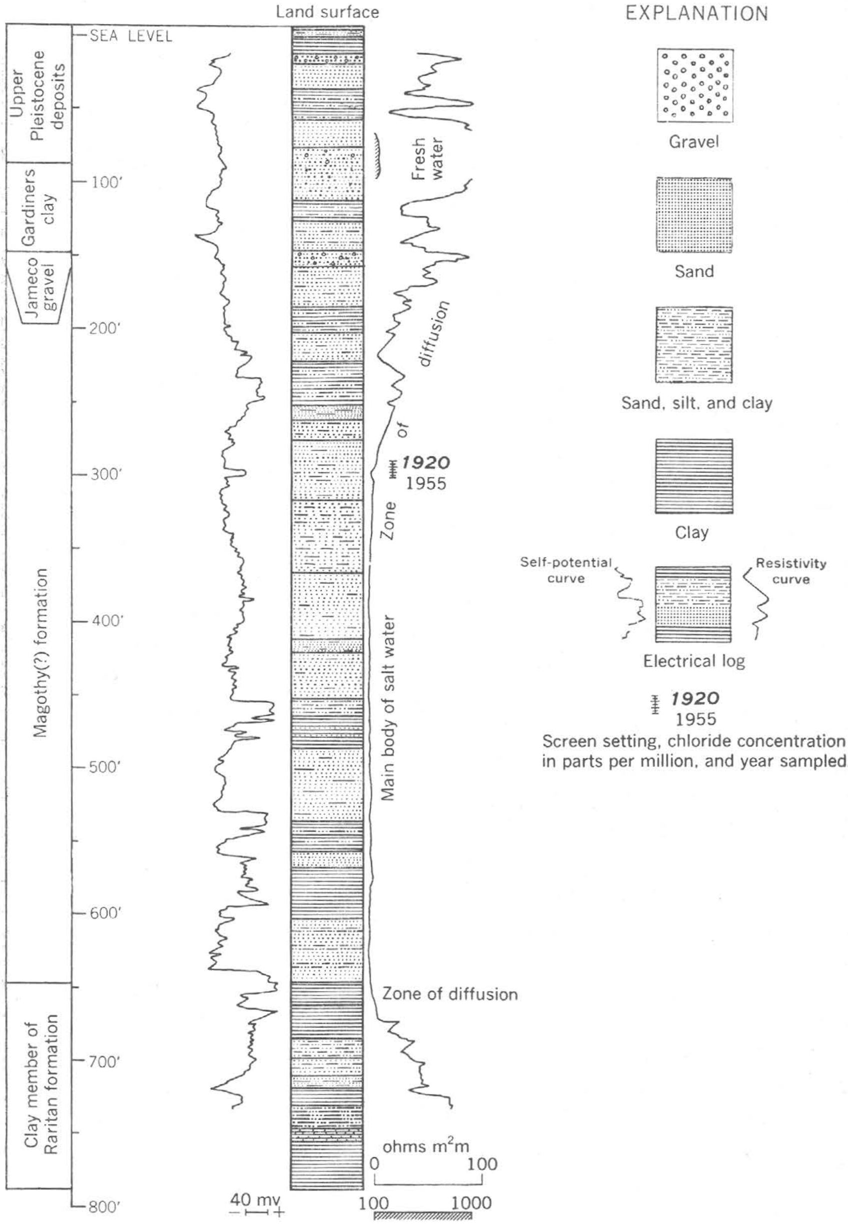


FIGURE 12.—Geologic column and electrical log of outpost well N3862, Lawrence, Nassau County, N.Y.

The electric log of well N3862 shows that water containing about 2,000 ppm of chloride occurs at a depth of −300 feet where the resistivity curve approaches zero. The resistivity curve for N3861 at Cedarhurst (pl. 2) approaches zero at a depth of about −380 feet, suggesting that water containing several thousand ppm of chloride occurs at that depth also.

At well N3864 in Woodmere a thin zone of salty water occurs near the bottom of the Magothy(?) formation from about −560 to −580 feet (pl. 2). This occurrence was first suggested by N. J. Lusczynski and W. V. Swarzenski (written communication, 1959) of the Geological Survey, on the basis of the anomalous reduction in the resistivity curve opposite the bottom of the Magothy(?) formation (pl. 2) and on evidence from chemical analyses that the original cores contained some interstitial salty water.

At a depth of −425 feet in well N4405 at Atlantic Beach (pl. 2), the near-zero values of the resistivity curves indicate the presence of water containing several thousand parts per million of chloride. The electric log for N4405 also suggests that water at a depth of about −175 feet has a chloride concentration of several thousand parts per million. Saltier water is present above −175 feet at well N4405, as indicated by the low value of the resistivity and by a measured chloride concentration of about 4,300 ppm at a depth of −140 feet in nearby well N3863.

The electric log of well N2597 at Long Beach (pl. 2) suggests that salty water having chloride concentrations in excess of 2,000 ppm occurs in the shallow zone above −225 feet and also in the deep zone below about −560 feet. The electric logs of wells N5308 at Long Beach, N5227 at Lido Beach, and N5129 at Jones Beach (pl. 2) are single-electrode logs which do not record the presence of salt water as clearly as do the multiple-electrode logs such as those of N4405 and N5768. According to the interpretation of the electric logs, salty water is present in the lower beds of the Magothy(?) formation as far east as well N5768 and possibly as far east as well N5227. The main salt-water body was not found beneath well N5129 at Jones Beach.

As thus delineated, the main body of salt water is a wedge. The thickness is greatest at the southwest and south, where the main body probably merges with salt water in the Recent and upper Pleistocene deposits to form a continuous salt-water zone extending from the sea bottom to about the base of the Magothy(?) formation (fig. 11). South of the shoreline, salt water doubtless occurs also throughout the full thickness of the unconsolidated deposits including the Lloyd sand. Northward and northeastward the salt-water body thins to a featheredge at the top of the Raritan formation approximately along the line shown on plate 5. This landward limit is estimated from relatively scanty data and is probably more lobate than is shown on the map.

The shallow extension of the main confined salty water, extending eastward beneath the area from Atlantic Beach to Lido Beach and northward for an unknown distance, can be delineated only approximately (pl. 2). It is in both the Jameco gravel and the upper part of the Magothy(?) formation. Along the barrier beach, west of the Queens-Nassau County line, the shallow extension merges with the main salt-water body.

FLUCTUATIONS OF WATER LEVELS

Fluctuations of water levels in wells provide valuable information about the hydrology and geology of the project area. First, they are an index of the natural balance between recharge and discharge of ground water and indicate modifications of that balance caused by pumping and climatic changes. Second, they indicate hydraulic interconnection or separation between aquifers and thus help to establish the extent of confining beds and the limits of the bodies of water.

Net changes in water levels over long periods of time are the most significant with respect to the long-term balance between recharge and discharge. Other minor and recurring fluctuations, particularly some of those in confined water bodies, are caused by variations in barometric pressure, tidal loading of aquifers near the shore, and earthquake shocks. They are related to certain hydraulic characteristics of the aquifers but have no direct bearing on the recharge-discharge balance. Fluctuations resulting from pumping often are larger, more readily interpreted, and more significant with respect to the problem of sea-water encroachment.

Records of water-level fluctuations are available for each of the major fresh- and salt-water bodies described previously. Systematic measurement of water levels in the unconfined aquifer was begun between 1932 and 1944 in about 130 observation wells in southern Nassau County. Most of the wells are screened in the unconfined fresh-water body, but a few of them are screened in unconfined salty water. In southeastern Queens County, measurements have been made periodically since 1940 in 15 observation wells in the unconfined fresh-water body. In addition to the periodic measurements, a contour map of the water table in 1903 is available (Burr and others, 1903, pl. 8).

In 1938 periodic observations of water levels were made in only 3 wells that tap artesian aquifers. By 1955, the number of artesian wells measured periodically had increased to about 30. Measurements of water level made in a few artesian wells as early as 1895 give some sketchy data on the altitude and shape of the piezometric surface at that time. These early records are listed in table 8 together with more recent measurements in nearby wells.

FLUCTUATIONS THAT SHOW THE RELATION BETWEEN RECHARGE AND DISCHARGE OF GROUND WATER

Under natural conditions a close relation exists between water levels and rates of recharge from precipitation. Thus, the long-term pattern of water-level fluctuations in the parts of the project area where pumping is light should reflect primarily the long-term precipitation pattern. A relation between the composite average water level in 14 selected observation wells screened in the water-table aquifer in Nassau and Suffolk Counties and the 25-year progressive average annual precipitation was developed by Jacob (1945b). A fair correlation can be made between graphs of the water-level and precipitation averages; consequently, long-term changes in the average water level of the 14 selected wells provide an index of fluctuations in natural rates of recharge. Water levels in artesian wells unaffected by pumping also fluctuate in a manner similar to those in water-table wells, but the seasonal range is much smaller. The hydrograph of the average of the 14 selected wells is compared with hydrographs for water-table and artesian observation wells on figures 13, 15, and 16.

Recharge from precipitation has a relatively prompt effect on the water levels in wells tapping the unconfined fresh-water body. Where the water table is close to the land surface, water levels rise almost immediately, or at any rate within a day or two, after a storm; where depths to water are great, however, periods of several months may elapse between a storm or the main "wave" of winter recharge and the resulting rises in water levels. The proportion of rainfall percolating to the water table varies seasonally, being greater in the winter months and less in the summer when vegetation and transpiration are at their peak. As a result, the water table normally declines during the spring and summer and recovers during the fall and winter. Hydrographs of shallow wells (figs. 13 and 16) show this seasonal pattern. The magnitude of the fluctuations depends largely on the location of the well with respect to the water-table divide and to the shoreline discharge area. Under natural conditions average water levels in shallow wells near the divide fluctuate as much as 3 or 4 feet per year; in some near the shore the fluctuation is less than 1 foot.

The hydrographs on figure 13 show fluctuations of water levels in several water-table wells in Queens County. Most of them record significant declines due to pumping. In well Q1252 in Jamaica the

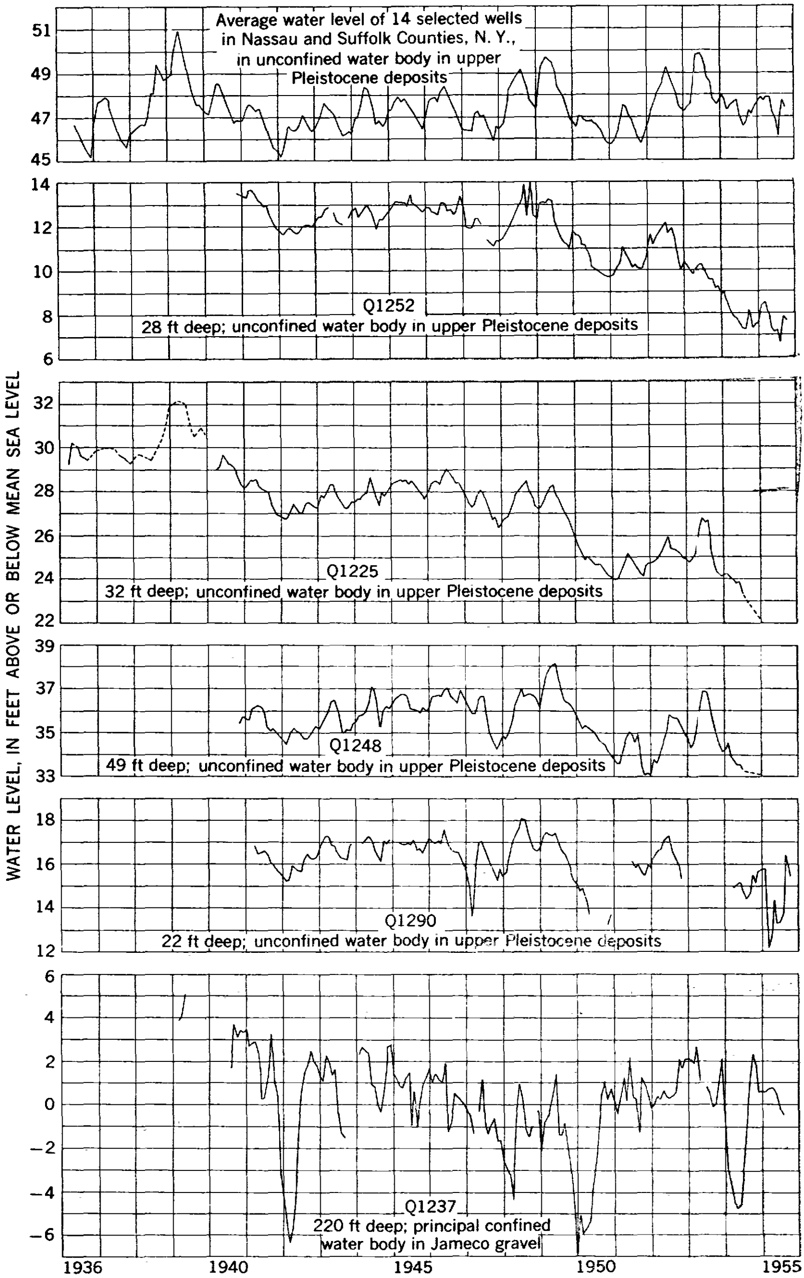


FIGURE 13.—Fluctuations of water levels in unconfined and confined water bodies in southeastern Queens County, N.Y., 1936–55.

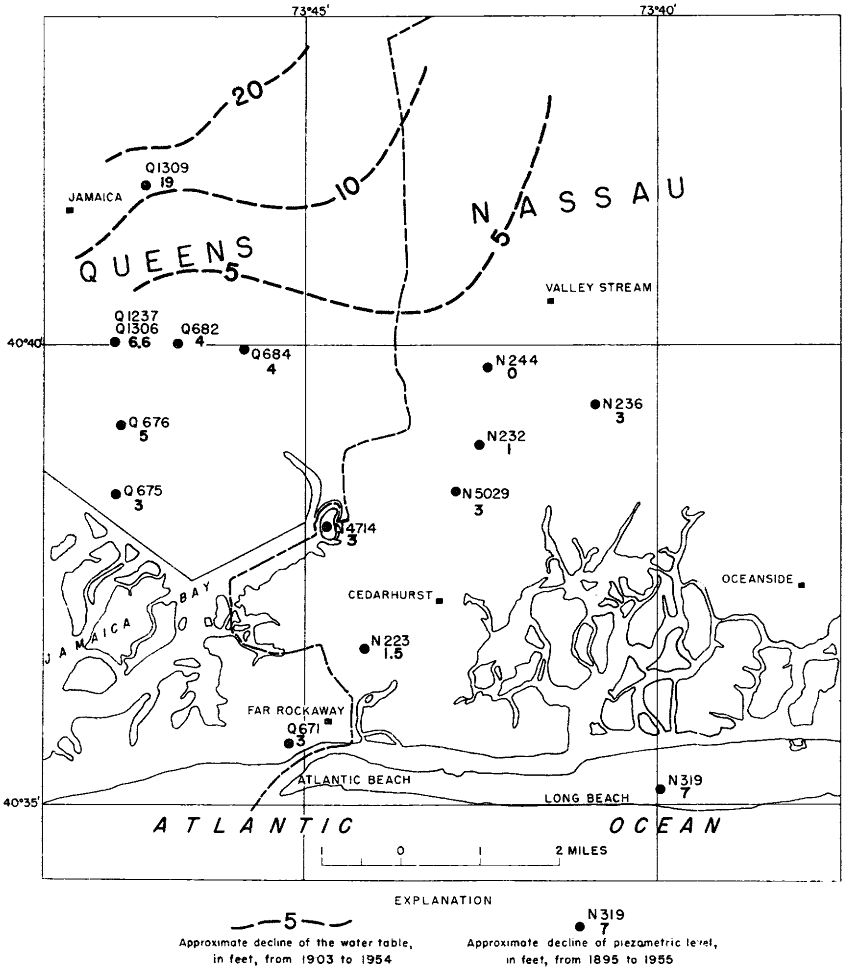


FIGURE 14.—Map showing approximate net decline of the water table and spot changes on the piezometric surface of the principal artesian aquifer, 1895 to 1955.

net decline was about 6 feet from December 1940 to the end of 1955; in well Q1225 the net decline was about 8 feet from early 1936 to the end of 1954; in well Q1248 the net decline was about 3 feet from the end of 1940 to the end of 1954; and in Q1290 the net decline was about 1 foot from the early part of 1941 to the end of 1955. The overall net declines since 1903 are about 20 feet at the site of well Q1252, 15 feet at the site of well Q1225, 12 feet near well Q1248, and 7 feet near well Q1290. Figure 14 gives contours illustrating this net change in southeastern Queens County.

In central and southeastern Nassau County the water table has shown no long-term declines since periodic observations were begun, whereas in southwestern Nassau County near the border of Queens County, water levels in a few wells have declined more than 5 feet. Near Valley Stream, the water table declined about 1 foot from 1939 to 1955 (N1110, fig. 16).

As a result of former pumping from the infiltration galleries of New York City's Ridgewood system in southeastern Nassau County, the water table was temporarily lowered as much as 8 feet in nearby wells (N1222, fig. 15). However, there was no long-term decline of water levels between 1939 and 1955.

The longest continuous record of water levels in artesian wells in southern Nassau County, begun in 1945, is that for well N180 near Seaford (fig. 15); the longest record in southeastern Queens County, begun in 1939, is that for well Q1237 (fig. 13).

Measurements of water levels have been made in most of the outpost wells since 1952. The record for well N2790 was started in 1950. Plate 6 illustrates hydrographs for the shallow and deep outpost wells and for observation wells N180 and N4547. The graphs are based

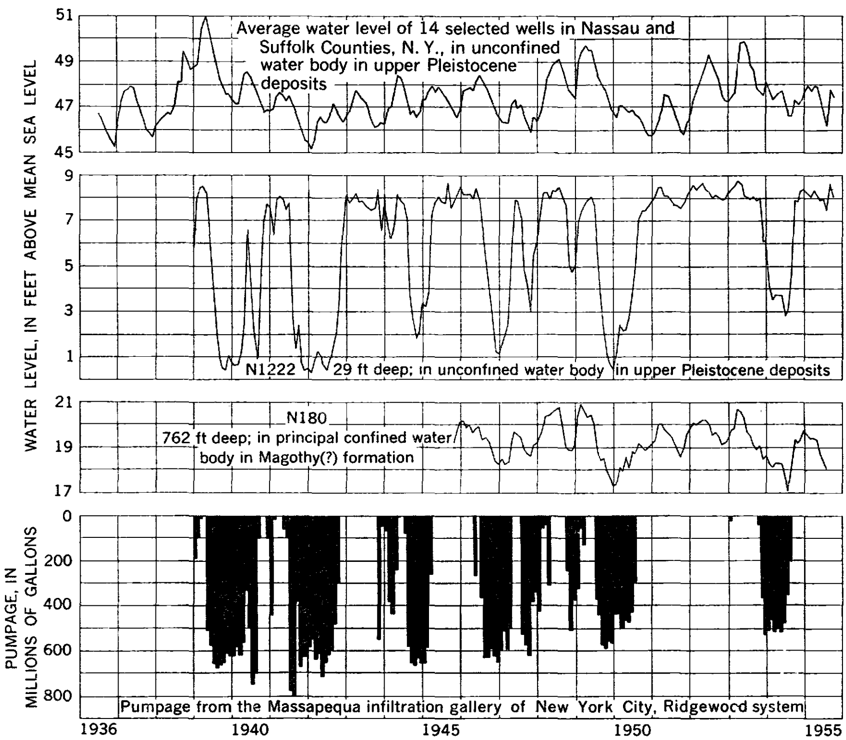


FIGURE 15.—Comparison of month-end water levels in unconfined and confined water bodies with monthly pumpage from the Massapequa infiltration gallery of the New York City Ridgewood system in southeastern Nassau County, N.Y., 1939–55.

on mean water levels for the 10th, 20th, and last day of each month. Plate 6 shows only part of the record for well N180; all of it is given in figure 15. A report by Isbister (1959) gives monthly measurements of water levels in all the outpost wells from 1953 to 1957.

All the hydrographs in plate 6 show similar responses at about the same time to changes in natural recharge and discharge. Thus the hydrographs suggest that the wells tap the same body of water. The natural fluctuations are modified by the declines and recoveries caused by changes in rates of pumping. The magnitude of the summer declines is greatest in the Rockaway Peninsula and less toward the east with increasing distance from the center of heavy pumping. For example, the summer declines in well N3864 largely reflect nearby pumping, whereas the summer declines in well N4149 largely reflect normal seasonal changes in recharge and discharge, and to a lesser extent increases in summer pumping at public-supply wells to the north. The hydrograph for well N180 shows effects of local pumping from the wells and infiltration galleries of the New York City Ridgewood system during early 1950 and the summer of 1954.

In the Valley Stream area, some declines due to pumping have been noted (fig. 16). For example, the record for well N1613, screened in the lower part of the Magothy(?) formation, shows a marked decline from 1952 to the end of 1955. The record for nearby well N9, screened in the upper part of the Magothy(?) formation, shows a similar though smaller decline. These declines reflect a substantial increase in withdrawals from nearby public-supply wells that were constructed during 1952–54.

A comparison of scattered water-level measurements for the years 1895–1905 with more recent data shows appreciable net declines of the piezometric surface at some places. Table 8 gives reported and estimated artesian water levels for the years 1895–1905 and estimated levels in the same areas for 1955. Water levels in April 1955 were selected for comparison with the early levels, as regional pumping was at a minimum at that time and both the Mill Road station of the Long Island Water Corp. and New York City's Ridgewood system were shut down. The wells for which older data are available are plotted on figure 14.

In 1903, which was a year of above-normal precipitation, the artesian head in well N5029 (screened in the upper part of the principal confined water body) near the south end of the Mill Road station, was about 9 feet above sea level. In April 1955 the head in this well field after a 2-week recovery period was about 6 feet above sea level (hydrographs of N1379 and N3864, pl. 6). Thus the apparent net decline of artesian head in this vicinity is not more than about 3 feet since 1903 (fig. 14).

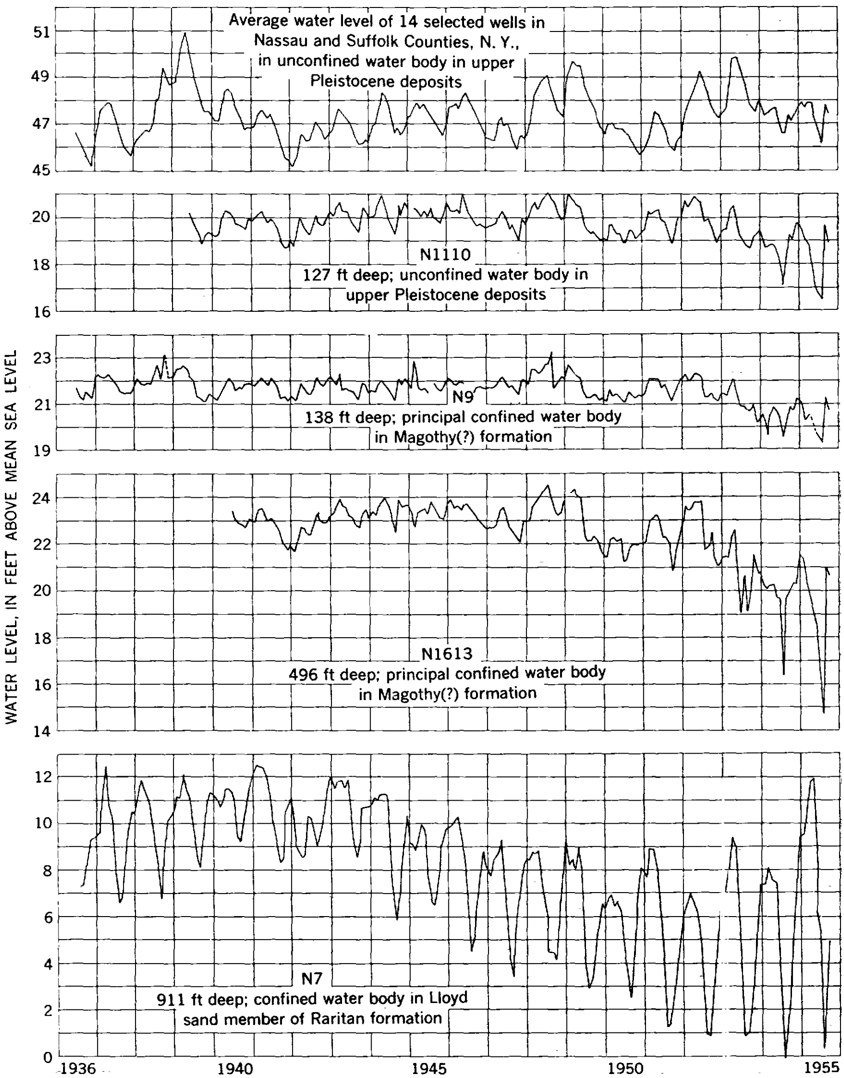


FIGURE 16.—Fluctuations of water levels in unconfined and confined water bodies near Valley Stream, southwestern Nassau County, N.Y., 1936–55.

Prior to 1905 the water level at well N223, screened at a depth of 150 feet in the principal confined water body at Lawrence, was estimated to be about 5 feet above sea level. The water level in the same general area in 1955, measured at well N3862, was only about 3.5 feet above sea level, indicating a possible net decline of about 1.5 feet.

TABLE 8.—*Comparison of estimated and measured water levels for the principal confined water body in April 1955 with those reported approximately 60 years earlier*

[Water levels in feet with reference to mean sea level]

Locality	Map coordinate	Well	Depth of well (feet)	Date measured [1]	Altitude of water level (feet)	Approximate decline (feet)	Remarks
Jamaica	4C	Q1309	352	Prior to 1896	[2] 28	19	
		--------	--------	April 1955	[3] 7-9		
South Ozone Park	4C	Q1306	170	Jan. 24, 1895	8.7	6.6	Water level reported about 11 feet above land surface in 1890. Hydrograph on fig. 13.
		Q1307	160	do	8.4		
		Q1237	220	Apr. 15, 1955	1.8		
Do	4B	Q681	156	Jan. 9, 1896	7.4	4	Nearby pumping station (Q1308) shut down 10 days prior to 1896 measurement.
		Q682	162	do	7.6		
		--------	--------	April 1955	[3] 4±		
Springfield Gardens.	4B	Q634	403	Jan. 8, 1896	10.7	4	
		Q1305	207	June 1897	[4] 10±		
		--------	--------	April 1955	[3] 6		
Idlewild Airport	4B	Q675	200	Prior to 1905	[4] 5+	3	
		Q676	203	do	[2] 7	5	
		--------	--------	April 1955	[3] 0-2		
Far Rockaway	4B	Q671	210	Prior to 1895	[4] 5+	3	
		--------	--------	April 1955	[3] 2		
Valley Stream	5B	N244	208	1895	10.7	0	Very small flow.
		N4393	474	April 1955	10-11		
Woodmere	5B	N232	190	Prior to 1905	[4] 8+		
		--------	--------	Apr. 10, 1955	[3] 7±	1	
Do	5B	N5029	181	July 5, 1903	0	3	Hydrograph, well N1379, pl. 6.
		N1379	196	Apr. 10, 1955	[2] 6.0		
Inwood	5B	N4714	228	Prior to 1905	6	3	Hydrograph, well N3932, pl. 6.
		N3932	177	Apr. 10, 1955	4.8		
Lawrence	5B	N223	150	Prior to 1905	[2] 5	1.5	Lower part of Magothy(?) formation reported to contain salty water in both wells. Hydrograph, well N3862, pl. 6
		N3862	306	Apr. 8, 1955	3.5		
Lynbrook	5B	N236	504	July 22, 1903	13.1	3	
		N4411	550	April 1955	10±		
Long Beach	6B	N319	386	July 11, 1903	10.8	7	
		--------	--------	April 1955	[3] 3-5		
Baldwin	6B	N343	289	July 17, 1903	[2] 7		
		--------	--------	April 1955	[3] 6.8	0	
Merrick	7B	N436	107	June 1900	10.3		
		N438	97	Prior to 1905	[4] 12.4+	0	
		--------	--------	April 1955	[3] 10-13		
Massapequa	8C	N514	106	Prior to 1905	[4] 11.4+	0	
		--------	--------	April 1955	[3] 15.8		

[1] Water levels before 1955 are from reports by De Varona (1896) and Veatch (1906).
[2] Approximate; based on reported measurement of water level and estimated altitude of land surface.
[3] Approximate; based on contours of piezometric surface (pl. 4).
[4] Well flowing; minimum estimated water level; figure refers to altitude of top of casing.

In the vicinity of Long Beach the head in well N319, 386 feet deep, was reported in 1903 to be about 11 feet above sea level; in 1955 the head in the same area was estimated to be about 4 feet above sea level (pl. 4), suggesting a net decline of about 7 feet. The apparent decline is difficult to explain, inasmuch as there are no heavily pumped wells tapping the principal confined water body within 4 or 5 miles of Long Beach. Moreover, if heavy pumping in the Magothy(?) formation to the north and northwest were the only cause of the apparent decline of about 7 feet at Long Beach, then the piezometric surface in the pumped area would have had to decline much more than the estimated 7 feet at Long Beach. A possible explanation for at least part of the decline may be found in large increases in pumping from the Lloyd sand member of the Raritan formation. In 1903 there was no pumping from the Lloyd in the Long Beach area. In 1954 the pumpage averaged 3.9 mgd. If water in the Lloyd normally discharges upward through the clay member of the Raritan formation and into the principal confined water body in the Magothy(?) formation, as suggested in section *Y–Y′*, plate 7, then a decrease in upward discharge due to pumping from the Lloyd may have caused some decline of water levels in the principal confined water body.

Hydrographs of several wells in the Valley Stream area show departures from the fluctuations of the average of the 14 selected wells. Whereas the average water level in the 14 wells shows a net rise from the highest stage in 1949 to the highest stage in 1953, the water levels in wells N1110, N9, and N1613 (fig. 16) show a decline, and from 1953 to 1955 there seems to have been a steady overall decline. The greatest divergence from the pattern of fluctuation of the 14 wells is shown by the hydrograph of N1613, which taps the deep part of the principal artesian aquifer and is affected by pumping from nearby public-supply wells drilled after 1952.

The hydrograph of well N7 (fig. 16) which is screened in the Lloyd sand member of the Raritan formation at Valley Stream, shows more completely confined conditions and a somewhat different pattern of fluctuation of water level than do hydrographs of wells that tap the Magothy(?) in the same area. For example, the rather marked rise from the February 1954 peak level to the April 1955 peak was not reflected in the hydrograph of nearby well N1613 that taps the principal confined water body. This recovery of water levels in well N7 reflects a temporary but large decrease in withdrawals from the Lloyd by the Jamaica Water Supply Co., which ceased pumping from the Lloyd in Nassau County and reduced its normal withdrawals from the Lloyd in Queens County by as much as half during the period from November 1954 to April 1955.

In southeastern Queens County, wells Q1152 and Q1237 serve as outpost wells because of their location (pl. 1) between public-supply wells to the north and Jamaica Bay and the ocean to the south. The hydrograph of well Q1237 (fig. 13), screened in the Jameco gravel in the upper part of the principal confined water body, shows a net decline in artesian head of about 4 feet from 1939 to 1955. The decline, however, was not continuous throughout this period, and water levels actually recovered slightly between 1947 and 1953. This pattern of fluctuation was caused chiefly by intermittent pumping from public-supply wells located within a mile or two of the observation wells. Hydrographs of wells Q1237 and Q1152 both show short-term declines of 6 or 7 feet during periods when New York City was pumping from its well fields in southeastern Queens. The decline of 19 feet in the vicinity of well Q1309 (fig. 14) in central Queens was caused by large withdrawals from public-supply wells screened chiefly in the Magothy(?) formation.

A comparison of early water levels (table 8) in southeastern Nassau County at artesian wells N436 (Merrick), N343 (Baldwin), and N514 (Massapequa) with present estimated levels at the same localities suggests that little or no change has taken place during the past 60 years. The record for N181 (Seaford) reported artesian flow from a depth of 715 to 805 feet in 1912. Neither the actual altitude of the artesian head nor the volume of flow was reported. In nearby well N180, the artesian head at a depth of 760 feet was about 5 feet above the land surface in 1956. Short-term records of water levels at N129 (Jones Beach) in 1933 and 1954 indicate no significant net change during that period. On October 28, 1933, the mean daily level was 7.9 feet above sea level, and on December 2, 1954, the level was 8.1 feet.

In summary, there have been some significant declines in water levels of both water-table and confined aquifers since about 1895 in southeastern Queens and southwestern Nassau Counties. In the Jamaica area of Queens County the water table has declined more than 20 feet since 1903. In west-central Nassau County the water table has declined 5 to 10 feet since 1903. In southeastern Nassau County and in the Rockaway Peninsula in southwestern Nassau County the water table has shown no significant net change in altitude since 1903. The piezometric surface of the principal confined water body in southeastern Queens County and southwestern Nassau County has declined 3 to 7 feet since about 1895. In the central and eastern parts of the project area, the piezometric surface apparently has not changed significantly since the early 1900's.

FLUCTUATIONS AND DIFFERENCES IN WATER LEVELS THAT SHOW HYDRAULIC INTERCONNECTION OR SEPARATION OF THE AQUIFERS

Fluctuations of water levels in wells have contributed much qualitative information about the hydraulic interconnection of the aquifers. Aside from showing the basic differences between patterns of fluctuation in unconfined and confined water bodies, hydrographs indicate the relative degrees of confinement provided by extensive clay beds, lenses of clay, and zones of clayey sand, or sandy clay.

Prior to the present report the Jameco gravel and the Magothy(?) formation had been considered to be separate aquifers. The formations, however, have good hydraulic interconnection in many places so that it is convenient and hydrologically correct to treat them as a single hydraulic unit which forms the principal artesian aquifer.

Evidence of the interconnection of the Jameco gravel and the Magothy(?) formation is shown by the similarity of the hydrographs of outpost wells N1379 and N3864 (pl. 6), screened respectively in the Jameco gravel and Magothy(?) formation at the south end of the Long Island Water Corp.'s well field in Woodmere (pl. 1). The southern part of the well field containing observation wells N1379 and N3864 and some former supply wells was sold for a housing development in 1958. Withdrawal from wells screened in the Jameco gravel at this field cause almost identical fluctuations in both observation wells. The water level in N3864, the deeper well, remains consistently about 1 foot higher than that in the shallower well, owing to the pattern of upward flow. About a mile northwest of these wells, another pair of wells, N4213 and N3867, shows a similar correspondence of water-level fluctuations in response to pumping at the Long Island Water Corp.'s well field.

This correspondence in fluctuations has been observed also in wells tapping adjacent fresh- and salt-water bodies in the two formations. Well N3932 at Cedarhurst taps fresh water in the Jameco gravel and nearby well N3861 taps salt water in the underlying Magothy(?) formation. The two hydrographs (pl. 6) display almost identical patterns of fluctuation, and a change of water level in one well is matched by a corresponding and approximately equal change of water level in the other. Measured water levels in these wells differ in altitude by about 8.5 feet because of the difference in density of the waters and the altitude of the fresh water-salt water interface.

In contrast to the hydraulic continuity within the principal artesian aquifer, there is a marked hydraulic separation between that aquifer and the Lloyd sand member. Everywhere in the project area the thick clay member of the Raritan formation retards the movement of water into or out of the underlying Lloyd. The hydrographs in figure 16 illustrate the difference in patterns of water-level fluctuations of confined aquifers above and below the clay member of the Raritan formation in Valley Stream, Nassau County. Well N7, screened in the Lloyd, is about 400 feet deeper than N1613, screened in the Magothy(?) formation, and is about 0.4 mile southeast. The fluctuations in well N7 generally have a much greater seasonal range than those in N1613, and the times of the seasonal peak water levels in both wells do not coincide in most years. Whereas the peak levels in well

N1613 showed a net decline from 1952 to 1955, those in well N7 showed a net rise. The general decline in well N7 began in 1941, and that in N1613 began in 1948, 7 years later. Thus it is concluded that the fluctuations of water levels in these two wells reflect different influences, and that the aquifers tapped by the wells are poorly interconnected. In contrast, there is close correspondence between fluctuations in levels in well N1613 and in N9 (about 0.1 mile north of well N7) which are screened in the lower and the upper part of the principal aquifer, respectively.

Additional evidence of a marked hydraulic separation between the Lloyd sand member and the principal confined unit is shown on flow section *X–X′* (pl. 7) for southwestern Nassau County. The section shows salty water in the lower part of the principal aquifer, but none in the underlying Lloyd sand member. The same relation exists in the area between Atlantic Beach and Long Beach (pl. 2). Despite seasonally heavy pumping from the Lloyd at Long Beach during the past 30 years, there is no evidence that salty water from the Magothy(?) formation has reached the Lloyd to date (1956).

In the central and northern parts of the report area, where the Gardiners clay is missing, the principal aquifer is connected hydraulically with the overlying unconfined aquifer in the upper Pleistocene deposits. Figure 16 shows fluctuations in three wells, N1110, N9, and N1613, respectively 27, 138, and 496 feet deep. The first well taps unconfined water; the second and third wells tap artesian water. Although fluctuations differ in magnitude from well to well, the monthly, seasonal, and yearly patterns are markedly similar.

In the southeastern part of Nassau County, in the vicinity of well N180, withdrawals from the unconfined aquifer seem to exert a small but recognizable influence on heads in the Magothy(?) formation, and the water levels measured in wells tapping both units show points of similarity. The hydrograph of well N1222 (fig. 15) registers changes in the water table and the hydrograph of well N170 registers changes in artesian pressure. The water levels show a marked difference in magnitude of fluctuation when withdrawals are made from nearby infiltration galleries and wells owned by New York City, but the pattern of fluctuation is about the same. The water-level fluctuations here may represent a loading and unloading effect produced by changes in storage in the unconfined aquifer.

PUMPAGE

GENERAL CONDITIONS

Principally all the water pumped in the project area is derived from ground-water sources, either directly by means of wells or from ponds that are maintained largely by ground-water discharge.

Accompanying the large population growth and industrial development in western Long Island since 1900, there has been a corresponding increase in water consumption. In 1954 the gross annual pumpage in the area south of the ground-water divide in southern Nassau and southeastern Queens Counties was about 60 billion gallons, or an average of about 163 mgd, but the net withdrawals were substantially less, owing to the return underground of a large part of the pumpage through cesspools and septic tanks.

In most years, pumpage for public supply has amounted to at least 90 percent of the total withdrawals. Table 9 gives the gross

TABLE 9.—*Gross pumpage, in millions of gallons per day, for public supply south of the ground-water divide in southeastern Queens and southern Nassau Counties in 1954, by aquifers*

Water-supply system	Water-bearing unit			Total
	Upper Pleistocene deposits	Principal artesian aquifer	Lloyd sand member	
Southeastern Queens County (subarea 1)				
Jamaica Water Supply Co.[1]	20.89	7.96	3.95	32.80
New York City (Ridgewood system)	2.12	1.49		3.61
Total	23.01	9.45	3.95	36.41
Southwestern Nassau County (subarea 2)				
Franklin Square Water District		0.97		0.97
Garden City, village of[1]	0.09	2.93		3.02
Hempstead, village of		4.84		4.84
Jamaica Water Supply Co[1]	4.82	5.05	1.03	10.90
Long Beach, City of			3.75	3.75
Long Island Water Corp	3.09	11.66	.11	14.86
Mineola, village of[1]		1.82		1.82
Mitchell Field[1]		.52		.52
New York City (Ridgewood system)[2]	6.94	.20		7.14
Rockville Center, village of		3.20		3.20
West Hempstead-Hempstead Gardens Water District		2.05		2.05
Total	14.94	33.24	4.89	53.07
Southeastern Nassau County (subarea 3)				
Bethpage Park[1]		0.25		0.25
Bethpage Water District[1]		1.48		1.48
Carle Place Water District[1]		.77		.77
East Meadow Water District		2.10		2.10
Farmingdale, Village of[1]	0.48	.02		.50
Freeport, Village of		2.45		2.45
Hicksville Water District[1]		3.61		3.61
Jones Beach State Park		.24		.24
Levittown Water District[1]	.86	2.87		3.73
Lido-Point Lookout Water-District			0.17	.17
Massapequa Water District		.07		.07
New York City (Ridgewood system)[2]	28.11	5.78		33.89
New York Water Service Corp	2.31	4.51		6.82
Plainview Water District[1]		.44		.44
South Farmingdale Water District	.71	.39		1.10
Westbury Water District[1]		1.29	.57	1.86
Total	32.47	26.27	.74	59.48
Grand total	70.42	68.96	9.58	148.96

[1] System is partly or wholly outside boundaries of project area shown on pl. 1.
[2] Includes pumpage from ponds fed by ground-water discharge.

pumpage in 1954, by aquifers, for all public-supply installations south of the ground-water divide, including a few installations outside the project area. Figure 17 shows graphs of the gross yearly pumpage since 1896 for each of three subdivisions of the report area; withdrawals by New York City and by private water companies and municipalities are shown separately.

There is some use of ground water for air conditioning, but most of this water is returned to the ground through recharge wells and basins. In addition there is some pumping for industrial and other miscellaneous uses, but these amounts are relatively small and have not been estimated separately in this report. In earlier years more than 5 mgd was pumped for agricultural use, but by 1954 this use had diminished to about 0.5 mgd as most of the agricultural land was taken over for real-estate development. The total pumpage of 163 mgd in 1954 includes 149 mgd for public supply and about 14 mgd for air conditioning, agricultural, and industrial uses.

All the water pumped by New York City from its installations in southern Nassau County is exported from the area and consequently represents a net draft on the available water. Much of the rest of the water pumped in Nassau County, however, is returned to the ground-water reservoirs through cesspools, septic tanks, diffusion (recharge) wells, recharge basins, and some inland sewage plants. The remainder passes through sewers and sewage-disposal plants and eventually is discharged into the bays and the Atlantic Ocean.

In the early 1900's much of the water pumped in Queens County probably was returned to the ground through cesspools and septic tanks. By 1956, however, practically all the water pumped for public supply in southeastern Queens (about 45 mgd) that was not evaporated from lawns and gardens was being discharged into the sea through sewers and therefore was a net loss from the ground-water reservoir. In southwestern Nassau County also there has been a substantial increase in the amount of waste water discharged into the sea through construction of new sewer systems. In 1954 about 19 mgd was lost through sewage-disposal plants at Bay Park, Long Beach, Cedarhurst, and Lawrence. The three last-named plants went into operation in 1919, 1934, and 1933, respectively and they have a total discharge of about 7 or 8 mgd. The Bay Park plant, which began operations in 1951, discharged about 10.5 mgd in 1954; the ultimate capacity may be expanded to about 60 mgd by 1961. In southeastern Nassau County, about 3 mgd was discharged at the Freeport sewage-disposal plant.

HISTORY OF WITHDRAWALS FROM 1896 TO 1954

For convenience in discussing pumpage, the area south of the ground-water divide has been arbitrarily divided into three subareas

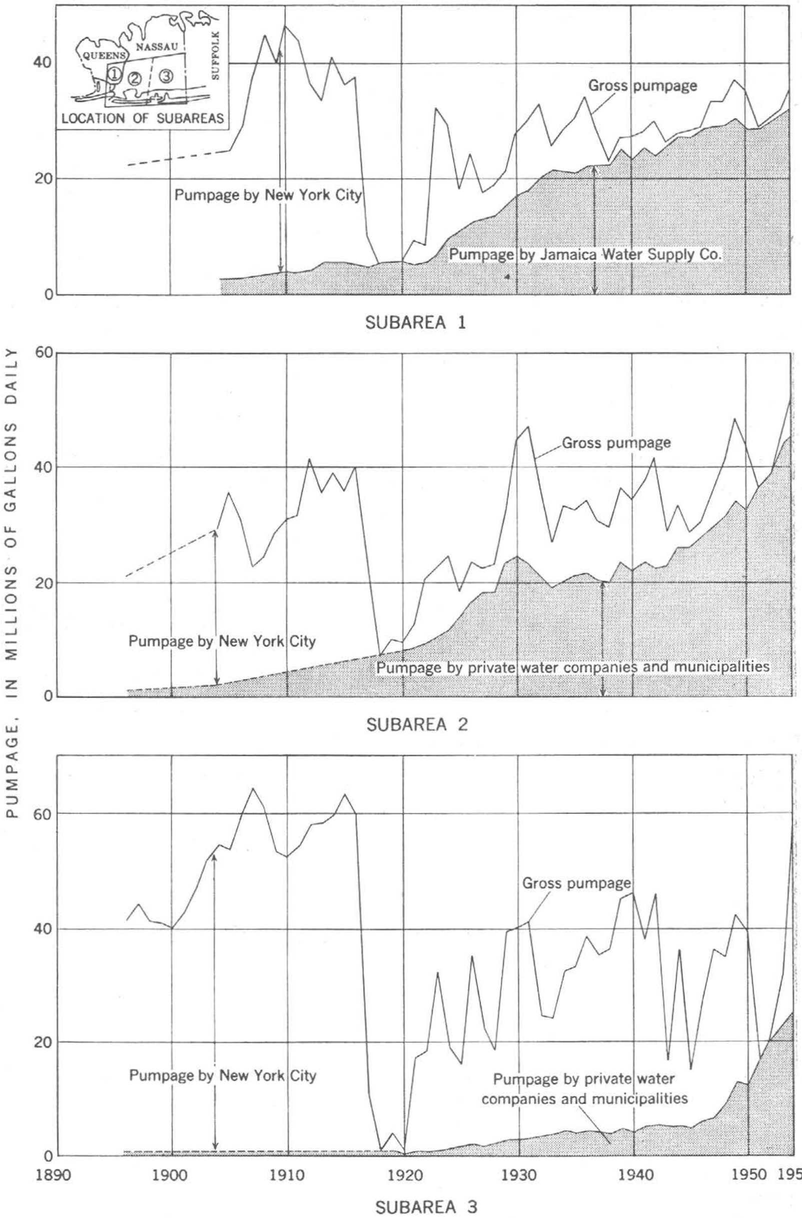


FIGURE 17.—Gross annual pumpage for public supply in southern Nassau and southeastern Queens Counties, N.Y., 1896–1954.

(fig. 17): (1) Southeastern Queens County, (2) southwestern Nassau County, and (3) southeastern Nassau County. Except for the ground-water divide at the north, the boundaries of the subareas have no particular geologic or hydrologic significance. The Queens-Nassau county line separates southeastern Queens County (subarea 1) from southwestern Nassau County (subarea 2). A north-south line approximately along the 73°35′ meridian has been selected as the boundary between southwestern Nassau County (subarea 2) and southeastern Nassau County (subarea 3). A few public-supply installations (N46, N62, N68–9, and N5227) a short distance west of the 73°35′ meridian are included in subarea 3. In each of these subareas, most of the water is pumped by both private water companies and municipalities for local use, and by New York City for export westward to Kings and Queens Counties. The graphs in figure 7 show combined gross withdrawals by the local systems serving each subarea and gross withdrawals for public supply by New York City, including pond water. In 1954, gross withdrawals for public supply were about 59.5 mgd in subarea 3, 53 mgd in subarea 2, and 36.4 mgd in subarea 1.

Prior to 1917, before completion of its upstate reservoirs, New York City accounted for nearly all the gross pumpage in subarea 1, which reached an all-time high of about 46 mgd in 1910. From 1917 on, except for a few years in the early 1920's, pumpage by the Jamaica Water Supply Co. was greater than New York City's withdrawals and by 1954 had increased to 33 mgd. The graphs (fig. 7) show an overall increase in gross pumpage from 1917 to 1954, but the most significant feature is the increase in withdrawals by the Jamaica Water Supply Co.

CHANGES IN WITHDRAWALS

PRIVATE COMPANIES AND MUNICIPALITIES

In early years, withdrawals by private water companies and municipalities were made mostly from the unconfined water body in the upper Pleistocene deposits. Since about 1920, however, there has been a marked increase in pumpage from the artesian aquifers, which has had an increasingly important effect on inducing sea-water encroachment in those aquifers. It is believed that the heavy withdrawals in earlier years did not have a large effect on inducing regional sea-water encroachment both because withdrawals were derived in large part from shallow sources and because much of the water pumped was returned to the ground through cesspools.

The trend toward development of the deep water-bearing zones, largely in the Magothy(?) formation and to a lesser extent in the Lloyd sand member, is reflected in pumpage records. For example, in southwestern Nassau County (subarea 2), pumpage of nonartesian water by private companies and municipalities in 1925 was about 11 mgd, but pumpage from the principal artesian aquifer was only 1 mgd. In 1954, of the 46 mgd pumped, 33 mgd came from the principal artesian aquifer, about 5 mgd from the Lloyd sand member of the Raritan formation, and 8 mgd from the nonartesian aquifer. Similarly, in subarea 3, the amount of pumpage from the principal artesian aquifer has increased considerably since earlier years. In 1951 about 21 mgd was drawn from the principal artesian aquifer, about 0.8 mgd from the Lloyd sand member, and about 4 mgd from the nonartesian aquifer.

In southwestern Nassau County (subarea 2), gross pumpage increased from about 29 mgd in 1904 to about 53 mgd in 1954. Prior to 1917, withdrawals by New York City were the heaviest on record and in some years amounted to as much as 37 mgd. During most of the years from 1917 to 1954 they were between 0 and 15 mgd. Pumpage by private companies and municipalities was probably less than 2 mgd prior to 1904 and increased to about 46 mgd in 1954. Except for some minor fluctuations, the rate of increase was generally steady from 1904 to about 1945. From then until 1954 the rate of increase accelerated.

In southeastern Nassau County (subarea 3), gross pumpage was as much as 64 mgd in 1907; in 1954 it was about 60 mgd. The pumpage between 1907 and 1954 largely represents a net draft on the groundwater reservoirs, as most of the water was pumped by New York City for use outside Nassau County. Pumpage by private water companies and municipalities for many years prior to 1949 was less than 10 mgd. In 1949 the pumpage reached 13 mgd, and by 1954 it had increased to almost 26 mgd owing to the large growth in population and the accompanying demand for water.

NEW YORK CITY RIDGEWOOD SYSTEM

The pumping installations owned by the City of New York in the project area constitute part of the Ridgewood system. According to early reports (De Varona, 1896; and Veatch, 1906) the original system, which was completed in 1862, consisted of six supply ponds in southeastern Queens and southwestern Nassau Counties. It constituted the first municipal public water supply for the former City of Brooklyn. By 1880 as much as 30 mgd was being pumped from these ponds. As the demand increased, additional facilities were constructed in the late 1880's and early 1900's, when the system was extended eastward to Massapequa in southeastern Nassau County. The new facilities included additional supply ponds, well fields in Queens and Nassau Counties, and two infiltration galleries in the Wantagh-Massapequa area of southeastern Nassau County (pl. 1). Before New York City completed a major part of its upstate reservoirs in 1917, the Ridgewood system, which had an estimated safe yield of about 80 to 90 mgd, furnished a large proportion of the water used in Kings County and a part of that used in Queens County. In 1955 the system included 14 well fields containing numerous shallow and deep wells, 7 supply and storage ponds, and 2 infiltration galleries, all along or near the Sunrise Highway in the southern part of the project area. These installations feed water into large-diameter underground conduits beneath Sunrise Highway which carry the water westward to Queens and Kings Counties. The infiltration galleries consist of vitrified pipe, 20 to 36 inches in diameter, laid 10 to 15 feet below the water table. The galleries total about 6 miles in length and have a combined yield of 30 to 40 mgd.

In southern Queens some well fields and ponds were abandoned through the years because of intermittent contamination by salty water or pollution by human wastes and others because of building and highway construction. Only one installation in Nassau County, the old well field at Agawam near Freeport, was abandoned in the early 1900's owing to high salinity which resulted from encroachment of salty water from a nearby tidal creek.

In subarea 1, somewhat less than 25 percent of the water pumped by New York City in the years 1904 to 1911 came from ponds. After 1911 no water was pumped from ponds in subarea 1. In subarea 2, most of the water pumped in years prior to 1917 came from ponds. After 1917, some water was still taken from ponds, but not more than about 10 mgd. In subarea 3, pumpage from ponds was between 25 and 52 mgd in the years 1904 to 1908, but it then declined sharply and after 1915 was never more than about 19 mgd. The ponds are all dammed reaches of streams that are sustained by ground-water outflow from the upper Pleistocene deposits. Pumping from the ponds salvages water that otherwise would be lost through natural discharge.

Most of the wells of the Ridgewood system tap the unconfined water body; a relatively small number tap the upper part of the principal artesian aquifer. A few of the wells in southwestern Nassau County tap the lower part of the principal artesian aquifer.

In 1954, approximately 80 percent of the pumpage from the entire Ridgewood system was derived from the unconfined water body in the upper Pleistocene deposits and 20 percent from the principal principal artesian aquifer (table 9). The general ratio of pumpage from the unconfined and principal confined water bodies is thought to have been roughly the same throughout most of the period of record shown on figure 17.

In 1957, New York City announced that it would shutdown and sell the entire part of the Ridgewood system in Nassau County within the next few years, as supplies from new reservoirs in upstate New York were sufficient to meet the city's needs.

RELATION OF WITHDRAWALS TO SEA-WATER ENCROACHMENT

It might be supposed that the heavy pumping during the past several decades was entirely responsible for the sea-water encroachment. However, a number of factors indicate that until about 1920 withdrawals of ground water were not sufficient to cause significant salt-water encroachment in the artesian aquifers. In the first place, much of the water pumped in early years was taken from artificially dammed ponds fed by natural ground-water discharge that otherwise would have been lost to the sea. Second, most of the withdrawals from wells came from shallow deposits and, at least in Nassau County, did not cause significant or permanent regional declines of head in the principal aquifer. Third, the increase in withdrawals from deeper aquifers has taken place mainly since 1920 (Johnson and Waterman, 1952). Finally, a substantial part of the water pumped in Nassau County has been returned to the ground, so that the gross withdrawals do not represent water extracted permanently from the ground-water reservoir.

Present-day withdrawals, however, are of such magnitude and are so distributed stratigraphically and areally that they are now contributing significantly to sea-water encroachment. However, available data on most of the project area do not provide an adequate basis for making quantitative estimates of the effects of withdrawals on landward movement of the salt-water body. Among the additional data needed to make such estimates are (1) more precise information on the position of the boundary between fresh and salty water, (2) measurement of heads and densities of the salt water at widely distributed points, and (3) determinations of the coefficients of transmissibility, permeability, and storage of the aquifers.

Certain generalizations can be made regarding the effects of pumping on salt-water encroachment. Landward gradients in a salt-water body can be caused by regional pumping remote from the interface or by pumping at points close to the boundary between fresh and salt water. Regional pumping may cause movement of the salt water on a wide front at relatively slow rates; concentrated pumping near the contact may cause lobes or tongues of salt water to move at relatively fast rates toward the centers of pumping. In most of the project area the withdrawals are regional, and accordingly the effects on movement of the interface are distributed over a broad area. However, in parts of southwestern Nassau and southeastern Queens Counties, some centers of pumping close to the interface have produced landward gradients in the salt-water body that have caused it to move further inland in the form of lobes or tongues. (See section on "Sea-water encroachment.")

MOVEMENT OF FRESH GROUND WATER

Because they are two-dimensional, the maps of the water table (pl. 3) and of the piezometric surface of the principal artesian aquifer (pl. 4) indicate only the horizontal components of flow. In Long Island the vertical components of flow also are significant, as the water moves through formations many hundreds of feet thick and the fresh water in the principal artesian aquifer moves over a large salt-water wedge. These relations are most clearly illustrated in flow sections that show the change in head with depth, and its bearing on the position of the salt-water wedge. This part of the report, then, discusses the movement of fresh water primarily in the vertical dimension and chiefly with reference to the confined water body in the principal artesian aquifer.

Plate 7 illustrates the pattern of fresh-water flow in the vertical dimension along lines *X–X′* and *Y–Y′*, shown on plates 1 and 4. The sections were constructed along lines where the data were most abundant and are oriented approximately at right angles to contours depicting the piezometric surface of the principal artesian aquifer. Figure 10 gives an enlargement of a part of the flow pattern along the line *Y–Y′*. The flow sections were constructed by inferring from water-level measurements and contour maps the location and slope of lines of equal head (isopotential lines). Most of the measurements were made in April 1954; some earlier measurements, adjusted to April 1954 by comparison with long-term hydrographs, also were used. Arrows drawn at right angles to the isopotential lines show the approximate direction of movement of the ground water.

The sections do not show the true slope of the isopotential lines and the paths of flow because the vertical scale is approximately 10 times larger than the horizontal scale. At the scale of these sections and with the data available, the paths of movement of water through the deposits appear to be generally smooth and no sharp deflections or refractions are shown except where thick and extensive beds of clay occur. Presumably, the flow lines and isopotential lines are deflected slightly at boundaries between beds of different permeability, but these irregularities are not apparent from present data and are of little significance with respect to the regional pattern of movement. Extensive and thick beds of clay or silt cause pronounced bending of the flow lines at the contact between these beds and adjoining beds of sand and gravel, and consequently, the direction of flow changes sharply. This fact is suggested on plate 7 by the isopotential lines and the arrows depicting flow in the upper part of the clay member of the Raritan formation, and also on figure 10 by the isopotential lines that pass through the "20-foot" clay.

One other point concerning the flow sections deserves emphasis. Strictly speaking, a flow net is a representation of the pattern of movement under steady-state conditions, and each flow line represents the path that a particle of water would follow with time. However, where two fluids are in contact in a ground-water reservoir, and where one is slowly encroaching on the space occupied by the other, it is impossible to illustrate on a single flow diagram the true paths of movement of the water because the position of the contact between the fluids and the orientation of the flow lines change with time. The directions of movement indicated by arrows on figure 10 and plate 7 are merely approximations under the conditions that prevailed from 1954 to 1955.

SOUTHEASTERN NASSAU COUNTY

In southeastern Nassau County, as indicated by contour maps of the water table (pl. 3) and of the piezometric surface of the principal confined water body (pl. 4), the fresh ground water moves generally southward. Water recharged from precipitation south of the ground-water divide moves downward and seaward through the geologic units and is discharged eventually into streams or open bodies of salt water at or near the shore. There is also some recharge from direct precipitation on the islands and barrier beaches in the southern part of the area, and this recharge sustains small localized bodies of fresh water.

Section *Y–Y′* (pl. 7) has been constructed approximately parallel to the direction of flow in southeastern Nassau County. It shows that all water after percolating downward to the water table south of about the 50-foot isopotential line moves in a nearly horizontal path through the shallow deposits and probably does not penetrate more than 100 feet into these deposits except where deflected toward pumping wells. This water eventually discharges into streams, bays, and lagoons. Water reaching the water table north of the 50-foot isopotential line and south of about the 70-foot isopotential line (beyond the north end of the section) descends along a gently sloping curvilinear path to the principal artesian aquifer. Part of the recharge in the vicinity of the ground-water divide, which is beyond the northern limit of the project area, descends to the Lloyd sand member. For a short distance in the vicinity of the 30-foot isopotential line, movement of water through the principal confined water body is almost horizontal. Farther south the flow is upward indicating that the water is moving toward areas of discharge in the tidal estuaries, bays, and the ocean.

It is apparent from this pattern of flow that the principal artesian aquifer receives all its natural recharge in a belt extending from about

2 miles north of the project area south to approximately the 50-foot isopotential line. The recharge area of the Lloyd sand member of the Raritan formation is even more restricted. Under natural conditions, none of the precipitation falling on southeastern Nassau County penetrates as deep as the Lloyd, which is recharged by slow downward movement of water from overlying deposits located beyond the northern boundary of the project area.

Section *Y–Y′* (pl. 7) indicates that the hydraulic gradient is fairly constant (about 12 ft per mile) in the central belt where water moves almost horizontally through the deposits. Farther south, however, where the flow is predominantly upward, the hydraulic gradient steepens. In large measure the gradient steepens because of the low permeability of the clay and silt beds through which the upward-moving water passes. Near the southern margins of the lagoons and beneath Jones Beach, water discharging upward into open bodies of water loses 6 or 7 feet of head in moving through beds of clay and sand 50 to 100 feet thick. These conditions imply that lateral movement southward for any great distance beyond the barrier beaches is unlikely.

The diagram shows that no salty water is in the Magothy(?) formation at and north of Jones Beach. The contact between salty ground water and fresh water in the Magothy(?) formation and in the underlying Lloyd probably is within 1 or 2 miles south of the shoreline.

Section *Y–Y′* does not show in detail the pattern of movement of shallow unconfined water. Such detail in the area south of Wantagh is shown on figure 10, an enlargement of a part of flow section *Y–Y′*. This enlarged section represents a distance of about 1.5 miles and shows hydrologic conditions down to about 70 feet below sea level. Along this part of the shoreline a clay, thought to be the "20-foot" clay, acts as a confining unit over the principal artesian aquifer, which contains fresh water. Above the clay, unconfined fresh water is in contact with unconfined salt water in the southern part of the section. Water levels in the unconfined body of fresh water range from less than 2 to about 5 feet above sea level and in the confined body of fresh water they are 7 to 9 feet above sea level. Water levels in the unconfined salty water range from 1 to 3 feet above sea level. The salty water is in the zone of diffusion and has a chloride concentration as high as 6,800 ppm; the fresh water above the confining clay beds contains less than 20 ppm of chloride and that below the clay, less than 10 ppm.

Along the plane of the section shown in figure 10, the nonartesian fresh water moves southward and the flow is nearly horizontal. In the vicinity of wells N1275 and N1276, part of the fresh water may mix with salty water. Some fresh water moving through a zone just below the water table probably proceeds southward to East Bay without substantial mixing with salty water, and some may move laterally out of the plane of the section to nearby tidal creeks. The confined fresh water also moves southward, with a small upward component, and ultimately discharges into the bay.

SOUTHWESTERN NASSAU COUNTY

Section *X–X′* (pl. 7) shows the general pattern of ground-water movement in southwestern Nassau County. The section shows that much of the fresh water moves seaward above a salt-water wedge that extends several miles inland in the lower part of the Magothy(?) formation, whereas in section *Y–Y′* the fresh water occupies the full thickness of the aquifer and the toe of the wedge of salt water must lie offshore.

In the northern part of Valley Stream, near the 20-foot isopotential line, the downward component of flow is locally increased. In large measure this is due to heavy pumping from nearby wells screened in the lower part of the Magothy(?) formation and perhaps to a much lesser extent from wells screened in the Lloyd sand member. South of Lynbrook the hydraulic gradient in the principal confined water body is not as steep as to the north, partly as a result of upward leakage near the extreme southern end of the section, partly as a result of pumping at the Mill Road well field of the Long Island Water Corp. (about 1.5 miles west of the flow section), and partly because of an increase in the average permeability of the aquifer due to the presence of the Jameco gravel.

On the Rockaway Peninsula most of the confined fresh water appears to leak upward into the sand beneath the "20-foot" clay and from there it moves laterally into the Atlantic Ocean or Jamaica Bay. The relatively high head of the water in the unconfined aquifer beneath the Rockaway Peninsula prevents upward leakage from the artesian aquifers.

The pattern of flow in the Lloyd sand member in southwestern Nassau County is affected by pumping and is not illustrated on section *X–X′*. The direction of flow in the Lloyd is mostly out of the plane of the section, especially in the extreme southern part.

SEA-WATER ENCROACHMENT

DEFINITION

In this report, sea-water encroachment is defined as the landward movement of sea water as a body so as to displace fresh water in an aquifer, either permanently or temporarily. Contamination occurs when the zone of diffusion between fresh and salt water reaches a fresh-water well. Contamination can result from regional encroachment; from pumping a well screened close to a salt-water body; or from inundation of low-lying coastal areas by salt water during storms, the salt water then percolating into the shallow aquifers.

Encroachment can occur as movement of salt water laterally and downward at shallow depths from the sea, bays, or estuaries adjacent to land areas. It can also occur as a nearly horizontal migration of a salt-water body already in an aquifer. Encroachment of the first type may account for some of the salt water at shallow depth in the upper Pleistocene deposits bordering the downstream parts of such streams as Watts Creek and Mott Creek (pl. 1) in southwestern Nassau County. Encroachment of the second type is the more important to this report, which is concerned mainly with the problem of movement of the confined body of salt water in the principal artesian aquifer.

THE BOUNDARY BETWEEN FRESH AND SALTY GROUND WATER

The boundary between two immiscible fluids such as oil and water is sharply defined and is commonly designated an interface. Generally, in a formation where these fluids are in contact, the interface has an orientation and depth related to the velocity, direction of movement, head, and density of the fluids. However, where miscible fluids such as fresh and salty ground water are in contact, there is no such sharp boundary. Instead, intermingling of the fluids results in a transitional zone of mixed water having a composition intermediate between the two principal fluids. This zone, called the zone of diffusion, reflects the chemical and hydraulic properties of each of the parent fluids in varying degree. It is a dynamic zone in which water is moving not only under the influence of density gradients but also in response to changes in heads and gradients in the adjacent bodies of fresh and salt water.

In southern Nassau County the contacts between fresh and salty water in both shallow and deep aquifers are marked by zones of diffusion (figs. 10 and 11) of varying thickness. The zone of diffusion in the principal artesian aquifer at several places has an apparent maximum thickness in the vertical dimension of about 200 feet. It is much less than this at other places. The boundaries of the zone of diffusion are defined in the present report by a chloride concentration in the range from about 10 to 40 ppm on the fresh-water side to about 18,000 ppm on the salt-water side. Within the zone of diffusion the density of the water and the concentration of chloride generally increase progressively toward the saltier water, but apparently not at a uniform rate. The data in a report on southeastern Florida (Parker and others, 1955) suggest that, whereas there is a considerable vertical distance between the waters of low and high chloride concentration in the zone of diffusion, most of the increase in concentration takes place within a relatively narrow band near the salt-water side of the zone. The data available from southwestern Nassau County suggest a similar change in chloride concentration (fig. 11). In the project area, the density of fresh water is 1.000 and the maximum measured density of salt water tapped by wells is 1.019 at 20°C.

The fresh-water boundary of the zone of diffusion is most significant in relation to contamination of a water supply, as it represents the lower and seaward limit of fresh-water storage. This boundary can be delineated accurately on the basis of chemical analyses of water from wells screened at different depths. It also can be determined approximately from electric logs. For example, where the resistivity gradually decreases without a corresponding lithologic change in the aquifer (as from sand to clay; see electric logs on section *C–C'*, pl. 2), it is likely that the water in the aquifer is increasingly salty.

The salt-water boundary of the zone of diffusion can be established on the basis of chemical analyses of water. It cannot be defined precisely from electric logs because the resistivity approaches zero where the concentration of chloride in the water exceeds a few thousand parts per million.

The concept of a sharp boundary, or interface, does not apply in southwestern Nassau County where the zone of diffusion is relatively thick. Therefore, calculations of the depth to salty water based on the assumption of a sharp interface are not accurate. In previous reports on Long Island (Suter, 1937; Spear, 1912, p. 149–155), and in reports dealing with salt-water encroachment in other areas, the Ghyben-Herzberg principle has been used as a means of estimating the depth to a contact between fresh and salt water. This formula gives erroneous results where fresh and salty ground water are in motion. In the present investigation, the authors have found that formulas given by Hubbert (1940) yield results close to those suggested by field data.

GHYBEN-HERZBERG FORMULA

The Ghyben-Herzberg formula is a mathematical expression of the relation between the depth to the contact of fresh and salty water and the hydrostatic heads and densities of the respective bodies of water. It was developed independently by W. B. Ghyben (1889) and Alexander Herzberg (1901), as a result of field observations in coastal areas of Holland and Germany. These men, working only a few years apart, found salty water beneath fresh water at substantial depths below sea level. They concluded that the fresh water floated on the salt water and that the salt water was depressed to a depth proportional to the height of the fresh-water level above sea level and inversely proportional to the difference in densities between the fresh and salt water. This principle, as applied to coastal ground-water conditions, is referred to as the Ghyben-Herzberg principle. The Ghyben-Herzberg formula, which is simply that of the U-tube, may be written as follows:

$$Z=\frac{\rho h_f}{\rho s-1.000}, \quad (1)$$

where Z is the depth, in feet, to the interface below sea level; h_f is the height of the water table, in feet above sea level, in the same vertical line; ρs is the density of sea water; and the number 1.000 is the assumed density of fresh water. The salt water is assumed to have a head of zero with reference to mean sea level; that is, the water level in a well tapping salty ground water stands at mean sea level.

According to this equation, the interface between the fresh- and salt-water bodies in any vertical section will be depressed 40 feet below sea level for every foot of elevation of the fresh-water table above sea level, if the density of sea water is 1.025. If the salt water is of lower density, the ratio between the depth to the interface and the height of the water table is greater—for example, 80 to 1 if the density is 1.012.

Major shortcomings of the Ghyben-Herzberg formula which limit its usefulness in interpreting fresh water-salt water relations on Long Island are that it applies strictly only where there is a sharp interface between fresh and salty water and where the altitude of the water table is a measure of the fresh-water head at the interface. The latter may not be valid where fresh water is in motion. Except at a few places where movement is practically horizontal, heads in a body of fresh ground water vary with depth. Furthermore, the formula assumes that the head of salty water is zero, which is not the case in the artesian units of southwestern Long Island, where the salty ground water is in motion. Thus, depending on the heads in the fresh and salty ground water, the interface may be at lesser or greater depths than those calculated from the Ghyben-Herzberg formula.

An example of the discrepancy between calcuations based on the Ghyben-Herzberg formula and known field relation is given by data for wells N3932 and N3861 drilled at the same site in Cedarhurst in 1952. Well N3861 is screened at about 526 feet below sea level and yields salty water having a density of about 1.018. The electric log of the well shows that fresh water extends to a depth of about 330 feet below sea level. Well N3932 is screened in fresh water; the altitude of the water level in the well was 2.7 feet in June 1952. Comparison with water-level records of other wells implies that the fresh-water level in the vicinity of well N3932 was about the same in March 1952 when nearby well N3861 was electrically logged. On the basis of the Ghyben-Herzberg formula, the depth to salty water of density 1.025 would have been predicted erroneously at 108 feet below mean sea level, or, if the salt-water density were 1.018, at a depth of 150 feet.

Another example of the inapplicability of the Ghyben-Herzberg formula is given by the data for well N128 at Jones Beach (1,034 ft. deep), where the static water level has ranged from about 7 to 9 feet above mean sea level during the period of record. According to the Ghyben-Herzberg formula, salty water of density 1.025 should have been found in the Magothy(?) formation at a depth of about 280 to 360 feet below sea level. Actually, the Magothy(?) formation contains fresh water to a depth of about 1,000 feet below sea level (pl. 2).

M. K. HUBBERT'S FORMULAS

Hubbert (1940, p. 864; 1953, p. 1991) presented formulas which give the altitude of any point on the interface or in either of the two fields of flow occupied by two fluids whose respective heads or potentials and densities are known. In the present study, the authors adapted these formulas specifically to the computation of the depth to the contact between fresh and salty ground water, with slight changes in the notation. The modified formula is given below as follows:

$$Z=\frac{\rho s}{\rho s-\rho f}\cdot h_s-\frac{\rho f}{\rho s-\rho f}\cdot h_f \qquad (2)$$

where Z is the altitude with reference to mean sea level of a point on the interface between fresh and salty water; ρ_f is the density of fresh water; ρ_s is the density of salty water; h_s is the altitude of the water level in a well filled with salty water of density ρ_s and terminated at the interface at the depth Z; and h_f is the altitude above sea level of the water level in a well filled with fresh water of density ρ_f and also terminated at the depth Z. This general equation may be applied to conditions where salty ground water either is encroaching (heads in the salty water are below mean sea level) or where it is receding (heads in salty water are above mean sea level). If the salty water is not in motion, $h_s=0$, and equation (2) reduces to the following form:

$$Z=\frac{-\rho f}{\rho s-\rho f}\cdot h_f \qquad (3)$$

This is similar to the original Ghyben-Herzberg formula except that the fresh-water head h_f is measured at the interface (Hubbert, 1940, p. 872).

Insertion in formula 2 of the data from well N3932 (Cedarhurst), used in the previous discussion of the Ghyben-Herzberg principle and of the head of −6.0 feet measured for the salty water at the end of June 1952 in well N3861 gives the following calculation of the depth to the boundary between fresh water and salt water:

$$Z=\frac{1.018}{1.018-1.000}\cdot(-6.0)-\frac{1.000}{1.018-1.000}\cdot(2.7)$$
$$=56.5(-6.0)-55.5(2.7)$$
$$=-339-149.8$$
$$=-489 \text{ feet}$$

In this calculation Z represents the theoretical depth below sea level of an interface between water of density 1.000 and water of density 1.018, assuming a sharp boundary and that the heads used in making the calculations were the actual heads at that boundary. Although these assumptions are not fully met in the example cited, the computed depth is within the boundaries of the zone of diffusion observed at well N3861 (fig. 11) and hence is more accurate than the depth of about 150 feet computed from the same data by use of the Ghyben-Herzberg formula.

Obviously, in applying formula 2 in situations similar to that cited, the smaller the vertical distance between the two well screens and the narrower the zone of diffusion, the more accurate is the computed depth to the contact. If the head and density of fresh water are known at a site, and if corresponding data can be obtained or estimated from other known information for the salt water at the same site, then the depth to the contact can be estimated with fair accuracy. Likewise, the approximate head in a body of salty ground water can be estimated if the other elements in formula 2 are known or can be estimated.

MOVEMENT OF SALTY GROUND WATER IN THE PRINCIPAL ARTESIAN AQUIFER

The salty ground water in the principal artesian aquifer is encroaching landward at a slow rate. This conclusion is based upon the following evidence: (1) The concentration of chloride has increased in several wells, (2) a landward gradient exists in the main confined salt-water body, as shown by direct measurements and estimates of salt-water heads, (3) heads in deep fresh-water wells near the shoreline are theoretically too low to maintain a balance between fresh water and static salty water, and (4) water levels in some fresh-water wells near the shoreline have shown long-term net declines.

The evidence for encroachment based on increase in concentration of chloride has been discussed in the section dealing with chemical quality of the water. The evidence for encroachment based on the existence of gradients in the salt-water body and apparent deficiencies in fresh-water head is discussed below.

LANDWARD GRADIENTS IN THE MAIN CONFINED SALT-WATER BODY

Water-level measurements in both salt-water and fresh-water wells indicate that hydraulic gradients in the main confined salt-water body are directed landward. In southwestern Nassau County the determinations of these gradients are based on direct measurements of heads in a few wells tapping salt-water of comparable density. In southeastern Nassau County the salt-water gradients are largely inferred from measurements of head in fresh-water wells near the shoreline.

The magnitude and direction of the gradient in southwestern Nassau County has been roughly estimated by comparing the range in altitude of the salt-water level at well N3861, Cedarhurst, with the salt-water level at well Q1230, near Far Rockaway. Well N3861 is screened in water containing about 16,000 ppm of chloride (density 1.018). Water levels in this well have ranged from about 3 to 7 feet below mean sea level since the start of record in 1952 (pl. 6). Well Q1230 is screened in water containing 12,000 ppm of chloride. In April 1954 the water level at Q1230 was about 0.8 foot above mean sea level. This head adjusted to water of density 1.018 would be only slightly lower. Therefore, the overall difference in head between the 2 wells has a range of about 4 to 8 feet in a distance of about 3 miles. The 4-foot difference in head may largely represent natural conditions; the 8-foot difference is partly the result of heavy pumping from the principal artesian aquifer in the area to the northeast. If it is assumed that this difference in head is distributed uniformly over the distance and if the smaller value is used, there is an apparent average gradient under natural conditions of about 1.5 feet per mile between the wells.

Rough calculations using formula 2 (p. A95) suggest that the head near the bottom of the main salt-water body beneath well N3862 at Lawrence (about 1.8 miles south of N3861, pl. 1) is probably several feet below sea level, but is slightly higher than that at well N3861. These calculations are further evidence of the existence of a landward gradient between the two wells.

The toe of the main confined salt-water wedge is within the cone of influence of pumping at the Mill Road well field in Woodmere. According to the pumping rate, the cone of influence extends to greater or lesser distances from the center of the field and therefore affects a larger or smaller segment of the deep salt-water body. It extends at least as far as Cedarhurst, as indicated by the fluctuations of water levels in wells N3932 and N3861 (pl. 6). The effects on the piezometric surface of continuous heavy pumping and of 2 weeks of shut-

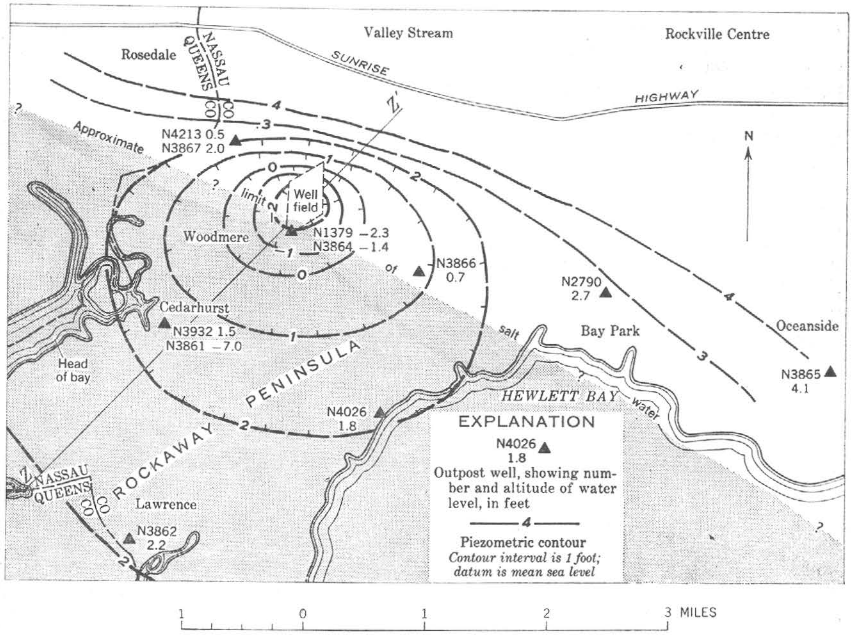


FIGURE 18.—Map showing piezometric surface of the principal artesian aquifer and the cone of influence in the vicinity of the Mill Road well field, Woodmere, during heavy pumping, July 31, 1954.

down are shown on maps (figs. 18 and 20) and cross sections (figs. 19 and 21). Figure 18, the map of the piezometric surface for July 31, 1954, shows the shape and extent of the cone of influence when water levels were at their lowest during the period of record, 1952–55. Figure 19, a section through the well field, also for July 31, 1954, illustrates the pattern of flow in the fresh water above the toe of the salt-water wedge and suggests movement of the salt water toward the center of pumping. Figure 20 shows that after several weeks of shutdown of the Mill Road field, the cone of influence disappears. The section (fig. 21) shows that during the shutdown, the hydraulic gradient in the fresh water is entirely seaward whereas the hydraulic gradient in the salt water remains landward as shown in figure 19.

The gradient in the toe of the main confined salt-water body near the Mill Road well field is not known exactly because the salt-water head could be measured directly only in well N3861 in 1955. In this vicinity, when the pumps are operating, the gradient of the fresh-water piezometric surface is locally landward—that is, in the same direction as the salt-water gradient—although regionally the slope on the fresh-water surface is seaward. The regional salt-water gradient is thought to be on the order of 1½ feet per mile. Consequently, when the influence of nearby pumping is superimposed on this regional gradient,

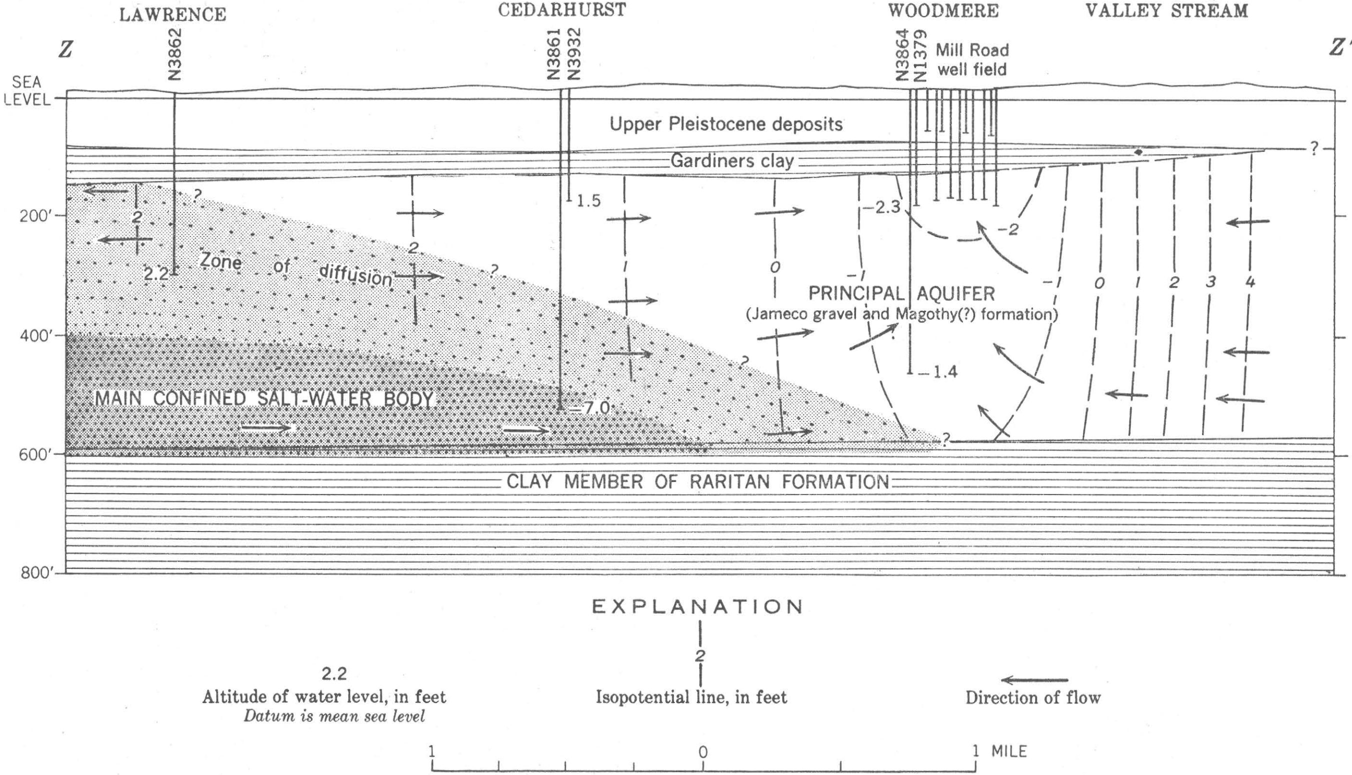


FIGURE 19.—Section showing movement and relation of fresh and salty ground water in the vicinity of the Mill Road well field, Woodmore, during heavy pumping, July 31, 1954.

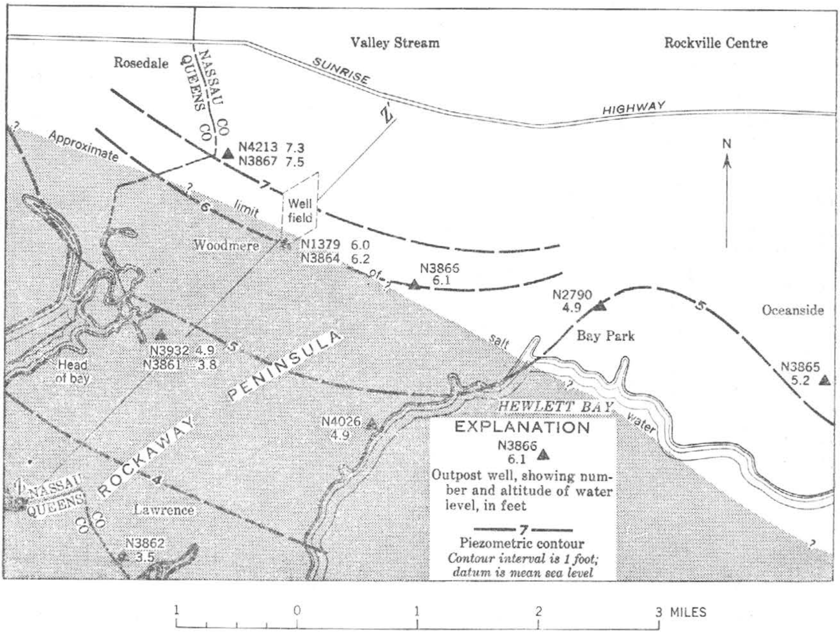


FIGURE 20.—Map showing piezometric surface of the principal artesian aquifer on April 10, 1955, after 2 weeks of shutdown of the Mill Road well field, Woodmere.

the gradient in the toe of the wedge is steepened. On July 31, 1954 (fig. 19), the gradient may have been roughly 3 to 5 feet per mile. This estimate of the gradient is made for conditions of maximum pumping which prevail for short periods. Under more moderate conditions of pumping, the gradients are less steep in both the fresh water and the salty water.

It is emphasized that the heads and thus the gradients both in the salt-water at the toe as well as in the overlying fresh water vary continuously with changing rates of pumping and recharge, and with tidal fluctuations. Therefore, rates of encroachment calculated from these gradients apply only for specific conditions.

The net declines of fresh-water heads near the shoreline in southwestern Nassau and southeastern Queens Counties since about 1900, indicated by the landward shift of the 10-foot piezometric contour (pl. 4) and measurements of heads at selected wells (fig. 14), are indirect evidence of salt-water encroachment. The declines probably were transmitted in part to the salt-water body, as they occurred in an aquifer in which fresh water and salt water are in hydraulic continuity. The result must have been to establish a landward hydraulic gradient in the salty water or to steepen an existing gradient.

The existence of natural landward gradients in the salt water unrelated to pumping may be inferred from data on the deep wells

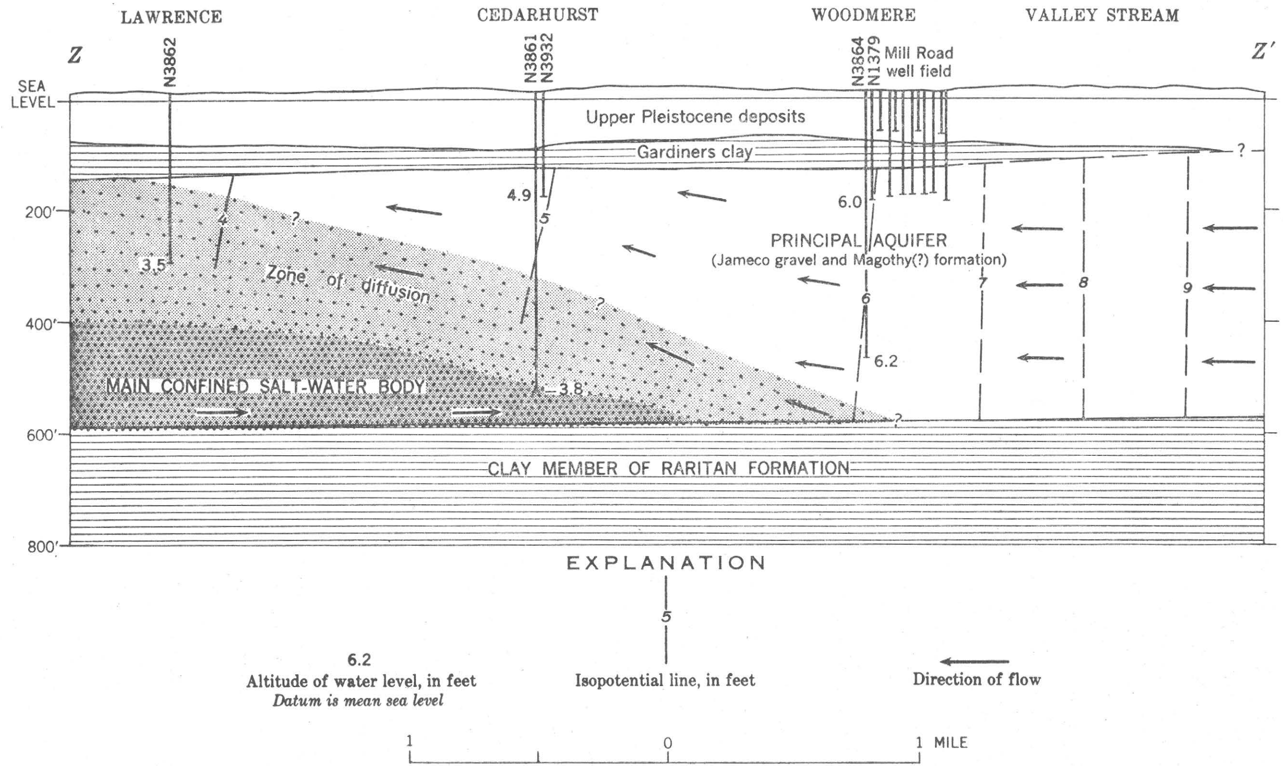


FIGURE 21.—Section showing movement and relation of fresh and salty ground water on April 10, 1955 after 2 weeks of shutdown of the Mill Road well field, Woodmere.

(N128 and N129) at Jones Beach in southeastern Nassau County. Both wells are screened in the Magothy(?) formation at a depth of about 1,000 feet below sea level. The maximum known altitude of the daily mean water level in the wells is 7 to 9 feet above mean sea level. The chloride content of the water from these wells has been 10 ppm or less since the start of record in 1929. From a U-tube analysis, a fresh-water head of 25 feet above mean sea level is required at a depth of 1,000 feet in order to balance salt water of density 1.025 and having a head of zero. As the actual head in N128 at a depth of about 1,000 feet is only about 8 feet above mean sea level, there is an apparent deficiency of some 17 feet in the fresh-water head. If the salt-water contact is assumed to be a short distance seaward of the well, by inference there must be a head deficiency of the same order of magnitude on the salt-water side of the contact at the same depth.

Theoretically, the described condition could result from a large decline in fresh-water head, a rise of sea level, or a combination of both. Studies by the Geological Survey in Florida have suggested that small negative heads in salty water may result from loss of salty water into the zone of diffusion. However, it is doubtful that this mechanism could be entirely responsible for the large apparent deficiencies in head noted in southeastern Nassau County.

There is no evidence that pumping from the Magothy(?) formation in and north of the area has been sufficient to cause a 17-foot decline of water head at Jones Beach (table 8). To the west, at Long Beach, water levels have declined about 7 feet since 1903 in the Magothy(?) formation (well N319, table 8) and 10 to 15 feet since the early 1920's in the Lloyd sand member. These declines are the result of pumping both at Long Beach and in the area north and northwest of Long Beach. The influence of this pumping doubtless extends eastward some distance, but it would be difficult to attribute the entire apparent deficiency of 17 feet of fresh-water head at Jones Beach to this cause. Furthermore, static water levels in the deep wells at Jones Beach have shown no significant change in altitude since 1929.

As the deficiency in fresh-water head at Jones Beach probably is not entirely due to pumping, it may be postulated that part of the apparent deficiency is a result of postglacial rise of sea level. There is abundant evidence of fluctuations of sea level during the Pleistocene and Recent epochs, and it is believed that sea level oscillated as much as several hundred feet during the Pleistocene and was lowest during maximum ice advances (Flint, 1957, p. 258–271). Since the end of the latest ice advance, sea level has been rising in response to melting of the continental ice sheets. At New York City it has risen about 0.6 foot since 1893, according to Marmer (1949, p. 201–204).

Under this hypothesis, the salty ground water is moving landward under a gradient developed partly in response to a rise in head in its "intake area" (the ocean), and is losing head as it moves slowly downward and laterally through the predominantly fine-grained beds of the Magothy(?) and other formations. The rate of landward movement of the salty ground water must be extremely slow, owing to the low permeability of the strata, thus accounting for the presence of fresh water at depths where salt water theoretically should occur.

In summary, it is concluded that the head of 8 feet in the deep wells at Jones Beach is inadequate to maintain a hydrodynamic balance with a static body of salty ground water, and thus provides indirect evidence that heads in the toe of the salt-water wedge offshore are below sea level. Inasmuch as salt-water heads in the intake area at the bottom of the ocean are undoubtedly equivalent to sea level, there must be a landward gradient in the deep, confined salt-water body offshore.

RATE OF MOVEMENT

The hydraulic factors that control the rate of movement of salty water are similar to those that control the rate of movement of fresh water. These are the gradients in the salt water, and the average permeability and effective porosity of the deposits through which the salty water is moving.

The velocity with which ground water moves under steady-state conditions is expressed quantitatively by Darcy's law (Wenzel, 1942, p. 3, 71–72), which may be written as follows:

$$V=\frac{PI}{7.48p} \qquad (4)$$

where V is velocity, in feet per day; P is the coefficient of permeability, in gallons per day per square foot; I is the hydraulic gradient, in feet per foot; p is the effective porosity of the conducting medium; and 7.48 is the number of gallons in a cubic foot of water. Although Darcy's law was derived from an analysis of fresh-water flow, it can be employed for computing approximate velocities of salt water as well. Differences of density and viscosity between fresh and salt water are small enough that they may be ignored in these calculations.

Calculations of rates of movement in the main confined salt-water body have been made only for southwestern Nassau County. In this area, the regional gradient in the salt water is estimated to be 1.5 feet per mile and the gradients in the toe of this body under different rates of pumping are estimated to range from 3 to 6 feet per mile. On the basis of the estimated gradients and of an assumed average porosity of 25 percent and permeabilities ranging from 200 to 2,000 gpd per sq ft, rates of enroachment for different conditions have been calculated (table 10). In deposits of the Magothy(?) formation having an average horizontal permeability of about 500 gpd per sq ft, the rates of encroachment for gradients of 1, 3, and 6 feet per mile would be about 19, 55, and 111 feet per year, respectively. The low rates probably are the approximate rates of regional encroachment and the high rate represents the approximate rate of movement near centers of pumping. The rate of movement in the direction perpendicular to the bedding would be much lower, owing to the lower permeability in that direction. It is emphasized that the rates suggested above are based on the best estimates of hydraulic gradients, permeability, and porosity that were available in 1955. They should not to be interpreted as established values but as approximations only.

TABLE 10.—*Estimated range in rates of encroachment of the main confined body of salt water in southwestern Nassau County under assumed permeabilities and gradients, 1955*

[Porosity assumed to be 25 percent]

Permeability (gpd per sq ft)	Hydraulic gradient (feet per mile)	Velocity (feet per year)	Approximate number of years to travel 1 mile
200	1	7.4	714
200	2	14.8	357
200	3	22.2	238
200	6	44.3	119
500	1	18.5	286
500	2	36.9	143
500	3	55.4	95
500	6	110.9	48
1,000	1	36.9	143
1,000	2	73.7	72
1,000	3	110.9	48
1,000	6	221.7	24
2,000	1	73.9	72
2,000	2	147.8	36
2,000	3	221.7	24
2,000	6	443.4	12

The reasonableness of the computed rates of encroachment may be evaluated by estimating from water-level and quality-of-water data the maximum distance that the leading edge or toe of the salt water has moved landward during the approximately 60 years prior to 1954. Sometime before 1903, salty water was reported in the principal artesian aquifer beneath the town of Lawrence, at well N223 (table 8). The record indicates that fresh water was obtained at 150 feet and very salty water at 416 feet, but no indication is given of the depth to the top or bottom of the zone of diffusion between the two water bodies. In 1952, well outpost N3862, drilled less than three-quarters of a mile southwest of N223, penetrated the top of the zone of diffusion at a depth of about 140 feet and entered very salty water at an estimated depth of 350 feet. In the same year, outpost well N3861, drilled about 1.5 miles north of well N223 in the town of Cedarhurst, penetrated the top of the zone of diffusion at a depth of about 330 feet and very salty water at a depth of 400 to 450 feet. In 1952, outpost well N3864, about 1.2 miles northeast of N3861, penetrated the toe of the deep salt-water wedge according to the electrical log. Thus, salty water could not have advanced more than the straight-line distance of about 2.5 miles between wells N223 and N3864 in approximately 60 years, and the average rate of movement could not have been more than about 220 feet per year. Actually, the leading edge prior to 1903 must have been some distance north of well N223, as the top of the salty water penetrated by the well was probably more than 200 feet above the bottom of the aquifer. Consequently, the maximum amount of encroachment in that area since about 1900 is inferred to have been less than the 2.5-mile distance previously mentioned and the rate must have averaged less than 200 feet per year. There is no direct evidence to show exactly how much encroachment took place, but the above reasoning lends support to the low rates of encroachment implied by the calculations given in table 10.

A further indication of the slow rate of encroachment of the main confined body of salt water is given by the graphs in figure 9 which compare increases in chloride concentration in water from public-supply well Q559 in southern Queens County with water levels in nearby observation wells. Despite the fact that the piezometric surface in the area has been as much as 6 feet below sea level at times, as shown by the hydrograph of well Q1237 (fig. 9), and has remained generally at or slightly below sea level during much of the past 10 years, the chloride content of the water from well Q559 increased only very slowly, from 4 ppm in 1935 to about 160 ppm in 1951. That increase took place during a period when pumpage for public supply was increasing steadily in the area and the piezometric surface on the principal aquifer was slowly declining. Although salty water must have been within the cone of depression of the well at least since 1935, the relatively low concentration of chloride in 1951 indicates that only a small part of the water moving toward the well came from the deep salt-water body. If the salt water had a chloride concentration of about 16,000 ppm and the fresh water about 10 ppm, less than 3 percent of the water pumped at Q559 came from the salt-water body. These data indicate that encroachment of salty water in the principal aquifer in southeastern Queens also is proceeding at comparatively low rates.

EFFECTIVENESS OF THE OUTPOST-WELL NETWORK

The original purpose for constructing outpost wells was to provide a network of monitoring stations between the salt water and centers of heavy pumping in the Magothy(?) formation and Jameco gravel. It was anticipated that water samples obtained periodically from these wells might show changes in concentrations of chloride in the ground water and would thereby indicate areas where encroachment was taking place and perhaps the rates of such encroachment.

The present network of outpost wells has provided a considerable amount of information on the relation of the fresh and salt waters in the project area and has furnished a basis for calculating approximate rates of encroachment at one locality. However, the results of this study have also pointed up the need for further exploration of the salt-water body and the desirability of constructing additional groups of observation wells screened at different depths in that body as well as in the fresh water near the interface. It is especially important to install observation wells in the salt-water body in order to obtain measurements of water-level fluctuations and density of the water. First, the salt-water body has its own intake area and an unlimited source of salt water in the ocean. Second, the rate of encroachment is only partly controlled by declines of heads in the adjacent fresh-water system, and sea-level fluctuations and the hydraulic characteristics of the deposits invaded by the salt water also are important factors. Third, measurements of salt-water levels in wells (adjusted to a common density) can be used to draw water-level contours and thus help to determine the direction of movement and gradients in the salt water.

This report shows that several of the deep outpost wells are too far inland from the main salt-water body to detect encroaching salt water for many decades. Three of the wells were drilled seaward of the fresh and salt-water boundary. One of these (well N3861) yields water having a concentration of chloride approaching that of sea water, and it would be difficult to detect small increments in chloride content through routine analyses. Another well (N3862) is screened in the upper part of the zone of diffusion where the water is only moderately salty and thus will show significant changes in chloride content more readily. The third well (N3864) penetrated a thin layer of salty water near the leading edge of the fresh and salt-water interface but was screened in fresh water about 100 feet above the salt water. The water from this well will become increasingly salty after the upper surface of the encroaching wedge of salt water reaches the screen.

Inasmuch as the salt-water body in the Magothy(?) formation is entirely seaward of the barrier beach in southeastern Nassau County, it is not practical to install salt-water observation wells in that area. However, existing deep supply wells at Jones Beach would be contaminated long before salty water reached public-supply wells to the north, and they are therefore useful as outpost wells for that area. Also, existing public-supply wells at Atlantic Beach, Long Beach, and Lido Beach screened in the Lloyd sand member serve as effective outpost wells for that aquifer in southwestern Nassau County.

CONCLUSIONS

1. The present gross rate of withdrawals in the report area, totaling about 163 mgd, probably can be maintained for many decades. However, partly as a result of past and present withdrawals, a large wedge of salt water which occupies part of the Magothy(?) formation and Jameco gravel in both southeastern Queens and southwestern Nassau Counties is moving slowly inland. The rate of movement is not known precisely, but it is probably less than 100 feet per year in most places. Water in the Lloyd sand member, the lowermost aquifer in the project area, is entirely fresh.
2. As most of the heavily pumped well fields are at least several miles from the estimated position of the fresh and salt-water interface, they are in no immediate danger from sea-water encroachment, but a few that are close to the interface may be contaminated in the future if the landward gradients in the salt water persist.
3. Any substantial increase in withdrawal near the interface will accelerate the movement of the salt water. Correspondingly, a decrease in withdrawal will reduce the rate of encroachment but will not necessarily prevent it unless the subsequent rise in water levels is sufficient to eliminate the landward gradient in the salt water. A reversal of the landward gradient by natural or artificial means would cause the salt water to move seaward.
4. The present network of outpost wells should be expanded both in southern Nassau and in southeastern Queens Counties to provide more adequate information on the extent and rate of movement of the salt water.

REFERENCES CITED

Badon Ghyben, W., 1889, Nota in verband met de voorgenomen put boring nabij Amsterdam (Notes in connection with a test boring near Amsterdam): The Hague, K. Inst. Ing. Tydschr., p. 8–22.

Brown, J. S., 1925, A study of coastal ground water, with special reference to Connecticut: U.S. Geol. Survey Water-Supply Paper 537, 101.

Burr, W. H., Hering, Rudolph, and Freeman, J. R., 1904, Report of the Commission on additional water supply for the City of New York: New York, Martin B. Brown Co., 980 p.

Colony, R. J., 1932, Sources of the sands on the south shore of Long Island and the coast of New Jersey: Jour. Sedimentary Petrology, v. 2, no. 3, p. 150–159.

Crosby, W. O., 1910, Report of the geological relations of the ground water of Long Island: New York City Board of Water Supply, open-file report, 64 p.

De Varona, I. M., 1896, Report of Engineer of water supply: City of Brooklyn Dept. City Works, Ann. Rept.

Flint, R. F., 1947, Glacial geology and the Pleistocene epoch: New York, John Wiley and Sons, Inc., 589 p.

——— 1953, Probable Wisconsin substages and late Wisconsin events in northeastern United States and southeastern Canada: Geol. Soc. America Bull., v. 64, p. 897–920.

——— 1957, Glacial and Pleistocene geology: New York, John Wiley and Sons, Inc., 553 p.

Fuller, M. L., 1914, The geology of Long Island, N.Y.: U.S. Geol. Survey Prof. Paper 82, 231 p.

Hem, J. D., 1959, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 678, 269 p.

Herzberg, Alexander, 1901, Die Wasserversorgung einiger Norseebaden (The water supply for several North Sea resorts): Jour. Gashelenchtung u. Wasserversorgung, Jahrg. 44 (Munich) p. 815–819; 842–844.

Hubbert, M. K., 1940, The theory of ground-water motion: Jour. Geology, v. 48, no. 8, p. 785–944.

——— 1953, Entrapment of petroleum under hydrodynamic conditions: Am. Assoc. Petroleum Geologists Bull., v. 37, no. 8, p. 1954–2026.

Isbister, John, 1959, Ground-water levels and related hydrologic data from selected observation wells in Nassau County, Long Island, N.Y.: New York Water Power and Control Comm. Bull. GW–41, 42 p.

Jacob, C. E., 1941, Notes on the elasticity of the Lloyd sand on Long Island, N.Y.: Am. Geophys. Union Trans., p. 783–787.

——— 1945a, The water table in the western and central parts of Long Island, N.Y.: New York State Water Power and Control Comm. Bull. GW–12, 24 p.

——— 1945b, Correlation of ground-water levels and precipitation on Long Island, N.Y.: New York State Water Power and Control Comm. Bull. GW–14, 20 p.

——— 1946, Drawdown test to determine effective radius of artesian well: Am. Soc. Civil Engineers Proc., v. 72, no. 5, p. 629–646.

Johnson, A. H., and Waterman, W. G., 1952, Withdrawal of ground water on Long Island, N.Y.: New York State Water Power and Control Comm. Bull. GW–28, 13 p.

Leggette, R. M., 1937, The mutual interference of artesian wells on Long Island, N.Y.: Am. Geophys. Union Trans., p. 493–494.

——— 1938, Records of wells in Nassau County, New York: New York State Water Power and Control Comm. Bull. GW–5, 139 p.

——— 1938, Records of wells in Queens County, New York: New York State Water Power and Control Comm. Bull. GW–6, 240 p.

Lohman, K. E., 1939, Pleistocene diatoms from Long Island, New York: U.S. Geol. Survey Prof. Paper 189–H, p. 229–237.

Lusczynski, N. J., 1950, The piezometric surface of the Lloyd sand, Long Island, New York in 1947: U.S. Geol. Survey open-file report, 4 pls.

Lusczynski, N. J. and Johnson, A. H., 1951, The water table in Long Island, New York, in January 1951: New York State Water Power and Control Comm. Bull. GW–27, 28 p.

Lusczynski, N. J. and Swarzenski, W. V., 1960, Position of the salt-water body in the Magothy(?) formation in the Cedarhurst-Woodmere area of southwestern Nassau County, Long Island, N.Y.: Econ. Geology, v. 55, no. 8, p. 1739–1750.

Marmer, H. A., 1949, Sea-level changes along the coasts of the United States in recent years: Am. Geophys. Union Trans., p. 201–204.

Meinzer, O. E., 1923a, The occurrence of ground water in the United States: U.S. Geol. Survey Water-Supply Paper 489, 321 p.

——— 1923b, Outline of ground-water hydrology, with definitions: U.S. Geol. Survey Water-Supply Paper 494, 71 p.

Muskat, Morris, 1946, The flow of homogeneous fluids through porous media: New York, McGraw-Hill Book Co., 300 p.

Parker, G. G., Ferguson, G. E., Love, S. K., and others, 1955, Water resources of southeastern Florida: U.S. Geol. Survey Water-Supply Paper 1255, 965 p.

Perlmutter, N. M., and Crandell, H. C., 1959, Geology and ground-water supplies of the south-shore beaches of Long Island, New York: New York Acad. Sci. Annals, v. 80, art. 4, p. 1060–1076.

Perlmutter, N. M., Geraghty, J. J., and Upson, J. E., 1959, The relation between fresh and salty ground water in southern Nassau and southeastern Queens Counties, New York: Econ. Geology, v. 54, no. 3, p. 416–435.

Piper, A. M., 1953, A graphic procedure in the geochemical interpretation of water analyses: U.S. Geol. Survey open-file report.

Roberts, C. M., and Brashears, M. L., Jr., 1946, Records of wells in Nassau County, New York, Supplement 1: New York State Water Power and Control Comm. Bull. GW–10, 191 p.

Roberts, C. M., and Jaster, M. C., 1947, Records of wells in Queens County, New York, Supplement 1: New York State Water Power and Control Comm. Bull. GW–11, 123 p.

Sayre, A. N., 1936, Geology and ground-water resources of Uvalde and Medina Counties, Texas: U.S. Geol. Survey Water-Supply Paper 678, 146 p.

Shupack, Benjamin, 1934, Some foraminifers from western Long Island and New York Harbor: Am. Mus. Novitates 737, 12 p.

Spear, Walter E., 1912, Long Island sources—an additional supply of water for the City of New York: New York City Board Water Supply, 708 p.

Stearns, N. D., 1928, Laboratory tests on physical properties of water-bearing materials: U.S. Geol. Survey Water-Supply Paper 596 F, p. 121–176.

Suter, Russell, 1937, Engineering report on the water supplies of Long Island, New York: New York State Water Power and Control Comm. Bull. GW–2, 64 p.

Suter, Russell, deLaguna, Wallace, and Perlmutter, N. M., 1949, Mapping of geologic formations and aquifers of Long Island, New York: New York State Water Power and Control Comm. Bull. GW–18, 212 p.

Sverdrup, H. U., Johnson, M. W., and Fleming, R. H., 1942, The oceans, their physics, chemistry, and general biology: New York, Prentice-Hall, 1,087 p.

Theis, C. V., 1935, The relation between the lowering of the piezometric surface and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., p. 519–524.

——— 1938, The significance and nature of the cone of depression in groundwater bodies: Econ. Geology, v. 33, no. 8, p. 894.

Thomas, H. E., 1952, Ground-water regions of the United States—their storage facilities: Physical and Economic Foundation of Natural Resources, v. 3: U.S. Cong., House Interior and Insular Affairs Comm., p. 7.

Thompson, D. G., Wells, F. G., and Blank, H. R., 1937, Recent geologic studies on Long Island with respect to ground-water supplies: Econ. Geology, v. 32, no. 4, p. 451–470.

Tolman, C. F., 1937, Ground water: New York, McGraw-Hill Book Co., 593 p.

U.S. Coast and Geodetic Survey, 1953, Density of sea water: Spec. Pub. 279, 62 p.

U.S. Public Health Service, 1946, Drinking water standards: Public Health Repts, v. 61, no. 11, p. 371–384.

Veatch, A. C., 1906, Fluctuation of the water level in wells with special reference to Long Island, N.Y.: U.S. Geol. Survey Water-Supply Paper 155, 83 p.

——— and others, 1906, Underground water resources of Long Island, New York: U.S. Geol. Survey Prof. Paper 44, 394 p.

Weiss, Lawrence, 1954, Foraminifera and origin of the Gardiners clay (Pleistocene), eastern Long Island, N.Y.: U.S. Geol. Survey Prof. Paper 254–G, p. 143–163.

Wenzel, L. K., 1942, Methods for determining permeability of water-bearing materials: U.S. Geol. Survey Water-Supply Paper 887, 192 p.

BASIC DATA

TABLE 11.—*Records of selected wells in southern*

Map coordinates: First number and letter indicate grid square on plate 1. Remainder is distance, in miles, first north and then west from southeast corner of grid square.
Owner: JWSC, Jamaica Water Supply Co.; LIWC, Long Island Water Corp.; NCDPW, Nassau County Department of Public Works; NYCDWSGE, New York City Department of Water Supply, Gas and Electricity; NYWSC, New York Water Service Corp.; USGS, U.S. Geological Survey.
Altitude of reference point: Reference point is not more than 3 feet above or below land surface unless indicated otherwise in remarks column. Figures given in tenths of feet are based on spirit levels; others are interpolated from topographic maps. Altitudes are referred to mean sea level, Sandy Hook, N.J. datum.
Depth of well: Total depth of drilled hole. Bottom of screen is depth of finished well.

Well	Map coordinates	Owner	Locality	Year completed	Altitude of reference point (feet)	Depth of well (feet)	Diameter (inches)
N3	5B, 5.2N, 2.2W	NYCDWSGE	Watts Pond Pumping Station.	1908	10	465	
N4	5B, 5.4N, 2.1W	do	do	1908	10	70	
N6	5B, 5.7N, 2.9W	do	Clear Stream Pumping Station.	1908	10	338	
N7	5C, 0.8N, 1.3W	USGS	Valley Stream	1908	22.8	970	6
N9	5C, 0.9N, 1.3W	do	do	1908	24.7	138	8
N10	5C, 2.8N, 2.4W	JWSC	Elmont	1927	49	402	18–12
N11	5C, 2.8N, 2.4W	do	do	1927	46	440	24–8
N12	5C, 2.8N, 2.4W	do	do	1927	45	425	18–12
N13	5C, 2.8N, 2.4W	do	do	1927	45	435	18–12
N42	6B, 0.7N, 4.2W	City of Long Beach	Long Beach	1929	5	1,203	18–8
N43	5B, 0.6N, 0.2W	do	do	1929	5	1,285	18–8
N46	6B, 0.6N, 0.4W	Lido-Point Lookout Water District.	Point Lookout	1937	8.0	1,291	18–8
N47	6B, 2.6N, 3.7W	Colonial Beacon Oil Co.	Oceanside	1934	6	182	4
N48	6B, 5.1N, 3.8W	Village of Rockville Centre.	Rockville Centre	1927	17.5	523	18–10
N49	6B, 5.1N, 3.8W	do	do	1927	16.8	355	18–10
N50	6B, 5.1N, 3.8W	do	do	1929	16.9	528	18–10
N51	6B, 5.4N, 3.9W	NYCDWSGE	Smith Pond	1929	15	93	
N52	6B, 5.2N, 3.1W	Village of Rockville Centre.	Rockville Centre	1930	27.8	550	18–8
N54	6B, 5.3N, 2.4W	NYCDWSGE	Rockville Centre Pumping Station.	1930	28	101	
N57	6B, 4.9N, 2.0W	do	Baldwin		11	150	
N61	6B, 4.9N, 2.0W	do	do	1909	11	137	14
N62	6B, 4.8N, 1.1W	do	Milburn Pumping Station.	1909	15	200	24
N67	6B, 5.2N, 0.5W	Village of Freeport	Freeport		21.5	1,052	12
N68	6B, 5.2N, 0.5W	do	do	1936	21	552	12
N69	6B, 5.2N, 0.5W	do	do	1936	21	505	18–12
N72	6C, 1.2N, 2.3W	Village of Rockville Centre.	Rockville Centre	1936	45	616	18–10
N73	6C, 1.0N, 0.8W	LIWC	Roosevelt	1909	42	716	
N76	6C, 1.9N, 3.2W	West Hempstead-Hempstead Gardens Water District.	Hempstead	1926	50	195	24–16

See footnote at end of table.

Nassau and southeastern Queens Counties

Water-yielding unit: uP, upper Pleistocene deposits; J, Jameco gravel; M, Magothy(?) formation; L, Lloyd sand member of Raritan formation.
Water level: Water levels given in tenths of feet are measured; others are reported. A plus (+) sign indicates water level is above reference point.
Type of well: A, abandoned; D, domestic or institutional; I, Industrial; O, observation; P, public supply; S, sprinkling; T, test.
Remarks: Numbers preceded by a "V" are the well numbers used in U.S. Geological Survey Professional Paper 44. Explanation of symbols: * For log, see table 12. ** For chemical analysis, see table 4. † For chloride analysis, see table 13.

Screen setting below land surface (feet)	Water-yielding unit	Water level		Specific capacity	Type of well	Chloride		Remarks
		Depth below reference point (feet)	Date			Parts per million	Date	
					T			
	uP				P			
	M				P	7	1941	
851-911	L	14.9	Apr. 7, 1954		O			For hydrograph, see fig. 16.
98-138	M	3.8	Apr. 27, 1954		O			Do.
330-397	M	11	June 17, 1926	19	P	13	June 24, 1957	Temperature of water 54° F.
205-273 288-408	M	17	Aug. 3, 1926	39	P	13	do	
362-422	M	16	Feb. 20, 1953		P	6	do	
229-287	M	10	February 1953.		P	12	do	
1,144-1,184	L	(1)	1929		P	8	July 14, 1953	Original screen setting 550-608 ft. Abandoned owing to increase in salinity of water. Temperature of water, 68°F.
1,193-1,264	L	(1)	1950		P	8	July 14, 1953	Temperature of water 69° F.
1,200-1,260	L	+6.9	Apr. 13, 1953		P	6	July 14, 1953	**Temperature of water 68° F.
167-182	M				I			
449-509	M	5	July 1927	16	P	6	Oct. 21, 1953	**Temperature of water 59° F.
304-334	M	5	August 1927	12	P	8	do	Temperature of water 59° F.
442-462 473-513	M	11	Aug. 5, 1929	44	P	8	do	Temperature of water 60° F.
					P			
468-526	M	17.8	Apr. 28, 1954	33	P	6	Oct. 21, 1953	Temperature of water 56° F.
	uP				A			
	M				A			
	uP				A			
	M				A			
	L	6.9	Mar. 31, 1953		I	8	Oct. 21, 1953	**Temperature of water 64° F.
450-500	M	11	May 7, 1937	17	P	8	do	**Temperature of water 58° F.
450-500	M	6	July 2, 1937	30	P	6	do	Temperature of water 58° F.
544-604	M			51	P	8	do	**Temperature of water 56° F.
					T			
145-192	M(?)	26	June 28, 1927	26	P	7	Mar. 24, 1947	(**).

TABLE 11.—*Records of selected wells in southern*

Well	Map coordinates	Owner	Locality	Year completed	Altitude of reference point (feet)	Depth of well (feet)	Diameter (inches)
N78	6C, 3.5N, 1.9W	Village of Hempstead	Hempstead	1926	59.1	381	26–12
N79	6C, 3.3N, 1.9W	do	do	1928	61.9	492	24–10
N80	6C, 3.4N, 1.8W	do	do	1930	57.9	489	18–12
N81	6C, 3.6N, 1.9W	do	do	1934	63.0	425	28–12
N83	6C, 3.7N, 1.9W	do	do	1934	65.0	1,003	12–10
N84	6C, 3.8N, 1.6W	U.S. Air Force	do	1930	73.0	307	10
N87	6C, 4.0N, 2.6W	Doubleday and Co., Inc.	Garden City		80	806	
N128	7B, 1.1N, 0.4W	L.I. State Park Commission.	Jones Beach	1929	6.1	1,034	16–8
N129	7B, 1.6N, 0.3W	do	do	1933	9.8	1,024	26–10
N131	7B, 5.7N, 3.8W	Village of Freeport	Freeport	1929	20.8	533	24–8
N132	7B, 5.7N, 3.8W	do	do	1929	20	658	12–6
N133	7B, 5.7N, 3.8W	do	do	1931	24.2	533	18–12
N134	7B, 5.7N, 3.8W	do	do	1935	21	557	18–12
N135	7C, 0.0N, 3.8W	NYCDWSGE	do		20	150	8
N137	7B, 5.7N, 0.8W	do	Bellmore	1909	10	90	8
N138	7C, 1.1N, 1.0W	do	North Bellmore	1909	25	125	8
N140	7C, 2.9N, 1.4W	do	do	1909	62	156	8
N141	7C, 2.0N, 4.0W	do	Uniondale	1909	40	109	8
N143	7C, 3.1N, 4.3W	do	do	1909	60	85	8
N178	8B, 5.6N, 3.8W	Harry Donniez	Seaford	1937	10	68	1¼
N180	8C, 0.6N, 4.2W	NYCDWSGE	do		25.1	762	
N181	8C, 0.6N, 3.7W	do	do		24	1,012	
N183	8C, 0.2N, 3.0W	School District No. 23.	Massapequa	1937	10	33	1¼
N184	8C, 0.5N, 2.7W	NYCDWSGE	do		10	161	
N219	5B, 0.8N, 3.0W	Lawrence Beach Bathing Association.	Lawrence Beach		5	62	1½
N220	5B, 0.8N, 3.0W	John Lawrence	Lawrence		7	100	8–2
N222	5B, 1.8N, 3.7W	Anson W. Hart	do		18	70	6
N223	5B, 1.9N, 3.6W	Edward Man	do		20	416	6–3
N232	5B, 4.5N, 2.3W	LIWC	Valley Stream	1903	6		
N236	5B, 5.0N, 0.8W	do	Lynbrook	1903	11.3	504	8
N237	5B, 5.1N, 0.7W	NYCDWSGE	do		17	200	5
N238	5B, 5.1N, 0.9W	do	do		17	390	5
N239	5B, 5.2N, 1.2W	do	do		18	370	5
N240	5B, 5.1N, 1.5W	do	do		18	410	5
N241	5B, 5.2N, 1.7W	do	do		15	242	5
N244	5B, 5.5N, 2.1W	do	Watts Pond Pumping Station.	1895	10.7	208	5
N248	5B, 5.6N, 2.5W	do	Clear Stream Pumping Station.		15	190	5
N319	6B, 0.2N, 4.3W	Long Beach Association.	Long Beach		8	386	6
N320	6B, 1.6N, 3.9W	Hempstead Poor House.	Barnum Island		5	383	
N324	6B, 5.5N, 4.0W	NYCDWSGE	Smith Pond		9.6	587	5
N325	6B, 5.5N, 3.2W	do	Rockville Centre		20	74	2
N329	6B, 5.1N, 2.2W	do	do		22	97	2
N343	6B, 3.4N, 1.3W	A. Schreiber	Baldwin	1905	6	370	8

See footnote at end of table.

Nassau and southeastern Queens Counties—Continued

Screen setting below land surface (feet)	Water-yielding unit	Water level		Specific capacity	Type of well	Chloride		Remarks
		Depth below reference point (feet)	Date			Parts per million	Date	
336–375	M	7.7	Dec. 1, 1948	32	P	5	July 23, 1943	
338–418	M	14.3	Mar. 1, 1954	40	P	4	Feb. 26, 1952	(**).
429–480	M	9.6	do	15	P	------	------	
360–420	M	12.5	do	38	P	6	May 26, 1943	Well N83, 542 ft deep nearby.
406	M	14.3	do	35	P	------	------	
------	M	8.3	1935	------	A	------	------	Location approximate.
------	------	------	------	------	A	------	------	
958–1,034	M	+1.2	Apr. 7, 1954	28	P	10	Mar. 11, 1953	
889–899 912–951	M	1.3	Nov. 10, 1953	45	P	8	Nov. 10, 1953	**Temperature of water 63° F.
169–227 473–523	M	8.2	July 1, 1933	79	P	6	Oct. 21, 1953	**Temperature of water 55° F.
466–506	M	7	Apr. 29, 1929	13	P	6	do	Temperature of water 56° F.
469–511	M	12.3	Mar. 25, 1932	36	P	6	do	Temperature of water 57° F.
467–517	M	7.5	August 1935	57	P	6	do	**Temperature of water 56° F.
------	------	------	------	------	T	------	------	
------	------	------	------	------	T	------	------	
------	------	------	------	------	T	------	------	
------	------	------	------	------	T	------	------	
------	------	------	------	------	T	------	------	
------	------	------	------	------	T	------	------	
66–68	uP	------	------	1	D	------	------	
------	M	6.9	Apr. 7, 1954	------	O	8	Oct. 7, 1953	**Reference point is 9.8 ft above land surface. For hydrograph, see pl. 6.
------	------	------	------	------	T	------	------	
31–33	uP	------	------	------	D	------	------	
------	------	------	------	------	T	------	------	
------	uP	------	------	------	A	------	------	V259.
20–30	uP	6	------	------	A	------	------	V260.
60–70	uP	------	------	------	A	------	------	V262.
------	M	------	------	------	A	------	------	V263. Water at 416 ft reported very salty.
------	uP, J	------		------	P	------	------	V273. About 150 wells ranging in depth from 30 to 190 ft. All are connected to a single pumping unit.
------	M	+1.8	July 22, 1903	------	T	3	Feb. 25, 1903	V277. See data for well N4411 nearby.
------	------	------	------	------	T	------	------	V278.
------	------	------	------	------	T	------	------	V279.
------	------	------	------	------	T	------	------	V280.
------	M	------	------	------	T	------	------	V281.
------	------	------	------	------	T	------	------	V282.
------	M	(1)	1895	------	T	------	------	V285.
------	------	------	------	------	T	------	------	V289.
------	M	+2.8	July 11, 1903	------	A	29	1903	V373.
------	------	------	------	------	A	------	------	V374.
------	M	(1)	------	------	T	------	------	V377.
------	------	------	------	------	T	------	------	V378.
------	------	------	------	------	T	------	------	V382.
------	M	+1	July 17, 1903	------	A	------	------	V396.

TABLE 11.—*Records of selected wells in southern*

Well	Map coordinates	Owner	Locality	Year completed	Altitude of reference point (feet)	Depth of well (feet)	Diameter (inches)
N434	7B, 5.3N, 3.9W	NYCDWSGE	Agawam Pumping Station.	------	15	110	6
N436	7B, 5.4N, 3.0W	do	Merrick Pumping Station.	------	15.5	107	4
N438	7B, 5.6N, 2.1W	do	Matowa Pumping Station.	------	10	97	4½
N440	7C, 0.1N, 0.9W	do	Wantagh Pumping Station.	------	8	92	6–4½
N514	8C, 0.5N, 2.7W	do	Massapequa Pumping Station.	1896	10	106	4½
N559	5B, 2.6N, 3.1W	Central Theatre	Cedarhurst	1937	25	150	10
N634	7C, 0.1N, 3.1W	NYWSC	Merrick	1938	25	45	12
N636	6B, 4.4N, 4.4W	Home-Like Laundry.	East Rockaway	1938	20	65	4
N637	7B, 3.9N, 4.2W	Freeport Yacht Club.	Freeport	1938	5	188	4
N652	5B, 3.3N, 0.6W	Seawane Golf Club	Hewlett	1937	5	137	6
N654	5B, 3.3N, 1.1W	do	do	1937	5	150	6–4
N666	7B, 2.6N, 0.1W	Long Island State Park Commission.	Jones Beach Causeway.	1938	10.4	104	2
N667	7B, 2.0N, 2.8W	do	Meadowbrook State Parkway.	1938	5	89	2
N693	5C, 2.8N, 2.3W	JWSC	Elmont	1939	50	107	44–26
N728	8C, 0.9N, 0.9W	NYWSC	Massapequa	1927	------	40	--------
N729	8C, 0.9N, 0.9W	do	do	------	------	73	16
N939	7B, 5.0N, 4.3W	F. W. Woolworth Co.	Freeport	1939	22	178	8
N941	5C, 2.2N, 0.1W	J. J. Rassweiler, Jr.	West Hempstead	1939	52	67	8
N1106 to N1273.	----------------	NCDPW	--------------------	------	------	-------	--------
N1274	7C, 0.1N, 0.6W	do	Wantagh	------	15.0	40	1¼
N1275	7B, 5.4N, 0.5W	do	do	------	9.3	13	1¼
N1276	7B, 5.4N, 0.5W	do	do	------	9.3	36	1¼
N1277	7B ,5.4N, 0.5W	do	do	------	9.4	67	1¼
N1278 to N1282.	----------------	do	--------------------	------	------	-------	--------

See footnote at end of table.

Nassau and southeastern Queens Counties—Continued

Screen setting below land surface (feet)	Water-yielding unit	Water level: Depth below reference point (feet)	Water level: Date	Specific capacity	Type of well	Chloride: Parts per million	Chloride: Date	Remarks
	uP, M				P			V487. Group of 32 wells 33 to 110 ft deep.
	M	5.2	June 1900		P			V489. Group of 62 wells 37 to 107 ft deep.
	M	[1]			P			V491. Group of 46 wells 38 to 97 ft. deep.
	M	[1]			P			V493. Group of 49 wells 24 to 92 ft. deep.
	M	[1]			P			V567. Group of 106 wells 37 to 106 ft. deep.
132–148	J	21	Nov. 27, 1937	16	I			
24–40	uP	10	July 23, 1938	42	P			**Group of 9 wells 30–83 ft. deep.
57–65	uP	7	Aug. 13, 1938	7	I			
185–188	M	[1]	Aug. 2, 1938		D			
121–137	J	2	May 10, 1937		S			Well N597 nearby, 32 ft. deep, on same pumping unit.
134–150	J	2	do	30	S			Well N598 nearby, 35 ft. deep on same pumping unit.
93–104	M	3.5	Mar. 20, 1954		D	8	Nov. 4, 1953	
78–89	uP	3	July 1938		D	6	do	
68–93	uP	8	June 26, 1939	38	P	20	June 24, 1957	**Temperature of water 56° F.
	uP				P			
43–73	uP			76	P			
102–123	M			9	I			
47–63	uP	20	Sept. 1, 1939	22	S			
	uP				O			Wells whose numbers fall within this group and which are shown on pl. 1, are shallow observation wells screened in the unconfined aquifer. Data for them are given in New York State Water Resources Comm. Bulls. GW-27 and GW-41.
38–40	uP	9.5	Apr. 7, 1954		O	6	Apr. 7, 1954	Temperature of water 55°F.
11–13	uP	6.6	do		O	6	do	Temperature of water 47°F.
34–36	uP	6.7	do		O	528	do	Temperature of water 54°F.
65–67	M	1.1	do		O	8	do	Temperature of water 53°F.
	uP				O			Wells whose numbers fall within this group and which are shown on pl. 1 are shallow observation wells screened in the unconfined aquifer. Data for them are given in New York State Water Resources Comm. Bulls. GW-27 and GW-41.

TABLE 11.—*Records of selected wells in southern*

Well	Map coordinates	Owner	Locality	Year completed	Altitude of reference point (feet)	Depth of well (feet)	Diameter (inches)
N1283	7B, 4.8N, 0.6W	NCDPW	Wantagh	1939	7.4	39	1¼
N1284	7B, 4.8N, 0.6W	do	do	1939	12.4	65	1¼
N1285	7B, 5.6N, 0.3W	do	do	1939	6.7	19	1¼
N1286	7B, 5.6N, 0.3W	do	do	1939	6.7	39	1¼
N1287	7B, 5.6N, 0.3W	do	do	1939	11.8	64	1¼
N1288	7B, 5.6N, 0.3W	do	do		10.0	19	1¼
N1335	5B, 3.2N, 2.3W	Colonial Pharmacy	Woodmere	1940	23	142	4
N1379	5B, 4.1N, 2.5W	LIWC	Valley Stream	1941	7.7	200	12–8
N1416T	6B, 0.7N, 4.0W	Lido Laundry	Long Beach	1940	10	200	6
N1421 to N1464.							
N1499	6B, 3.3N, 3.9W	Sun Oil Co	Oceanside	1940	5	245	4
N1601	6C, 0.9N, 0.7W	LIWC	Roosevelt	1940	40	666	30–12
N1602	6C, 0.5N, 4.1W	do	Lakeview	1940	33.5	595	30–12
N1603	6C, 1.4N, 4.0W	do	Malverne	1940	40	551	30–12
N1613	5C, 1.0N, 1.5W	L.I. State Park Commission.	Valley Stream		25.0	496	6–1¼
N1615	7C, 2.7N, 3.6W	NCDPW	East Meadow		62.8	26	1½
N1621 to N1628.							
N1633	7C, 2.7N, 2.5W	M. Hartman	East Meadow	1940	55	40	4
N1682 to N1685							
N1742	6B, 4.9N, 0.2W	Grove Theatre	Freeport	1941	20	272	10
N1826	8B, 5.2N, 1.0W	R. A. Wilkinson	Nassau Shores	1942	8	35	1¼
N1864	5B, 5.5N, 3.1W	Demco, Inc	Valley Stream	1942	10	40	12–8
N1869	7B, 4.5N, 2.7W	Aerial Products, Inc.	Merrick	1942	5	132	8
N1927	6B, 0.4N, 2.9W	City of Long Beach.	Long Beach	1943	10	1,471	20–8
N2045	7B, 4.2N, 4.3W	Nassau Boat Basin	Freeport	1945	10	133	4
N2115	5C, 1.5N, 3.1W	JWSC	Elmont	1946	42	116	48–26
N2203	5B, 3.6N, 3.7W	W. G. Feger	Woodmere	1946	5	182	2½

See footnote at end of table.

Nassau and southeastern Queens Counties—Continued

Screen setting below land surface (feet)	Water-yielding unit	Water level		Specific capacity	Type of well	Chloride		Remarks
		Depth below reference point (feet)	Date			Parts per million	Date	
37-39	uP	6.2	Apr. 7, 1954		O	6,600	Apr. 7, 1954	Temperature of water 54°F.
63-65	M	4.8	Feb. 2, 1954		O	8	do	Temperature of water 53°F.
17-19	uP	3.1	Apr. 7, 1954		O	20	do	Temperature of water 50°F.
37-39	uP	3.9	do		O	8	do	Temperature of water 54°F.
62-64	M	2.8	do		O	6	do	Temperature of water 53°F.
17-19	uP	7.2	Apr. 8, 1954		O	20	Apr. 8, 1954	
137-142	J	20	Apr. 9, 1940		I			
175-196	J	5.9	Apr. 5, 1954		O	4	July 9, 1954	** †Reference point is about 4 ft above land surface.
					T			(*).
	uP				O			Wells whose numbers fall within this group and which are shown on pl. 1, are shallow observation wells screened in the unconfined aquifer. Data for them are given in New York State Water Resources Comm. Bull. GW-27.
229-245	M	3	May 2, 1940	3	I			
530-580	M	18	Aug. 7, 1940	20	P			(**).
445-495	M	14	July 11, 1940	25	P	3	Aug. 12, 1947	(**).
484-529	M	10	Aug. 29, 1940	17	P	6	Jan. 18, 1952	
	M	4.7	Apr. 27, 1954		O			
24-26	uP	17.5	Mar. 30, 1953		O			
	uP				O			Shallow observation wells screened in the unconfined aquifer. Data are given in New York State Water Resources Comm. Bull. GW-27 (except well N1622, abandoned in 1947). Chloride analyses for wells N1627 and N1628 are listed in table 13.
33-38	uP	16	July 8, 1940	38	S			
								Wells whose numbers fall within this group and which are shown on pl. 1, are shallow observation wells screened in the unconfined aquifer. Data for them are given in New York State Water Resources Comm. Bulls. GW-27 and GW-41.
33-57	uP	1	July 7, 1941	27	I			
32-35	uP	8	May 29, 1942		D			
20-40	uP	2	Dec. 17, 1942	25	I			
116-129	M	(1)	1942		I			
1,159-1,219	L	do	December 1943.	35	P	4	Nov. 20, 1951	Temperature of water 69° F.
112-122	M	do	July 1945		I			
63-83	uP	9	July 9, 1946	55	P	16	1958	*Temperature of water 56° F.
158-164	J	1	June 1947		D			(*).

TABLE 11.—*Records of selected wells in southern*

Well	Map coordinates	Owner	Locality	Year completed	Altitude of reference point (feet)	Depth of well (feet)	Diameter (inches)
N2225	8B, 5.0N, 1.0W	M. J. Stanton	Massapequa	1947	5	173	4
N2239	6C, 1.9N, 3.2W	West Hempstead-Hempstead Gardens Water District.	West Hempstead	1947	50	178	30–16
N2359	8B, 4.7N, 3.1W	R. Pelletier	Seaford	1947	5	63	2
N2413	5C, 1.7N, 1.9W	JWSC	Elmont	1949	52	526	26–10
N2414	5C, 1.7N, 1.9W	do	do	1949	52	90	44–18
N2530	5B, 3.7N, 3.7W	A. D. Lansing	Woodmere	1947	5	161	2¼
N2572	6B, 2.9N, 3.2W	NCDPW	Oceanside	1946	3	100	4
N2573	5B, 3.6N, 1.5W	J. J. Siegal	Hewlett	1948	5	64	4
N2574	6B, 5.7N, 1.2W	LIWC	Baldwin	1948	18	548	10–8
N2578	5C, 0.7N, 2.8W	do	Valley Stream	1949	25	570	60–10
N2580	7C, 4.0N, 1.6W	Levittown Water District.	Levittown	1950	74.8	362	20–12
N2581	7C, 4.0N, 1.5W	Bethpage Realty	do	1948	82.8	82	12
N2597	5B, 0.6N, 0.5W	City of Long Beach	Long Beach	1948	6	1,252	8
N2603	8C, 0.9N, 0.8W	NYWSC	Massapequa	1948	20	71	12
N2613	6B, 5.7N, 1.2W	LIWC	Baldwin	1948	18	548	26–12
N2790	6B, 3.5N, 4.3W	USGS	Bay Park	1949	9.7	870	6
N2921	6B, 2.0N, 3.4W	S. Ivierson	Island Park	1948	10	120	4
N3078	6B, 2.4N, 3.6W	Gulf Oil Corp	Oceanside	1949	5	146	6
N3242	6B, 1.6N, 3.3W	F. Gaudiosi	Island Park	1951	5	269	4
N3245	8B, 4.8N, 2.5W	R. S. Mauther	Massapequa	1949	5	215	4
N3246	5B, 1.3N, 3.2W	W. Clurman	Lawrence	1949	12	151	4
N3312	7C, 3.6N, 0.4W	Levittown Water District.	Levittown	1949	70	307	12
N3313	7C, 3.6N, 0.4W	do	do	1949	70	95	12
N3314	6B, 5.3N, 4.2W	New York Telephone Co.	Lynbrook	1950	20	80	6
N3325	7B, 3.0N, 4.0W	W. Vaughan	Freeport	1949	6	120	2
N3327	5C, 0.7N, 2.8W	LIWC	Valley Stream	1949	27.4	457	16–12
N3427	8C, 0.9N, 4.2W	NYWSC	Wantagh	1949	31.0	186	12
N3448	5B, 0.3N, 1.7W	City of Long Beach	Long Beach	1950	7	1,250	30–8
N3451	5B, 1.7N, 3.1W	S. Rosen	Lawrence	1950	8	88	4
N3456	7C, 3.7N, 2.9W	East Meadow Water District.	East Meadow	1950	81.5	367	24–12
N3457	7C, 3.7N, 2.9W	do	do	1950	81	364	24–12
N3463	7C, 1.8N, 1.1W	NYWSC	Wantagh	1950	30.2	303	12
N3465	7C, 3.7N, 2.9W	East Meadow Water District.	East Meadow	1951	80	562	24–12
N3498	8B, 1.8N, 0.6W	Town of Oyster Bay.	Tobay Beach	1950	10	338	8
N3519T	5C, 0.6N, 1.5W	LIWC	Lynbrook	1950	22	619	6
N3520	6C, 1.4N, 4.0W	do	Malverne	1950	34	475	24–12
N3529	6B, 0.4N, 4.0W	Lido Theatre	Long Beach	1950	8	106	8
N3548	5B, 5.1N, 0.1W	Temple Beth David	Lynbrook	1950	20	92	6
N3564	8C, 0.9N, 4.2W	NYWSC	Wantagh	1950	31	60	16
N3570	7B, 4.6N, 3.4W	Town of Hempstead	Merrick	1951	5	151	8
N3581	6B, 3.5N, 3.7W	A.M.A. Corp	Oceanside	1950	8	57	6
N3603	5C, 3.2N, 0.3W	Franklin Square Water District.	Franklin Square	1951	75.3	533	24–12
N3604	5C, 2.2N, 0.3W	do	do	1951	76.5	533	24–12
N3605	5C, 2.3N, 0.9W	do	do	1951	47.5	438	24–12
N3636	6C, 2.6N, 2.2W	State Laundry	Hempstead	1951	50	356	8
N3653	5B, 3.8N, 0.7W	A. Bring	Hewlett Harbor	1951	15	47	4
N3668	6C, 1.8N, 2.4W	Village of Hempstead.	Hempstead	1953	57.5	505	28–12

See footnote at end of table.

Nassau and southeastern Queens Counties—Continued

Screen setting below land surface (feet)	Water-yielding unit	Water level: Depth below reference point (feet)	Water level: Date	Specific capacity	Type of well	Chloride: Parts per million	Chloride: Date	Remarks
165–170	M	-----	-----	-----	D	-----	-----	(*).
108–148	uP	26	Mar. 18, 1947	-----	P	21	Oct. 21, 1959	
57–63	uP	(1)	April 1947	-----	D	-----	-----	(*).
478–508	M	26	December 1953.	71	P	4.5	June 24, 1957	*Temperature of water 56° F.
60–89	uP	25	Jan. 19, 1949	48	P	16	do	**Temperature of water 55° F.
155–161	J	1	October 1947	-----	D	-----	-----	
-----	-----	-----	-----	-----	T	-----	-----	(*).
55–60	uP	-----	-----	8	D	-----	-----	(*).
-----	M	0	July 7, 1948	-----	T	-----	-----	
56–88	uP	7.5	June 1949	40	P	37	Aug. 8, 1958	**Temperature of water 57° F.
310–347	M	22	Sept. 29, 1950	18	P	4	Jan. 21, 1952	(*).
55–81	uP	25	Apr. 20, 1948	29	P	20	do	Temperature of water 51° F.
1,175–2,135	L	(1)	July 22, 1948	-----	P	8	July 14, 1952	Temperature of water 69° F. For electric log, see pl. 2.
35–66	uP	5	August 1948	40	P	-----	-----	
460–500	M	(1)	July 7, 1948	38	P	-----	-----	(** *).
538–560	M	5.2	Apr. 7, 1954	2	O	8	July 19, 1954	** * † Reference point is about 7 ft above land surface. For electric log see pl. 2.
114–119	J	7	September 1948.	-----	D	10	Jan. 10, 1953	(*).
135–145	J	1	January 1949	15	I	-----	-----	(*).
264–269	M	4	July 1951	-----	D	-----	-----	(*).
209–215	M	(1)	May 17, 1949	-----	D	-----	-----	(*).
132–136	J	11	July 19, 1949	-----	D	-----	-----	(*).
252–304	M	24	Sept. 26, 1949	11	P	4	Jan. 21, 1952	(*).
64–95	M	24	July 15, 1949	33	P	16	do	
73–79	uP	12	Feb. 7, 1950	-----	I	22	Sept. 30, 1952	(*).
116–120	M	5	July 1949	-----	D	-----	-----	(*).
399–451	M	11.3	Oct. 13, 1949	25	P	6	Jan. 18, 1952	* Temperature of water 57° F.
126–161	M	11.4	May 13, 1950	-----	P	-----	-----	(*).
1,194–1,234	L	+3	Mar. 16, 1950	23	P	10	July 14, 1953	** Temperature of water 70° F.
82–88	J	6	Sept. 27, 1951	20	D	21	July 1950	(*).
280–320	M	27	Jan. 18, 1951	-----	P	-----	-----	
280–320	M	25	Jan. 10, 1951	23	P	-----	-----	
246–298	M	3.2	June 15, 1950	23	P	-----	-----	
275–315	M	26.5	Dec. 1, 1950	21	P	-----	-----	(*).
313–338	M	6	May 26, 1950	4	P	12	July 10, 1956	(**).
-----	-----	-----	-----	-----	T	-----	-----	(*).
126–178	M	7	Mar. 1, 1951	8	P	-----	-----	(*).
93–104	uP	7	June 20, 1950	-----	I	3,450	July 10, 1956	(*).
81–92	uP	15	Sept. 1950	4	I	-----	-----	(*).
34–50	uP, M	-----	-----	-----	P	-----	-----	
115–130	M	(1)	Sept. 4, 1950	9	I	6	Sept. 5, 1950	(*).
46–57	uP	5	Sept. 9, 1950	7	I	-----	-----	(*).
443–493	M	26	Mar. 1954	10	P	-----	-----	(*).
438–498	M	28	Mar. 1951	12	P	-----	-----	
398–438	M	15	June 1954	37	P	-----	-----	(*).
329–355	M	8	Apr. 6, 1951	9	I	-----	-----	(*).
29–39	uP	11	Dec. 1950	-----	D	-----	-----	(*).
449–499	M	21.3	Mar. 1, 1954	45	P	-----	-----	(*).

TABLE 11.—*Records of selected wells in southern*

Well	Map coordinates	Owner	Locality	Year completed	Altitude of reference point (feet)	Depth of well (feet)	Diameter (inches)
N3680	7C, 1.8N, 1.1W	NYWSC	Wantagh	1951	32.4	373	12
N3687	6B, 0.7N, 4.2W	City of Long Beach	Long Beach	1951	5	1,266	18–8
N3691	5B, 3.3N, 1.6W	S. Zwerling	Hewlett Bay Park	1951	18	64	6
N3704	6C, 1.9N, 3.1W	West Hempstead-Hempstead Gardens Water District.	West Hempstead	1951	57	200	20–12
N3705	5B, 3.9N, 1.8W	Associated Food Stores.	Hewlett	1951	24	190	6
N3707	5B, 4.2N, 1.8W	NCDPW	do	1951	8	13	1¼
N3708	5B, 4.4N, 2.6W	do	Valley Stream	1951	5	18	1¼
N3709	5B, 4.3N, 2.8W	do	do	1951	5	19	1¼
N3710	5B, 3.8N, 2.9W	do	Woodmere	1951	5.4	18	1¼
N3711	5B, 4.6N, 2.7W	do	Valley Stream	1951	8.0	18	1¼
N3720	5C, 1.4N, 0.7W	JWSC	Franklin Square	1951	37	586	24–12
N3721	6C, 0.9N, 0.7W	LIWC	Roosevelt	1951	44	101	12
N3734	5B, 2.5N, 4.1W	Peninsula Laundry	Inwood	1951	8	140	6
N3745	6C, 1.3N, 2.4W	Village of Rockville Centre.	Rockville Centre	1951	45	608	24–12
N3780	8C, 2.7N, 4.1W	NYWSC	North Wantagh	1951	56.9	502	16
N3781	5C, 0.6N, 1.5W	LIWC	Valley Stream	1952	22	584	24–10
N3782	5C, 0.6N, 1.5W	do	do	1952	22	650	24–10
N3828	8B, 4.9N, 2.6W	Dr. D. Tutrone	Massapequa	1951	6	196	4
N3832	6C, 0.9N, 0.7W	LIWC	Roosevelt	1951	44	109	12
N3845	8C, 2.7N, 4.1W	NYWSC	North Wantagh	1952	57	94	4–2
N3861	5B, 3.3N, 3.5W	USGS	Cedarhurst	1952	9.4	623	6
N3862	5B, 1.5N, 3.7W	do	Lawrence	1952	7.7	795	6
N3863	5B, 0.3N, 2.7W	do	Atlantic Beach				
N3864	5B, 4.0N, 2.5W	do	Woodmere	1952	6.7	636	6
N3865	6B, 2.9N, 2.5W	do	Oceanside	1952	7.3	849	6
N3866	5B, 3.7N, 1.5W	do	Hewlett Bay Park	1952	9.4	452	6
N3867	5B, 4.6N, 2.7W	do	Green Acres	1952	9.2	550	6
N3881	5C, 3.9N, 0.5W	Village of Garden City.	Garden City	1953	80	492	24–12
N3886	8C, 0.9N, 1.1W	NYWSC	Massapequa	1952	25	75	16
N3893	8C, 2.8N, 4.0W	do	North Wantagh	1952	57	151	16
N3894	7C, 1.2N, 3.8W	do	North Merrick	1953	34.1	415	18–10
N3895	7C, 1.5N, 2.2W	do	North Bellmore	1952	38.1	503	16
N3926	5B, 2.8N, 2.6W	Woodmere Country Club.	Woodmere	1952	14	115	10
N3932	5B, 3.3N, 3.5W	USGS	Cedarhurst	1952	10.2	177	4
N3937	5C, 0.1N, 0.3W	LIWC	Malverne	1952	23.3	705	16
N3949	7B, 4.5N, 0.1W	Wantagh Fire District.	Wantagh	1952	7	35	4
N3981	6B, 3.1N, 2.4W	R. Clausen	Oceanside	1952	5	86	4
N4026	5B, 2.6N, 1.8W	USGS	Hewlett Neck	1952	7.6	197	6–4
N4033	5B, 3.8N, 1.2W	Mr. Pollock	Hewlett Harbor	1953	15	55	4
N4042	8C, 3.3N, 2.2W	South Farmingdale Water District.	Farmingdale	1953	53.0	154	16
N4043	8C, 3.3N, 2.2W	do	do	1953	73.1	482	16
N4062	5B, 1.5N, 3.7W	USGS	Lawrence	1952	7.3	165	6–4
N4077T	5C, 4.0N, 1.5W	JWSC	West Floral Park	1953	76.2	538	8
N4118	6C, 1.9N, 3.1W	West Hempstead-Hemspead Gardens Water District.	West Hempstead	1953	57	212	20–16
N4120T	5C, 0.9N, 0.9W	JWSC	Franklin Square	1953	40	458	8
N4132	6B, 5.4N, 1.5W	LIWC	Baldwin	1953	20	631	24–12

Nassau and southeastern Queens Counties—Continued

Screen setting below land surface (feet)	Water-yielding unit	Water level		Specific capacity	Type of well	Chloride		Remarks
		Depth below reference point (feet)	Date			Parts per million	Date	
270–328	M	4.0	May 3, 1951	19	P	------	------	(*).
1,195–1,245	L	------	------	------	P	10	Mar. 14, 1953	*Temperature of water 70°F.
55–64	uP	13	Oct. 1951	------	S	------	------	(*).
107–160	uP	26	June 4, 1951	80	P	14	Oct. 21, 1959	(*).
162–174	J	18	Mar. 1951	3	I	------	------	(*).
10–12	uP	3.0	Sept. 26, 1953	------	O	------	------	(†).
15–17	uP	3.7	Dec. 17, 1953	------	O	124	Nov. 9, 1953	(†).
17–19	uP	4.8	Sept. 26, 1953	------	O	4,200	do	(†).
15–17	uP	4.0	Dec. 17, 1953	------	O	24	Dec. 17, 1953	(†).
15–17	uP	7.5	Nov. 9, 1953	------	O	12	Nov. 9, 1953	(†).
476–516	M	8	Dec. 12, 1951	28	P	5	June 24, 1957	(*).
55–71	M	15	June 1951	4	P	------	------	Well N3722, 79 ft deep nearby.
116–136	J	4.5	Aug. 30, 1951	5	I	21	Sept. 1951	(*).
545–595	M	20	July 24, 1951	28	P	6	Oct. 1953	
88–141	uP, M	11	Apr. 9, 1952	56	P	------	------	(*).
370–430	M	0	Dec. 4, 1951	23	P	------	------	
348–408	M	4	Jan. 10, 1952	15	P	------	------	
190–195	M	2	Oct. 27, 1951	------	D	------	------	
63–89	M	17	Nov. 26, 1951	15	P	------	------	
90–94	M	------	------	------	T			
522–533	M	15.1	Apr. 8, 1954	7	O	16,000	Apr. 7, 1954	** * †For hydrograph, see pl. 6.
296–306	M	5.0	do	5	O	1,920	do	Do.
------	------	------	------	------	------	------	------	* Well destroyed, 1959.
459–470	M	4.1	Apr. 7, 1954	1	O	4	Apr. 6, 1954	** * †For hydrograph, see pl. 6.
555–565	M	2.3	do	1	O	4	Apr. 8, 1954	Do.
401–411	M	4.9	do	4	O	3	do	Do.
506–517	M	5.0	do	8	O	4	Apr. 6, 1954	Do.
426–466	M	26	Apr. 2, 1953	12	P	------	------	(*).
42–75	uP	15	Apr. 15, 1952	65	P	------	------	(*).
98–151	M	------	------	43	P	------	------	(*).
120–147	M	5.7	Mar. 15, 1953	68	P	------	------	(*).
312–361								
377–414	M	8.0	June 18, 1952	14	P	------	------	(*).
51–64	uP	9	July 7, 1952	------	S	------	------	(*).
172–176	J	7.4	Apr. 8, 1954	------	O	4	Apr. 7, 1954	** * †Temperature of water 58°F.
392–465	M	8.0	Sept. 18, 1952	60	P	------	------	(*).
20–35	uP	5.5	Oct. 17, 1952	33	I	------	------	(*).
83–85	uP	.5	July 1952	1	D	------	------	Temperature of water 53° F.
149–153	J	3.9	Apr. 7, 1954	------	O	4	Apr. 8, 1954	------
45–55	uP	8	Sept. 18, 1952	15	S	------	------	** * †Temperature of water 56°F.
96–154	M	------	------	------	P	3	May 18, 1959	(**).
317–369	M	27	Feb. 26, 1953	------	P	3	do	(*).
137–142	J	------	------	------	O	500	Mar. 26, 1956	*Accuracy of water level uncertain because of leaky casing.
360–380	M	36	January 1953	------	T	------	------	*N4077, nearby, 90 ft deep.
146–204	uP, M	23	June 29, 1953	62	P	28	Oct. 21, 1959	------
------	------	------	------	------	T	------	------	(*).
549–619	M	10.5	June 15, 1953	28	P	------	------	------

654861—62——9

TABLE 11.—*Records of selected wells in southern*

Well	Map coordinates	Owner	Locality	Year completed	Altitude of reference point (feet)	Depth of well (feet)	Diameter (inches)
N4149	7B, 4.7N, 2.5W	USGS	Merrick	1953	14.7	878	10–6
N4150	7B, 4.3N, 3.6W	do	Freeport	1953	16.2	826	10–6
N4213	5B, 4.8N, 3.0W	do	Green Acres	1953	8.3	140	6–4
N4257	5B, 3.4N, 2.2W	Congregation-Sons of Israel.	Woodmere	1954	25	144	6
N4270T	5C, 1.2N, 1.1W	JWSC	North Valley Stream	1954	34	522	12–10
N4298	5C, 4.0N, 1.4W	do	West Floral Park	1954	76.2	390	18–12
N4359	7C, 0.1N, 0.9W	NYCDWSGE	Wantagh Pumping Station.	1953	8	80	6
N4393	5B, 5.3N, 1.5W	LIWC	Lynbrook	1953	21.1	506	6
N4394	5B, 0.1N, 0.3W	do	Malverne	1953	23	350	7
N4401T	8C, 2.1N, 1.1W	Massapequa Water District.	Massapequa Park	1954	40	721	7
N4405	5B, 0.3N, 2.7W	LIWC	Atlantic Beach	1954	14.0	1,117	20–8
N4411	5B, 5.1N, 0.7W	do	Lynbrook	1954	16.8	568	24–12
N4425	6C, 3.3N, 1.9W	Village of Hempstead.	Hempstead	1954	60	375	20–12
N4447	7C, 3.8N, 2.9W	East Meadow Water District.	East Meadow	1955	80	335	18–12
N4448	7C, 3.8N, 2.9W	do	do	1955	80	555	18–12
N4512	5C, 1.2N, 1.1W	JWSC	North Valley Stream	1954	34	509	24–12
N4545	7B, 2.3N, 0.2W	L.I. State Park Commission.	Wantagh State Parkway.	------	10.9	167	4
N4546	7B, 3.2N, 0.3W	do	do	------	4.7	62	2
N4547	7B, 0.8N, 0.1W	do	Jones Beach	------	15.1	245	8
N4714	5B, 3.5N, 4.1W	William C. Baker	Hook Creek	------	8	228	--------
N4602	8C, 2.1N, 1.1W	Massapequa Water District.	Massapequa Park	1955	40	450	18–12
N4603	8C, 2.1N, 1.1W	do	do	1955	40	184	18–12
N4756	7C, 2.4N, 4.3W	Uniondale Water District.	Uniondale	1954	62.3	908	18–12
N4757	7C, 2.3N, 4.5W	do	do	1954	62.8	392	18–12
N4758	7C, 2.3N, 4.5W	do	do	1954	57.8	501	18–12
N4759	7C, 2.3N, 4.5W	do	do	1954	57.8	402	18–12
N5029	5B, 3.9N, 2.5W	Formerly Queens County Water Co.	Valley Stream	1903	5	181	--------
N5129	7B, 1.4N, 0.4W	L.I. State Park Commission.	Jones Beach	1955	10	1,130	18–12
N5227	6B, 0.6N, 0.4W	Lido-Point Lookout Water District.	Point Lookout	1955	10	1,228	12–8
N5233	6B, 0.5N, 1.0W	Monaco Surf Club	Lido Beach	1955	12	549	8
N5308	6B, 0.4N, 3.1W	City of Long Beach	Long Beach	1955	10	1,246	18–8
N5768	6B, 0.4N, 3.9W	Lido Golf Club	Lido Beach	1956	7	850	12–6
N6241	6B, 3.5N, 4.3W	USGS	Bay Park	1952	5.3	39	1¼

See footnote at end of table.

Nassau and southeastern Queens Counties—Continued

Screen setting below land surface (feet)	Water-yielding unit	Water level: Depth below reference point (feet)	Water level: Date	Specific capacity	Type of well	Chloride: Parts per million	Chloride: Date	Remarks
546–562	M	5.3	Apr. 7, 1954	6	O	6	Apr. 12, 1954	** * †Reference point is about 10 ft above land surface. For hydrograph, see pl. 6.
729–745	M	8.1	Apr. 7, 1954	10	O	8	Apr. 12, 1954	** * †Reference point is about 11 ft above land surface. For hydrograph, see pl. 6.
130–134	J	4.6	do	--	O	4	Apr. 6, 1954	* †For hydrograph, see pl. 6.
131–143	J	23	Apr. 24, 1954	8	I	--	--	*Temperature of water 56.5°F.
--	--	--	--	--	T	--	--	
349–384	M	30	Oct. 16, 1953	--	P	14	1958	Temperature of water 53°F.
70–80	M	4	Mar. 31, 1953	3	P	--	--	
421–474	M	10.1	Apr. 4, 1954	42	P	4	June 1955	(*).
132–175	M	6	December 1953.	--	P	--	--	
--	--	--	--	--	T	--	--	*Supply wells nearby N4602, 184 ft deep and N4603, 444 ft deep; depth to water 6 ft, May 1954.
1,005–1,075	L	3.9	Apr. 16, 1954	41	P	10	September 1955.	** *For electric log, see pl. 2.
480–550	M	7.0	Apr. 27, 1954	--	P	5	do	(*).
325–365	M	15	Mar. 19, 1954	--	P	--	--	
280–330	M	28	Mar. 10, 1955	30	P	--	--	
500–550	M	26	Mar. 8, 1955	38	P	--	--	
454–504	M	18	May 20, 1954	--	P	4	June 24, 1957	
--	M	3.7	May 16, 1954	--	A	8	Mar. 9, 1954	Temperature of water 57°F.
--	M	(1)	Apr. 9, 1954	--	A	6	Apr. 5, 1954	Do.
--	M	8.9	Apr. 7, 1954	--	A	30	Apr. 6, 1954	
--	J	(1)	1903	--	D	--	--	V272 Reference point is 3 ft above land surface.
382–444	M	6	June 10, 1955	33	P	4	Feb. 9, 1959	**N4401T, nearby.
112–184	M	7	July 12, 1954	35	P	4	do	Do.
243–312	M	19.6	Dec. 30, 1954	--	P	--	--	(*).
262–318	M	19.7	do	--	P	--	--	
363–375 380–410 420–440	M	14.2	do	52	P	--	--	
285–310 320–355	M	15.3	do	--	P	--	--	
--	J	+4	July 5, 1903	--	T	--	--	Data from USGS Water-Supply Paper 155, p. 18–19.
890–960	M	1.9	June 26, 1956	38	P	--	--	*For electric log, see pl. 2.
1,200–1,260	L	(1)	June 18, 1956	24	P	4	June 28, 1955	*For electric log, see pl. 2.
517–541	M	6	May 28, 1955	10	D	7	May 28, 1955	*Temperature of water 59.5°F.
1,160–1,220	L	--	--	33	P	5	Mar. 9, 1956	*For electric log, see pl. 2.
445–466 508–530	M	1	June 1956	--	S	8	July 7, 1956	For electric log, see pl. 2.
37–39	uP	2.6	Feb. 7, 1953	--	O	45	July 8, 1955	†Temperature of water 54.8°F.

TABLE 11.—*Records of selected wells in southern*

Well	Map coordinates	Owner	Locality	Year completed	Altitude of reference point (feet)	Depth of well (feet)	Diameter (inches)
N6242	5B, 3.3N, 3.5W	do	Cedarhurst	1952	7.8	12	1¼
N6243	5B, 3.3N, 3.5W	do	do	1952	7.4	19	1¼
N6244	5B, 1.5N, 3.7W	do	Lawrence	1952	7.4	23	1¼
N6245	6B, 2.9N, 2.5W	do	Oceanside	1952	------	10	1¼
N6246	5B, 4.0N, 2.5W	do	Woodmere	1952	6.4	9	1¼
							QUEENS
Q111	4B, 1.8N, 0.6W	LongIsland Lighting Co.	Far Rockaway	1932	9.0	1,016	16-8
Q129	4B, 1.3N, 0.2W	Columbia Theatre	do	1938	11.3	121	10
Q131	4B, 1.2N, 0.2W	Strand Theatre	do	1938	26	118	10
Q305	4C, 3.3N, 0.6W	JWSC	Hollis	1923	62.2	92	38-24
Q310	4C, 1.9N, 3.7W	do	St. Albans	1924	47.2	111	38-26
Q311	4C, 1.3N, 2.7W	do	South Ozone Park	1924	27.9	260	24-16
Q312	4C, 0.9N, 0.7W	do	Springfield Gardens	1925	22.1	276	20-13
Q313	4C, 4.1N, 0.1W	do	Queens Village	1925	97.0	111	38-26
Q314	4C, 1.0N, 2.6W	do	South Ozone Park	1925	34.6	310	24-13
Q318	4C, 3.4N, 2.8W	do	Jamaica	1930	130.7	250	26-16
Q319	4C, 3.2N, 2.2W	do	do	1929	123.6	142	38-18
Q331	5B, 5.8N, 3.3W	NYCDWSGE	Hook Creek Pumping Station.	1910	15	105	8
Q332	5B, 5.4N, 4.1W	do	Forest Stream Pumping Station.	1885	7	375	6
Q333	4B, 5.8N, 0.1W	do	Rosedale Pumping Station.	1906	12	140	8-6
Q334	4B, 5.6N, 0.6W	do	Springfield Pumping Station.	1897	8	207	8

Nassau and southeastern Queens Counties—Continued

Screen setting below land surface (feet)	Water-yielding unit	Water level		Specific capacity	Type of well	Chloride		Remarks
		Depth below reference point (feet)	Date			Parts per million	Date	
10–12	uP	6.7	Oct. 17, 1953		O	240	do	†Temperature of water 63°F.
17–19	uP	5.3	Feb. 28, 1953		O	28	Dec. 7, 1953	Temperature of water 61.8°F.
21–23	uP	1.6	Feb. 14, 1953		O	16	July 8, 1955	†Temperature of water 56.8°F.
8–10	uP				O	700	July 31, 1952	(†).
7–9	uP	3.8	Jan. 3, 1953		O	16	Dec. 16, 1953	†Temperature of water 58.4°F.

COUNTY

Screen setting below land surface (feet)	Water-yielding unit	Depth below reference point (feet)	Date	Specific capacity	Type of well	Parts per million	Date	Remarks
963–1,002	L	0.5	Apr. 14, 1953		I	18	September 1953.	**Temperature of water 67° F.
99–120	uP	16.7	June 23, 1938	12	I	1,500	Sept. 2, 1953	†Temperature of water 71° F. Reference point is about 15 ft below land surface.
97–118	uP	22	do	12	I	360	Sept. 18, 1944	†Temperature of water 63° F.
44–87	uP	24	July 31, 1923	55	P	16	June 28, 1954	**Temperature of water 54° F.
58–101	uP	15.8	Aug. 20, 1924	36	P	12	June 10, 1957	**Temperature of water 54° F.
202–260	J	28	March 1953	63	P	6	do	**Temperature of water 54° F.
216–276	J	12	do	28	P	7	1944	(**).
63–106	uP	58	Apr. 6, 1925	109	P	17	June 17, 1957	Temperature of water 56° F. Chloride content, 8ppm, 1945.
244–304	J	32	July 2, 1925	58	P	20	June 10- 1957	**Temperature of water 54° F. Chloride content, 8 ppm, 1945.
216–246	M	115	March 1953	13	P	9	June 21, 1954	Temperature of water 52° F. Replaced by well Q2137 in 1955.
120–140	uP	98	May 14, 1930	22	P	16	June 7, 1954	Temperature of water 55° F.
	uP				P	8	1932	Chloride content of composite sample from well field. Wells range in depth from 50 to 105 ft.
	uP	1	1933		P	9	Nov. 24, 1941	Chloride content of composite sample from well field. Wells range in depth from 55 to 100 ft.
	uP, J				P	8	1932	Chloride content of composite sample from well field. Wells range in depth from 40 to 130 ft.
	uP, J				P	49	1936	Chloride content of composite sample from well field. Wells range in depth from 40 to 207 ft.

TABLE 11.—*Records of selected wells in southern*

QUEENS

Well	Map coordinates	Owner	Locality	Year completed	Altitude of reference point (feet)	Depth of well (feet)	Diameter (inches)
Q335	4C, 0.1N, 1.2W	NYCDWSGE	St. Albans Pumping Station.	1905	12	335	6
Q336	4C, 0.3N, 2.0W	do	Jameco Pumping Station.	1908	7	173	6
Q337	4C, 0.1N, 2.3W	do	Baisley Pumping Station.	1883	8	222	
Q339	4B, 5.8N, 3.1W	do	Oconee Pumping Station.	1897	10	212	8–6
Q556	4C, 2.4N, 1.5W	JWSC	Jamaica	1923	31	423	
Q559	4C, 0.5N, 3.2W	do	South Ozone Park	1925	16.4	214	24–16
Q562	4C, 2.0N, 2.0W	do	Jamaica	1935	29.0	681	18–10
Q563	4C, 3.5N, 0.2W	do	Hollis	1929	70.3	138	26–18
Q564	4C, 3.5N, 0.2W	do	do	1930	70.3	299	26–18
Q567	4C, 3.4N, 2.8W	do	Jamaica	1929	130.6	635	18–8
Q568	5C, 2.3N, 3.6W	do	St. Albans	1933	60.6	869	20–12
Q671	4B, 0.8N, 0.2W	B. L. Carrol	Far Rockaway	1895	5	210	6
Q674	4B, 1.6N, 0.2W	Formerly Queens County Water Co.	do		10	200	5
Q675	4B, 3.9N, 2.4W	Idlewild Hotel	Idlewild		5	200	2
Q676	4B, 4.8N, 2.3W	T. R. Chapman	Cornell Creek		5	203	8
Q678	4B, 5.7N, 0.4W	NYCDWSGE	Springfield Pumping Station.	1895	12	271	5
Q681	4B, 5.8N, 2.0W	NYCDWSGE	South Ozone Park	1895	6.8	156	5
Q682	4B, 5.8N, 1.6W	do	do	1895	8.7	258	5
Q683	4B, 5.8N, 0.9W	do	Springfield Gardens	1895	11	295	5
Q684	4B, 5.7N, 0.8W	do	do	1895	17.3	420	5
Q690	4C, 1.6N, 2.4W	do	Jamaica	1895	20.5	200	5
Q720	5B, 5.8N, 4.2W	do	Rosedale	1895	19	406	5
Q721	5B, 5.7N, 3.5W	do	do	1895	23	412	5
Q724	5C, 0.9N, 4.3W	do	Springfield Gardens	1895	28	357	5
Q957	4C, 2.5N, 2.8W	Savoy Theatre	Jamaica	1938	45	182	10
Q981	4B, 0.3N, 3.0W	J. H. Murray Ice Co.	Rockaway Beach	1935	7	120	6
Q989	4B, 1.3N, 0.4W	Columbia Theatre	Far Rockaway	1938	26	135	10–6
Q1035	4C, 2.6N, 2.5W	B. Gertz, Inc	Jamaica	1939	41.8	253	12
Q1036	4C, 2.5N, 3.1W	Hillside Theatre	do	1939	41.2	183	12

See footnote at end of table.

Nassau and southeastern Queens Counties—Continued

COUNTY—Continued

Screen setting below land surface (feet)	Water-yielding unit	Water level: Depth below reference point (feet)	Water level: Date	Specific capacity	Type of well	Chloride: Parts per million	Chloride: Date	Remarks
----	uP	4	1933	----	P	11	1932	Chloride content of composite sample from well field. Wells range in depth from 40 to 80 ft.
----	uP, J	----	----	----	P	100	1936	Chloride content of composite sample from well field. Wells range in depth from 40 to 175 ft.
----	uP, J	----	----	----	A	----	----	
----	uP, J	----	----	----	P	64	1933	Chloride content of composite sample from well field. Wells range in depth from 50 to 200 ft.
----	----	----	----	----	T	----	----	Wells Q324, Q569, and Q570, about 60 ft deep, nearby.
174–213	J	15.5	July 22, 1926	----	P	159	September 1951.	** †Abandoned and sealed 1952.
500–520 538–608	L	35.8	Apr. 21, 1953	50	P	7	June 17, 1957	**Temperature of water 59°F.
111–131	uP	30.5	Oct. 7, 1930	8	P	19	June 10, 1957	Temperature of water 56°F.
241–282	M	38	June 16, 1931	48	P	5	1936	Temperature of water 55°F.
544–584 596–621	L	140.8	Apr. 23, 1946	22	P	7	June 24, 1957	**Temperature of water 56°F.
302–362	M	35	May 15, 1953	61	P	7	do	Q323, 98 ft. deep, nearby. Temperature of water 55°F.
----	J	[1]	----	----	A	----	----	V188. Salty water reported at 180 to 190 ft. in 1895.
----	J	----	----	----	A	----	----	V191. Brackish water reported at 200 ft prior to 1905.
----	J	[1]	----	----	A	----	----	V192. Flowed several feet above land surface prior to 1903.
----	J	[1]	----	----	A	----	----	V193.
----	----	----	----	----	T	----	----	V197.
----	J	+0.6	Jan. 9, 1896	----	T	5.5	1895	V202.
146–162	J	1.1	do	----	T	7	1895	V203.
----	----	----	----	----	T	----	----	V205.
at 403	M	6.6	Jan. 9, 1896	----	T	----	----	V206, at a depth of 182 ft, water level reported as 7 ft below reference point.
at 198	J	----	----	----	T	----	----	V212.
----	----	----	----	----	T	----	----	V291.
----	----	----	----	----	T	----	----	V292.
----	----	----	----	----	T	----	----	V295.
149–180	M	26	Apr. 13, 1938	19	I	12	Sept. 16, 1952	Temperature of water 55°F.
100–120	uP	----	----	----	I	----	----	
109–131	uP	30.5	Aug. 30, 1938	----	I	----	----	
188–253	M	27.7	Jan. 3, 1949	30	I	----	----	Reference point about 16 ft below land surface.
126–168	M	28.7	Apr. 11, 1949	----	I	10	Sept. 1, 1949	Reference point about 12 ft below land surface. Temperature of water 54° F.

TABLE 11.—*Records of selected wells in southern*

QUEENS

Well	Map coordinates	Owner	Locality	Year completed	Altitude of reference point (feet)	Depth of well (feet)	Diameter (inches)
Q1152	4B, 5.8N, 3.1W	NYCDWSGE	Oconee Pumping Station.	1940	13.2	200	8
Q1187	4C, 5.7N, 0.1W	do	Rosedale Pumping Station.	1941	15	89	8
Q1197	4B, 5.7N, 0.1W	do	do	1941	15	135	8
Q1223	4C, 0.5N, 2.5W						
Q1225	4C, 2.8N, 0.5W						
Q1230	4B, 0.8N, 1.2W	American Ice Co	Far Rockaway	1940	8.2	164	10
Q1237	4C, 0.0N, 2.4W	USGS	South Ozone Park	1940	18.7	220	12
Q1248 to Q1252.							
Q1285 to Q1289.							
Q1290	4C, 0.9N, 0.2W	NYCDWSGE	Springfield		24.0	22	2
Q1305	4B, 5.5N, 0.6W	do	Springfield Pumping Station.	1896	10	207	8
Q1306	4C, 0.0N, 2.4W	do	South Ozone Park	1894	8.0	200	2
Q1307	4C, 0.2N, 2.0W	do	Jameco Pumping Station.	1894	7	160	4
Q1308	4C, 0.1N, 1.2W	do	St. Albans Pumping Station.	1896	11	277	5
Q1309	4C, 2.0N, 2.0W	JWSC	Jamaica	1895	20	352	10–4
Q1312	5B, 5.4N, 4.1W	NYCDWSGE	Forest Stream Pumping Station.	1894	7	435	4–2
Q1372	5C, 3.6N, 3.5W	J. DeKnatel & Son	Queens Village	1945	80	222	12
Q1383	4B, 1.3N, 0.2W	Strand Theatre	Far Rockaway	1945	26	250	10–8
Q1392	4C, 2.8N, 2.5W	R. H. Macy & Co	Jamaica	1945	45.1	361	12
Q1423	4C, 2.9N, 1.4W	Ideal Novelty & Toy Co.	Hollis	1946	55	302	20–12
Q1448	5C, 3.5N, 3.5W	Rubel Corporation	Queens Village	1947	80	100	30–12
Q1449T	4C, 1.3N, 2.7W	JWSC	Jamaica	1947	28	136	12–6
Q1450	5C, 2.4N, 4.4W	do	St. Albans	1947	58.3	132	20–18
Q1456T	4C, 0.9N, 2.5W	do	South Jamaica	1947	35	112	
Q1503	4C, 3.8N, 3.2W	Parsons Theatre	Jamaica	1948	75	107	10
Q1506	4B, 5.5N, 2.9W	Port of New York Authority.	New York International (Idlewild) Airport.	1949	10	106	16–8
Q1507	4C, 2.7N, 2.5W	Jam Kay Realty Corp.	Jamaica	1949	58	157	12
Q1521	4C, 0.6N, 0.8W	Garden Theatre	Springfield Gardens	1949	20	182	8
Q1532T	4C, 1.9N, 0.3W	JWSC	Jamaica	1949	40	454	8
Q1534	5C, 3.2N, 4.1W	do	Queens Village	1950	70.5	99	38–20
Q1535T	5C, 3.2N, 4.1W	do	do	1950	70.5	450	10
Q1600	4C, 4.0N, 0.1W	do	do	1949	97.5	454	28–12
Q1629	5C, 3.2N, 4.1W	do	do	1950	71.2	312	26–12
Q1630	4B, 0.3N, 3.0W	New York Telephone Co.	Rockaway	1950	8.3	175	8

See footnote at end of table.

Nassau and southeastern Queens Counties—Continued

COUNTY—Continued

Screen setting below land surface (feet	Water-yielding unit	Water level: Depth below reference point (feet)	Water level: Date	Specific capacity	Type of well	Chloride: Parts per million	Chloride: Date	Remarks
	J	16.3	Mar 24, 1954		O			Abandoned.
					P			
					P			
								Shallow observation well screened in the unconfined aquifer. Data given in New York State Water Resources Comm. Bull. GW-27.
								Do.
123–161	J	7.0	May 8, 1955	21	I	12,200	May 13, 1955	(**).
	J	22.3	Apr. 7, 1954		O	140	Mar. 3, 1954	Temperature of water 55°F.
								Shallow observation wells screened in the unconfined aquifer Data are given in New York State Water Resources Comm. Bull. GW-27.
								Do.
20–22	uP	8.9	Apr. 27, 1954		O			
	J	+.6	June 1897		P	14	1941	V196.
140–170	J	+.7	Jan. 24, 1895		T	38	1894	V200.
	J	+1.4	do		P	4.5	1894	V201.
					T			V204. Abandoned.
	M	1	1895		P			V213.
	M	(1)	1894		P	8	1894	V290.
194–222	M	41	Feb. 14, 1945	18	I			
230–250	M	22	Aug. 7, 1945	12	I	7,500	Sept. 2, 1953	†Temperature of water 57°F.
	M	32.3	Dec. 19, 1950		A			Reference point is about 15 ft. below land surface.
62–78	uP	24	Nov. 4, 1946	21	I			
74–94	uP	40	May 23, 1947	36	I			
	uP	8	Mar. 12, 1947		T			
95–115	uP	31	Mar. 29, 1948	19	P	18	June 17, 1957	*Temperature of water 55°F.
	uP	27	July 31, 1947		T			
91–107	uP				I			*Temperature of water 54°F.
94–106	uP	8	May 9, 1949	24	I	1,430	1950	(*).
118–149	uP	45	1949		I			(*).
171–182	J	7	June 25, 1949	21	I			(*).
at 370	M	19	Oct. 20, 1949		T			
78–98	uP	40	May 2, 1950	53	P	20	1958	Temperature of water 53°F.
386–401	M	41.0	do		T			(*).
270–290	M	67	1949		P	8	June 10, 1957	*Temperature of water 53°F.
236–276	M	40.7	May 2, 1950	16	P	9	June 17, 1957	
159–175	J	8.0	Apr.‡7, 1955	41	I	16,200	Apr. 7, 1955	(* †).

TABLE 11.—*Records of selected wells in southern*

QUEENS

Well	Map coordinates	Owner	Locality	Year completed	Altitude of reference point (feet)	Depth of well (feet)	Diameter (inches)
Q1747	4C, 3.8N, 0.7W	JWSC	Jamaica	1950	190.3	273	38-16
Q1815	4C, 2.4N, 4.4W	do	St. Albans	1951	58.4	306	24-12
Q1818	4B, 1.6N, 0.3W	H. C. Bohack	Far Rockaway	1951	20	118	6
Q1835T	4C, 2.3N, 2.1W	JWSC	Jamaica	1951	33	348	6
Q1839	4C, 2.0N, 2.0W	do	do	1952	24.8	86	24-18
Q1843	4C, 2.3N, 2.1W	do	do	1952	32.9	92	24-18
Q1929	4B, 1.8N, 0.6W	Long Island Lighting Co.	Far Rockaway	1953	14.7	1045	18-8
Q1931	4B, 1.8N, 0.6W	do	do	1953	8	140	16-10
Q1957	4C, 3.3N, 0.6W	JWSC	Hollis	1953	62	301	18-12
Q1958	5C, 1.9N, 3.7W	do	St. Albans	1953	47	442	18-12
Q1982T	5C, 4.0N, 3.9W	do	Queens Village	1953	77	393	10
Q1984T	4C, 1.9N, 0.3W	do	St. Albans	1953	45	401	8
Q1985T	4C, 3.6N, 1.4W	do	Hollis	1953	145	300	6
Q1997	4C, 3.2N, 0.9W	do	do	1953	57.0	112	24-18
Q1999T	4C, 2.2N, 1.0W	JWSC	St. Albans	1953	35	401	10-6
Q2000	5C, 4.0N, 3.9W	do	Queens Village	1954	77	112	24-20
Q2001	4C, 3.5N, 1.3W	do	Hollis	1954	119.3	207	38-16
Q2003T	4C, 2.3N, 0.4W	do	St. Albans	1954	55	336	8
Q2026	5C, 0.9N, 3.2W	do	Rosedale	1954	40	450	8
Q2027	4C, 2.3N, 0.4W	do	St. Albans	1954	55	85	24-18
Q2028	4C, 2.3N, 0.4W	do	do	1954	55	315	18-12

[1] Flows.

Nassau and southeastern Queens Counties—Continued

COUNTY—Continued

Screen setting below land surface (feet	Water-yielding unit	Water level: Depth below reference point (feet)	Water level: Date	Specific capacity	Type of well	Chloride: Parts per million	Chloride: Date	Remarks
235–260	uP	165	Jan. 24, 1951	23	P	8	June 10, 1957	*Temperature of water 51°F.
240–280	M	33	July 7, 1952		P	12	1958	*Temperature of water 52°F.
110–118	uP	20	Dec. 18, 1951	12	I			(*).
190–218	M	26	Dec. 8, 1951		T			(*).
65–85	uP	23	Feb. 22, 1952	23	P	24	June 10, 1957	**Temperature of water 55°F.
65–85	uP	29	Apr. 14, 1952	34	P	24	1958	Temperature of water 56°F.
979–1029	L	5.4	Apr. 25, 1953		I	20	Mar. 27, 1956	Reference point is about 6 ft above land surface.
107–127	J	12	Dec. 1, 1953	135	I	4,100	do	*Water reported to be very salty.
230–282	M	39	July 13, 1953	48	P	7	1958	** *Temperature of water 53°F.
380–432	M	25	July 30, 1953	31	P	6	1958	Temperature of water 55°F.
	M	47	1953		T			(*).
272–303	M	25	Oct. 9, 1953		T			(*).
171–202	uP	101	Nov. 17, 1953		T			(*).
82–112	uP	37	Jan. 27, 1954	56	P	15	June 10, 1957	*Temperature of water 54°F.
177–209	M	15	Dec. 1953		T			(*).
75–96	uP	48	Feb. 25, 1953	81	P	18	June 8, 1959	Temperature of water 57°F.
167–207	uP	97	Mar. 16, 1954		P	8	1958	Reference point is 3.5 ft below land surface. Temperature of water 53°F.
	M				T			(*).
397–431	M	22	October 1954	27	P	5	June 24, 1957	** *Temperature of water 54°F.
65–85	uP	29	May 13, 1954		P	17	June 17, 1957	Temperature of water 57°F.
240–283	M	30	May 25, 1954		P	10	do	Temperature of water 54°F.

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*

[Stratigraphic correlations by N. M. Perlmutter and J. J. Geraghty. Altitudes approximate and above or below mean sea level]

NASSAU COUNTY

N1416T. (6B, 0.7N, 4.0W)

[Drilled by S. Molinari. Altitude about 10 ft. Abandoned: screen setting unknown. Driller's log]

	Thickness (feet)	Depth (feet)
Recent and upper Pleistocene deposits:		
Sand and mud	39	39
Clay, blue ("20-foot" clay?)	1	40
Sand, hard	15	55
Sand, yellow, and gravel	40	95
Gardiners clay:		
Clay and sand	4	99
Clay, blue	1	100
Clay and sand	4	104
Sand, yellow	21	125
Clay, hard, blue	12	137
Jameco gravel:		
Gravel, large, and black sand	3	140
Sand, white, and gravel	8	148
Magothy(?) formation:		
Clay, green, and sand	21	169
Sand, fine, white, and wood	31	200

N2115. (5C, 1.5N, 3.1W)

[Drilled by Layne-New York Co., Inc. Altitude about 42 ft. Screened between 63 and 83 ft. Discharge 1,266 gpm with drawdown of 23 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, coarse, mixed	12	12
Sand and gravel	5	17
Sand, rusty brown	7	24
Sand, brown, and gravel	6	30
Sand, medium	10	40
Sand, medium, gray	15	55
Sand, coarse, white, and gravel	17	72
Sand, coarse, and gravel	8	80
Sand, very coarse, and gravel	6	86
Magothy(?) formation:		
Clay, blue	3	89
Sand, blue-gray; wood and clay	12	101
Clay, blue; wood and pyrite	15	116

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N2203. (5B, 3.6N, 3.7W)

[Drilled by C. W. Lauman and Co. Inc., Altitude about 5 ft. Screened between 158 and 164 ft. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, brown, and grit	35	35
Sand, beach	15	50
Sand, brown, and grit	25	75
Gardiners clay:		
Clay, dark-gray	37	112
Sand, black	8	120
Clay, hard, dark-gray	27	147
Jameco gravel:		
Sand, brown, and grit	16	163
Magothy(?) formation:		
Sand, gray	19	182

N2225. (8B, 5.0N, 1.0W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 5 ft. Screened between 165 and 170 ft. Discharge 60 gpm. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill	3	3
Swamp muck	7	10
Upper Pleistocene deposits:		
Sand, fine to medium, and stones	22	32
Sand, beach	22	54
Gardiners clay:		
Sand, fine, and clay	10	64
Sand, dirty; clam shells	11	75
Magothy(?) formation:		
Clay, dark-gray; little sand	19	94
Sand, soupy; clay and hardpan	12	106
Sand, very fine, soupy	29	135
Hardpan, clay, and wood	1	136
Sand, fine	29	165
Sand, medium to coarse, gray	8	173

N2359. (8B, 4.7N, 3.1W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 5 ft. Screened between 57 and 63 ft. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill	5	5
Upper Pleistocene deposits:		
Sand, brown, and gravel	34	39
"20-foot" clay:		
Clay, gray	8	47
Sand, gray	2	49
Clay, gray	5	54
Sand, light-gray	9	63

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N2413. (5C, 1.7N, 1.9W)

[Drilled by Layne-New York Co., Inc. Altitude about 52 ft. Screened between 478 and 508 ft. Discharge 975 gpm with drawdown of 14 ft after 3 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, brown	31	31
Sand, brown, and gravel	61	92
Magothy(?) formation:		
Clay, tough, blue	6	98
Sand, clay, and wood	20	118
Clay, black, and sand	23	141
Clay, tough, blue	48	189
Clay and sand	39	228
Sand, fine	6	234
Clay, sandy, and wood	45	279
Clay, sandy	16	295
Sand and wood	18	313
Clay, tough, blue	3	316
Sand, medium, gray	8	324
Sand and gravel	55	379
Sand and clay	21	400
Sand, fine, and wood	14	414
Clay	12	426
Sand, medium to coarse	45	471
Clay, tough	3	474
Sand, coarse, and gravel	35	509
Raritan formation:		
Clay member:		
Clay, tough	17	526

N2572. (6B, 2.9N, 3.2W)

[Drilled by Nassau County Department of Public Works. Altitude about 3 ft. Abandoned, screen setting unknown. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Meadow bog and black muck	4	4
Clay, sandy, and grit	2	6
Upper Pleistocene deposits:		
Sand and grit	6	12
Sand	6	18
Sand and grit	5	23
Gravel and a little sand	1	24
Sand and grit	10	34
Gravel and a little sand	15	49
Sand and a few large stones	3	52
Gravel and very little sand	1	53
Gardiners clay:		
Clay and grit, mixed	7	60
Gravel and sandy clay	5	65
Gravel and stones half an inch in diameter	11	76
Clay, blue	21	97
Magothy(?) formation:		
Sand, beach, white	3	100

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N2573. (5B, 3.6N, 1.5W)

[Drilled by Eastern Well and Pump Co. Altitude about 5 ft. Screened between 55 and 60 ft. Discharge 60 gpm with drawdown of 8 ft after 2 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill	3	3
Upper Pleistocene deposits:		
Sand, coarse, brown; gravel and layers of hard gray clay	7	10
Clay, solid, gray	3	13
Sand, fine, brown, and grit	2	15
Clay, solid, gray	7	22
Sand, coarse, brown; grit and gravel	2	24
"20-foot" clay:		
Clay, light-gray	5	29
Clay, sandy, gray	2	31
Shells, grit, gravel and sand	7	38
Clay, solid, gray	10	48
Sand, fine, dirty, white; grit and gravel	7	55
Sand, medium, white; grit and gravel	4	59
Sand, fine, light-brown	5	64

N2580. (7C, 4.0N, 1.6W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 75 ft. Screened between 310 and 347 ft. Discharge 1,200 gpm with drawdown of 67 ft after 5½ hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand and gravel	69	69
Magothy(?) formation:		
Clay, solid, brown	1	70
Clay, sand, and gravel	9	79
Sand, fine to coarse; some clay and mica	14	93
Sand, clayey, fine, dark-brown	2	95
Sand, fine, reddish-brown; lumps of clay	10	105
Clay, sandy, brown	22	127
Clay, solid, dark-gray	13	140
Clay, sandy, gray	33	173
Clay, solid, very sticky, dark-gray	27	200
Clay, sandy, dark-gray	13	213
Clay, sandy, grayish-brown; wood and hardpan	27	240
Clay, solid, sticky, brown	5	245
Clay, sandy, grayish-white	50	295
Sand, clayey, fine, and hardpan; some small gravel, hard packed	11	306
Sand, clayey, fine, soft	6	312
Sand, clayey, fine, grayish-brown; some lumps of soft white clay at 349 ft	43	355
Same as above, a little more clayey	7	362

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N2613. (6B, 5.7M, 1.2W)

[Drilled by Layne-New York Co., Inc. Altitude about 18 ft. Screened between 460 and 500 ft. Discharge 1,212 gpm with drawdown of 32 ft after 8½ hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand and gravel	36	36
Clay, sand, and shells ("20-foot" clay)	26	62
Magothy(?) formation:		
Sand, coarse	27	89
Sand, fine, packed; streaks of clay	10	99
Sand, clay, and wood	65	164
Clay, tough	19	183
Sand, hard packed	18	201
Sand, clay, and wood	47	248
Clay and sand	8	256
Sand, muddy, packed	35	291
Sand, hard packed	18	309
Clay, blue	4	313
Sand, muddy, hard packed	10	323
Sand, clay, and wood	85	408
Sand, clay, and wood	13	421
Sand, fine, packed	27	448
Sand, medium, and fine gravel	54	502
Clay	1	503
Sand, medium, and fine gravel	22	525
Sand, fine	19	544
Clay and mica	4	548

N2790. (6B, 3.5N, 4.3W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 3 ft. Screened between 538 and 560 ft. Discharge 120 gpm with drawdown of 70 ft after 4 hr of pumping. Log based on examination of core samples by N. M. Perlmutter, L. Weiss, and T. Arnow]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Topsoil and black swamp muck [1]	2	2
Upper Pleistocene deposits:		
Sand, fine to coarse, brown; gravel and some gray clayey sand [1]	25	27
Clay, sandy, gray-green and brown; some fine to coarse sand and gravel ("20-foot" clay)[1]	7	34
Sand, fine, clayey, gray and brown; some coarse clayey sand and gravel	3	37
Sand, medium to coarse, brown; fine gravel; lumps of gray clay	8	45
Sand, fine to medium, tan, slightly clayey; some fine gravel	2	47
Sand, medium to coarse, brown; fine gravel; lumps of gray clay [1]	7	54
Clay, gray	1	55
Sand, fine to coarse, tan; some fine gravel; lumps of light-gray clay	4	59
Clay, sandy, gray	5	64
Sand, medium to coarse, brown; fine gravel; a few thin streaks of gray clay	24	88

[1] Flume sample.

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N2790. (6B, 3.5N, 4.3W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation:		
Sand, fine, clayey, gray; some lignite	22	110
Sand, very fine, silty, light-gray, and thin layers of solid gray clay and lignite	32	142
Sand, fine, clayey, gray; layers of silt; thin streaks of light- and dark-gray clay and lignite	73	215
Sand, fine, silty and clayey, gray; thin layers of lignite; streaks of gravel reported by driller between 221–231 ft	41	255
Sand, fine, gray; thin layers of lignite and some gray clay	45	300
Sand, fine, clayey, gray; some medium sand and lignite	10	310
Sand, fine, clayey, gray and white; some pyrite and lignite	30	340
Sand, fine, clayey, gray; some pyrite	19	359
Clay, solid, dark-gray, and layers of lignite	7	366
Sand, fine to medium, gray; layers of pyrite and lignite	17	383
Sand, fine, clayey and silty, gray; some lignite	31	414
Sand, fine, clayey, gray; some thin layers of medium sand	11	425
Clay, solid, black; layers of lignite; and gray clayey sand	10	435
Sand, fine to medium, gray, slightly clayey	16	451
Sand, fine, silty, and clayey, gray; thin layers of lignite	16	467
Sand, fine to medium, gray	8	475
Sand, medium to coarse, gray	8	483
Clay, solid, gray; some thin layers of gray sandy clay	10	493
Sand, fine, gray; with some medium clayey sand and thin layers of solid clay	22	515
Clay, solid, gray	3	518
Sand, fine, clayey, gray; some thin streaks of medium to coarse sand and gravel	7	525
Sand, fine, silty, and clayey, gray	14	539
Sand, fine, gray; some silt and lignite	27	566
Clay, silty, gray, and layers of lignite	13	579
Sand, fine to coarse, gray, with silt and fine gravel	2	581
Sand, fine, silty and clayey, gray	11	592
Clay, solid, gray, red, and white; some lignite	37	629
Clay, sandy, gray	10	639
Sand, medium to coarse, gray; some fine to medium gravel and layers of gray sandy clay	8	647
Clay, silty and sandy, gray; some layers of fine to medium sand and gray clay	31	678
Sand, fine to medium, gray	15	693
Raritan formation:		
Clay member:		
Clay, silty and sandy, gray, and layers of fine clayey sand	34	727
Clay, solid and silty, dark-gray; some layers of silty and fine sandy clay	130	857
Lloyd sand member:		
Sand, medium, gray	13	870

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N2921. (6B, 2.0N, 3.4W)

[Drilled by Mathies Well and Pump Co. Altitude about 10 ft. Screened between 114 and 119 ft. Discharge 40 gpm. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Sand, beach	2	2
Sand and black clay	2	4
Upper Pleistocene deposits:		
Sand, coarse, brown; grit and gravel	28	32
Sand, fine, brown; grit and brown clay	13	45
Clay, dark-gray ("20-foot" clay?)	11	56
Sand, coarse, white	6	62
Sand, coarse, brown; grit and gravel	3	65
Gardiners clay:		
Clay, gray	47	112
Jameco gravel:		
Sand, coarse, white, and gravel	8	120

N3078. (6B, 2.4N, 3.6W)

[Drilled by Eastern Well and Pump Co. Altitude about 5 ft. Screened between 135 and 145 ft. Discharge 60 gpm with drawdown of 4 ft after 3 hr of pumping. Log based on examination of bailer samples by N. M. Perlmutter]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand and gravel, white, dirty	5	5
Clay, soft, black; some fine gray sand	23	28
Sand, medium to coarse, gray; some fine gravel	24	52
Sand, fine gray	10	62
Gardiners clay:		
Clay, sandy, dark-gray; some shells	42	104
Clay, dark-gray	10	114
Jameco gravel:		
Sand, fine to medium, gray; some coarse sand, fine gravel, and gray clay	9	123
Sand, fine to medium, gray; some fine gravel	10	133
Sand, fine to coarse, gray; fine gravel	12	145

N3242. (6B, 1.6N, 3.3W)

[Drilled by Fred Habenicht and Sons. Altitude about 5 ft. Screened between 264 and 269 ft. Discharge 41½ gpm. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill	4	4
Bog	5	9
Upper Pleistocene deposits:		
Sand, dirty, white, with black mud ("20-foot" clay)	60	69
Gardiners(?) clay:		
Sand, dirty, gray	51	120
Sand, dirty, brown	9	129
Clay, brown; clam shells	44	173

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3242. (6B, 1. 6N, 3.3W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation:		
Sand, dirty, white	28	201
Clay, hard, gray, dry	48	249
Sand, very fine, light-gray	20	269

N3245. (8B, 4.8N, 2.5W)

[Drilled by Mathies Well and Pump Co. Altitude about 5 ft. Screened between 209 and 215 ft. Discharge 55 gpm with drawdown of 11 ft after 3 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent and upper Pleistocene deposits(?):		
Sand, beach	1	1
Sand, coarse, brown; grit and gravel	3	4
Bog	1	5
Upper Pleistocene deposits:		
Sand, coarse, brown; grit and gravel	39	44
Sand, medium, brown	16	60
Gardiners clay:		
Clay, gray	10	70
Clay, black, and clam shells	1	71
Magothy(?) formation:		
Clay, black	25	96
Clay, black; fine white sand and mica	4	100
Sand, fine, white; wood and mica	21	121
Sand, very fine, white, and gray clay	32	153
Clay, black	1	154
Sand, fine, white; mica and gray clay	21	175
Sand, very fine, white; gray clay	23	198
Sand, medium, white, with a little wood	17	215

N3246. (5B, 1.3N, 3.2W)

[Drilled by Eastern Well and Pump Co. Altitude about 12 ft. Screened between 132 and 136 ft. Discharge 59 gpm with drawdown of 14 ft after 2 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, light brown; grit	14	14
Sand, very fine, gray	2	16
Sand, dirty, white, beach	6	22
Sand, light brown, beach; mica	1	23
Sand, fine, light brown, and gravel	5	28
Clay, hard, brown ("20-foot" clay)	6	34
Upper Pleistocene deposits and Gardiners(?) clay:		
Sand, fine, dirty brown, streaks of clay	82	116
Gardiners(?) clay:		
Clay, hard, black	4	120
Sand, fine, dirty	4	124
Jameco gravel:		
Sand, fine to coarse, and grit	4	128
Sand, fine to medium; and grit	8	136
Magothy(?) formation:		
Clay, solid, black	15	151

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3312. (7C, 3.6N, 0.4W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 70 ft. Screened between 252 and 304 ft. Discharge 870 gpm with drawdown of 74 ft after 8 hr of pumping. Driller's log based on examination of core samples]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Loam	1	1
Upper Pleistocene deposits:		
Sand, coarse, and gravel	34	35
Sand, coarse, and grit	28	63
Magothy(?) formation:		
Sand, medium; layers of white clay	9	72
Clay, sandy, fine, white	9	81
Sand, fine, white; lumps of white clay	12	93
Sand, fine, white; reddish clay; pieces of sandstone	11	104
Sand, fine, white; reddish clay	5	109
Sand, fine, white; clay and mica	37	146
Sand, fine, white; brown clay and mica	9	155
Clay, sandy, blue; mica and hardpan	12	167
Sand, fine, white; brownish clay, mica, silt, and hardpan	23	190
Sand, fine, yellow; yellow clay, mica, silt, and hardpan	20	210
Sand, fine, brown; some yellow clay, mica, and hardpan	36	246
Clay, sandy, fine, light-yellow; mica, and hardpan	11	257
Sand, fine, yellow, and mica	2	259
Sand, fine, yellow; lumps of clay, mica, and hardpan	26	285
Sand, fine to medium; some lumps of white clay, and hardpan	18	303
Sand, fine, brown; clay, mica, and hardpan	4	307

N3314. (6B, 5.3N, 4.2W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 20 ft. Screened between 73 and 79 ft. Discharge 105 gpm. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill	20	20
Upper Pleistocene deposits:		
Clay, brown	10	30
Clay, gray	13	43
Clay, gray, and gray fine sand	3	46
Sand, fine, brown, clean, sharp	5	51
Sand, coarse, dark brown, and gravel	3	54
Sand, very fine, gray; with about 40 percent clay ("20-foot" clay)	10	64
Sand, fine, brown, clean, sharp	9	73
Sand, coarse, dark brown; clay and gravel	7	80

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3325. (7B, 3.0N, 4.0W)

[Drilled by C. F. Fritz, Inc. Altitude about 6 ft. Screened between 116 and 120 ft. Discharge 3½ gpm. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Bog and clay	40	40
Clay and sand ("20-foot" clay?)	?	?
Gravel, coarse, and fine sand	?	68
Magothy(?) formation:		
Sand, white	22	90
Sand, coarse, white, and gravel	10	100
Sand, fine, white	13	113
Gravel, white	7	120

N3327. (5C, 0.7N, 2.8W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 27 ft. Screened between 399 and 451 ft. Discharge 1,200 gpm with drawdown of 48 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Sand and loam	3	3
Upper Pleistocene deposits:		
Sand, medium, brown	6	9
Sand, medium to coarse, brown; some gravel	61	70
Sand, coarse, and medium gravel	22	92
Magothy(?) formation:		
Sand, medium, gray, and lignite	18	110
Clay, hard, gray	45	155
Sand, muddy, gray, and lignite	63	218
Clay, hard, gray	27	245
Silt, gray	15	260
Clay, gray	45	305
Sand, muddy, gray	40	345
Sand, medium, clean, gray	20	365
Clay, sandy, gray	35	400
Clay, medium to coarse, gray; some mud	22	422
Sand, muddy, gray	10	432
Sand, medium to coarse, gray	13	445
Sand, coarse, gray; some gravel	7	452
Sand, grit, and small amount of gravel	7	459
Raritan formation:		
Clay member:		
Clay, sticky, gray	5	464
Sand, coarse, gray; grit and hard clay	14	478
Sand, fine, grit and gravel	6	484
Clay, hard, gray	19	503
Clay, red, yellow, and brown	23	526
Clay, gray, and lignite	44	570

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3427. (8C, 0.9N, 4.2W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 31 ft. Screened between 126 and 161 ft. Discharge 300 gpm with drawdown of 72 ft after 8-hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Loam	3	3
Upper Pleistocene deposits:		
Sand, coarse, brown, and gravel	37	40
Sand, medium, brown, and grit	5	45
Sand, fine, gray, and mica	9	54
Sand, fine, gray; gravel and mica	5	59
Sand, fine, brown; mica and gray clay	8	67
Clay, dark-gray ("20-foot" clay)	20	87
Magothy(?) formation:		
Sand, medium, gray; mica and lignite	11	98
Clay, sandy, gray, and mica	8	106
Sand, medium, dirty, gray	5	111
Sand, medium gray; mica and lumps of clay	9	120
Sand, fine gray	10	130
Sand, coarse, gray; lignite and lumps of clay	13	143
Sand, medium to coarse, and mica	22	165
Sand, fine, gray, and lumps of clay	12	177
Clay, medium to coarse, sandy	9	186

N3451. (5B, 1.7N, 3.1W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 8 ft. Screened between 82 and 88 ft. Discharge 60 gpm with drawdown of 3 ft after 1 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, medium, brown	6	6
No record	16	22
Sand, medium, brown, and gravel	15	37
Sand, coarse, yellow, and gravel	5	42
Sand, fine to medium	7	49
Sand, fine, gray	5	54
Sand, fine, brown	19	73
Gardiners clay:		
Sand, fine, gray; some lumps of clay	8	81
Jameco(?) gravel:		
Sand, coarse, brown, and gravel	6	87

N3465. (7C, 3.7N, 2.9W)

[Drilled by Layne-New York Co., Inc. Altitude about 80 ft. Screened between 275 and 315 ft. Discharge 1,015 gpm with drawdown of 49 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, brown, and gravel	40	40
Sand and gravel, gray and brown	30	70
Magothy(?) formation:		
Sand, gravel, and white, yellow, and red clay	30	100
Gravel, red, and fine sand	29	129
Sand, gravel, and brown clay	101	230
Clay, sandy, black	14	244

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3465. (7C, 3.7N, 2.9W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation—Continued		
Sand, fine, muddy	22	266
Sand, fine to medium, white	39	305
Sand; streaks of black clay	25	330
Clay, black and white	11	341
Sand, and white and yellow clay, in streaks	104	445
Sand, coarse	10	455
Clay and sand, in streaks	70	525
Sand, coarse	37	562

N3519T. (5C, 0.6N, 1.5W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 22 ft. Abandoned. Driller's log based on examination of core samples]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Topsoil and loam	2	2
Upper Pleistocene deposits:		
Sand, coarse, brown; grit and gravel	31	33
Sand, medium to coarse, brown	19	52
Magothy(?) formation:		
Clay, solid, gray, and lignite	15	67
Sand, fine, gray, dirty	10	77
Sand, fine, gray; solid clay, in layers	17	94
Sand, fine, gray	19	113
Sand, fine, gray, and clay	8	121
Sand, fine, gray; layers of lignite	8	129
Clay, sandy, fine; solid clay, in layers	17	146
Sand, fine, gray, dirty; some clay	12	158
Sand, fine, gray	6	164
Clay, sandy, fine, gray	5	169
Sand, fine, gray	6	175
Clay, sandy, fine; solid clay, in layers	14	189
Sand, fine, gray, dirty; some clay	37	226
Clay, solid, gray	7	233
Clay, sandy, fine gray	14	247
Sand, fine, gray	21	268
Clay, sandy, fine, gray	9	277
Sand, fine, gray; sandy clay, in layers	30	307
Sand, fine, gray	32	339
Clay, sandy, fine, gray	6	345
Sand, fine, gray; streaks of clay and sandy clay	40	385
Sand, medium to coarse, brown	5	390
Clay, sandy, fine, gray	11	401
Sand, fine, gray	18	419
Clay, sandy, fine, gray	7	426
Sand, fine, gray	22	448
Clay, sandy, fine, gray	8	456
Clay, solid, gray; some gravel	7	463
Sand, medium to coarse, gray	3	466
Clay, sandy; solid clay, in layers	19	485
Sand, coarse; gravel, and solid clay, in layers	11	496
Clay, solid, gray	12	508
Clay, solid, and gravel	4	512
Clay, solid, gray; some gravel	7	519
Sand, fine, gray; some clay	13	532
Sand, fine to coarse, brown	6	538

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

(N3519T. (5C, 0.6N, 1.5W)

	Thickness (feet)	Depth (feet)
Raritan formation:		
Clay member:		
Clay, solid, brown	7	545
Clay, sandy, gray	4	549
Clay, solid, gray	10	559
Clay, sandy, fine, gray	22	581
Clay, solid, gray	16	597
Clay, sandy, fine, gray	21	618
Clay, solid, gray	1	619

N3520. (6C, 1.5N, 4.0W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 34 ft. Screened between 126 and 178 ft. Discharge 840 gpm with drawdown of 106 ft after 8 hrs of pumping. Driller' log based on examination of core samples]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Loam	3	3
Upper Pleistocene deposits:		
Sand, fine to medium, brown; grit	47	50
Sand, medium to coarse, brown; grit and some gravel	12	62
Magothy(?) formation:		
Clay, solid, dark-gray	6	68
Clay, sandy, fine, gray; gravel	5	73
Sand, fine, gray; layer of clay	14	87
Clay, solid, gray	19	106
Clay, sandy, fine, gray	8	114
Clay, solid, gray	10	124
Clay, sandy, fine, gray	12	136
Sand, fine, gray, dirty	10	146
Clay, sandy, fine, gray	9	155
Sand, fine, gray; layers of sandy clay	38	193
Clay, solid, gray	8	201
Sand, fine, brown	9	210
Clay, sandy, fine, gray	3	213
Clay, solid, gray	7	220
Sand, fine, gray; layers of gray sandy clay	15	235
Clay, solid, gray	7	242
Sand, fine, gray	17	259
Clay, solid, gray	9	268
Sand, fine, gray; lignite	3	271
Clay, sandy, fine, gray	18	289
Sand, fine, gray; layers of lignite	15	304
Clay, solid, gray	5	309
Sand, fine, gray; clay	10	319
Clay, solid, gray	20	339
Sand, fine, gray	17	356
Clay, solid, gray	11	367
Clay, sandy, fine, gray; layers of clay	9	376
Sand, fine to medium, gray	16	392
Clay, sandy, fine, gray; layers of clay	12	404
Sand, fine, gray	3	407
Sand, coarse, gray	5	412
Clay, sandy, fine, gray; layers of clay	4	416
Sand, fine, gray	55	471
Clay, solid, hard, gray	4	475

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3529. (6B, 0.4N, 4.0W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 8 ft. Screened between 93 and 104 ft. Discharge 150 gpm. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill	6	6
Upper Pleistocene deposits:		
Sand, fine, gray	2	8
Clay, gray	6	14
Sand, fine, gray	30	44
Clay, gray ("20-foot" clay)	5	49
Sand, coarse; grit	4	53
Sand, medium, gray	13	66
Sand, medium, brown	4	70
Sand, coarse, brown	5	75
Sand, coarse, brown; grit	14	89
Sand, medium, dark-brown	4	93
Sand, coarse; grit and gravel	7	100
Sand, medium, brown; grit	4	104
Gardiners(?) clay:		
Clay, hard, gray	2	106

N3548. (5B, 5.1N, 0.1W)

[Drilled by Eastern Well and Pump Co. Altitude about 20 ft. Screened between 81 and 92 ft. Discharge 80 gpm with drawdown of 19 ft after 2 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, coarse, clean, light-brown	10	10
Sand, medium to coarse, brown; gravel	8	18
Sand and gravel, clayey	2	20
Sand, medium, clayey, brown ("20-foot" clay?)	53	73
Sand, medium, brown; grit	19	92

N3570. (7B, 4.6N, 3.4W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 5 ft. Screened between 115 and 130 ft. Discharge 267 gpm with drawdown of 31 ft after 4 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Loam and gravel	3	3
Sand, medium to coarse; grit	8	11
Sand, coarse, brown; grit and gravel	22	33
Sand, medium to coarse, white, and gravel	7	40
Clay, solid, gray ("20-foot" clay)	18	58
Magothy(?) formation:		
Sand, gravel, clay	7	65
Sand, dirty white; grit and some clay	13	78
Sand, fine to medium; grit and mica	20	98
Sand, fine; mica; layers of wood and clay	22	120
Sand, medium to coarse; grit and lumps of clay	2	122
Sand, fine, white; mica; white clay	9	131
Sand, very fine, gray; mica; lumps of clay	18	149
Sand, very fine, white; clay	2	151

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3581. (6B, 3.5N, 3.7W)

[Drilled by Eastern Well and Pump Co. Altitude about 8 ft. Screened between 46 and 57 ft. Discharge 82 gpm with drawdown of 12 ft after 2 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill	4	4
Bog	2	6
Upper Pleistocene deposits:		
Sand, dirty, brown; gravel	4	10
Sand, dark-grey, brown; gravel	6	16
Sand, fine to medium, light-brown, and gravel	14	30
Clay, gray ("20-foot" clay?)	1	31
Sand, fine to medium, brown; gravel	26	57
Gardiners clay:		
Clay, hard, gray	at	57

N3603. (5C, 3.2N, 0.3W)

[Drilled by Layne-New York Co., Inc. Altitude about 75 ft. Screened between 443 and 493 ft. Discharge 1,005 gmp with drawdown of 104 ft after 8 hr of pumping. Driller's log.]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, red and brown	30	30
Sand and gravel, brown	76	106
Magothy(?) formation:		
Sand, coarse, white; white and yellow clay	55	161
Sand, fine, gray, lignite	31	192
Clay, blue	45	237
Sand, fine, white; clay	28	265
Sand, fine, white; lignite	53	318
Clay, white, black, and yellow	8	326
Sand, hard-packed	49	375
Sand and white clay, in streaks	47	422
Sand, medium to coarse	61	483
Clay, white	5	488
Sand and gravel	14	502
Raritan formation:		
Clay member:		
Clay, blue	16	518
Sand and clay, in streaks	15	533

N3605. (5C, 2.3N, 0.9W)

[Drilled by Layne-New York Co., Inc. Altitude about 48 ft. Screened between 398 and 438 ft. Discharge 1,012 gpm with drawdown of 27 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, red, and gravel	65	65
Clay, black ("20-foot" clay?)	27	92
Magothy(?) formation:		
Clay, sandy; lignite	202	294
Sand, gravel, and clay, in streaks	90	384
Sand, coarse	36	420

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3605. (5C, 2,3N, 0.9W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation—Continued		
Sand, coarse; streaks of clay	47	467
Clay	5	472
Sand and gravel	16	488
Clay, tough, red and white	24	512
Sand and gravel	12	524
Raritan formation:		
Clay member:		
Clay, tough, black	61	585

N3636. (6C, 2.6N, 2.2W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 50 ft. Screened between 329 and 355 ft. Discharge 500 gpm with drawdown of 51 ft after 2 hr of pumping. Driller's log based on examination of core samples]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Fill	6	6
Marsh mud	3	9
Sand, medium to coarse, yellow; gravel	54	63
Magothy(?) formation:		
Sand, muddy, yellow	7	70
Clay, sandy, gray	135	205
Clay, hard, gray	22	227
Clay, sandy, soft, gray	19	246
Sand, muddy, fine, gray	35	281
Clay, sandy, soft, gray	49	330
Sand, muddy, medium to coarse, gray	26	356

N3653. (5B, 3.8N, 0.7W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 15 ft. Screened between 32 and 42 ft. Discharge 66 gpm. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, fine	6	6
Sand, fine to medium; grit and gravel	36	42
Clay, gray ("20-foot" clay)	5	47

N3668. (6C, 1.8N, 2.4W)

]Drilled by Layne-New York Co., Inc. Altitude about 58 ft. Screened between 449 and 499 ft. Discharge 1,265 gpm with drawdown of 28 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, red and gravel	85	85
Magothy(?) formation:		
Clay, black, and lignite	47	132
Sand, fine, gray; streaks of clay	90	222
Clay, tough, gray	6	228

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3668. (16C, 1.8N, 2.4W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation—Continued		
Sand and gravel	12	240
Clay; few streaks of sand	31	271
Sand, fine, muddy	22	293
Clay, gray	12	305
Sand, hard	8	313
Clay, gray	3	316
Sand, fine, gray	22	338
Clay	4	342
Sand, fine, gray	25	367
Sand; streaks of clay	10	377
Sand, gray	27	404
Clay	2	406
Sand, fine, gray	109	515
Sand, hard-packed; clay	51	566

N3680. (7C, 1.8N, 1.1W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 32 ft. Screened between 270 and 328 ft. Discharge 1,350 gpm with drawdown of 72 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill	3	3
Muck	3	6
Upper Pleistocene deposits:		
Sand, coarse, brown; gravel and grit	43	49
Sand, fine, brown; mica and a small amount of grit	4	53
Magothy(?) formation:		
Sand, fine, gray; mica; small amount of clay	13	66
Sand, fine to medium, brown; mica; brown clay	9	75
Sand, very fine, gray; mica; gray clay	16	91
Clay, sandy, gray	27	118
Sand, medium, brown; mica; small amount of clay	30	148
Sand, medium, gray; mica; gray clay	4	152
Sand, medium, dark gray; mica; gray clay; pieces of decayed wood	4	156
Clay, sticky, dark-gray	23	179
Sand, fine to medium, dark-gray; mica; some clay; lignite	30	209
Sand, medium, gray; lignite	9	218
Sand, fine, gray; mica; gray clay	7	225
Clay, sandy, gray	23	248
Sand, medium, gray; mica; small amount of gray clay	5	253
Clay, sandy, sticky, gray	21	274
Sand, very fine, gray; mica and gray clay	8	282
Sand, fine to medium, gray; mica	15	297
Clay, sandy, gray	16	313
Sand, fine to medium, gray; mica; lignite	11	324
Sand, fine to medium, gray; some clay; mica; pyrite	7	331
Clay, sandy, sticky, gray	36	367
Sand, very fine, gray; mica; lignite	6	373

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3687. (6B, 0.7N, 4.2W)

[Drilled by Layne-New York Co., Inc. Altitude about 5 ft. Screened between 1,195 and 1,245 ft. Discharge 1,210 gpm with drawdown of 70 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent and upper Pleistocene deposits:		
Sand	117	117
Gardiners(?) clay:		
Clay, soft	21	138
Jameco gravel and Magothy(?) formation:		
Sand	34	172
Magothy(?) formation:		
Clay, sandy, blue	10	182
Sand, gray	45	227
Sand, clay, and wood	13	240
Clay, tough	10	250
Clay; streaks of sand and wood	59	309
Clay	7	316
Sand, clay, and wood	22	338
Sand, gravel, and wood	82	420
Clay, hard	6	426
Sand, clay, and hard streaks	30	456
Clay, sandy, soft	20	476
Sand, clay, and hard streaks	16	492
Sand, clay, and gravel	66	558
Clay, sand, and hard streaks	25	583
Sand and gravel	23	606
Clay, sand, and hard streaks	18	624
Sand and gravel	23	647
Sand, gravel, and streaks of clay	59	706
Clay, hard, and hard streaks	72	778
Clay, hard	12	790
Sand, gravel, and hard streaks	10	800
Raritan formation:		
Clay member:		
Clay, sand, and hard streaks	23	823
Clay, hard, and hard streaks	159	982
Sand, red clay, and hard streaks	46	1,028
Lloyd sand member:		
Clay, sand, and gravel	81	1,109
Sand and gravel	43	1,152
Clay and hard streaks	25	1,177
Sand, gravel, and hard streaks	71	1,248
Sand, gravel, and clay	18	1,266

N3691. (5B, 3.3N, 1.6W)

[Drilled by Eastern Well and Pump Co. Altitude about 18 ft. Screened between 55 and 64 ft. Discharge 62 gpm. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Clay, sandy, brown	3	3
Sand, medium to coarse, and gravel	6	9
Sand, fine, and a small amount of gravel	10	19
Clay, sandy, gray	10	29

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3691. (5B, 3.3N, 1.5W)

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits—Continued		
"20-foot" clay:		
Clay, hard, gray	14	43
Clay, sandy	3	46
Sand, fine, and a small amount of gravel	5	51
Sand, medium to coarse, and grit	13	64

N3704. (6C, 1.9N, 3.1W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 57 ft. Screened between 107 and 160 ft. Discharge 2,000 gpm with drawdown of 25 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Loam	3½	3½
Upper Pleistocene deposits:		
Sand, coarse, brown; grit and some gravel	54½	58
Sand, fine to medium, brown	16	74
Sand, coarse, brown, and grit	11	85
Clay, solid, blue ("20-foot" clay)	9	94
Sand, white, brown, and gray, in layers; grit and gravel	72	166
Magothy(?) formation:		
Sand, fine to medium, gray; some clay	17	183
Sand, medium to coarse; grit and gravel	13	196
Clay sandy and solid; layers of lignite	4	200

N3705. (5B, 3.9N, 1.8W)

[Drilled by Fred Habenicht and Sons. Altitude about 24 ft. Screened between 162 and 174 ft. Discharge 60 gpm with drawdown of 20 ft after several hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Topsoil	2	2
Upper Pleistocene deposits:		
Sand and gravel	25	27
Clay, soft, black ("20-foot" clay?)	46	73
Gardiners clay:		
Clay, gray, and shells	28	101
Mud, soft, red	18	119
Clay, sandy, gray; oyster shells	41	160
Jameco gravel:		
Sand, coarse, red	14	174
Magothy(?) formation:		
Clay, gray	16	190

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3720. (5C, 1.4N, 0.7W)

[Drilled by Layne-New York Co., Inc. Altitude about 37 ft. Screened between 476 and 516 ft. Discharge 1,400 gpm after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene(?) deposits:		
Sand and gravel	28	28
Clay, sandy	12	40
Magothy(?) formation:		
Clay; streaks of sand	58	98
Sand, clay, and wood	66	164
Clay; streaks of sand	23	187
Clay, sandy	41	228
Clay, tough; streaks of sand	39	267
Sand and gravel	28	295
Clay, sand, and gravel	10	305
Clay, tough	15	320
Clay, sand, and gravel	17	337
Sand; gravel; streaks of clay	24	361
Clay	8	369
Sand, clay, and wood	16	385
Clay, tough	23	408
Sand, muddy, hard-packed	19	427
Clay, tough	4	431
Sand and gravel	22	453
Clay and hard streaks	16	469
Sand and gravel	39	508
Sand, clay, and gravel	12	520
Raritan formation:		
Clay member:		
Clay, tough, and streaks of gravel	22	542
Clay and streaks of gravel	22	564
Clay, tough; hard streaks	22	586

N3734. (5B, 2.5N, 4.1W)

Drilled by C. W. Lauman and Co., Inc. Altitude about 8 ft. Screened between 116 and 136 ft. Discharge 60 gpm with drawdown of 13 ft after 2 hr of pumping. Log based on examination of bailer samples by N. M. Perlmutter]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Topsoil, sandy, dark-brown	2	2
Upper Pleistocene deposits:		
Sand, fine, brown	7	9
Sand, fine to coarse, brown; coarse gravel	7	16
Clay, sandy, gray [2]	7	23
Sand and gravel, gray [2]	3	26
Clay, soft, gray; shells ("20-foot" clay)	25	51
Sand, white, and stones [2]	16	67
Sand, fine, light brown	12	79
Gardiners(?) clay:		
Clay, gray and brown, mixed [2]	1	80
Sand, fine, dark-brown; some grit [2]	6	86
Sand, fine, silty, dark-brown	14	100
Sand, fine to medium, dark-brown; some silt; and fine to medium gravel	3	103
Sand, fine, silty, dark-brown	6	109

[2] From driller's log.

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3734. (5B, 2.5N, 4.1W)—Continued

	Thickness (feet)	Depth (feet)
Jameco gravel:		
Sand, fine, some medium, dark-brown	5	114
Sand, medium, dark-brown	10	124
Sand, fine to coarse, brown	12	136
Sand, fine, dark-brown	2	138
Magothy(?) formation:		
Sand, fine, clayey, micaceous, gray	2	140

N3780. (8C, 2.7N, 4.1W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 57 ft. Screened between 88 and 141ft. Discharge 1,800 gpm with drawdown of 32 ft after 7 hr of pumping. Driller's log based on examination of core samples]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Loam and rocks	2	2
Upper Pleistocene deposits:		
Sand, coarse, and gravel	56	58
Sand, medium to coarse; small gravel	11	69
Sand, fine to medium; small amount of grit	9	78
Gravel, coarse; small amount of sand	2	80
Magothy(?) formation:		
Sand, medium to coarse, dark; grit	8	88
Sand, coarse, light brown	3	91
Sand, coarse, brown; large amount of grit	10	101
Sand, coarse, medium brown; grit	6	107
Sand, coarse, medium gray; grit	3	110
Sand, medium to coarse, brown; grit	3	113
Sand, light-brown; grit	3	116
Sand, coarse, light-gray; grit	5	121
Sand, fine to medium, gray; some grit	7	128
Sand, fine to medium, brown	10	138
Clay, sandy, fine, gray	11	149
Sand, medium to coarse, brown	5	154
Clay, sandy, fine, gray	22	176
Sand, fine, gray; some clay	13	189
Clay, sandy, fine, gray	26	215
Sand, fine, gray	4	219
Clay, solid, gray	6	225
Sand, fine, brown	9	234
Sand, fine, gray; gray sandy clay, in layers	58	292
Clay, solid, dark-gray; lignite	5	297
Sand, fine, gray; some clay	49	346
Clay, solid, dark-gray	8	354
Sand, fine, gray; some clay	4	358
Clay, sandy, fine, gray; lignite	5	363
Clay, solid, dark-gray	6	369
Sand, fine to medium, gray; lignite	25	394
Clay, sandy, fine, gray; lignite	18	412
Clay, solid, dark-gray	36	448
Clay, sandy, fine, gray; layers of solid clay and lignite	54	502

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3861. (5B, 3.3N, 3.5W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 7 ft. Screened between 522 and 533 ft. Discharge 100 gpm with drawdown of 16 ft after 2 hr of pumping. Log based on examination of core samples by N. M. Perlmutter and R. E. Whitson, Jr]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Topsoil [2]	1	1
Upper Pleistocene deposits:		
Sand, coarse, brown; grit and gravel [2]	3	4
Mud, swamp, black [2]	2	6
Sand, fine, brown, and mica [2]	8	14
Sand, fine to coarse, brown, and gravel [2]	16	30
Clay, solid, gray; layers of fine to medium gray clayey sand ("20-foot" clay)	12	42
Sand, fine to coarse, brown	24	66
Clay, solid, gray and brown; some brown clayey sand	7	73
Sand, fine to mediun, brown; some coarse sand	15	88
Gardiners clay:		
Sand, fine to medium, clayey, dark-gray; some thin layers of gray solid clay	15	103
Sand, fine, clayey, glauconitic, green	8	111
Sand, fine to medium, clayey, dark-gray	8	119
Clay, solid, gray; some thin layers of fine clayey sand	19	138
Jameco gravel:		
Sand, medium to very coarse, grayish-brown, and gravel	50	188
Sand, fine to medium, grayish-brown; some lignite	10	198
Sand, medium to very coarse, grayish-brown	10	208
Magothy(?) formation:		
Sand, fine to medium, grayish-brown; some layers of medium to coarse brown sand	22	230
Sand, fine to medium, gray; some lignite	90	320
Sand, fine to very coarse, gray; some gravel	14	334
Sand, fine to medium, gray; lignite	40	374
Sand, medium to coarse, gray	24	398
Sand, medium to coarse, gray; some fine sand; thin layers of gray clay and lignite	27	425
Sand, fine to very coarse, gray; some fine gravel and lignite	23	448
Clay, sandy, gray	6	454
Sand, fine to very coarse, gray; some gravel	21	475
Sand, fine to medium, gray, and gray sandy clay	25	500
Sand, medium to coarse, gray; some very coarse sand and gravel	50	550
Sand, medium to very coarse, gray; some gravel; white sandy clay	19	569
Clay, silty, white	11	580
Sand, fine to medium, gray; layers of gray silty clay and clayey sand	29	609
Raritan formation:		
Clay member:		
Clay, solid, light- and dark-gray, brown, purple; some layers of lignite	14	623

654861—62——11

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3862. (5B, 1.5N, 3.7W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 7 ft. Screened between 296 and 306 ft. Discharge 100 gpm with drawdown of 20 ft after 6 hr of pumping. Log based on examination of core samples by N. M. Perlmutter, J. J. Geraghty, and R. E. Whitson, Jr]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Topsoil [2]	1	1
Upper Pleistocene deposits:		
Sand, fine, gray and clay [2]	6	7
Clay, solid, gray [2]	11	18
Sand, coarse, brown; grit and gravel [2]	7	25
Sand, very fine to fine, brown	18	43
Clay, solid, gray; layers of fine to coarse gray clayey sand ("20-foot" clay)	20	63
Sand, fine to medium, gray, brown	19	82
Sand, fine to very coarse, grayish-brown; some gravel	12	94
Gardiners clay:		
Sand, medium to coarse, greenish-brown, glauconitic	25	119
Clay, solid, gray; some layers of gray sandy clay	12	131
Sand, fine to medium, silty, grayish-green; some layers of grayish-green sandy clay	22	153
Jameco gravel:		
Sand, fine to coarse, grayish-green; gravel	11	164
Magothy(?) formation:		
Sand, fine to medium, clayey, gray; some layers of lignite and solid gray clay	27	191
Clay, sandy, solid, dark-gray; some pyrite and lignite	18	209
Sand, fine to medium, gray; some silty and sandy clay	19	228
Clay, solid, dark-gray; layers of lignite; and some sandy clay	30	258
Sand, fine, gray; some thin layers of lignite	10	268
Sand, fine, clayey, gray	14	282
Sand, fine to medium, gray; some coarse sand and lignite	41	323
Sand, fine, clayey, gray; thin layers of lignite	50	373
Sand, fine to medium, gray; some clay and lignite	45	418
Sand, fine, silty, gray	9	427
Sand, fine to medium; some coarse sand; trace of gray clay and lignite	32	459
Clay, sandy, gray; fine clayey sand; lignite	11	470
Clay, solid, light gray; some interbedded sandy layers	23	493
Sand, fine to medium, gray; some silt and gray clay; thin layers of lignite	50	543
Clay, solid and silty, gray, thin layers of lignite and sandy clay	19	562
Sand, fine to medium, gray; some coarse sand	12	574
Clay, solid, dark-gray; thin layers of silt and lignite	35	609
Sand, fine, clayey, white, and layers of white silty clay	44	653
Raritan formation:		
Clay member:		
Clay, tough and solid, dark gray; some lignite layers	15	668
Clay, silty, dark-gray	23	691
Sand, fine, silty and clayey, gray, and gray clay	14	705
Sand, fine to very coarse, gray; some gray sandy clay layers, and calcareous concretions	11	716
Sand, fine, silty and clayey, gray	9	725
Clay, solid and silty, dark-gray	12	737
Silt, clayey; some very fine micaceous sand and lignite	16	753
Clay, silty, micaceous, gray; some fine sand	9	762
Clay, solid and silty, light and dark-gray; some brown, white, tan, and salmon red layers	33	795

[2] From driller's log.

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3863. (5B, 0.4N, 2.7W)

[Drilled by Nassau County Department of Public Works. Altitude about 11 ft. Not completed, no screen. Log based on examination of bailer samples by W. V. Swarzenski]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill, sand, and gravel	10	10
Peat and gray clay	3	13
Sand, medium, gray; shell fragments and some coarse gravel	1	14
Sand, medium to coarse, gray; shell fragments	4	18
Sand, fine to medium, gray, and shell fragments	6	24
Sand, medium to coarse, gray; shell fragments and some coarse gravel	9	33
Sand, coarse to very coarse, gray; fine gravel and shell fragments	2	35
Upper Pleistocene deposits:		
Sand, fine to medium, buff, and fine to coarse gravel; some clay and shell fragments	1	36
Sand, fine to medium, buff; some clay	5	41
Clay, silty, greenish-gray; some lignite and shells ("20-foot" clay)	13	54
Sand, medium, gray; some clay and shell fragments	11	65
Sand, fine to medium, gray; some clay; shell fragments	7	72
Gravel, fine; some clayey fine gray sand	8	80
Gravel, fine to coarse, and fine to medium gray sand	10	90
Gardiners clay:		
Clay, solid, fossiliferous, grayish-green; some lignite	36	126
Jameco gravel:		
Sand, clayey, gray; some gravel	5	131
Sand, medium to coarse, tan, and fine to medium gravel	15	146
Sand, fine to medium, tan; trace of clay	5	151
Gravel, medium to coarse; pyrite; lignite	9	160
Magothy(?) formation:		
Sand, fine to medium, gray; traces of clay and lignite	3	163
Clay, silty, gray and clayey sand; pyrite, lignite	21	184
Sand, fine to medium, silty, gray; pyrite, lignite	33	217

N3864. (5B, 4.0N 2.5W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 4 ft. Screened between 459 and 470 ft. Discharge 20 gpm with drawdown of 25 ft after 5 hrs of pumping. Log based on examination of core samples by J. J. Geraghty and N. M. Perlmutter]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Muck and clay [2]	2	2
Upper Pleistocene deposits:		
Sand, coarse, brown, and grit [2]	22	24
Clay, solid, light gray; small shells; some layers of gray sandy clay and gravel ("20-foot" clay)	18	42
Sand, medium to coarse, grayish-brown; gravel; layers of fine gray sandy clay; shells from 48 to 53 ft	27	69
Gardiners clay:		
Clay, solid, grayish-green; some thin layers of gray silty clay	69	138

[2] From driller's log.

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3864. (5B, 4.0N, 2.5W)—Continued

Jameco gravel:		
Sand, medium to very coarse, grayish-brown; some lignite	21	159
Sand, medium to very coarse, brown; gravel and some brown clay	25	184
Sand, medium to very coarse, grayish-brown, and coarse gravel	26	210
Magothy(?) formation:		
Sand, very fine to fine, clayey, gray; some layers of gray solid clay; silty clay; lignite	129	339
Sand, fine to medium, gray; some coarse sand; thin layers of gray solid clay	36	375
Sand, fine, clayey, gray; some thin layers of medium sand and gray clay	102	477
Clay, solid, gray and red	42	519
Sand, fine to medium, clayey, gray; some layers of solid gray clay	32	551
Gravel, fine to coarse, gray; layers of gray coarse sand, and trace of clay	29	580
Raritan formation:		
Clay member:		
Clay, tough, light- and dark-gray; some thin layers of silt; lignite	56	636

N3865. (6B, 2.9N, 2.5W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 5 ft. Screened between 555 and 565 ft. Discharge 96 gpm with drawdown of 90 ft after 24 hrs of pumping. Log based on examination of core samples by J. J. Geraghty and H. T. Hopkins]

	Thickness (feet)	Depth (feet)
Recent and upper Pleistocene deposits:		
Fill and bog [2]	20	20
Upper Pleistocene deposits:		
Sand, coarse, brown [2]	13	33
Clay, gray ("20-foot" clay) [2]	17	50
Sand, medium, brown	10	60
Magothy(?) formation:		
Clay, solid and silty, gray; thin layers of lignite	25	85
Sand, fine to coarse, gray; some layers of clayey sand, gray solid clay; lignite	45	130
Clay, sandy, gray; layers of solid clay, medium-gray sand; lignite	46	176
Sand, fine to medium, gray; trace of gray clay; lignite	15	191
Clay, solid and sandy, gray; some layers of fine to medium gray sand	35	226
Sand, medium, gray; some fine sand and clay	19	245
Clay, sandy and silty, gray; some layers of lignite and and gray clayey sand	24	269
Sand, medium, clayey, gray	27	296
Clay, solid, gray; thin layers of fine sand and silt	12	308
Sand, fine to medium, clayey, gray; layers of sandy clay and lignite	26	334
Clay, solid, dark-gray, and lignite	15	349
Sand, medium, gray; layers of gray sandy clay, fine sand and lignite	59	408
Sand, fine to medium, clayey gray; thin layers of solid gray clay	34	442

[2] From driller's log.

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3865. (6B, 2.9N, 2.5W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation—Continued		
Sand, fine, clayey, gray; some layers of medium gray sand, solid clay, and lignite	68	510
Sand, fine to medium, clayey, gray; thin layers of lignite	32	542
Sand, medium to coarse, gray; some layers of fine clayey sand	32	574
Clay, solid, gray	17	591
Sand, very fine to fine, gray; some layers of solid gray clay and fine to medium clayey sand	23	614
Sand, medium to very coarse, gray; trace of gray clay	24	638
Clay, solid, gray	8	646
Sand, fine to medium, clayey, gray; some layers of coarse to very coarse sand; gravel; and lignite	21	667
Clay, solid, light gray	12	679
Sand, fine, clayey, gray; layers of medium to very coarse sand, gravel, and lignite	33	712
Sand, fine to medium, clayey, gray	36	748
Raritan formation:		
Clay member:		
Clay, solid and silty, gray; some layers of sandy clay	12	760
Sand, fine to medium, clayey, gray; layers of sandy clay and lignite	26	786
Clay, solid and silty, light-brown and gray; layers of sandy clay and lignite	63	849

N3866. (5B, 3.7N, 1.5W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 6 ft. Screened between 400 and 412 ft. Discharge 114 gpm with drawdown of 30 ft after 24 hr of pumping. Log based on examination of core samples by N. M. Perlmutter, J. J. Geraghty and H. T. Hopkins]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Topsoil [2]	1	1
Upper Pleistocene deposits:		
Clay, brown, and gravel [2]	3	4
Sand, coarse, brown; grits [2]	10	14
Clay, solid, gray ("20-foot" clay)	22	36
Sand, medium, gray and light-brown; traces of fine and coarse sand	47	83
Sand, fine to very coarse, light-brown; gravel and a trace of clay	11	94
Gardiners clay:		
Clay, solid, gray	42	136
Jameco gravel:		
Sand, coarse to very coarse, brown	50	186
Magothy(?) formation:		
Clay, solid, gray; sandy clay and lignite in layers	29	215
Clay, solid, gray; thin layers of silt and lignite	12	227
Sand, fine to medium, clayey, gray; some layers of solid clay, silt, and lignite	70	297
Clay, solid, gray; silty clay and sandy clay in layers	13	310
Sand, very fine to medium, clayey, gray	22	332
Clay, solid, gray, and layers of fine, clayey sand	15	347
Sand, fine to medium, gray; some clay and lignite	26	373

[2] From driller's log.

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3866. (5B, 3.7N, 1.5W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation—Continued		
Clay, solid, gray	11	384
Sand, medium, gray; some fine and coarse sand and trace of gray clay	24	408
Clay, solid, gray; some thin layers of silt and lignite	10	418
Sand, medium, gray; some thin layers of solid gray clay	12	430
Sand, very fine to fine, clayey, gray; thin zone of medium to coarse sand at about 444 ft	15	445
Clay, solid, gray; layers of lignite and pyrite	7	452

N3867. (5B, 4.6N, 2.7W)

Drilled by C. W. Lauman and Co., Inc. Altitude about 6 ft. Screened between 506 and 517 ft. Discharge 84 gpm with drawdown of 9 ft after 26 hr of pumping. Log based on examination of core samples by J. J. Geraghty and H. T. Hopkins]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill	3	3
Upper Pleistocene deposits:		
Sand, coarse, brown, and grit	33	36
Sand, medium to very coarse, gray; gravel; some thin layers of green and gray clay ("20-foot" clay?)	21	57
Gardiners clay:		
Sand, very fine to fine, clayey, grayish-green; layers of gray silty clay	27	84
Jameco gravel:		
Sand, medium to coarse, grayish-brown	23	107
Sand, coarse to very coarse, grayish-brown; some gravel	26	133
Sand, medium to coarse, gray	17	150
Magothy(?) formation:		
Clay, sandy, gray; some thin layers of solid gray clay, lignite, and pyrite	21	171
Sand, fine to medium, gray; some layers of lignite	11	182
Clay, solid, dark gray; some thin layers of lignite	5	187
Clay, sandy and silty, gray; layers of solid gray clay; medium sand and lignite	53	240
Sand, medium, gray; a few layers of lignite	15	255
Clay, solid, gray; fine to medium clayey sand; lignite; layers of silt	47	302
Sand, medium, gray; some clay; layers of silty sand	28	330
Clay, solid, gray, silt; lignite; fine to medium clayey sand in layers	22	352
Sand, medium, gray; trace of clay	9	361
Sand, medium to very coarse, gray; lignite; some layers of clay	19	380
Sand, very fine to medium; some silt; thin layers of solid gray clay	29	409
Clay, sandy, gray	19	428
Sand, medium to very coarse, gray; some gravel and clay	19	447
Sand, fine to medium, clayey, gray; some layers of coarse sand, solid clay, silt, and lignite	42	489
Sand, medium to very coarse, gray; some gravel and clay	16	505
Gravel; coarse to very coarse gray sand; trace of clay	14	519

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3867. (5B, 4.6N, 2.7W)—Continued

	Thickness (feet)	Depth (feet)
Raritan formation:		
Clay member:		
Sand, fine to medium, clayey, gray; some layers of solid gray clay and silt	12	531
Clay, solid, light-gray; thin layer of fine sand at about 545 ft	19	550

N3881. (5C, 3.9N, 0.5W)

[Drilled by Layne-New York Co., Inc. Altitude about 80 ft. Screened between 426 and 466 ft. Discharge 1,200 gpm with drawdown of 101 ft after 8 hrs of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand and gravel	100	100
Magothy(?) formation:		
Sand; streaks of clay	40	140
Clay, sandy, hard	43	183
Clay, tough	12	195
Clay, sandy	32	227
Sand, fine, and clay	23	250
Sand, gravel; streaks of clay	34	284
Clay; streaks of hard sand	15	299
Sand, clay, and wood	51	350
Sand, and gravel, hard-packed	54	404
Clay and hard streaks	16	420
Sand and gravel	49	469
Clay and gravel	23	492

N3886. (8C, 0.9N, 1.1W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 25 ft. Screened between 42 and 75 ft. Discharge 1,550 gpm with drawdown of 24 ft after 8 hrs of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Topsoil	1	1
Upper Pleistocene deposits:		
Sand, brown, and grit	34	35
Sand, medium, brown	20	55
Sand, medium to coarse, brown, and grit	17	72
Sand, fine to medium, brown; some clay	3	75
Gardiners(?) clay:		
Clay, sandy, black; lignite	at	75

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3893. (8C, 2.8N, 4.0W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 57 ft. Screened between 98 and 151 ft. Discharge 1,739 gpm with drawdown of 40 ft after 8 hrs of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Topsoil	2	2
Upper Pleistocene deposits:		
Sand, coarse, brown, and grit	87	89
Magothy(?) formation:		
Clay, lignite, and streaks of sand	6	95
Sand, fine to medium, brown	55	150
Clay, sandy, fine	at	150

N3894. (7C, 1.2N, 3.8W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 34 ft . Screened between 120 and 147, and 312 and 361 ft. Discharge, 1,641 gpm, with drawdown of 24 ft after 3 hrs of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, coarse, brown; clay and large stones	5	5
Sand, coarse, brown; gravel and large stones	32	37
Clay, solid, gray ("20-foot" clay?)	20	57
Magothy(?) formation:		
Sand, medium, coarse, brown	14	71
Clay, fine, gray; sandy; lignitic and micaceous streaks	21	92
Sand, fine, gray; layers of sandy clay, solid clay, and lignite	30	122
Sand, medium, fine; some clay	16	138
Clay, fine, sandy, gray; mica and lignite	10	148
Clay, solid, dark-gray	15	163
Clay, fine, gray; layers of sand and lignite	25	188
Clay, solid, gray; lignite	11	199
Clay, fine, sandy, gray	8	207
Sand, fine, gray; some clay and mica	17	224
Clay, solid, gray; streaks of sandy clay	2	226
Clay, fine, sandy, gray; mica	35	261
Sand, fine, gray; mica	16	277
Clay, fine, sandy, gray; mica, pyrite, and lignite	14	291
Sand, medium, gray; layers of clay and lignite	9	300
Sand, fine, gray; mica	29	329
Sand, medium, gray; some lignite	28	357
Clay, solid, dark-gray; streaks of sandy clay and lignite	25	382
Sand, medium, fine, gray; streaks of lignite	20	402
Clay, solid, hard, gray	13	415

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3895. (7C, 1.5N, 2.2W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 38 ft. Screened between 377 and 414 ft. Discharge 1,016 gpm with drawdown of 70 ft after 4 hr of pumping. Driller's log based on examination of core samples]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill	4	4
Mud and clay	4	8
Upper Pleistocene deposits:		
Sand, coarse, gray; grit and lumps of clay	20	28
Sand, coarse, brown, and grit	63	91
Magothy(?) formation:		
Clay, solid, black; layers of lignite	39	130
Clay, sandy, fine, gray	5	135
Sand, fine to medium, gray; some clay	25	160
Sand, fine to medium, gray; lignite: some clay	11	171
Sand, fine to medium, gray; some clay	4	175
Clay, solid, gray; streaks of fine gray sand	15	190
Sand, fine, gray; some clay; layers of solid clay and lignite	35	225
Sand, fine, gray; some clay	16	241
Clay, sandy, fine, gray, and lignite	59	300
Clay, solid; layers of lignite and fine gray sand	15	315
Sand, fine, gray; some clay	34	349
Clay, solid, gray, and sandy clay, in layers	16	365
Clay, sandy, fine, gray; layers of lignite and pyrite	42	407
Sand, fine, gray; some clay	7	414
Clay, solid, gray	2	416
Clay, sandy, fine, gray	4	420
Sand, fine, gray; some clay	35	455
Clay, solid, and sandy clay, in layers	15	470
Clay, sandy, fine, gray	33	503

N3926. (5B, 2.8N, 2.6W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 14 ft. Screened between 51 and 64 ft. Discharge 450 gpm. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand and gravel	17	17
Sand, brown, and gravel	12	29
Clay, reddish-brown; brown clayey sand; grit	3	32
"20-foot" clay:		
Clay, sandy, gray	1	33
Clay, sticky, gray	25	58
Sand, gray; and gravel	7	65
Sand, fine, grayish-brown; and grit	4	69
Gardiners clay:		
Clay, sticky, gray	26	95
Clay, soft, gray	20	115

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3932. (5B, 3.3N, 3.5W)

[Drilled by Nassau County Department of Public Works. Altitude about 7 ft. Screened between 172 and 176 ft. Log based on examination of bailer samples by N. M. Perlmutter]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, medium to coarse, brown; some gravel	6	6
Sand, fine to medium, clayey, grayish-brown	10	16
Sand, fine to coarse, brown, and fine to coarse gravel	20	36
Clay, solid, gray ("20-foot" clay)	7	43
Sand, fine to coarse, grayish-brown	23	66
Clay, sandy, gray and yellow	8	74
Sand, fine to coarse, rusty-brown; some fine gravel	4	78
Sand, medium, light-brown	12	90
Gardiners clay:		
Clay, solid, gray	4	94
Sand, medium to coarse, gray	3	97
Clay, solid, gray; sandy clay	39	136
Jameco gravel:		
Sand, medium to coarse, gray; some lignite	28	164
Sand, coarse, gray, and gravel	13	177

N3937. (5B, 0.1N, 0.3W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 23 ft. Screened between 393 and 465 ft. Discharge 1,630 gpm with drawdown of 27 ft, after 4 hr of pumping. Log based on examination of core samples by J. J. Geraghty and H. T. Hopkins]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, coarse, brown; grit; gravel [2]	43	43
Sand, coarse, brown; lumps of gray clay [2]	11	54
Magothy(?) formation:		
Clay, sandy, gray	7	61
Clay, solid, gray and brown	10	71
Sand, medium, light-brown; some clay	31	102
Sand, medium, gray; some layers of solid gray clay; sandy clay; and lignite	80	182
Sand, fine to medium, clayey, gray; layers of lignite and solid clay	20	202
Clay, solid, dark-gray; layers of lignite	19	221
Sand, fine to medium, clayey gray	16	237
Clay, solid, gray; layers of clayey sand	19	256
Sand, fine to medium, clayey, gray; some layers of solid clay and lignite	20	276
Clay, solid, gray; layers of clayey sand	17	293
Sand, fine to medium, gray; layers of clayey sand, coarse sand, and lignite	49	342
Sand, fine to medium, clayey, gray; layers of sandy clay, solid clay, and medium to coarse sand	81	423
Clay, solid, gray; layers of lignite	8	431
Sand, fine to medium, gray; layers of coarse sand and clayey sand	37	468
Clay, solid, gray; some layers of sandy clay and lignite	69	537
Clay, sandy, gray; layers of solid clay and clayey gravel	10	547
Sand, fine to medium, gray; traces of fine gravel and clay	16	563

[2] From driller's log.

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3937. (5B, 0.1N, 0.3W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation—Continued		
Sand, fine to coarse, gray; gravel, clayey sand, and silt, in layers	54	617
Raritan formation:		
Clay member:		
Clay, solid, gray to black, some thin layers of sandy clay and lignite	88	705

N3949. (7B, 4.5N, 0.1W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 7 ft. Screened between 20 and 35 ft. Discharge 260 gpm with drawdown of 8 ft after 1 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent and upper Pleistocene deposits:		
Topsoil	1	1
Sand, coarse	3	4
Clay, gray; marsh mud	8	12
Sand, coarse, gray; gravel	23	35

N4026. (5B, 2.6N, 1.8W)

[Drilled by Nassau County Department of Public Works. Altitude about 5 ft. Screened between 149 and 153 ft. Log based on examination of bailer samples by J. J. Geraghty and H. T. Hopkins]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, medium, brown	15	15
Sand, medium to coarse, brown; gravel as much as 5 mm in diameter; some rock fragments	4	19
Gravel, large, brown	5	24
Clay, sandy, fine, gray ("20-foot" clay)	20	44
Sand, fine to medium, gray; trace of clay; some gravel	5	49
Sand, fine to very coarse, gray; gravel	22	71
Sand, medium to coarse, brown; gravel	4	75
Gardiners clay:		
Clay, plastic, dark-gray; trace of fine sand	25	100
Sand, fine, clayey, gray	10	110
Sand, fine to medium, dark-gray, and traces of clay	14	124
Clay, sandy, grayish-green; some gravel; medium to very coarse sand	4	128
Jameco gravel:		
Sand, medium to coarse, grayish-green; some gravel (as much as 6 mm in diameter)	11	139
Sand, medium, grayish-green, some small gravel; trace of clay	2	141
Sand, coarse, gray; gravel	17	158
Sand, medium to very coarse, grayish-black; fine gravel	2	160
Magothy(?) formation:		
Sand, medium, gray; lignite	10	170
Sand, fine, gray; lignite	15	185
Sand, fine to medium, gray	12	197

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N4043. (8C, 3.3N, 2.2W)

[Drilled by C. W. Lauman and Co.,Inc. Altitude about 73 ft. Screened between 317 and 369 ft. Discharge 1,212 gpm with drawdown of 36 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Loam	3	3
Upper Pleistocene deposits:		
Sand, coarse, brown; grit and gravel	89	92
Upper Pleistocene deposits and Magothy(?) formation:		
Sand, coarse, brown; grit; gravel; lumps of clay	42	134
Magothy(?) formation:		
Sand, fine to medium, brown	5	139
Sand, clayey, fine to medium, light-brown	11	150
Sand, fine to medium, brown	20	170
Clay, solid, light-brown	5	175
Sand, fine to medium; thin layers of clay	5	180
Clay, sandy, fine, brown; layers of solid clay	6	186
Sand, fine to medium, brown	24	210
Clay, sandy, fine to medium, gray	27	237
Clay, sandy, fine, gray; streaks of solid clay	52	289
Sand, fine, gray; some clay	15	304
Sand, fine, gray	5	309
Clay, gray, and sand; solid clay and lignite	13	322
Sand, fine to medium, gray; layers of lignite	50	372
Sand, fine, gray; some clay	21	393
Sand, fine to medium, gray	21	414
Sand, fine to medium, gray; layers of solid clay	7	421
Clay, sandy, fine, gray; layers of lignite	61	482

N4077T. (5C, 4.0N, 1.5W)

[Drilled by Layne-New York Co., Inc. Altitude about 76 ft. Screened between 360 and 380 ft. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, gravel, and hard layers	46	46
Sand, coarse; gravel	69	115
Magothy(?) formation:		
Clay, white and yellow; sand	34	149
Sand, gravel; clay; black wood	49	198
Clay	12	210
Sand, gravel, and clay streaks	51	261
Sand, coarse; gravel, reddish-brown	49	310
Sand, gravel, clay streaks, and clay balls	22	332
Clay, tough	12	344
Sand, coarse; gravel	42	386
Sand, gravel, and red clay	50	436
Raritan formation:		
Clay member:		
Clay, blue	9	445
Clay and sand streaks	23	468
Clay, hard	21	489
Sand and gravel	17	506
Clay, hard	4	510
Sand and gravel	3	513
Clay, tough, black and blue	25	538

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N4120T. (5C, 0.9N, 0.9W)

[Drilled by Layne-New York Co., Inc. Altitude about 40 ft. Abandoned, screen setting unknown. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, red and brown	10	10
Sand, brown; gravel	36	46
Gravel	4	50
Sand, gray	10	60
Sand, dark-green	15	75
Sand, brown; gravel	2	77
Magothy(?) formation:		
Sand, muddy, white	11	88
Clay, white	4	92
Sand, muddy, white	46	138
Clay, white	2	140
Sand, muddy, white	37	177
Clay, black	8	185
Sand and clay	51	236
Clay, blue	8	244
Sand	12	256
Clay	12	268
Clay, sandy	32	300
Sand, fine to medium	28	328
Sand; some clay	22	350
Sand; clay streaks	54	404
Clay, tough	6	410
Sand, coarse	38	448
Clay	10	458

N4149. (7B, 4.7N, 2.5W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 5 ft. Screened between 546 and 562 ft. Discharge 127 gpm with drawdown of 21 ft after 7½ hr of pumping. Log based on examination of core samples by N. M. Perlmutter and H. T. Hopkins]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill [2]	3	3
Bog [2]	1	4
Upper Pleistocene deposits:		
Sand, medium to very coarse, brown; and gravel	34	38
Clay, solid, gray ("20-foot" clay)	11	49
Magothy(?) formation:		
Sand, fine to medium, clayey, gray; thin layers of gray solid clay	14	63
Sand, medium to coarse, gray; traces of gray clay and lignite	48	111
Sand, medium to coarse, gray; thin layers of gray solid clay	10	121
Sand, fine to medium, clayey, gray; thin layers of gray solid clay	8	129
Sand, medium, gray	51	180

[2] From driller's log.

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N4149. (7B, 4.7N, 2.5W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation—Continued		
Sand, fine to medium, gray; some thin layers of gray clay and lignite	30	210
Clay, solid, gray	10	220
Sand, fine to medium, gray; some coarse sand; thin layers of gray solid clay	14	234
Sand, fine to medium, gray, with some clay; thin layers of gray solid clay	24	258
Clay, solid, gray; some thin layers of gray fine to medium sand and silt	10	268
Sand, fine to medium, gray; lignite	10	278
Clay, sandy, gray	4	282
Sand, fine to medium, gray, and lignite	9	291
Clay, solid, dark gray; some thin layers of fine to medium clayey sand	29	320
Sand, fine, gray; some clay; thin layers of lignite	22	342
Clay, solid, black	14	356
Sand, fine to medium, gray; some clay and thin lignite layers	64	420
Sand, fine, gray; some silt and gray clay; thin lignite layers	37	457
Clay, solid and fine silty sand, gray	15	472
Sand, fine, gray; some clay	18	490
Clay, sandy	12	502
Sand, medium, gray; thin lignite layers	17	519
Sand, fine to medium, gray; some thin layers of clay; and lignite layers	16	535
Clay, solid, gray	8	543
Sand, medium, gray; some fine and coarse grains; trace of gray clay	25	568
Sand, fine to medium, gray; trace of gray clay; some thin layers of solid clay and lignite	50	618
Sand, medium, gray; some fine and coarse grains; trace of clay and lignite	38	656
Clay, solid, gray; thin lignite layers	22	678
Sand, fine to medium; some gray clay	36	714
Sand, medium to coarse, gray; gravel, mixed with some clay; layers of gray solid clay	22	736
Clay, sandy, gray; thin layers of solid clay	9	745
Sand, medium to coarse, gray; gravel; layers of gray solid clay and sandy clay	24	769
Raritan formation:		
Clay member:		
Clay, solid and silty, gray; some very fine sand	11	780
Sand, fine to medium, gray; some coarse grains; trace of clay	20	800
Clay, silty and solid, gray	15	815
Clay, sandy, gray; layers of fine to medium clayey sand and lignite	41	856
Clay, solid and silty, gray, layers of lignite	22	878

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N4150. (7B, 4.3N, 3.6W)

Drilled by C. W. Lauman and Co., Inc. Altitude about 5 ft. Screened between 729 and 745 ft. Discharge 326 gpm with drawdown of 34 ft after 17 hr of pumping. Log based on examination of core samples by N. M. Perlmutter and H. G. Healy]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill [2]	3	3
Bog [2]	9	12
Upper Pleistocene deposits:		
Sand, coarse, brown; grit; gravel [2]	10	22
Sand, coarse, gray; grit; gravel; lumps of clay [2]	14	36
Sand, very fine to fine, silty, grayish-green; layers of grayish-green silt and solid clay ("20-foot" clay?)	15	51
Magothy(?) formation:		
Sand, fine to coarse, gray; layers of lignite; some thin layers of gray solid clay	21	72
Sand, fine to medium, gray	7	79
Sand, medium to coarse, gray; some thin layers of gray solid clay, sandy clay, and lignite	31	110
Clay, solid, gray; layers of lignite and gray medium to coarse clayey sand	6	116
Sand, medium to coarse, gray	20	136
Sand, fine, clayey, gray; thin layers of lignite and gray medium sand	15	151
Sand, fine to medium, gray; some clay	18	169
Sand, medium to coarse, gray; layers of lignite	8	177
Sand, fine to medium, gray; some clay; layers of lignite	18	195
Clay, solid, gray; thin layers of gray fine to medium sand and lignite	13	208
Sand, fine to medium, gray; thin layers of gray clayey sand and lignite	20	228
Sand, fine to medium, gray; layers of gray sandy and solid clay	16	244
Clay, solid, gray; some thin layers of clayey fine sand	8	252
Sand, fine to medium, gray; some thin layers of gray solid clay and lignite	13	265
Sand, fine to medium, gray; trace of clay	20	285
Sand, fine to medium, gray; layers of clayey sand and lignite	31	316
Clay, silty and sandy, laminated, gray	18	334
Sand, fine to medium, gray; trace of clay and lignite layers	31	365
Sand, fine, clayey, gray; layers of gray sandy clay	11	376
Sand, fine to medium, gray; layers of gray clayey sand, lignite, and pyrite	7	383
Clay, silty and sandy, gray; some thin layers of gray fine to medium clayey sand and lignite	20	403
Sand, fine to medium, gray; some layers of clay and lignite	15	418
Sand, fine to medium, gray	12	430
Sand, fine, gray; some clay	16	446
Clay, solid, gray; layers of gray sandy silt	9	455
Sand, fine to medium, gray; some layers of clay and lignite	15	470

[2] From driller's log.

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N4150. (7B, 4.3N, 3.6W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation:		
Sand, fine to medium, gray; some thin layers of clayey sand	22	492
Sand, fine, clayey, gray	14	506
Sand, fine to medium, gray; thin layers of lignite	16	522
Sand, fine to medium, gray; some clay	12	534
Sand, very fine to fine, gray; some clay and silt	34	568
Clay, solid, gray; some thin silt and layers of lignite	12	580
Clay, sandy and silty, gray; and layers of fine to medium clayey sand	18	598
Sand, fine to medium, gray; trace of clay	10	608
Clay, solid, gray; some thin layers of gray clayey medium sand	23	631
Sand, medium to very coarse, gray	8	639
Sand, fine to medium, gray; some thin layers of clay and lignite	14	653
Sand, fine to coarse, gray; layers of lignite	8	661
Sand, coarse to very coarse, gray; some thin layers of clayey coarse sand	6	667
Clay, solid, and silty, gray, laminated	14	681
Sand, coarse to very coarse, gray; gravel; some layers of solid clay	22	703
Sand, medium to coarse, gray	22	725
Sand, medium to very coarse, gray; gravel; trace of clay; thin layers of gray solid clay	27	752
Raritan formation:		
Clay member:		
Clay, solid, gray	13	765
Sand, fine, clayey, gray	17	782
Sand, fine to medium, gray; some clay	11	793
Clay, solid, light and dark gray and salmon red; some thin layers of silt	33	826

N4213. (5B, 4.8N, 3.0W)

[Drilled by Nassau County Department of Public Works. Altitude about 5 ft. Screened between 130 and 134 ft. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill and sandy loam	4	4
Upper Pleistocene deposits:		
Sand, medium to coarse; some gravel	6	10
Sand, fine, gray, beach	32	42
Sand, fine; some gravel	3	45
Clay, blue, sandy ("20-foot" clay)	2	47
Sand, fine, gray	13	60
Gardiners clay:		
Clay, blue, fine, sandy	33	93
Jameco gravel:		
Sand, fine to coarse, light-brown	19	112
Sand, gray, coarse; some gravel	3	115
Sand, medium to coarse, brown	25	140

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N4257. (5B, 3.4N, 2.2W)

[Drilled by Mathies Well and Pump Co. Altitude about 25 ft. Screened between 131 and 143 ft. Discharge 150 gpm with drawdown of 19 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill	5	5
Upper Pleistocene deposits:		
Gravel, heavy; fine sand	3	8
Sand, fine; large stones	3	11
Sand, coarse; gravel	24	35
Sand, fine; trace of clay ("20-foot" clay?)	55	90
Gardiners clay:		
Clay, black	30	120
Sand, fine; clay	1	121
Clay, green	2	123
Jameco gravel:		
Sand, medium; small amount of grit	9	132
Sand, coarse; grit	10	142
Sand, medium; black specks	2	144
Sand, fine, gray	35	283
Clay, sandy, gray, and gray solid clay, in layers	6	289
Sand, fine, gray; streaks of lignite	25	314
Sand, fine, gray, and solid clay, in layers	5	319
Clay, sandy, fine, gray; streaks of lignite	5	324
Sand, fine, gray	7	331
Sand, fine, gray; pyrite; lignite; layers of solid gray clay	4	335
Sand, medium to coarse, gray; streaks of solid clay	4	339
Clay, sandy, fine, gray; streaks of lignite	9	348
Sand, medium to coarse, gray	10	358
Clay, sandy, fine, gray; streaks of lignite	11	369
Sand, fine, gray	8	377
Clay, solid, gray	12	389
Sand, fine, gray, and solid clay, in layers	9	398
Clay, solid, gray	6	404
Sand, fine, gray; streaks of solid clay	5	409
Sand, medium to coarse, gray	10	419
Sand, fine gray; streaks of coarse gray sand	9	428
Sand, fine, gray	6	434
Sand, medium to coarse, gray	15	449
Sand, fine, gray; some mica	12	461

N4393. (5B, 5.2N, 1.5W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 20 ft. Screened between 421 and 474 ft. Discharge 1,421 gpm with drawdown of 34 ft after 8 hr of pumping. Driller's log based on examination of core samples]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Loam	2	2
Upper Pleistocene deposits:		
Sand, medium to coarse, brown	40	42
Sand, medium to coarse, brown; some grit	22	64
Sand, coarse, brown; some grit	9	73
Sand, medium to coarse, brown; some grit	10	83
Magothy(?) formation:		
Sand, fine, multicolored; some clay	6	89
Sand, fine, gray; some clay	14	103

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N4393. (5B, 5.2N, 1.5W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation—Continued		
Sand, fine, gray; streaks of solid clay	11	114
Clay, solid, black	5	119
Sand, fine, gray; streaks of solid clay and lignite	6	125
Clay, sandy, fine, gray; streaks of solid gray clay and lignite	22	147
Sand, fine, gray; some clay and mica	6	153
Sand, fine, gray, and sandy clay in layers	29	182
Sand, fine, gray; streaks of lignite	10	192
Clay, solid, gray	10	202
Clay, sandy, fine, gray; streaks of lignite	5	207
Sand, fine, gray; streaks of lignite	29	236
Sand, fine, gray, and sandy clay, in layers	12	248
Sand, coarse, gray	6	467
Clay, sandy, fine, gray	11	478
Lignite and streaks of sand and clay	3	481
Sand, medium to coarse, gray; streaks of clay	5	486
Clay, solid, gray	9	495
Sand, fine, gray; layers of clay	11	506

N4401T. (8C, 2.1N, 1.1W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 40 ft. Abandoned, screen setting unknown. Driller's log based on examination of core samples]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, coarse, brown; gravel	68	68
Clay, solid, gray ("20-foot" clay)	10	78
Sand, fine, gray, mica, shells; layers of solid and sandy clay	16	94
Magothy(?) formation:		
Clay, solid, gray	10	104
Clay, sandy, gray; layers of solid clay	12	116
Sand, very fine, gray; some clay; mica; lignite	7	123
Clay, sandy, gray; lignite	6	129
Sand, coarse, gray; grit; streaks of solid clay	5	134
Clay, sandy, fine, gray; lignite	15	149
Clay, sandy, fine, gray	21	170
Sand, fine to medium, gray; little clay	7	177
Sand, fine to medium, gray; solid clay; lignite	6	183
Sand, fine to medium, gray; small amount of clay	51	234
Sand, fine, gray; layers of solid clay and lignite	6	240
Sand, fine, gray; small amount of clay; mica	27	267
Clay, sandy, gray; layers of lignite and solid clay	16	283
Clay, solid, gray; streaks of sandy clay	4	287
Clay, sandy, gray; lignite; layers of solid clay	20	307
Clay, sandy, gray; mica; lignite	10	317
Sand, fine, gray, mica; some lignite; layers of solid clay	20	337
Sand, fine, gray; lignite	13	350
Clay, solid, hard, gray	18	368
Clay, solid, gray; streaks of sandy clay; lignite	14	382
Clay, solid, gray, and sandy gray clay	10	392
Clay, sandy, gray	5	397
Clay, solid, gray, and fine gray sand	6	403

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N4401T. (8C, 2.1N, 1.1W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation—Continued		
Sand, fine, gray; lignite	23	426
Sand, fine, gray; mica	27	453
Sand, fine, gray; mica; streaks of solid clay	15	468
Sand, fine, gray; clay; mica	30	498
Clay, solid, gray	5	503
Sand, fine, gray; mica; streaks of solid and sandy clay	5	508
Clay, solid, gray	4	512
Sand, fine, gray; mica; streaks of solid clay	5	517
Sand, fine gray; mica; some clay	26	543
Sand, medium to coarse, gray; streaks of lignite	5	548
Clay, sandy, gray	7	555
Clay, solid, gray; streaks of sandy clay and lignite	12	567
Sand, fine, gray; little lignite	15	582
Sand, medium to coarse, gray	10	592
Sand, fine to medium, gray	15	607
Clay, sandy, fine, gray	15	622
Clay, sandy, fine, gray, and solid clay	30	652
Clay, solid, light-gray	5	657
Sand, fine, gray; mica; layers of solid clay	11	668
Sand, medium to coarse; mica; some clay	15	683
Sand, fine, gray; mica; some clay	26	709
Clay, sandy, gray; streaks of lignite	3	712
Clay, solid, gray; streaks of sandy clay	5	717
Clay, solid, hard, gray	4	721

N4411. (5B, 5.0N, 0.8W)

[Drilled by Layne-New York Co., Inc. Altitude about 17 ft. Screened between 480 and 550 ft. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, brown	60	60
Magothy(?) formation:		
Muck, black; wood	15	75
Sand, muddy, white	29	104
Sand, coarse, brown	15	119
Sand, muddy; streaks of clay and wood	61	180
Clay, dark-gray, and wood	24	204
Clay, hard; streaks of sand	28	232
Clay, hard, dark-brown	22	254
Clay, hard, brown	16	270
Sand and gravel; streaks of white clay	23	293
Clay, soft	6	299
Sand and gray clay	20	319
Sand and gravel	45	364
Clay	2	366
Sand and fine gravel	29	395
Clay	2	397
Sand and gravel	7	404
Clay, soft, gray	8	412
Sand; gravel; streaks of clay	24	436
Sand	8	444
Clay	3	447
Sand	2	449

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N4411. (5B, 5.0N, 0.8W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation—Continued		
Clay	4	453
Sand	4	457
Clay	1	458
Sand and fine gravel	38	496
Clay	5	501
Sand and fine gravel	55	556
Clay	12	568

N4756. (7C, 2.4N, 4.3W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 60 ft. Screened between 243 and 312 ft. Driller's log based on examination of core samples]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Loam	3	3
Upper Pleistocene deposits:		
Sand, coarse, brown, and gravel	50	53
Sand, coarse, brown; gravel; trace of brown clay	3	56
Magothy(?) formation:		
Clay, solid, gray; layers of lignite	12	68
Sand, fine to medium, gray; grit; gravel; some clay	12	80
Sand, fine, gray; some clay	27	107
Sand, fine, brown	11	118
Sand, fine, gray; streaks of sandy clay; solid clay; lignite	36	154
Clay, solid, gray	19	173
Clay, sandy, fine, gray	6	179
Sand, fine, gray; layers of sandy clay and lignite	34	213
Sand, fine, gray; mica; small amount of clay	17	230
Sand, fine, gray; mica; streaks of sandy clay and lignite	14	244
Sand, fine, gray, mica; streaks of lignite	10	254
Sand, fine, gray; streaks of lignite and solid clay	6	260
Sand, fine, gray, mica; streaks of lignite	28	288
Sand, fine, gray, mica; streaks of lignite and solid clay	17	305
Clay, solid, gray; streaks of fine gray sand and lignite	6	311
Clay, sandy, fine, gray; mica; streaks of lignite and solid clay	9	320
Sand, fine to medium, gray; mica; streaks of lignite and pyrite	29	349
Clay, sandy, gray	5	354
Sand, fine, gray; mica; some clay layers	53	407
Clay, solid, gray	10	417
Sand, fine, gray; layers of solid clay and lignite	6	423
Sand, very fine, brown; mica; some clay	4	427
Sand, fine to medium, brown; mica	17	444
Sand, medium to coarse, brown; traces of clay	17	461
Clay, sandy, gray; layers of solid clay and lignite	5	466
Sand, fine, brown; sandy and solid clay; lignite, in layers	5	471
Sand, fine, brown	10	481
Sand, fine, gray; layers of sandy clay and lignite	10	491
Clay, sandy, gray	4	495
Clay, solid, gray	6	501
Sand, fine, brown	5	506
Sand, fine, brown; streaks of sandy clay and lignite	6	512
Sand, fine, brown; grits; streaks of sandy clay	6	518

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N4756. (7C, 2.4N, 4.3W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation—Continued		
Clay, sandy, gray	35	553
Sand, medium, brown; streaks of sandy gray clay	5	558
Sand, fine, brown; grit; gravel; streaks of clay	15	573
Clay, solid, gray	5	578
Sand, medium to coarse, brown; gray sand; grit; streaks of clay	12	590
Sand, coarse, pinkish-brown; clay; grit; gravel; streaks of solid clay	16	606
Sand, coarse, brown; grits; gravel	21	627
Sand, medium, brown	5	632
Sand, coarse, brown; grit; gravel; stones; streaks of solid clay	3	635
Raritan formation:		
Clay member:		
Clay, solid, hard, red, gray, and white; clay, silty, white; gravel	16	651
Clay, sandy, fine, gray; streaks of solid clay	31	682
Clay, solid, gray; streaks of sandy clay; lignite	12	694
Clay, solid, hard, brown and gray	10	704
Clay, solid, gray; streaks of pyrite	32	736
Clay, sandy, fine, gray; mica	21	757
Clay, solid, gray; streaks of pyrite	28	785
Clay, solid, gray; streaks of sandy clay; lignite	22	807
Clay, solid, hard, gray and red	9	816
Clay, sandy, gray; mica	6	822
Lloyd sand member:		
Sand, fine, gray; mica; streaks of solid clay	5	827
Sand, fine, gray; mica	36	863
Sand, medium, gray; grit and gravel	19	882
Clay, sandy, fine, gray; mica	17	899
Sand, fine to medium and clay, gray; streaks of gray solid clay	9	908

N5129. (7B, 1.4N, 0.4W)

[Drilled by Layne-New York Co., Inc. Altitude about 7 ft. Screened between 890 and 960 ft. Discharge 1,230 gpm with drawdown of 35 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill and beach sand	20	20
Recent(?) and upper Pleistone deposits and Gardiners clay:		
Clay, soft, blue; sand and shells	79	99
Magothy(?) formation:		
Sand; streaks of clay; some gravel	129	228
Clay, sandy, hard streaks; sand and gravel	54	282
Clay	10	292
Sand and gravel; streaks of clay; lignite	43	335
Clay, tough	10	345
Sand and clay; some gravel	40	385
Sand; clay; hard clay streaks	22	407
Sand and gravel	14	421
Sand; some clay	29	450
Clay, tough	9	459
Clay, sandy; streaks of sand	14	473
Clay, tough	29	502
Sand, medium to coarse; sandy clay	59	561

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N5129. (7B, 1.4N, 0.4W)—Continued

	Thickness (feet)	Depth (feet)
Sand and gravel; streaks of clay; lignite—Continued		
Clay, tough	9	570
Sand, clay, and streaks of sand	42	612
Clay, sandy, hard, pyrite; lignite	51	663
Clay, hard, and pyrite	44	707
Sand, coarse and gravel; streaks of clay	14	721
Clay, sandy; pyrite; streaks of sand	39	760
Sand, fine to coarse; clay streaks	50	810
Sand, coarse; clay streaks; lignite	61	871
Clay, sandy, blue; hard streaks, clay, and mica	12	883
Sand, coarse; streaks of white clay	10	893
Sand, coarse, and gravel	10	903
Clay, sandy, white	4	907
Sand, coarse, and gravel; thin clay streaks	32	939
Clay, white	3	942
Sand, coarse, and heavy gravel; streaks of clay	18	960
Sand, coarse; coarse gravel; clay streaks	31	991
Gravel, coarse	8	999
Raritan formation:		
Clay member:		
Clay, tough, black	28	1027
Clay, sandy, white	31	1058
Clay, tough, black	16	1074
Clay, black; streaks of sandy clay; lignite	29	1103

N5227. (6B, 0.6N, 0.4W)

[Drilled by Layne-New York Co., Inc. Altitude about 10 ft. Screened between 1,200 and 1,260 ft. Discharge 1,209 gpm with drawdown of about 50 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill and sand	49	49
Upper Pleistocene deposits and Gardiners clay:		
Clay, sandy; coarse sand; shells	14	63
Clay, blue	17	80
Sand, coarse; gravel; shells; and streaks of clay	17	97
Magothy(?) formation:		
Sand; wood; streaks of clay	19	116
Clay, sandy; wood	13	129
Sand, fine, muddy; streaks of clay	56	185
Clay and wood	17	202
Clay; streaks of sand	6	208
Sand, medium to coarse	38	246
Clay and coarse sand	20	266
Clay, tough, gray	18	284
Sand, coarse; fine gravel; streaks of clay	67	351
Clay, gray; streaks of muddy fine sand	13	364
Sand, fine, muddy; streaks of clay	113	477
Sand, coarse; lignite; streaks of clay	36	513
Clay, sandy	21	534
Clay, hard, and sand	10	544
Sand; fine gravel; clay	41	585
Clay	15	600

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N5227. (6B, 0.6N, 0.4W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation—Continued		
Sand, fine; gravel; and clay	11	611
Clay	6	617
Sand and gravel	81	698
Sand, clay, and coarse sand	15	713
Clay, gray	10	723
Sand, coarse, and streaks of clay	46	769
Clay, sandy; and sand	32	801
Clay, gray	4	805
Sand, coarse, and fine gravel	30	835
Clay, hard, tough, red	7	842
Clay, blue	9	851
Clay; sand; and gravel	7	858
Sand, coarse, and gravel	22	880
Sand, coarse; gravel; and clay	3	883
Sand, coarse, and gravel	18	901
Sand, coarse; gravel; and clay	8	909
Raritan formation:		
Clay member:		
Clay, tough, gray	30	939
Pyrite, very hard	1	940
Clay, tough, blue; streaks of iron pyrite	10	950
Clay, tough, blue	100	1, 050
Clay, hard, red	26	1, 076
Clay; streaks of coarse sand; fine gravel	23	1, 099
Lloyd sand member:		
Sand, coarse; and gravel	45	1, 144
Sand, coarse; gravel; thin streaks of clay	20	1, 164
Sand, coarse; gravel	14	1, 178
Clay	15	1, 193
Sand, coarse; gravel; streaks of clay	5	1, 198
Sand, coarse; gravel	16	1, 214
Sand, coarse; gravel; streaks of clay	5	1, 219
Sand, coarse; gravel	37	1, 256
Clay	10	1, 266
Sand; gravel; clay	11	1, 277
Clay, sandy; coarse sand; gravel	11	1, 288

N5233. (6B, 0.5N, 0.8W)

[Drilled by Mathies Well and Pump Co., Altitude about 10 ft. Screened between 517 and 547 ft. Discharge 210 gpm with drawdown of 21 ft after 4 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Sand, fine	7	7
Clay, sandy	13	20
Recent and upper Pleistocene deposits:		
Sand, fine, gray	10	30
Sand, fine, gray	17	47
Upper Pleistocene deposits:		
Clay, sandy, solid ("20-foot" clay)	9	56
Sand, coarse; grit	4	60
Sand, medium; grit	1	61
Gardiners clay:		
Clay, solid, gray	11	72
Clay; gravel; stones	7	79

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N5233. (6B, 0.5N, 0.8W)—Continued

	Thickness (feet)	Depth (feet)
Gardiners clay—Continued		
Clay; gravel	2	81
Clay; grit	7	88
Jameco gravel:		
Sand, coarse; and brown gravel	2	90
Clay, sandy, gray	12	102
Sand, fine, gray	18	120
Sand, medium, fine, gray	10	130
Sand, brown, and grit	5	135
Sand, light-brown, and grit	15	150
Magothy(?) formation:		
Clay, sandy, gray	20	170
Clay, sandy, hard, gray	10	180
Clay, soft, solid, gray	10	190
Clay, solid, hard, gray	10	200
Sand, coarse, gray; grit	6	206
Clay, sandy, gray	4	210
Sand, fine, gray	40	250
Sand, fine, gray, and lignite	15	265
Clay, solid, gray	15	280
Clay, sandy, gray	15	295
Sand, fine, gray	2	297
Clay, solid, tough, gray	21	318
Clay, solid, tough	5	323
Clay, sandy	18	341
Lignite	1	342
Clay, black	15	357
Clay, sandy	18	375
Sand, fine; a little clay	9	384
Clay, black	8	392
Lignite	1	393
Clay, black	17	410
Clay, sandy, and mica	15	425
Clay, sandy, fine	12	437
Sand, fine, gray	8	445
Clay, solid, gray	5	450
Sand, fine, gray	5	455
Sand, very fine, gray	6	461
Clay, gray; and very fine sand	35	496
Clay, sandy	4	500
Sand, fine	7	507
Clay, gray, and fine sand	4	511
Sand, fine	22	533
Sand, fine; thin layer of black clay at 534 ft	16	549

N5308. (6B, 0.4N, 3.1W)

[Drilled by Layne-New York Co., Inc. Altitude about 10 ft. Screened between 1,160 and 1,220 ft. Discharge 1,245 gpm with drawdown of 38 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Sand, gray	25	25
Upper Pleistocene deposits:		
Clay, marsh ("20-foot" clay?)	20	45
Sand and gravel	65	110

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

N5308. (6B, 0.4N, 3.1W)—Continued

	Thickness (feet)	Depth (feet)
Gardiners clay:		
Clay, soft, sandy	40	150
Jameco(?) gravel:		
Sand; gravel; streaks of wood	64	214
Magothy(?) formation:		
Clay	8	222
Sand and gravel; streaks of clay	54	276
Sand and gravel	40	316
Sand; gravel, clay; wood	15	331
Sand, fine	39	370
Sand; dark clay; coarse sand	150	520
Sand, hard	18	538
Sand, hard; clay in streaks	95	633
Clay	55	688
Sand; clay in streaks	65	753
Clay; hard streaks	13	766
Magothy(?) formation and clay member of the Raritan formation:		
Clay, hard streaks	191	957
Raritan formation:		
Clay member:		
Pyrite	2	959
Clay	66	1,025
Sand; streaks of clay	24	1,049
Lloyd sand member:		
Sand, coarse	28	1,077
Clay, tough	4	1,081
Sand, coarse; clay streaks	31	1,112
Clay	16	1,128
Sand	12	1,140
Sand; streaks of clay	13	1,153
Sand, coarse	75	1,228
Clay, streaks of sand	16	1,244
Clay, tough	2	1,246

QUEENS COUNTY

Q1450. (5C, 2.4N, 4.4W)

[Drilled by Layne-New York Co., Inc. Altitude about 58 ft. Screened between 95 and 115 ft. Discharge 1,194 gpm with drawdown of 64 ft after 8 hr of pumping. Log based on examination of bailer samples by N. M. Perlmutter]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, medium to coarse, grayish-brown; fine gravel and pebbles	21	21
Sand, coarse, dark-brown; fine to medium gravel	24	45
Sand, medium to coarse, light-brown; fine gravel	31	76
Sand, fine to medium, brown; some grit	11	87
Sand, fine to medium, brown; some brown clay and fine gravel	7	94
Sand, coarse, light-brown; fine to medium gravel	23	117
Magothy(?) formation:		
Clay, sandy, white; streaks of brown sand; a few grit	11	128
Clay, sandy, dark-gray; streaks of brown sand and yellow clay	4	132

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

Q1503. (4C, 3.7N, 3.2W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 75 ft. Screened between 97 and 107 ft. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Clay, sandy, brown; boulders	42	42
Clay, brown; and boulders	21	63
Clay, brown	7	70
Sand, coarse, brown; gravel	18	88
Sand, medium, brown; mica	9	97
Sand, coarse, brown; and gravel	10	107
Magothy(?) formation:		
Sand, fine, gray; mica; lumps of brown and white clay	at	107

Q1506. (4B, 5.5N, 2.9W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 10 ft. Screened between 94 and 106 ft. Discharge 312 gpm with drawdown of 13 ft after 5 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill	6	6
Upper Pleistocene deposits:		
Sand, fine	13	19
Sand, coarse, gray; and a few grit	21	40
Sand, medium to coarse, gray	36	76
Sand, sharp, gray; small gravel; grit	6	82
Sand, medium to coarse; small gravel; grit	24	106

Q1507. (4C, 2.7N, 2.5W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 58 ft. Screened between 118 and 149 ft. Log based on examination of bailer samples by N. M. Perlmutter]

	Thickness (feet)	Depth (feet)
Cellar [2]	11	11
Upper Pleistocene deposits:		
Sand, fine, brown [2]	7	18
Sand; gravel; abundance of fine brown sand [2]	40	58
Sand, fine, brown; few grit [2]	15	73
Sand, fine, brown [2]	12	85
Sand, fine, brown; some large gravel [2]	10	95
Sand, fine, silty, grayish-brown; a little gray clay	11	106
Sand, medium to coarse, brown, and fine to medium gravel	9	115
Sand, medium to coarse, brown, and fine to coarse gravel	37	152
Magothy(?) formation:		
Clay, sandy, white; layers of fine to coarse white sand; some white clay and fine gravel	5	157

[2] From driller's log.

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

Q1521. (4C, 0.6N, 0.8W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 20 ft. Screened between 171 and 182 ft. Discharge 170 gpm with drawdown of 8 ft after 1 hr of pumping. Log based on examination of bailer samples by N. M. Perlmutter]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, fine to coarse, brown, and fine gravel	10	10
Sand, medium to coarse, dark-brown; and fine to medium gravel	20	30
Sand, fine to coarse, brown	10	40
Sand, fine to medium, brown	10	50
Sand, medium to coarse, grayish-brown; and fine gravel	14	64
Gardiners clay:		
Clay, silty, sticky, greenish-gray	81	145
Jameco gravel:		
Sand, fine to coarse, gray; fine gravel; some gray clay	1	146
Sand, medium to coarse, gray; some fine clayey gravel; lumps of gray clay	19	165
Sand, medium to coarse, grayish-brown; fine to medium gravel	17	182

Q1535T. (5C, 3.2N, 4.1W)

[Drilled by Layne-New York Co., Inc. Altitude about 70 ft. Screened between 386 and 401 ft. Log based on examination of flume samples by T. Arnow]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, medium to coarse; and fine to medium gravel	109	109
Magothy(?) formation:		
Sand, fine to medium, white; and yellow clay	9	118
Sand, medium to coarse	60	178
Clay, tough	22	200
Sand, fine to coarse, colorless to light-yellow	16	216
Sand, fine to coarse, colorless to light-yellow; some gray clay; pyrite	17	233
Sand, fine to coarse, tan	20	253
Clay	2	255
Sand, fine to coarse, white and brown	57	312
Sand, fine to medium; black to dark-brown clay	61	373
Sand, fine to coarse, white to yellow	12	385
Sand, fine to very coarse, white to yellow	14	399
Raritan formation:		
Clay member:		
Clay, tough	5	404
Sand, fine to medium; small amount of clay	22	426
Clay, black	24	450

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

Q1600. (4C, 4.0N, 0.1W)

[Drilled by Layne-New York Co., Inc. Altitude about 98 ft. Screened between 270 and 290 ft. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Clay, sandy	5	5
Sand and gravel	60	65
Sand, brown, and gravel	45	110
Magothy(?) formation:		
Sand, hard-packed, clay	21	131
Sand, white and brown	40	171
Sand and clay, white and brown	21	192
Sand, light brown	23	215
Clay, and brown sand	10	225
Sand, coarse	10	235
Clay, sandy	28	263
Sand, fine, white	31	294
Clay and sand, in streaks	66	360
Sand, coarse; gravel	21	381
Raritan formation:		
Clay member:		
Clay, blue	73	454

Q1630. (4B, 0.3N, 3.0W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 7 feet. Screened between 159 and 175 ft. Discharge 250 gpm with drawdown of 6 ft after 4 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill	8	8
Sand, fine brown,	12	20
Recent(?) and upper Pleistocene deposits, and Gardiners(?) clay:		
Sand, very fine, gray; clean shells	30	50
Sand, very fine, dark; mica	45	95
Sand, fine, clean, gray	3	98
Sand, very fine, silty, dark-gray; mica	6	104
Sand, silty, very fine, dark-gray, and clay	7	111
Sand, fine, brown	4	115
Sand, very fine, brown	4	119
Sand, very fine, brown, sharp; small amount of coarse sand	4	123
Sand, very fine, brown	3	126
Jameco gravel:		
Sand, coarse, brown; some gravel	49	175

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

Q1747. (4C, 3.8N, 0.7W)

[Drilled by Layne-New York Co., Inc. Altitude about 190 ft. Screened between 235 and 260 ft. Discharge 1,155 gpm with drawdown of 51 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand; gravel; boulders	158	158
Sand, coarse; gravel	105	263
Magothy(?) formation:		
Clay	10	273

Q1815. (4C, 2.4N, 4.4W)

[Drilled by Layne-New York Co., Inc. Altitude about 58 ft. Screened between 240 and 280 ft. Discharge 1,200 gpm with drawdown of 69 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand and gravel	18	18
Sand, red, and gravel	24	42
Sand, dirty, brown	33	75
Sand, brown	13	88
Clay	6	94
Sand, brown	20	114
Magothy(?) formation:		
Clay	2	116
Sand, fine, gray	18	134
Lignite; clay; muddy sand	71	205
Clay	21	226
Sand, fine, brown	58	284
Clay and fine sand	22	306

Q1818. (4B, 1.6N, 0.3W)

[Drilled by Sweeney and Gray Co., Inc. Altitude about 20 ft. Screened between 110 and 118 ft. Discharge 50 gpm with drawdown of 4 ft after 4 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Cellar	10	10
Upper Pleistocene deposits:		
Sand, fine	40	50
Sand and clay(includes "20-foot" clay?)	48	98
Sand, medium	20	118

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

Q1835T. (4C, 2.3N, 2.1W)

[Drilled by Layne-New York Co., Inc. Altitude about 33 ft. Screened between 190 and 218 ft. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand and gravel	59	59
Lignite; black muck	1	60
Sand, light brown	20	80
Sand, muddy, black	11	91
Sand, muddy, dark	1	92
Gardiners(?) clay and Magothy(?) formation:		
Clay and sand	98	190
Magothy(?) formation:		
Sand, white	36	226
Clay, black	37	263
Sand, and white clay	69	332
Raritan formation:		
Clay member:		
Clay, black	16	348

Q1931. (4B, 1.8N, 0.6W)

[Drilled by Layne-New York Co., Inc. Altitude about 8 ft. Screened between 107 and 127 ft. Discharge 540 gpm with drawdown of 4 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill	4	4
Upper Pleistocene deposits:		
Clay, sandy, blue	3	7
Clay, sandy; gravel	4	11
Sand and clay (includes "20-foot" clay?)	37	48
Sand, fine, muddy	18	66
Gardiners clay:		
Clay, sandy, blue	38	104
Jameco gravel:		
Sand, green; fine gravel	28	132
Magothy(?) formation:		
Clay, blue	8	140

Q1957. (4C, 3.3N, 0.6W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 62 ft. Screened between 230 and 282 ft. Discharge 1,600 gpm with drawdown of 33 ft after 2 hr of pumping. Driller's log based on examination of core samples]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Loam	3	3
Upper Pleistocene deposits:		
Sand, coarse, brown; grit; and gravel	85	88
Clay, solid, gray; streaks of sandy clay	13	101
Sand, coarse, gray; grit; some gravel	7	108
Sand, fine to medium, brown	15	123

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

Q1957. (4C, 3.3N, 0.6W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation:		
Sand, fine ,brown; some clay	5	128
Sand, fine to medium, brown	6	134
Clay, solid, gray	9	143
Clay, solid, multicolored; sandy clay in layers	10	153
Sand, fine, light-brown	16	169
Sand, coarse, brown	11	180
Clay, sandy, multicolored	4	184
Sand, fine, brown	61	245
Sand, medium to coarse, brown; some grit	9	254
Clay, solid, light-gray	3	257
Sand, fine, brown	29	286
Clay, sandy, fine, multicolored	11	297
Clay, solid, brown	2	299
Clay, solid, gray	2	301

Q1958. (5C, 1.9N, 3.7W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 47 ft. Screened between 380 and 432 ft. Discharge 1,600 gpm with drawdown of 51 ft after 6 hrs of pumping. Driller's log based on examination of core samples]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Fill	2	2
Upper Pleistocene deposits:		
Sand, coarse, brown; grit and gravel	50	52
Sand, medium to coarse, brown; streaks of sandy clay	41	93
Magothy(?) formation:		
Sand, fine, brown; streaks of sandy clay	9	102
Sand, fine, brown	11	113
Clay, sandy, fine, multicolored	5	118
Sand, fine, gray	27	145
Clay, sandy, fine, gray	11	156
Clay, solid, gray	10	166
Clay, solid; lignite and sandy clay, in layers	9	175
Sand, fine, gray; layers of solid clay	41	216
Clay, solid, gray; streaks of sandy clay	5	221
Sand, fine, gray; streaks of lignite and pyrite	16	237
Clay, sandy, fine, gray	11	248
Sand, fine, gray; streaks of solid clay	9	257
Sand, multicolored; streaks of clay	8	265
Sand, fine, brown	38	303
Clay, solid, gray; streaks of sandy clay	28	331
Clay, sandy, fine, gray	16	347
Sand, fine, gray and some clay	6	353
Sand, fine, pink; some clay	24	377
Clay, multicolored; sandy clay and lignite in layers	6	383
Sand, fine, pink	14	397
Sand, medium to coarse, gray	12	409
Sand, coarse, gravel; some clay	25	434
Raritan formation:		
Clay member:		
Clay, solid, gray	8	442

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

Q1982T. (5C, 4.0N, 3.9W)

[Drilled by Layne-New York Co., Inc. Altitude about 77 ft. Abandoned, no screen, Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand and gravel	99	99
Magothy(?) formation:		
Clay, sandy	9	108
Sand, fine, white and brown	28	136
Clay and sand	23	159
Sand, fine, white; some clay	35	194
Sand, medium	21	215
Clay	4	219
Sand and clay	38	257
Clay	5	262
Sand and clay	22	284
Sand	12	296
Clay, black, and various colors	33	329
Sand, coarse, light-gray; fine gravel	35	364
Raritan formation:		
Clay member:		
Clay, grayish-blue	29	393

Q1984T. (4C, 1.9N, 0.3W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 45 ft. Screened between 272 and 303 ft. Discharge 170 gpm with drawdown of 75 ft after 8 hrs of pumping. Driller's log based on examination of core samples]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Loam and fill	3	3
Upper Pleistocene deposits:		
Sand, coarse, brown; grit and gravel	65	68
Sand, fine to medium, brown	12	80
Magothy(?) formation:		
Clay, sandy, fine, gray	6	86
Sand, fine, gray; gray solid and sandy clay in streaks	11	97
Clay, solid, gray	5	102
Sand, fine to medium, brown	10	112
Clay, sandy, fine, gray; streaks of lignite	7	119
Sand, fine, clayey, gray, mica; layers of solid clay and lignite	11	130
Clay, sandy, fine, gray; lignite; layers of solid clay	6	136
Sand, medium, gray; streaks of solid clay; lignite	10	146
Sand, medium, brown; some clay; lignite	6	152
Clay, sandy, gray; mica; layers of solid clay	5	157
Sand, fine, gray; mica; streaks of sandy clay	5	162
Sand, fine, brown; layers of lignite	6	168
Clay, solid, gray; layers of lignite and sandy clay	8	176
Sand, fine, brown; mica; layers of clay and lignite	12	188
Sand, medium, brown; mica	7	195
Sand, coarse, brown; some clay; layers of lignite	8	203
Sand, fine, brown; mica; some clay	7	210
Clay, solid, gray	11	221
Sand, fine, gray; mica; some clay	14	235
Sand, fine to medium, gray	16	251
Sand, fine, gray; streaks of clay and pyrite	5	256
Clay, solid, gray	5	261
Sand, fine to medium, gray	11	272
Sand, coarse, gray; some clay	14	286
Clay, solid, gray; layers of sandy clay	5	291

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

Q1984T. (4C, 1.9N, 0.3W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation—Continued		
Sand, fine to medium, gray; streaks of lignite	30	321
Clay, solid, gray	11	332
Sand, fine, gray, in layers; some clay and solid clay	14	346
Clay, solid, multicolored	17	363
Clay, solid, light-gray; streaks of sandy clay	4	367
Grits, sandy, medium, brown; gravel; some clay	14	381
Raritan formation:		
Clay member:		
Clay, solid, hard, red and gray	20	401

Q1985T. (4C, 3.6N, 1.4W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 145 ft. Screened between 171 and 202 ft. Discharge 104 gpm. Driller's log based on examination of core samples]

	Thickness (feet)	Depth (feet)
Recent and upper Pleistocene deposits:		
Fill and boulders	25	25
Upper Pleistocene deposits:		
Sand, coarse, brown; large gravel; boulders; some clay	76	101
Sand, coarse, brown; gravel; large stones	44	145
Sand, fine, brown; mica	17	162
Clay, gray	11	173
Sand, medium, brown	6	179
Sand, coarse, brown; grit and gravel	28	207
Magothy(?) formation:		
Clay, solid, gray	7	214
Clay, solid, brown	5	219
Sand, fine, gray; mica	15	234
Sand, medium, brown; streaks of solid clay	3	237
Sand, medium, brown	14	251
Clay, solid, multicolored; medium brown sand, in layers	9	260
Sand, medium, brown	7	267
Sand, coarse; layers of solid and sandy clay	5	272
Sand, medium to coarse, brown; some clay	10	282
Sand, fine, brown; some clay; layers of solid clay	18	300

Q1997. (4C, 3.2N, 0.9W)

[Drilled by Layne-New York Co., Inc. Altitude about 57 ft. Screened between 82 and 112 ft. Discharge 1,400 gpm with drawdown of 25 ft after 8 hr of pumping. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, fine	10	10
Sand	10	20
Sand and gravel	10	30
Sand, coarse	10	40
Sand and gravel	20	60
Sand	10	70
Sand, coarse	10	80
Sand, fine	15	95
Magothy(?) formation:		
Clay, in streaks	17	112

654861—62——13

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

Q1999T. (4C, 2.2N, 1.0W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 35 ft. Screened between 177 and 209 ft. Discharge 200 gpm with drawdown of 8 ft after 8 hr of pumping. Driller's log based on examination of core samples]

	Thickness (feet)	Depth (feet)
Recent deposits:		
Topsoil and loam	5	5
Upper Pleistocene deposits:		
Sand, medium to coarse, brown; grit	70	75
Gardiners clay:		
Clay, hard, blue	7	82
Clay, hard, solid, gray; streaks of lignite	34	116
Sand, medium to coarse, gray; solid multicolored clay, in layers	2	118
Magothy(?) formation:		
Clay, solid, brown	12	130
Clay, solid, brown; layers of fine brown sand and lignite	49	179
Sand, fine to medium gray; lignite	29	208
Sand, fine to medium, gray; grit; streaks of clay and lignite	24	232
Clay, solid, black; lignite	5	237
Clay, sandy, gray; solid clay and lignite in layers	12	249
Sand, fine, gray; some clay; streaks of solid clay	5	254
Clay, solid, gray; layers of sandy clay and lignite	21	275
Sand, fine, gray; layers of solid gray clay	9	284
Sand, medium, gray; layers of solid clay	5	289
Sand, fine, gray; clay; mica; layers of lignite	15	304
Sand, fine, gray; layers of solid clay; lignite; some large gravel	6	310
Clay, solid, gray; layers of sandy clay and lignite	6	316
Sand, fine, gray, mica; layers of solid clay	7	323
Sand, medium, gray; some grit	13	336
Sand, medium, gray; some grit	4	340
Raritan formation:		
Clay member:		
Clay, solid, gray; streaks of sandy clay	16	356
Clay, solid, gray	11	367
Clay, solid, multicolored	34	401

Q2003T. (4C, 2.3N, 0.4W)

[Drilled by Layne-New York Co., Inc. Altitude about 55 ft. Abandoned, no screen. Driller's log]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, brown	40	40
Sand, dirty, red	20	60
Sand and gravel	44	104
Magothy(?) formation:		
Sand, muddy, white	40	144
Clay, gray	2	146
Clay, sandy	25	171
Sand and black wood	11	182
Sand and gravel	10	192
Clay, sandy	20	212
Sand and gravel	15	227

TABLE 12.—*Logs of selected wells in southern Nassau and southeastern Queens Counties*—Continued

Q2003T. (4C, 2.3N, 0.4W)—Continued

	Thickness (feet)	Depth (feet)
Magothy(?) formation—Continued		
Clay	1	228
Sand and gravel	3	231
Clay	1	232
Sand and gravel	5	237
Sand	8	245
Sand and gravel	5	250
Sand and streaks of clay	10	260
Sand and gravel; some clay	15	275
Sand and gravel	8	283
Clay	2	285
Sand; gravel; clay	30	315
Sand; gravel; clay	9	324
Clay, tough, white	12	336

Q2026T. (5C, 0.9N, 3.2W)

[Drilled by C. W. Lauman and Co., Inc. Altitude about 40 ft. Screened between 397 and 431 ft. Discharge 1,250 gpm with drawdown of 45 ft after 4 hr of pumping. Driller's log based on examination of core samples]

	Thickness (feet)	Depth (feet)
Upper Pleistocene deposits:		
Sand, coarse, brown; grit and gravel	88	88
Magothy(?) formation:		
Clay, solid, gray; streaks of sandy clay	5	93
Clay, sandy, fine, gray; streaks of solid clay and fine sand	15	108
Lignite; streaks of solid and sandy clay	5	113
Sand, fine, brown	20	133
Sand, fine, gray, in layers; sandy and solid clay; lignite	15	148
Sand, fine, gray; streaks of solid clay; lignite	10	158
Clay, solid, gray	10	168
Sand, fine, gray; and clay	10	178
Sand, fine, gray	17	195
Clay, sandy and solid, gray	10	205
Sand, fine, gray	18	223
Sand, fine, gray; sandy and solid clay; lignite	10	233
Sand, fine, gray; clay	10	243
Sand, fine, gray	15	258
Sand, fine, gray; streaks of solid clay; lignite	5	263
Sand, fine, gray; clay; mica	17	280
Sand, fine to medium, gray	8	288
Sand, medium to coarse, gray	10	298
Clay, solid, gray	30	328
Sand, medium to coarse, gray; clay	5	333
Clay, solid, gray	5	338
Sand, medium to coarse, gray; streaks of clay	20	358
Sand, fine, gray; clay; mica	26	384
Clay, sandy, fine, gray; lignite	20	404
Sand, coarse, gray; some grit	32	436
Clay, solid, multicolored	6	442
Clay, solid, gray; gravel; sandy clay	6	448
Clay, solid, hard, gray	2	450

TABLE 13.—*Chloride concentrations in water from outpost wells and other selected wells in southern Nassau and southeastern Queens Counties*

N1379. (5B, 4.1N, 2.5W) [1]

[Screened in Jameco gravel at depth of 175 to 196 ft. Analyses by Nassau County Dept. of Public Works, except as indicated]

Date sampled	Chloride (ppm)	Date sampled	Chloride (ppm)
1952		*1955*	
Nov. 21	[2] 5	Mar. 3	2
		Apr. 18	4
1953		May 17	4
Feb. 18	[2] 6	June 13	3
Apr. 11	7	Aug. 3	5
May 15	6	Sept. 7	4
June 17	4	Oct. 3	7
Aug. 15	5	Dec. 29	4
Sept. 14	[2] 6		
Oct. 21	5	*1956*	
Nov. 18	5	Feb. 3	5
Dec. 15	4	Mar. 30	5
		May 7	2
1954		June 7	4
Jan. 19	4	July 2	3
Mar. 3	4		
Apr. 6	3	*1957*	
May 12	4	Feb. 14	4
June 7	6	Mar. 14	4
July 9	4	Apr. 12	5
Aug. 12	4		
Oct. 25	3		
Dec. 15	3		

N1627. (5B, 4.9N, 3.0W)

[Screened in upper Pleistocene deposits at depth of 17 to 19 ft. Analyses by Nassau County Dept. of Public Works]

1951		*1951*—Continued	
Mar. 2	18	May 26	18
31	17	June 30	36
May 5	20	July 30	16

N1628. (5B, 3.6N, 3.0W)

[Screened in upper Pleistocene deposits at depth of 17 to 19 ft. Analyses by Nassau County Dept. of Public Works]

1951		*1951*—Continued	
Mar. 2	22	June 30	28
31	26	July 30	28
May 5	32		
26	28	*1953*	
		November	[2] 24

Footnotes at end of table.

TABLE 13.—*Chloride concentrations in water from outpost wells and other selected wells in southern Nassau and southeastern Queens Counties*—Continued

N2790. (6B, 3.5N, 4.3W)

[Screened in Magothy(?) formation at depth of 538 to 560 ft. Analyses by U.S. Geol. Survey, except as indicated]

Date sampled	Chloride (ppm)	Date sampled	Chloride (ppm)
1949		*1953*—Continund	
Dec. 15	608	Apr. 16	6
Dec. 22	36	June 15	10
		Sept. 9	6
1950		Dec. 8	6
Jan. 10	32		
Feb. 3	26	*1954*	
Mar. 24	28	Feb. 5	8
Apr. 6	36	Apr. 12	6
June 28	17	May 12	4
Nov. 17	11	June 10	4
		June 24	12
1951		July 19	5
Feb. 23	11	Aug. 6	8
Apr. 27	10	Aug. 26	7
June 1	8	Sept. 28	12
June 27	8		
Aug. 2	7	*1956*	
Aug. 31	7	May 4	[3] 5
Sept. 27	7	June 13	[3] 4
Oct. 31	6	July 10	[3] 5
Nov. 27	7	Oct. 15	6
1952		*1957*	
Nov. 19	7	Mar. 22	[3] 4
		Apr. 18	[3] 5
1953		Sept. 20	[3] 6
Feb. 19	8	Nov. 19	[3] 6
Mar. 12	6		

N3707. (5B, 4.2N, 1.8W)

[Screened in upper Pleistocene deposits at depth of 11 to 13 ft. Analyses by Nassau County Dept. of Public Works]

Date sampled	Chloride (ppm)	Date sampled	Chloride (ppm)
1951		*1951*—Continued	
Mar. 2	12	July 30	24
Mar 31	20		
May 5	24	*1953*	
May 26	24	Nov. 9	18
June 30	24		

Footnotes at end of table.

TABLE 13.—*Chloride concentrations in water from outpost wells and other selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3708. (5B, 4.4N, 2.6W)

[Screened in upper Pleistocene deposits at depth of 16 to 18 ft. Analyses by Nassau County Dept. of Public Works, except as indicated]

Date sampled	Chloride (ppm)	Date sampled	Chloride (ppm)
1951		*1953*	
Mar. 2	12	Nov. 9	[2] 124
Mar. 31	138		
May 5	14	*1955*	
May 26	106	July 22	[2] 450
June 30	90		
July 30	20		

N3709. (5B, 4.3N, 2.3W)

[Screened in upper Pleistocene deposits at depth of 17 to 19 ft. Analyses by Nassau County Dept. of Public Works, except as indicated]

Date sampled	Chloride (ppm)	Date sampled	Chloride (ppm)
1951		*1953*	
Mar. 2	6	Nov. 9	[2] 4, 200
Mar. 31	36		
May 5	158	*1955*	
May 26	366	July 25	[2] 3, 850
June 30	480		
July 30	515		

N3710. (5B, 3.8N, 2.9W)

[Screened in upper Pleistocene deposits at depth of 16 to 18 ft. Analyses by Nassau County Dept. of Public Works, except as indicated]

Date sampled	Chloride (ppm)	Date sampled	Chloride (ppm)
1951		*1951*—Continued	
Mar. 31	14	July 30	102
May 5	60		
May 26	70	*1953*	
June 30	44	Dec. 17	[2] 24

N3711. (5B, 4.6N, 2.7W)

[Screened in upper Pleistocene deposits at depth of 16 to 18 ft. Analyses by Nassau County Dept. of Public Works, except as indicated]

Date sampled	Chloride (ppm)	Date sampled	Chloride (ppm)
1951		*1953*	
Mar 31	7	Nov. 9	[2] 12
May 5	14		
May 26	14	*1955*	
June 30	10	July 19	[2] 6
July 30	10		

See footnotes at end of table.

TABLE 13.—*Chloride concentrations in water from outpost wells and other selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3861. (5B, 3.3N, 3.5W)

[Screened in Magothy(?) formation at depth of 522 to 533 ft. Analyses by Nassau County Dept. of Public Works except as indicated]

Date sampled	Chloride (ppm)
1952	
Mar. 31	15,500
Oct. 10	[2] 15,600
1953	
Feb. 19	[2] 15,800
May 13	16,000
June 15	16,000
July 21	17,000
Aug. 15	16,000
Sept. 15	[2] 16,200
Oct. 22	16,000
Nov. 2	15,800
Nov. 17	16,000
Dec. 7	16,600
Dec. 17	16,000
1954	
Jan. 21	16,400
Feb. 5	16,200
Mar. 5	16,400
Apr. 7	16,000
May 13	16,000
June 8	16,400
July 9	16,000
Aug. 12	16,000
Oct. 25	16,400
1954—Continued	
Dec, 16	16,000
1955	
Mar. 7	16,000
Apr. 19	16,200
May 19	16,200
June 14	16,100
Aug. 5	16,000
Sept. 12	16,000
Oct. 5	16,400
November	16,200
1956	
Jan. 4	15,800
Feb. 7	16,000
Apr. 5	16,000
May 1	16,000
June 11	15,800
July 5	15,900
1957	
Feb. 18	16,400
Mar. 18	16,500
Apr. 16	16,200
Sept. 17	16,100
Nov. 13	16,700

N3862. (5B, 1.5N, 3.7W)

[Screened in Magothy(?) formation at depth of 296 to 306 ft. Analyses by Nassau County Dept. of Public Works, except as indicated]

Date sampled	Chloride (ppm)
1952	
Apr. 19	[2] 1,900
Oct. 31	[2] 1,920
Nov. 24	[2] 1,800
1953	
Apr. 14	2,150
May 18	2,000
June 19	2,200
July 21	2,000
Aug. 12	[2] 2,300
Sept. 8	[2] 2,100
Oct. 23	2,200
Nov. 2	1,930
Nov. 17	[2] 2,000
Dec. 7	1,960
Dec. 18	1,920
1954	
Jan. 21	2,000
Feb. 5	[2] 2,100
Mar. 5	1,920
Apr. 7	1,920
May 13	1,920
June 8	2,040
July 9	1,920
Oct. 27	2,080
1954—Continued	
Dec. 17	1,880
1955	
Mar. 7	1,920
Apr. 19	1,920
May 20	1,920
June 14	1,920
Aug. 4	1,960
Sept. 12	1,960
Oct. 10	2,600
Nov. 22	1,920
1956	
Jan. 5	1,920
Feb. 8	1,920
Apr. 4	1,920
May 2	1,920
June 12	1,960
July 6	1,880
1957	
Feb. 19	1,920
Mar. 20	1,920
Apr. 17	1,920
Sept. 18	1,920
Nov. 15	2,040

See footnotes at end of table.

TABLE 13.—*Chloride concentrations in water from outpost wells and other selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3864. (5B, 4.0N, 2.5W)

[Screened in Magothy(?) formation at depth of 459 to 470 ft. Analyses by Nassau County Dept. of Public Works, except as indicated]

Date sampled	Chloride (ppm)	Date sampled	Chloride (ppm)
1952		*1955*	
May 2	[2] 4	Mar. 3	3
Oct. 24	[2] 3	Apr. 18	5
Nov. 20	[2] 3	May 17	3
		May 7	4
1953		June 7	3
Feb. 18	[2] 6	July 2	4
Apr. 11	8	June 13	3
May 15	6	Sept. 7	5
June 17	5	Oct. 3	2
Aug. 14	5	Dec. 29	5
Sept. 14	[2] 8		
Oct. 20	5	*1956*	
Nov. 16	4	Feb. 3	5
Dec. 15	4	Mar. 30	4
1954		*1957*	
Jan. 19	6	Feb. 14	5
Mar. 3	4	Mar. 14	6
Apr. 6	4	Apr. 12	5
May 12	4	Nov. 8	5
June 7	6		
July 9	3		
Aug. 12	3		
Oct. 25	4		
Dec. 15	2		

N3865. (6B, 2.9N, 2.5W)

[Screened in Magothy(?) formation at depth of 555 to 565 ft. Analyses by Nassau County Dept. of Public Works, except as indicated]

Date sampled	Chloride (ppm)	Date sampled	Chloride (ppm)
1952		*1955*	
July 31	[2] 7	Mar. 4	3
Oct. 21	[2] 3	Apr. 20	5
Nov. 18	[2] 3	May 18	5
		June 15	4
1953		Aug. 2	4
Feb. 18	[2] 8	Sept. 9	4
May 16	8	Oct. 11	6
June 19	6	Nov. 23	5
July 16	[2] 8	Dec. 28	6
Aug. 20	5		
Sept. 16	[2] 8	*1956*	
Oct. 7	[2] 8	Feb. 8	4
Oct. 23	5	Apr. 5	5
Nov. 18	6	May 4	5
Dec. 18	4	June 13	5
		July 10	4
1954			
Jan. 22	6	*1957*	
Mar. 6	5	Feb. 21	5
Apr. 8	4	Mar. 22	5
May 14	5	Apr. 18	6
June 5	5	Sept. 20	7
July 8	4	Nov. 19	7
Aug. 10	6		
Oct. 23	3		
Dec. 20	5		

See footnotes at end of table.

TABLE 13.—*Chloride concentrations in water from outpost wells and other selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3866. (5B, 3.7N, 1.5W)

[Screened in Magothy(?) formation at depth of 400 to 412 ft. Analyses by Nassau County Dept. of Public Works, except as indicated]

Date sampled	Chloride (ppm)	Dated sampled	Chloride (ppm)
1952		*1955*	
Sept. 2	[2] 7	Mar. 4	4
Oct. 14	[2] 3.5	Apr. 20	4
Nov. 20	[2] 3	May 20	4
		June 15	4
1953		Aug. 2	5
May 15	6	Sept. 9	4
June 17	5	Oct. 11	7
Aug. 20	5	Nov. 23	5
Sept. 9	[2] 8		
16	[2] 8	*1956*	
Oct. 21	5	Jan. 5	3
Nov. 18	4	Feb. 8	4
Dec. 16	5	Apr. 5	3
		May 2	3
1954		June 12	3
Jan. 22	4		
Mar. 4	5	*1957*	
Apr. 8	3	Feb. 20	3
May 14	3	Mar. 21	5
June 5	4	Apr. 19	4
July 8	3		
Aug. 12	5		
Oct. 26	5		
Dec. 17	2		

N3867. (5B, 4.6N, 2.7W)

[Screened in Magothy(?) formation at depth of 506 to 517 ft. Analyses by Nassau County Dept. of Public Works, except as indicated]

Date sampled	Chloride (ppm)	Dated sampled	Chloride (ppm)
1952		*1954*—Continued	
Sept. 18	[2] 4	Dec. 15	3
Dec. 11	[2] 3.5		
		1955	
1953		Mar. 3	4
Feb. 20	[2] 6	Apr. 18	5
Mar. 12	[2] 6	May 19	4
Apr. 15	[2] 4	June 13	5
June 15	[2] 8	Aug. 3	4
July 20	4	Sept. 8	5
Aug. 18	5	Nov.	7
Sept. 9	[2] 8	Dec. 30	3
Sept. 14	[2] 8		
Oct. 21	5	*1956*	
Nov. 16	5	Feb. 6	5
Dec. 16	4	Apr. 2	4
		Apr. 30	5
1954		June 8	4
Jan. 19	4	July 3	4
Mar. 4	4		
Apr. 6	4	*1957*	
May 12	5	Mar. 15	5
June 7	7	Apr. 15	4
July 10	3	Sept. 16	4
Aug. 11	5	Nov. 12	4
Oct. 26	3		

See footnotes at end of table.

TABLE 13.—*Chloride concentrations in water from outpost wells and other selected wells in southern Nassau and southeastern Queens Counties*—Continued

N3932. (5B, 3.3N, 3.5W)

[Screened in Jameco gravel at depths of 172 to 176 ft. Analyses by Nassau County Dept. of Public Works except as indicated]

Date sampled	Chloride (ppm)	Date sampled	Chloride (ppm)
1952		*1954*—Continued	
Nov. 24	[2] 7	Oct. 27	5
		Dec. 16	[2] 7
1953			
Apr. 18	7	*1955*	
May 13	6	Mar. 7	2
May 18	6	Apr. 19	5
June 15	6	May 19	4
June 20	7	June 14	3
July 20	5	Sept. 12	4
Aug. 12	3	Oct. 15	5
Aug. 18	5	Nov. 21	5
Sept. 16	[2] 6		
Oct. 22	5	*1956*	
Nov. 2	6	Jan. 4	2
Nov. 17	4	Feb. 7	3
Dec. 7	4	Apr. 3	3
Dec. 17	4	May 1	6
		June 11	4
1954		July 5	5
Jan. 21	4		
Feb. 5	4	*1957*	
Mar. 5	4	Feb. 18	5
Apr. 7	4	Mar. 18	7
May 13	6	Apr. 16	4
June 8	5	Sept. 17	5
July 9	7	Nov. 13	5
Aug. 12	5		

[Drive-point well, 11 ft northwest of well N3932, screened in upper Pleistocene deposits at depth of 11 to 13 ft. Analyses by U.S. Geol. Survey]

1952		*1953*—Continued	
Nov. 24	7	Dec. 7	106
1953		*1955*	
Nov. 2	84	July 8	500

See footnotes at end of table.

TABLE 13.—*Chloride concentrations in water from outpost wells and other selected wells in southern Nassau and southeastern Queens Counties*—Continued

N4026. (5B, 2.6N, 1.8W)

[Screened in Jameco gravel at depth of 149 to 153 ft. Analyses by Nassau County Dept. of Public Works, except as indicated]

Date sampled	Chloride (ppm)	Dated sampled	Chloride (ppm)
1952		*1954*—Continued	
Nov. 21	[2] 5	Apr. 8	4
		May 14	3
1953		June 8	5
Feb. 23	[2] 6	July 8	6
Apr. 14	6	July 19	[2] 8
May 16	5	Aug. 10	3
June 18	5	Oct. 27	5
July 20	4	Dec. 17	4
Aug. 19	5		
Sept. 16	[2] 10	*1955*	
Oct. 22	5	Mar. 7	3
Nov. 18	6	Apr. 20	4
Dec. 17	4	May 20	3
		June 15	4
1954		Aug. 4	11
Jan. 22	5	Sept. 9	11
Mar. 5	5	Oct. 11	5

N4149. (7B, 4.7N, 2.5W)

[Screened in Magothy(?) formation at depth of 546 to 562 ft. Analyses by U.S. Geol. Survey]

Date sampled	Chloride (ppm)	Dated sampled	Chloride (ppm)
1953		*1955*	
June 8	7	Mar. 3	3
Sept. 29	6		
Sept. 30	2. 5	*1956*	
		Oct. 10	6
1954			
Apr. 12	6	*1957*	
May 10	6	June 21	6
June 9	6		
July 7	6		

N4150. (7B, 4.3N, 3.6W)

[Screened in Magothy(?) formation at depth of 729 to 745 ft. Analyses by U. S. Geol. Survey, except as indicated]

Date sampled	Chloride (ppm)	Dated sampled	Chloride (ppm)
1953		*1954*—Continued.	
Nov. 19	[4] 8	July 7	6
1954		*1955*	
Jan. 19	8	Mar. 3	6
Feb. 2	4. 2		
Apr. 12	8	*1956*	
May 10	6	Oct. 10	6

See footnotes at end of table.

TABLE 13.—*Chloride concentrations in water from outpost wells and other selected wells in southern Nassau and southeastern Queens Counties*—Continued

N4213. (5B, 4.8N, 3.0W)

[Screened in Jameco gravel at depth of 130 to 134 ft. Analyses by Nassau County Dept. of Public Works, except as indicated]

Date sampled	Chloride (ppm)	Date sampled	Chloride (ppm)
1953		*1955*—Continued.	
Aug. 18	5	May 19	5
Sept. 14	[2] 8	June 13	4
Sept. 16	[2] 8	Aug. 3	5
Oct. 21	5	Sept. 8	4
Nov. 16	5	Oct	3
Dec. 16	4	Nov. 18	5
		Dec. 30	5
1954			
Jan. 19	4	*1956*	
Mar. 4	5	Feb. 6	4
Apr. 6	4	Apr. 2	3
May 12	5	Apr. 30	4
June 7	6	June 8	4
July 10	24	July 3	5
Aug. 11	17		
Oct. 26	5	*1957*	
Dec. 15	2	Feb. 15	4
		Mar. 15	6
1955		Apr. 15	5
Mar. 3	3	Sept. 16	5
Apr. 18	4	Nov. 12	5

N6241. (6B, 3.5N, 4.3W)

[Drive-point well, 6 ft northeast of well N2790, screened in upper Pleistocene deposits at depth of 37 to 39 ft. Analyses by U.S. Geol. Survey]

Date sampled	Chloride (ppm)	Date sampled	Chloride (ppm)
1952		*1953*—Continued	
June 12	32	Dec. 8	40
Nov. 21	30		
		1955	
1953		July 8	45
Nov. 4	42		

N6242. (5B, 3.3N, 3.5W)

[Drive-point well, 1½ ft northwest of well N3861, screened in upper Pleistocene deposits at depth of 10 to 12 ft. Analyses by U.S. Geol. Survey]

Date sampled	Chloride (ppm)	Date sampled	Chloride (ppm)
1952		*1953*	
Apr. 11	14	Nov. 2	1,300
June 12	8	Dec. 7	2,700
Nov. 24	8		
		1955	
		July 8	240

TABLE 13.—*Chloride concentrations in water from outpost wells and other selected wells in southern Nassau and southeastern Queens Counties*—Continued

N6244. (5B, 1.5N, 3.7W)

[Drive-point well, 10 ft south of well N3862, screened in upper Pleistocene deposits at depth of 21 to 23 ft. Analyses by U.S. Geol. Survey]

Date sampled	Chloride (ppm)	Date sampled	Chloride (ppm)
1952		*1953*—Continued	
Nov. 24	22	Dec. 7	12
Nov. 26	10	*1955*	
1953		July 8	16
Nov. 4	74		

N6245. (6B, 2.9N, 2.5W)

[Drive-point well, 20 ft southwest of well N3865, screened in Recent deposits at depth of 8 to 10 ft. Analyses by U.S. Geol. Survey]

1952		*1952*—Continued	
July 13	750	July 31	700

N6246. (5B, 4.0N, 2.5W)

[Drive-point well, 18.5 ft north of well N3864, screened in upper Pleistocene deposits at depth of 7 to 9 ft. Analyses by U.S. Geol. Survey]

1952		*1953*	
Nov. 18	6	Nov. 4	12
		Dec. 7	16

Q129. (4B, 1.3N, 0.4W)

[Screened in upper Pleistocene deposits at depth of 99 to 120 ft. Analyses by U.S. Geol. Survey]

1939		*1944*	
Aug. 3	77	Sept 18	200
1940		*1949*	
Aug. 15	100	Aug. 29	1, 092
1941		*1953*	
Sept. 10	138	Sept. 2	1, 500
1942			
Aug. 31	310		

Q131. (4B, 1.2N, 0.2W)

[Screened in upper Pleistocene deposits at depth of 97 to 118 ft. Analyses by U.S. Geol. Survey]

1939		*1942*	
Aug. 3	410	Aug. 31	140
1940		*1944*	
Aug. 15	420	Sept. 18	360
1941			
Sept. 10	365		

TABLE 13.—*Chloride concentrations in water from outpost wells and other selected wells in southern Nassau and southeastern Queens Counties*—Continued

Q559. (4C, 0.5N, 3.2W)

[Screened in Jameco gravel at depth of 174 to 213 ft. Analyses by Jamaica Water Supply Co.]

Date sampled	Chloride (ppm)	Dated sampled	Chloride (ppm)
1933		*1941*—Continued	
April	4.6	August	24
July	4.4		
December	4.2	*1942*	
		January	28
1934		February	32
June	4.0	July	37
July	4.6	August	35
August	5.0	October	35
November	4.6	December	36
1935		*1943*	
January	4.6	January	37
May	5.0	June	39
June	5.2	August	40
August	6.2	September	35
October	6.8	December	40
1936		*1944*	
January	8.2	February	42
June	9.0	June	46
July	11	August	48
September	12	September	50
December	14		
		1945	
1937		January	54
February	13	April	48
July	15	July	49
August	19	August	48
September	15	November	51
October	22		
		1946	
1938		January	60
April	20	March	64
July	22	May	71
August	22	July	72
1939		*1947*	
May	22	January	84
July	23	June	103
August	24	July	89
		August	88
1940			
January	14	*1948*	
July	22	July	128
August	24	August	119
September	22	October	109
December	19		
		1949	
1941		June	120
January	23	August	113
June	23	October	116

See footnotes at end of table.

TABLE 13.—*Chloride concentrations in water from outpost wells and other selected wells in southern Nassau and southeastern Queens Counties*—Continued

Q559. (4C, 0.5N, 3.2W)—Continued

Date sampled	Chloride (ppm)	Dated sampled	Chloride (ppm)
1950		*1951*	
March	159	May	162
May	137	June	160
July	144	July	164
August	138	August	165
October	138	September	[5] 159

Q1383. (4B, 1.3N, 0.2W)

[Screened in Magothy(?) formation at depth of 230 to 250 ft. Analyses by U.S. Geol. Survey]

1949		*1953*	
Aug. 30	6, 400	Sept. 2	7, 500
1952			
Sept. 9	7, 100		

Q1630. (4B, 0.3N, 3.0W)

[Screened in the Jameco gravel at depth of 159 to 175 ft. Analyses by Water Service Laboratories, Inc., except as indicated]

1950		*1953*	
Mar. 3	18, 100	July 3	18, 300
Apr. 4	17, 900		
		1955	
1952		Apr. 7	[2] 16, 200
Oct. 3	18, 000		
		1956	
		June 6	[2] 17, 400

[1] Map coordinates: First number and letter indicate the grid square on plate 1. Remainder is distance in miles north and west of SE. cor. of grid square.
[2] Analysis by U.S. Geol. Survey.
[3] Analysis by Nassau County Department of Public Works.
[4] Analysis by C. W. Lauman and Co., Inc.
[5] Last determination. Well abandoned and filled in.

INDEX

○