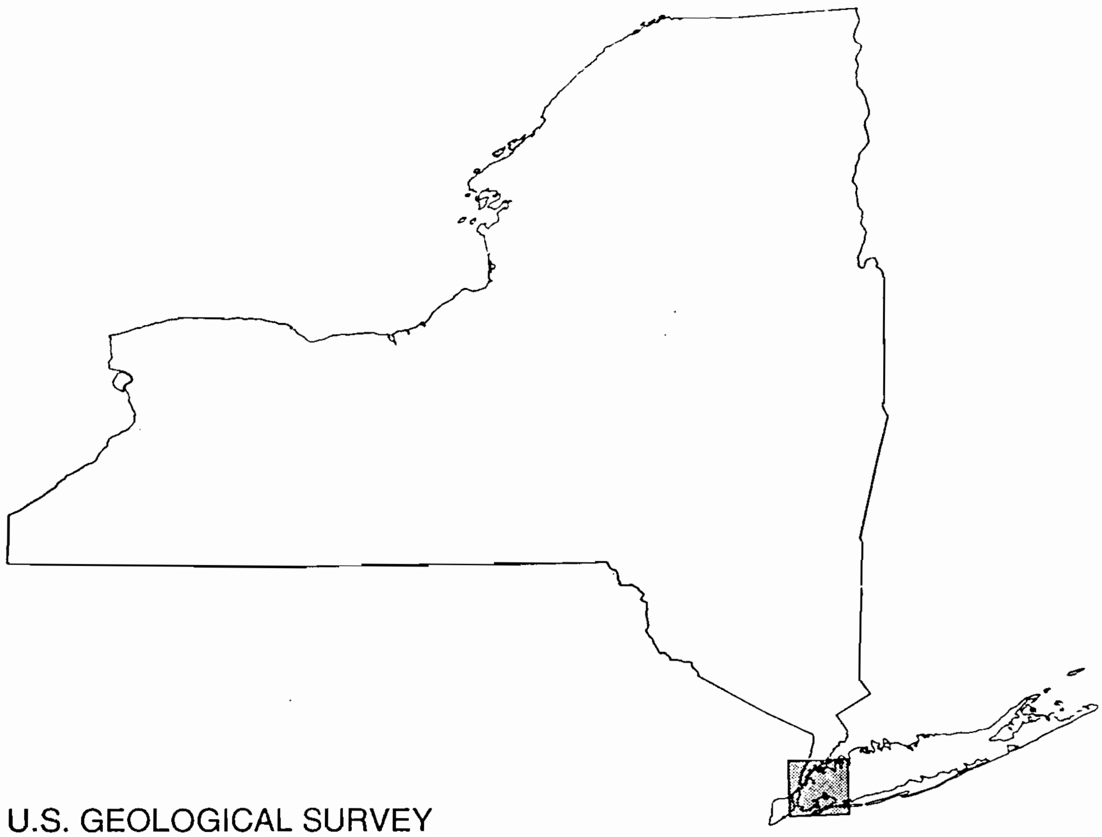
Ground-Water Resources of Kings and Queens Counties, Long Island, New York



U.S. GEOLOGICAL SURVEY
Open-File Report 92-76

Prepared in cooperation with
NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION
and
NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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By Herbert T. Buxton and Peter K. Shernoff

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	*By*	*To Obtain*
	Length	
inch (in.)	25.40	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	2.590	square kilometer
acre	0.4047	hectare
	Volume	
gallon (gal)	3.785	liter
million gallons (Mgal)	3,785	cubic meter
billion gallons (Bgal)	3,785,000	cubic meter
	Flow	
inch per year (in/yr)	25.4	millimeter per year
foot per day (ft/d)	0.3048	meter per day
foot per mile (ft/mi)	0.1894	meter per kilometer
million gallons per day (Mgal/d)	0.04381	cubic meter per second
million gallons per day per square mile [(Mgal/d)/mi^2]	0.01692	cubic meter per second per square kilometer

Water Density

grams per cubic centimeter (g/cm^3)

Chemical Concentration

milligrams per liter (mg/L)

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

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ABSTRACT

The aquifers beneath Kings and Queens Counties supplied an average of more than 120 Mgal/d (million gallons per day) for industrial and public water supply during 1904-47, but this pumping caused saltwater intrusion and a deterioration of water quality that led to the cessation of pumping for public supply in Kings County in 1947 and in western Queens County in 1974. Since the cessation of pumping in Kings and western Queens Counties, ground-water levels have recovered steadily, and the saltwater has partly dispersed and become diluted. In eastern Queens County, where pumpage for public supply averages 60 Mgal/d, all three major aquifers contain a large cone of depression. The saltwater-freshwater interface in the Jameco-Magothy aquifer already extends inland in southeastern Queens County and is moving toward this cone of depression. The pumping centers' proximity to the north shore also warrants monitoring for saltwater intrusion in the Flushing Bay area.

Urbanization and development on western Long Island since before the turn of this century have caused significant changes in the ground-water budget (total inflow and outflow) and patterns of movement. Some of the major causes are: (1) intensive pumping for industrial and public supply; (2) paving of large land-surface areas; (3) installation of a vast network of combined (storm and sanitary) sewers; (4) leakage from a water-supply-line network that carries more than 750 Mgal/d; and (5) burial of stream channels and extensive wetland areas near the shore.

Elevated nitrate and chloride concentrations throughout the upper glacial (water-table) aquifer indicate widespread contamination from land surface. Localized contamination in the underlying Jameco-Magothy aquifer is attributed to downward migration in areas of hydraulic connection between aquifers where the Gardiners Clay is absent. A channel eroded through the Raritan confining unit provides a pathway for migration of surface contaminants to the Lloyd aquifer sooner than anticipated. Although ground water in the Lloyd aquifer is still pristine, present pumping rates and potentiometric levels in the Lloyd indicate that this aquifer is much more sensitive to withdrawals than the other aquifers are and contains an extremely limited water supply.

INTRODUCTION

Kings and Queens Counties (the boroughs of Brooklyn and Queens in New York City) are at the western end of Long Island (fig. 1). This area has been extensively urbanized for more than 100 years. In 1980, the population of Kings County was 2.2 million, and the population of Queens was 1.89 million. The Long Island ground-water system, including the part beneath Kings and Queens Counties, is the sole source of water supply for the 2.6 million inhabitants of Nassau and Suffolk Counties to the east.

Ground water has been a source of public supply for western Long Island since the mid-19th century. Rapid increases in population since the turn of this century, and the attendant increases in pumping for public supply and industry, have resulted in severe water-level declines and intrusion of saline water from the surrounding bays. As a result, pumping for public supply in Kings County was stopped in 1947 and in western Queens County in 1974. (These areas now obtain water from mainland surface-water reservoirs.) As the early pumping centers in Kings and western Queens County were abandoned, new ones were established farther east in areas more distant from the shore, where water-table altitudes are higher.

Since the cessation of pumping, water levels in Kings and western Queens Counties have recovered continually. Even in areas where the water table had been drawn down to as much as 35 ft below sea level, it is now above sea level. In many of these areas, subways and deep basements that were constructed in the early 20th century, when water levels were depressed, are now being flooded as the water table recovers and need to be dewatered continually. By 1983, eastern Queens County was withdrawing almost 60 Mgal/d for public supply, enough to cause concern that salt-water intrusion may resume.

In 1981-86, the U.S. Geological Survey (USGS) conducted an investigation of the western part of the Long Island ground-water system in cooperation with the New York State Department of Environmental Conservation and the New York City Department of Environmental Protection. The area included all of Kings (about 76 mi^2) and Queens (about 113 mi^2) Counties and about 50 mi^2 in westernmost Nassau County (fig. 1).

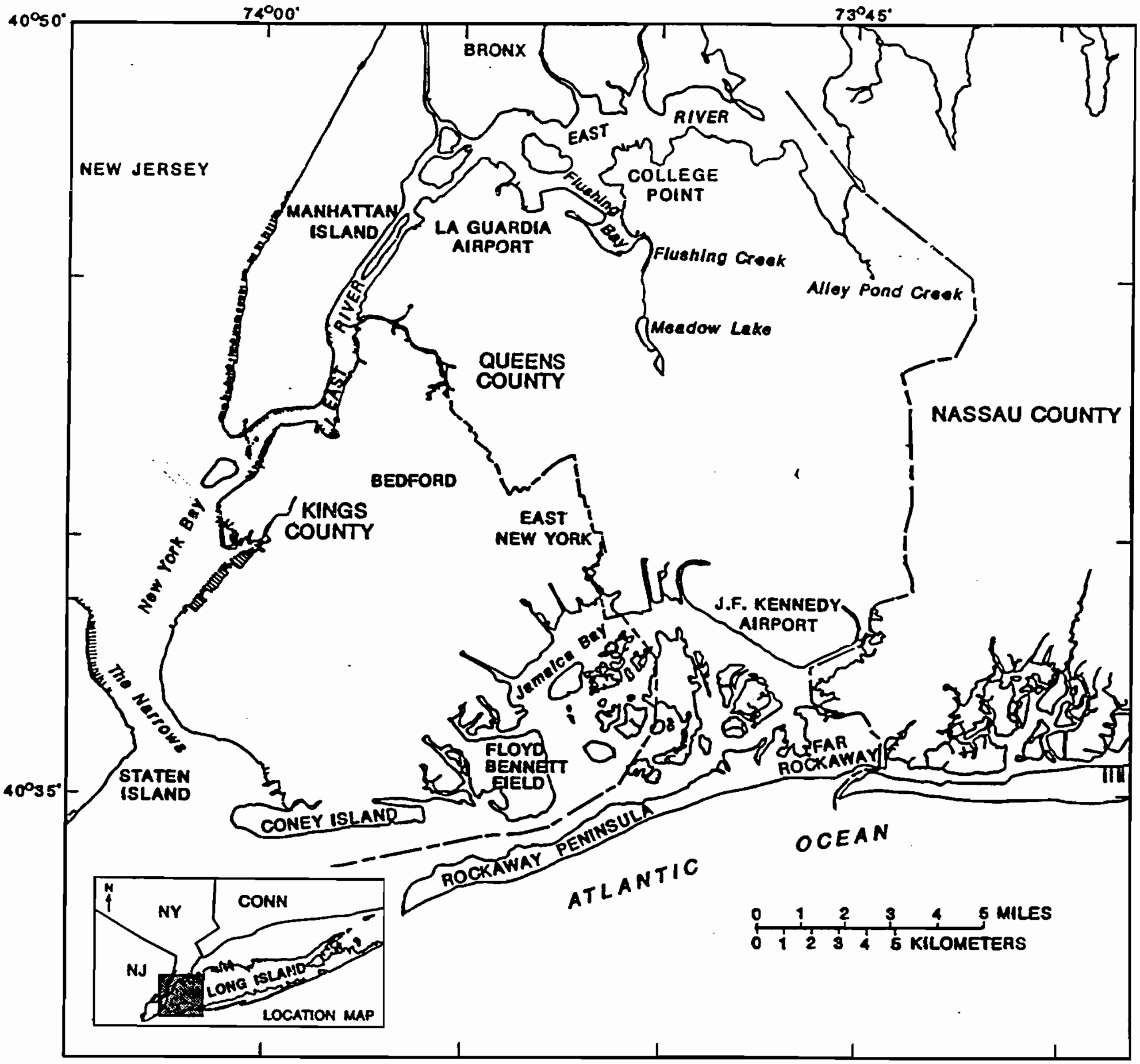


Figure 1. Location of Kings, Queens, and western Nassau County study area, Long Island, N.Y.

Purpose and Scope

This report describes the structure and operation of the western part of the Long Island ground-water system. It describes the hydrologic effects associated with human development in this highly urbanized environment from 1900 to the early 1980's. The ground-water quantity and quality of recent (early 1980's) conditions is characterized and a discussion of ground-water resource concerns is offered. Specifically, it:

1. delineates the hydrogeologic framework of the western part of the Long Island ground-water system and defines its water-bearing characteristics,
2. describes ground-water flow patterns, the ground-water-system budget, and ground-water quality under predevelopment conditions,
3. summarizes the development of the ground-water system and the effects of urbanization by presenting historical pumpage data and other urbanizing factors, and presenting the subsequent response of the ground-water system, and
4. presents the recent patterns and distribution of ground-water flow, and concentrations of selected chemical constituents that indicate the extent of human-derived contamination and salt-water intrusion throughout the ground-water system.

Acknowledgments

The authors thank the New York State Department of Environmental Conservation and the New York City Department of Environmental Protection for support and cooperation. Special thanks are given to Jerry Iwan and the staff of the Bureau of Water Supply Laboratory of the New York City Department of Environmental Protection for cooperation in handling and chemical analysis of water samples.

HYDROGEOLOGIC FRAMEWORK

The ground-water system that underlies western Long Island consists of a series of unconsolidated deposits of clay, sand, and gravel of Late Cretaceous and Pleistocene age that are underlain by Precambrian(?) bedrock. The stratigraphic relations of the geologic units are summarized in table 1; the geometry of these units is depicted in vertical sections on plate 2 and in hydrogeologic maps on plate 3. The water-transmitting properties of the corresponding hydrogeologic units are described also.

Hydrostratigraphy

Bedrock was eroded to a peneplain before deposition the overlying Cretaceous sediments; its surface shows signs of later erosion by Pleistocene glaciation in the northwest (pl. 3A; see also sections A-A' and B-B' on pl. 2). Bedrock crops out in northwestern Queens County near the East River and slopes southeastward at about 80 ft/mi. Consequently, the overlying unconsolidated formations form a wedge-shaped mass that attains a maximum thickness of more than 1,100 ft in the southeastern corner of Queens County. The maximum thickness in Kings County is about 900 ft, in southeastern Kings.

Overlying bedrock is the Raritan Formation of Late Cretaceous age, which consists of the Lloyd Sand Member and an upper, unnamed clay member. Overlying the Raritan Formation are the Magothy Formation and Matawan Group, undifferentiated, also of Late Cretaceous age; the Jameco Gravel and the Gardiners Clay, both of Pleistocene age; upper Pleistocene deposits of Wisconsin age; and a generally thin soil mantle of Holocene age (table 1 and pl. 2). Holocene beach deposits form most of the Rockaway Peninsula and Coney Island in the south, and Holocene salt-marsh deposits underlie and fringe the south-shore bay areas. Artificial filling has buried some marsh deposits in low and swampy shore areas. Because Holocene deposits occur only in relatively small areas of Kings and Queens and are not significant water bearers, they are not included in the geologic descriptions that follow.

Table 1. Western Long Island stratigraphic column with geologic and hydrogeologic interpretation

System	Series	Geologic Unit		Hydrogeologic unit	Range of thickness, in feet	Range of altitude of upper surface, in feet above sea level
QUATERNARY	Holocene	Shore, beach salt-marsh deposits, and alluvium				
QUATERNARY	Pleistocene	Wisconsin Glaciation (Harbor Hill, interstadial marine and Ronkonkoma? Drift	Till (ground and terminal moraine) Outwash "20-foot" clay (marine)	Upper Glacial aquifer	0 to 300	Land surface
		unconformity?				
		Sangamon Interglaciation	Gardiners Clay (marine)	Gardiners Clay	0 to 150	-40 to -200
		unconformity?				
		Pre-Wisconsin Glaciation (Illinoian?)	Jameco Gravel	Jameco aquifer[1]	0 to 200	-90 to -240
		unconformity?				
CRETACEOUS	Upper Cretaceous	Magothy Matawan Group undifferentiated		Magothy aquifer[1]	0 to 500	40 to -400
		unconformity?				
		RARITAN FORMATION	Clay member	Raritan confining unit	0 to 200	30 to -650
		RARITAN FORMATION	Lloyd sand member	Lloyd aquifer	0 to 300	-90 to -825
		unconformity?				
Precambrian		Crystalline bedrock		Bedrock	–	15 to -1100

[1] The Magothy and Jameco aquifers are often considered as one hydrologic unit with differing hydraulic properties. (See discussion in text.)

Erosion of the Cretaceous strata from Late Cretaceous through Pleistocene time has created a complex buried topography, as is seen in sections on plate 2. The data from which the hydrogeologic correlations were formulated consisted mainly of drillers' geologic logs, geophysical data, descriptive logs prepared by the USGS during inspection of cores of well-bore samples, and selected bridge and tunnel-boring data. These data are interpreted in relation to the area's erosional and depositional history. The altitude of each hydrogeologic unit's upper surface at each well is listed in table 9 (at end of report); locations of wells are shown on plate 1. The numbers of all wells at multiple-well sites are given in table 7 (at end of report) to facilitate location of wells.

Upper Cretaceous Deposits

Lloyd Sand Member of the Raritan Formation.—The Lloyd Sand Member, the oldest Cretaceous deposit in the area, lies unconformably on bedrock. Its surface and extent were shaped by post-Cretaceous erosion. It is absent in northwestern Kings and Queens Counties (pl. 3B) and in a tributary buried-valley-system that trends southward from Flushing Bay to central Queens County (section E-E', pl. 2).

The Lloyd Sand Member consists mainly of deltaic deposits of fine to coarse quartzose sand interbedded with sand and small- to large-pebble quartzose gravel. Interbeds of silt and clay and silty and clayey sand are common throughout the unit (Soren, 1978). The member is overlain by the clay member of the Raritan Formation. The northern extent of the Lloyd Sand Member and the clay member are largely coincident where eroded in the buried-valley system in northern Queens (pl. 2), but the clay member extends well north of the underlying Lloyd Sand Member in western Queens and Kings Counties.

The Lloyd Sand Member ranges in thickness from zero at its northern edge to about 200 ft in southeastern Kings County and 300 ft in southeastern Queens County. The unit's surface is as high as 90 ft below sea level in northern Queens and more than 800 ft below sea level in southeastern Queens.

Clay Member of the Raritan Formation.—This unit is absent along the northwest shore of Kings and Queens Counties (pl. 3C) and is eroded in central Queens in the same buried-valley system as the Lloyd Sand Member, but the clay member has been more extensively eroded, especially to the south. The clay member consists mainly of deltaic clay and silty clay beds and some interbedded sand (Soren, 1978). It increases in thickness from a pinchout at its northern limit to about 250 ft in southeastern Kings County and about 200 ft in southeastern Queens County. Its upper surface is less than 50 ft below sea level in Kings County and a few feet above sea level in parts of northern Queens. It is more than 400 ft below sea level in southern Kings and 600 ft below sea level in southeastern Queens.

The clay member overlies the Lloyd Sand Member with apparent conformity and, where the Lloyd Sand Member is absent, it lies unconformably on bedrock. It was disconformably overlain by Upper Cretaceous deposits, but during a complex geologic history after the Late Cretaceous Epoch, it became overlain from south to north by the Magothy Formation and Matawan Group, undifferentiated, the Jameco Gravel, the Gardiners Clay, and upper Pleistocene deposits, respectively (pl. 2).

Magothy Formation and Matawan Group.—The Magothy Formation and Matawan Group, undifferentiated, contains the remaining Cretaceous deposits in this area. This uppermost Cretaceous unit was severely eroded from the Late Cretaceous to the time of deposition of the Jameco Gravel (pl. 3D). The erosion is most severe in what was probably a complex channel network from an ancestral diversion of the Hudson River (Soren, 1978, p. 12-15). The Cretaceous unit in Kings and Queens Counties has a buried erosional surface with two prominent north-south trending channels, one through central Queens and one generally parallel to the Kings-Queens County line. These channels are eroded through the unit to near the south shore, where they apparently join and continue south as a single channel. Where the unit has been completely removed, dissection is evident in the underlying clay member and Lloyd Sand Member of the Raritan Formation (pl. 3B and 3C) and even in the bedrock in a small area of north-central Queens (pl. 3A).

The deposits of the Magothy Formation and Matawan Group, like the earlier Cretaceous deposits, are of continental origin and are mostly deltaic quartzose very fine to coarse sand and silty sand with lesser amounts of interbedded clay and silt. The unit commonly has a coarse quartzose sand and in many places a basal gravel zone 25 to 50 ft thick.

The unit ranges in thickness from zero at its northern limits to more than 200 ft in southern Kings and 500 ft in southeastern Queens. It is thinner in the buried valleys. The altitude of the Magothy-Matawan surface ranges from a few feet above sea level in northeast Queens to more than 400 ft below sea level in the buried valley to the south.

Pleistocene Deposits

Jameco Gravel.—The Jameco Gravel is the oldest Pleistocene deposit in the area (pl. 3E). It is considered to be a channel filling associated with an ancestral pre-Sangamon (Illinoian?) diversion of the Hudson River (Soren, 1978, p. 8). This episode of fluvial erosion probably was largely responsible for the irregular configuration of the Late Cretaceous land surface. The Jameco Gravel is present in most of Kings County and southern Queens County. It is thickest in the deep channels eroded into the underlying Magothy-Matawan unit and is thinnest over the higher areas. For example, a small area in southeastern Queens at Far Rockaway in which the Jameco Gravel has not been found coincides with a high point on the surface of the underlying formation (pl. 3D and section D-D' on pl. 2). Thickness of the Jameco Gravel ranges from a feather edge at its northern limit to more than 200 ft in the main buried valley in the center of Jamaica Bay.

Jameco deposits consist mainly of a hetero–geneous suite of igneous, metamorphic, and sedimentary rocks and are typically dark brown. The deposits grade from coarse sand and gravel with many cobbles and some boulders in the northern part of Kings County to finer grains southward. The presence of diabase fragments indicates transport by meltwater from a glacial terminus northwest of New York City. Soren (1978, p. 12-13) suggests that the Hudson River was diverted from its channel on the west of Manhattan Island to Queens County via the Harlem River channel and that distributary streams carried diabase fragments from there into Kings and Queens Counties.

The upper surface altitude of the Jameco Gravel is generally highest along the unit's northern edge—as little as 90 ft below sea level in western Kings County and 80 ft below sea level in eastern Queens County. It is generally lower to the south and over the deep erosional channels in the Late Cretaceous surface, where it is more than 200 ft below sea level. The upper surface of the Jameco Gravel was probably modified by subsequent stream erosion and glaciation.

Gardiners Clay.—The Gardiners Clay underlies most of Kings County and southern Queens County (pl. 3F). It unconformably overlies the Jameco Gravel and generally overlaps it along most of its extent. It consists mainly of greenish-gray clay and silt and some interbedded sand and was probably deposited in lagoonal and marine environments during an interglacial (Sangamon) interval (Soren, 1978, p. 10). The typical blue or green color of these beds is due to glauconite, chlorite, and weathered biotite. The Gardiners Clay was described as "blue clay" in many early 20th-century drillers' logs. Fossil shells, foraminifera, and disseminated lignite are widespread in the formation. The Gardiners Clay ranges in thickness from a feather edge at its northern limit to more than 100 ft in areas of previous erosion. The surface of the Gardiners Clay is predominantly flat but is affected locally by glacial erosion along its northern extent and by compaction in areas of greatest thickness. The upper surface ranges from less than 50 ft below sea level in the north to more than 150 ft below sea level in southern Kings County. It has not been found higher than 40 ft below sea level anywhere on Long Island, probably because its deposition was controlled by a relatively constant sea level. The Gardiners Clay is probably absent in two localized areas in the southern part of the area where underlying deposits (Magothy Formation and Matawan Group and Jameco Gravel) are at a higher altitude than the projected surface of the Gardiners Clay (pl. 3F). One area is near Floyd Bennet field in southern Kings (section B-B', pl. 2); the other is in Far Rockaway.

Upper Pleistocene Deposits.—These deposits are of Wisconsin age and of glacial origin. They unconformably overlie all underlying units and are found at land surface in nearly all of Kings and Queens Counties. The surficial geology of this area was mapped by Fuller (1914). The glacial deposits include: (1) terminal moraine deposits emplaced by an ice front of Harbor Hill age (location shown in fig. 3, p. 10); (2) ground-moraine deposits north of the terminal moraine; and (3) glacial outwash deposits south of the terminal moraine. The upper Pleistocene deposits range in thickness from zero in small areas of northwestern Queens, where bedrock crops out, to as much as 300 ft in the terminal moraine and near the buried valleys.

The terminal moraine is an unsorted and unstratified mixture of clay, sand, gravel, and boulders that were accumulated at the front of a continental glacier. The ground moraine is similar to the terminal-moraine deposits but was deposited at the base of the ice sheet during periods of melting. Meltwater from the ice front flowed southward and carried sand and gravel in broad, coalescing sheets to form an outwash plain that extends from the terminal moraine south to the coast.

Pre-Harbor Hill deposits are present at depth in the sequence of upper Pleistocene deposits (table 1). The "20-foot" clay in eastern Queens and Nassau Counties is a marine clay deposited during the Ronkonkoma-Harbor Hill interstade (Soren, 1978, p. 11). This unit locally separates the Harbor Hill Drift from the underlying Ronkonkoma Drift and earlier deposits.

Water-Transmitting Properties

The six major geologic units described in the preceding section generally correspond to hydrologic units with specific water-bearing characteristics. These hydrologic units and their corresponding geologic names (table 1) are, in ascending order, the Lloyd aquifer (Lloyd Sand Member of the Raritan Formation), the Raritan confining unit (the clay member of the Raritan Formation), the Magothy aquifer (Magothy Formation and Matawan Group, undifferentiated), the Jameco aquifer (Jameco Gravel), the Gardiners Clay (Gardiners Clay), and the upper glacial aquifer (upper Pleistocene deposits).

The aquifers are areally extensive unconsolidated formations that yield significant quantities of water to wells. The most permeable units are the beds of predominantly sand or sand and gravel. The two clayey formations (the Gardiners Clay and Raritan confining unit) are significant confining units and have been estimated to have a vertical hydraulic conductivity of 0.001 ft/d (Franke and Cohen, 1972), several orders of magnitude lower than that of the aquifers. Where present, they separate the ground-water reservoir into three major aquifer units—the Lloyd, the Jameco-Magothy, and the upper glacial aquifers (pl. 2). The Gardiners Clay restricts vertical flow between the upper glacial and Jameco-Magothy aquifers, and the Raritan confining unit restricts vertical flow between the Jameco-Magothy and Lloyd aquifers. Where these confining units are absent, ground-water flow between aquifer units is uninhibited. The extent of the confining units is critical in defining the distribution of hydraulic head and ground-water flow patterns.

The bedrock underlying the unconsolidated deposits has a low hydraulic conductivity and does not yield more than a few gallons per minute to wells. The quantity of water that can flow across this boundary is insignificant compared with the quantities that flow in the overlying unconsolidated units. Therefore, the bedrock surface is considered to be the bottom boundary of the ground-water flow system.

Lloyd Aquifer

The Lloyd aquifer has moderate horizontal hydraulic conductivity, which McClymonds and Franke (1972) estimated to range from 50 to 70 ft/d, although individual sandy and gravelly beds within the aquifer could have much higher values. High-capacity wells that tap the Lloyd aquifer generally have been pumped at rates less than 1,000 gal/min, but pumpage as high as 1,600 gal/min from a single well has been reported (Soren, 1971, p. 11). Specific capacities of wells screened in the Lloyd aquifer, in gallons per minute pumped per foot of drawdown in the well, (gal/min)/ft, range from 4 to about 40 (gal/min)/ft (Soren, 1971, p. 11). The Lloyd aquifer is confined between the bedrock and the Raritan confining unit but is in good hydraulic connection with the overlying aquifers where the confining unit has been eroded (pl. 3B).

Jameco-Magothy Aquifer

Although the Magothy and Jameco deposits differ in origin, lithologic character, and water-transmitting properties, they are considered as one aquifer unit in this report and are referred to as the Jameco-Magothy aquifer. The Jameco Gravel was deposited in deep channels incised in the Magothy aquifer and provides good hydraulic connection between these units as shown in plate 2 (sections A-A', B-B', D-D', and E-E'). In addition, these deposits are hydraulically separated from the underlying Lloyd aquifer by the Raritan confining unit and from the overlying upper glacial aquifer by the Gardiners Clay. The lateral hydraulic continuity between the Jameco and Magothy aquifers enables both to act as a single aquifer in which the Jameco is merely a zone of higher hydraulic conductivity.

The hydraulic conductivity of the Magothy aquifer has been estimated to range from 60 to 90 ft/d (McClymonds and Franke, 1972), but, as in the Lloyd aquifer, individual sandy and gravelly beds could have values several times higher. No pumping of the Magothy aquifer in Kings County is known, but wells that tap the Magothy in Queens County have yielded as much as 1,500 gal/min. The specific capacities of wells tested have ranged from 15 to 30 (gal/min)/ft in fine sand to 50 (gal/min)/ft in coarser material (Soren, 1971, p. 10).

Soren (1971, p. 9) estimated the horizontal hydraulic conductivity of the Jameco aquifer to be at least 270 ft/d. Wells tapping the Jameco have yielded 1,600 gal/min; and specific capacities of wells in the Jameco as high as 180 (gal/min)/ft have been reported (Soren, 1971, p. 9). Although the Jameco aquifer is considerably thinner than the Magothy, their transmissivities are comparable.

The Jameco-Magothy aquifer system is confined in southern Queens and in Kings County wherever it lies between the Gardiners Clay and the Raritan confining unit (pls. 2 and 3F). In northern Queens, however, the Magothy attains altitudes above sea level and is in good hydraulic connection with the water-table aquifer. Lenses and beds of clay and silty clay whose overlapping arrangement produces an anisotropy of perhaps as high as 100:1 tend to cause a confining effect with depth.

Upper Glacial Aquifer

The upper glacial aquifer consists of saturated glacial drift. Sand and gravel beds deposited as outwash south of the terminal moraine are highly permeable and are capable of yielding large quantities of water. Horizontal hydraulic conductivity of glacial outwash has been estimated to be 270 ft/d (Franke and Cohen, 1972); horizontal hydraulic conductivity of moraine deposits on the north shore, which include considerable clay and silt and are poorly sorted, is probably less than half that value. Public-supply and other high-capacity wells that tap outwash deposits have commonly yielded as much as 1,500 gal/min and have specific capacities ranging from 50 to 60 (gal/min)/ft (Soren, 1971, p. 8). Scattered coarse sand and gravel lenses within the morainal deposits have the potential for yielding significant amounts of water, but their locations can not be predicted.

Water in the upper glacial aquifer is under water-table (unconfined) conditions but probably is confined locally between beds of clay and silt within the morainal deposits. Such clayey and silty beds, where near the water table, impede ground-water recharge and thus locally cause unusually high water levels and temporary ponding that is often confused with perched conditions.

PREDEVELOPMENT HYDROLOGIC CONDITIONS

The only natural source of freshwater recharge to the Long Island ground-water system is precipitation, which replenishes the large volume of fresh water stored in the unconsolidated deposits. The ground-water system is bounded on top by the water table, on the bottom by bedrock, and on the sides by saline ground water or surface-water bodies (fig. 2). The ground water is in continuous motion from the water table to its point of discharge. The path of flow is three dimensional and is affected by the geometry and hydraulic characteristics of the aquifers and confining units, and by the proximity and nature of discharge boundaries.

Much of the water that enters the ground-water system remains in the upper glacial aquifer, where it moves laterally and discharges to streams or the surrounding saltwater bodies (fig. 2). ground-water seepage to streams results in shallow ground-water circulation patterns or flow subsystems (Franke and Cohen, 1972). (These shallow flow systems are not shown in fig. 2.)

The rest of the water that enters the system flows downward to the Jameco-Magothy aquifer (fig. 2), and some flows still deeper to the Lloyd aquifer. This downward movement of water is greater in areas of continuity between aquifer units than in areas of confining units, where it moves much more slowly and is refracted to near vertical through the confining units. All ground water eventually moves seaward. Near the shore, downward gradients reverse, and water moves upward into shallower aquifers. The seaward extent of fresh ground water in the confined aquifers is the interface between fresh and saline ground water. Water generally flows upward along this interface. Saline water has a greater density than freshwater; at large scales, the two fluids behave largely as though immiscible. Although a zone of diffusion forms at the interface, mixing is minimal under nonpumping conditions, and flow across the interface is virtually nil. Water from the confined aquifers flows upward through the Raritan confining unit or Gardiners Clay and mixes with overlying saline ground water and thus is lost from the freshwater system.

Water-Table Configuration

The configuration of the water table indicates the horizontal pattern of ground-water movement and the amount of freshwater stored in the ground-water reservoir. The first map of the water-table configuration on Long Island, made in 1903 (fig. 3), provides the best available estimate of the predevelopment water-table configuration, although urbanization and development of the ground-water system even then had begun to affect water levels.

The water table in 1903 had a steep gradient westward into Queens County (fig. 3), which indicates that a significant quantity of ground water entered Queens County from the east and helped maintain water levels in both Kings and Queens Counties. The water table reached an altitude of over 50 ft at the Queens-Nassau County line (fig. 3) and, in central Nassau County, attained a maximum altitude of over 90 ft (Veatch and others, 1906).

Long Island's major ground-water divide trends east-west through northern Queens County, then gradually southward through Kings County (fig. 3). The asymmetry of the water table from north to south, with steep northward gradients and flatter southward gradients (fig. 3), has three causes: (1) the thickening of the aquifers southward, (2) higher hydraulic conductivity in the outwash plain south of the divide than in moraine deposits north of it, and (3) more ground-water seepage to south-shore streams than to north-shore streams. These characteristics also are observed in the present water-table configuration.

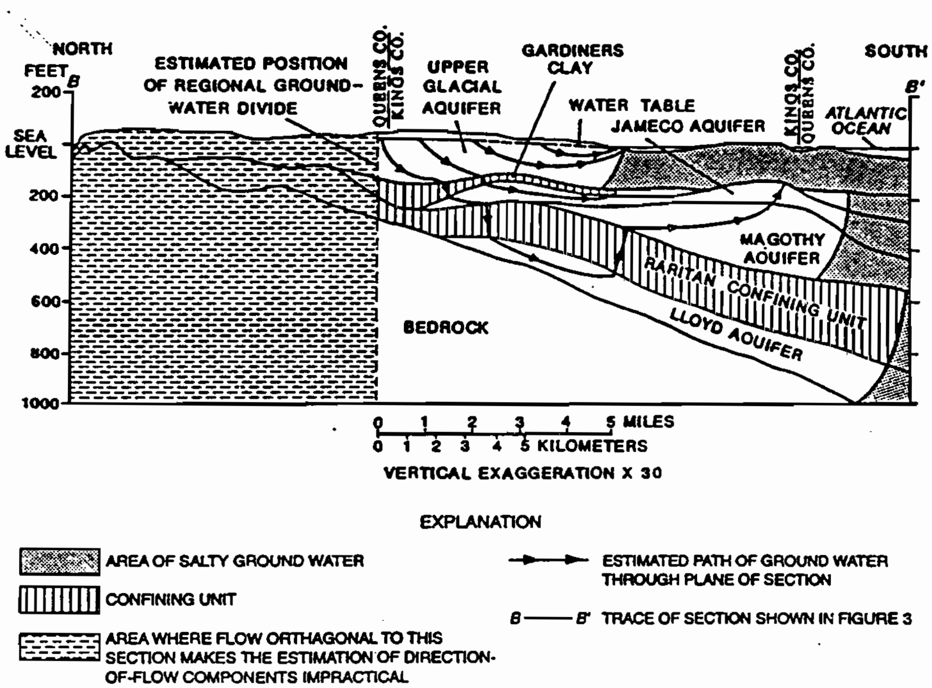
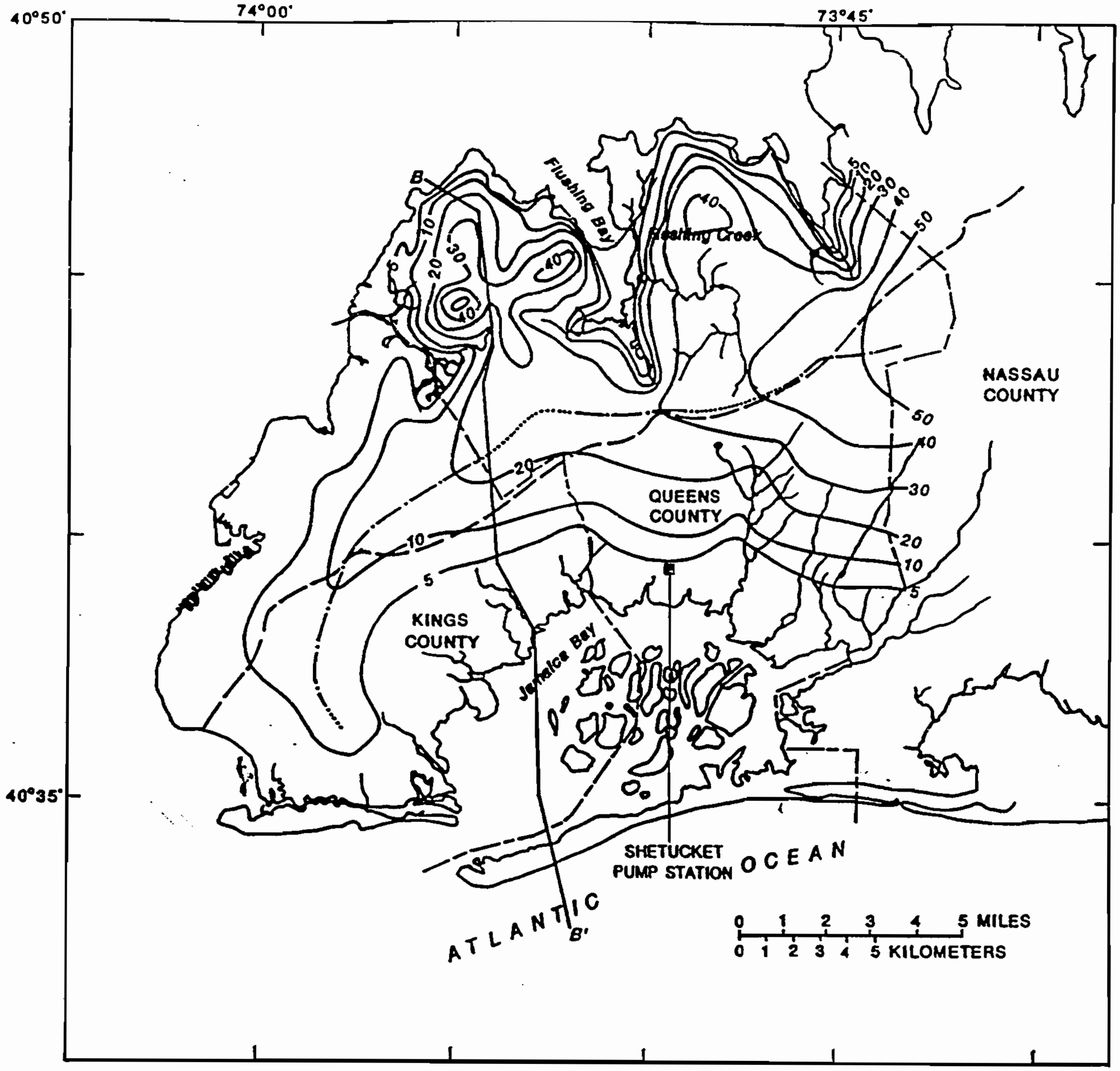


Figure 2. Estimated flow patterns along Section B-B' under predevelopment conditions. (Location is shown in fig. 3.)



EXPLANATION

—— 5 —— WATER-TABLE CONTOUR--Shows altitude of water table. Contour interval 5 and 10 feet. Datum is sea level.

— — — — SOUTHERN EXTENT OF HARBOR HILL MORAINE

—·—········ ESTIMATED POSITION OF MAJOR GROUND-WATER DIVIDE--Dotted where approximately located

B———B' TRACE OF HYDROLOGIC SECTION SHOWN IN FIGURE 2

Figure 3. Water table in 1903. Section B-B' is depicted in figure 2. (Modified from Veatch and others, 1906.)

The ground-water levels of 1903 indicate steep ground-water gradients toward several stream channels in Kings and Queens Counties. Flow in these channels, which are relict from the glacial period, was sustained primarily by ground-water seepage. The presence of many stream channels and swampy areas in southern Kings and Queens Counties suggests that a significant quantity of ground water discharged to surface-water bodies in this area.

Areas of anomalously high water levels are evident on the north shore of Queens County (fig. 3). These are caused by the high altitude of the bedrock surface (pl. 2A) in this area and by zones of low hydraulic conductivity in the moraine deposits, which restrict ground-water discharge to Long Island Sound. Similarly high water levels are associated with moraine deposits farther east on Long Island.

Water Budget

Before development, the Long Island ground-water system was in a state of dynamic equilibrium. Although the system fluctuates in response to natural variations in precipitation, an average predevelopment hydrologic condition can be estimated. Under predevelopment conditions, water entered the part of the Long Island ground-water system that underlies Kings and Queens Counties as recharge from precipitation and, to a lesser degree, as ground-water inflow from Nassau County. Water discharged by seepage to streams and to the surrounding saline ground-water and surface-water bodies. The quantities of these inflows and outflows under predevelopment (equilibrium) conditions are presented in table 2. The estimates given in table 2 were obtained through evaluation of hydrologic records in conjunction with results of flow-model analysis of the entire Long Island ground-water system. This model is being developed in a concurrent study by the U.S. Geological Survey (H. T. Buxton and D. A. Smolensky, U.S. Geological Survey, written commun., 1988), and much of the hydrogeologic information presented here was used in model construction.

Hydrologic data from central and eastern Long Island indicate that, under predevelopment conditions, about 50 percent of the annual precipitation infiltrated to the water table and recharged the ground-water system (Franke and McClymonds, 1972); the remainder was lost through evapotranspiration and direct (overland) runoff. Precipitation on Long Island ranges from 42 to 47 inches per year and averages 44 inches (Miller and Frederick, 1972). About 21 inches is estimated to have been lost through evapotranspiration, and only 1 inch lost as direct runoff.

About 396 Mgal/d of precipitation fell on the 189-mi^2 area of Kings and Queens Counties during predevelopment conditions. Of this total, 209 Mgal/d is estimated to have become recharge (table 2); this equals an average recharge rate of 1.1 (Mgal/d)/mi^2 (82 Mgal/d over the 76 mi^2 of Kings County and 127 Mgal/d over the 113 mi^2 of Queens County). The remaining inflow to western Long Island (from Nassau County) is estimated to have been 6 Mgal/d. Therefore, the total inflow to the ground-water reservoir beneath Kings and Queens Counties under predevelopment conditions was 215 Mgal/d.

An equal rate of ground-water discharge to streams (base flow) and to saline ground-water bodies (subsea discharge) balances this inflow. Before 1900, about 15 streams flowed in Kings and Queens Counties, the base flow of which is estimated to have been between 90 and 95 percent of their total flow. An examination of streamflow measurements made around the turn of the century (Veatch, 1906; Burr, Hering, and Freeman, 1904; and Spear, 1912), indicated that about 62 Mgal/d discharged from the ground-water system to streams as base flow—almost 30 percent of the water budget of the area. Thus, the remaining 153 Mgal/d discharged as subsea discharge, as explained in the previous section and shown in figure 2.

Table 2. Predevelopment ground-water budget

[Values are in million gallons per day.]

Inflow	
Recharge from precipitation	209
Ground-water inflow from Nassau County	6
Total	215
Outflow	
Base flow of streams	62
Subsea discharge	153
Total	215

Ground-Water Quality

Little if any information on ground-water quality in western Long Island under predevelopment conditions is available. The chemical composition of water samples taken from wells in eastern Long Island during 1932-65 is summarized in table 3. The eastern part of the island generally is similar to Kings and Queens geologically and climatically but was not urbanized until much later. These data, therefore, are the most reliable indication of predevelopment ground-water quality in the western part of Long Island.

The Jameco Gravel, which underlies only western Long Island, could affect the ground-water quality there, however, because it contains abundant ferromagnesium minerals, but no data are available to indicate its effect on water quality under predevelopment conditions. Elsewhere the aquifers consist primarily of quartz and, except for the dissolution of silica, are relatively unreactive. Much of the dissolved-solids content of Long Island's ground water under predevelopment conditions was derived from constituents dissolved in precipitation (table 3). Pearson and Fisher (1971) suggest a method of estimating chemical concentrations in water that recharges the ground-water system--the concentration in precipitation is multiplied by a specific factor to account for the effects of evapotranspiration. Given that about half of the precipitation on Long Island is lost through evapotranspiration (Franke and McClymonds, 1972, p. 19), a factor of 2 would be used. This method can be used throughout the following discussion to indicate what proportion of a conservative constituent was introduced in recharge water.

As water passes through the soil zone and moves through the aquifer, it undergoes reactions that modify its chemical character. The following paragraphs briefly describe the major inorganic constituents of Long Island's ground water.

Nitrate.--Nitrate is the only major constituent found in lower concentrations in ground water than in precipitation (table 3). Nitrogen in the form of nitrate is an essential nutrient for most plants. When water from precipitation enters the soil zone, it is absorbed by roots and converted to organic nitrogen (nucleic acids and proteins). As a result, ground water contains less nitrogen than does precipitation (table 3). Kimmel (1972, p. D200) surveyed the available data on nitrate in ground water on eastern Long Island and concluded that the nitrate concentration of water in the upper glacial aquifer under predevelopment conditions was 0.2 mg/L. The nitrate analyses shown in table 3 suggest that the predevelopment levels of nitrate could have been even lower.

Silica.—Silica (SiO_2) is the most abundant dissolved constituent of ground water under predevelopment conditions. Little if any silica enters the ground with recharge from precipitation (Hem, 1970, p. 48-50). Silica is taken into solution during the chemical decomposition of silicate minerals, such as quartz, feldspars, and amphiboles. Silica concentrations are about equal to the solubility of quartz (6 mg/L at 25 C), the most common mineral in Long Island aquifers. Silica concentrations listed in table 3 range from 5.9 to 10 mg/L. The silica in pristine ground water makes up 20 to 33 percent (by weight) of the total dissolved-solids content.

Iron.—Iron concentrations of pristine ground water range from 0.01 to 3.2 mg/L. Only 4 of 22 analyses given in table 3 show iron concentrations above 0.75 mg/L, and all samples were from the Magothy and Lloyd aquifers. The dissolution of iron-bearing minerals, such as pyrite (FeS_2) and ferromagnesium silicates, is the most likely source of iron. Iron occurs in the upper glacial aquifer where dissolved oxygen is present. Under these oxidizing conditions, the iron-bearing minerals are generally stable because the iron is already in the ferric (Fe^{+3}) oxidation state (Vecchioli and others, 1974). In the deeper aquifers, where dissolved oxygen is lacking, reducing conditions cause the iron-bearing minerals to decompose, releasing ferrous iron (Fe^{+2}) into the ground water. Iron in ground water generally is in the ferrous state (Hem, 1970). Ground water in western Long Island could be affected by contact with the iron-bearing Jameco Gravel.

Sulfate.—Concentrations of sulfate in the upper glacial aquifer range from 2.6 to 12 mg/L; those in five of six analyses were 8 mg/L or less. In shallow ground water, where dissolved oxygen is high, additional sulfate can be introduced by oxidation of pyrite and marcasite deposits. Sulfate concentrations in precipitation are about 4 mg/L (table 3) and, when concentrated by evapotranspiration, can account for most sulfate in solution.

As ground water moves downward along natural flow paths and enters a reducing environment, bacteria and organic matter can decrease sulfate concentrations through reactions that produce hydrogen sulfide and bicarbonate (Hem, 1970, p. 170). Sulfate concentrations in both the Magothy and Lloyd aquifers vary locally (table 3), ranging from 1.0 to 20 mg/L in the Magothy aquifer and from 0.8 to 20 mg/L in the Lloyd aquifer. These variations can be attributed to local variation in abundance of (1) bacteria, and (2) an organic food supply required for sulfate reduction. Several analyses show high bicarbonate concentrations in association with low sulfate concentration; this may indicate sulfate reduction. These variations also could result from local differences in the availability of pyrite as a source, or from the presence of water that entered the ground-water system before the mid-19th century, when sulfate concentrations in precipitation were lower than 4 mg/L. Average sulfate concentrations appear to be higher in the Lloyd than in the Magothy, but this cannot be explained.

Hardness.—Water hardness is due to the presence of calcium and magnesium ions. Calcium and magnesium are present in several of the silicate minerals, such as feldspar (plagioclase), amphiboles, and pyroxenes, which are prevalent throughout the upper glacial aquifer (DeLaguna, 1964). The dissolution of these minerals is the most likely source of hardness in the ground water. The data in table 3 indicate that the hardness of ground water is extremely low, ranging from 1.5 to 21.9 mg/L as $CaCO_3$. Natural hardness on western Long Island could be higher than farther east because the Jameco aquifer contains abundant ferromagnesium minerals. Soren (1971) states that uncontaminated ground water in Queens contains less than 60 mg/L of hardness.

Sodium.—Sodium in ground water is derived from two sources—airborne salt from the sea, and aquifer materials. Salt spray from the ocean is blown landward, then carried to the water table with infiltrating precipitation. The sodium concentration of precipitation is about 1.5 mg/L, which then increases through evaporation before it reaches the ground-water system. The rest of the sodium in the ground water is derived from the dissolution of minerals such as sodic feldspars in the soil zone and aquifer. DeLaguna (1964) concludes that the sodium in natural ground water on Long Island is probably derived in about equal amounts from sea salt in precipitation and the dissolution of minerals.

Chloride.—The source of practically all chloride in Long Island's ground water under predevelopment conditions was salt spray picked up by the wind and introduced into the ground-water system through infiltration of precipitation (Franke and McClymonds, 1972).

Jackson (1905, p. 29-31) estimates that the predevelopment concentrations of chloride in water on Long Island ranged from 3 to 8 mg/L. This agrees with concentrations shown in table 3 for the eastern part of Long Island. Lusczynski and Swarzenski (1966, p. 19) assumed that, before development, ground water on Long Island contained less than 10 mg/L chloride. Chloride contamination was evident by the turn of this century in Kings and Queens Counties, where contamination from land surface began long before 1900. During 1898-1902, average chloride concentrations in the base flow of four streams in Queens County ranged from 8.8 to 12.4 mg/L, whereas those in 12 streams in Nassau County ranged from 5.3 to 6.7 mg/L (Burr, Hering, and Freeman, 1904, p. 406-423). (Base-flow samples represent ground water that originated over large areas of the land surface and thus are reliable indicators of ground-water quality.)

Dissolved Solids.—The dissolved-solids concentration of water in all aquifers on Long Island is generally low compared to that in most other places and ranges from 15 to 53 mg/L (table 3). This is due to the lack of soluble minerals in the aquifer materials (Cohen and others, 1968). The highest dissolved-solids concentrations are in the Lloyd aquifer, probably because this water has traveled longer and farther through the ground-water system than water in the other aquifers and has had a greater contact time in which to react with the aquifer material.

Table 3.- Chemical composition of Long Island ground water and precipitation under predevelopment conditions.

[Data from U.S. Geological Survey records. mg/L, milligrams per liter; -, no analysis available; ND, not detected; methods of analysis and detection limits vary.

Source of sample	Date of sample collection	Silica, dis-solved (mg/L as SiO_2)	Iron (mg/L as Fe)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Hard-ness (mg/L as $CaCO_3$)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Bicar-bonate (mg/L as HCO_3)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Nitrate, dis-solved (mg/L as NO_3)	Total dis-solved solids (mg/L)	pH (units)
PRECIPITATION														
[a] Station A	11/65 to 3/66	-	-	0.5	0.3	2.5	1.6	0.1	-	3.8	2.7	0.8	10.	4.5
[b] Station B	8/31/65 to 9/30/65	-	-	.3	.4	2.4	1.5	.2	-	4.	2.2	.4	-	-
GROUND WATER														
Upper glacial aquifer														
S 3197	4/16/48	9.1	0.37	1.6	1.2	-	3.9	.5	8.	4.	4.	.2	28.	6.3
S 5518	10/15/48	6.	.01	1.5	1.3	9.1	3.2	.6	4.	6.	5.	.1	28.	6.5
S 6405	12/17/48	5.9	.19	2.1	1.6	11.8	4.7	.9	1.	12.	6.	.1	36.	5.5
S 6432	12/17/48	9.6	.75	2.1	1.1	9.8	3.8	.4	11.	2.6	4.4	.1	29.	6.7
S 9141	2/13/50	6.1	.41	1.3	1.3	8.6	5.4	1.1	10.	6.6	5.9	.1	32.	6.9
S 9142	2/13/50	6.	.23	1.4	2.	11.7	5.5	1.4	8.	8.	6.9	.2	34.	6.5
Magothy aquifer														
N 2790	c -	7.4	.6	.34	.17	1.5	3.7	.60	6.0	4.1	3.75	ND	23.	5.6
N 3866	10/14/52	9.8	2.9	1.3	.4	5.	3.9	.5	6.0	5.0	3.5	.31	28.	6.0
N 4149	9/30/53	6.5	.61	.5	.1	2.0	2.4	.3	2.6	1.6	2.5	.1	15.	5.8
N 7887	c -	7.5	.18	1.08	.24	3.7	3.9	.68	7.5	4.0	3.78	ND	24.	5.58
N 7889	c -	7.5	.25	.39	.30	2.2	4.0	.50	6.0	3.9	3.75	ND	23.	5.25
S 12	5/02/33	-	-	1.0	-	4.	-	-	10.	20.	7.0	ND	-	-
S 40	10/26/32	-	.38	1.0	-	<5	-	-	22.	10.	4.0	.04	-	-
S 51	10/10/32	-	.13	2.0	-	10.	-	-	20.	1.0	6.8	.04	-	-
S24769	7/07/65	5.9	.31	1.4	.6	6.	3.7	.6	9.	3.2	4.0	ND	24.	6.2
S24770	8/10/65	6.4	.14	2.1	.2	6.	3.0	.3	8.	2.0	3.5	.1	16.	6.2
Lloyd aquifer														
N 67	8/02/62	8.2	3.2	.9	.8	6.0	3.2	.4	2.0	6.5	4.2	ND	25.	5.1
N 1618	4/30/57	7.5	.14	2.6	1.4	12.	2.9	.7	12.	5.0	3.8	ND	30.	6.00
N 2602	5/26/57	8.3	-	1.1	.6	5	2.8	.7	8.	.8	3.8	.09	22.	6.10
N 3355	6/25/51	9.2	ND	2.2	.8	9.	3.8	.6	13.	.8	4.5	ND	28.	6.80
N 3448	7/31/62	9.0	-	1.8	2.7	16.0	8.9	1.2	ND	20.	8.2	ND	52.	4.5
N 3687	1/16/52	10.	.37	-	-	8.	7.6	ND	1	16.	5.0	ND	-	4.80
N 4405	9/15/54	8.2	-	2.0	.7	8.	-	-	6.	15.	10	.09	53.	6.80
N 5227	11/14/61	-	1.5	.9	.5	4.3	6.2	.5	4.	14.	2.	.1	36.	5.3
S 6409	11/08/48	7.5	1.3	1.5	1.6	10.3	4.4	2.2	16.	3.5	4.1	.1	32.	6.4
S 6434	6/02/49	8.4	.47	4.3	2.7	21.9	7.2	2.4	24.	12.	5.6	.1	53.	6.5

a Average of six composite monthly samples from gage near Brookhaven National Laboratory, October 1965 through March 1966. From Franke and McClymonds (1972, p. 36.)

b Composite of 1.02 inches of precipitation collected from gage at Upton, N.Y. Analyses by U.S. Geological Survey. Data from U.S. Geological Survey (1965).

c From Vecchioli and others (1974, p. C25.)

EFFECTS OF URBANIZATION ON THE HYDROLOGIC SYSTEM

Ground water on western Long Island was developed rapidly in the early 19th century along with the rapid population growth in Kings and western Queens Counties. The early residents obtained water from shallow wells and from streams (which are primarily base flow) and springs and returned most of it to the aquifer through septic systems. This withdrawal and return probably caused only minor changes in the water-table configuration and in shallow ground-water flow patterns.

As the demand for public and industrial water supply increased, the number of wells and the quantity pumped also increased, increasing the infiltration of wastewater contaminants introduced to the ground-water system. In the mid-19th century, storm and sanitary sewers were installed in Kings and discharged wastewater to the sea. Although this prevented contaminants from entering the ground-water system, it also diverted a large quantity of water that would have recharged the ground-water system. At the same time, the ever-increasing amounts of paved land surface reduced the area available for infiltration of precipitation, further decreasing recharge. By the 1930's, these changes, along with the continuous increase in industrial and water-supply pumpage, caused severe declines in the water table and in the hydraulic head in the deeper aquifers. Declines in the water-table altitude caused many lakes and streams to disappear and severely decreased the flow in remaining streams. At the same time, the decrease in hydraulic head caused intrusion of saltwater into the aquifers in nearshore areas.

Development of Ground-Water Supply

Pumping for industrial and public supply in the 20th century has imposed a severe stress on the western part of the Long Island ground-water system. Ground water pumped and lost either by evaporation or discharge to the sea is considered consumptive (net) pumpage and is a net draft on the ground-water system.

Virtually all of the ground water pumped in western Long Island is lost either through evaporation or to combined (storm and sanitary) sewers with ocean outfall. Developed parts of Kings and Queens had an extensive sewer network by the turn of this century. As a result, only a small, undetermined fraction of pumped ground water infiltrated back to the ground-water system in unpaved areas and from leaking sewer and water-supply lines.

History of Ground-Water Development

Public-supply and industrial pumpage from 1904-83 are plotted in figure 4. (No data are available for industrial pumpage in Queens County before 1948; it probably was considerably less than in Kings County but followed similar trends.) Pumpage and ground-water development through the 20th century are summarized in four general phases, described below.

1900-17.—By 1900, the ground-water reservoir of western Long Island was used extensively for both public-supply and industrial uses. Johnson and Waterman (1952, p. 7) estimate that in 1904, 6.4 Mgal/d was obtained from surface storage of ground-water-fed springs and streams in Queens County, and 77.4 Mgal/d was obtained from surface storage from nearby Nassau County.

By 1904, pumpage for public supply had reached 14 Mgal/d in Kings County and 28 Mgal/d in Queens, most of which was used in Kings County. The average pumpage for public supply during 1909-16 was 30 Mgal/d in Kings County and 58 Mgal/d in Queens County (fig. 4). Industrial pumpage in 1904, although only a few million gallons per day in Queens, was 14 Mgal/d in Kings County and increased markedly in both counties thereafter.

In 1917, New York City water tunnel 1 was completed, and surface water from reservoirs in upstate New York was transported to the water-supply-distribution system in Kings and Queens. This water replaced a significant amount of ground-water pumpage, as indicated in figure 4. The City of New York, Department of Water Supply, Gas, and Electricity, which had pumped more than 14 Mgal/d in Kings County and 40 Mgal/d in Queens County during the preceding 10 years, all but ceased pumping in 1917.

1918-30.—The post-World War I period in western Long Island was marked by a consistent increase in consumptive ground-water use for both public supply and industrial use. After the abrupt reduction in pumpage for public supply in 1917, continued demand resulted in an increase in public-supply pumpage from 13 Mgal/d in Kings County and 23.1 Mgal/d in Queens in 1918 to 29.2 Mgal/d and 62.0 Mgal/d, respectively, in 1931 (fig. 4). Industrial pumpage also continued to increase and, by 1930, had exceeded 50 Mgal/d in Kings County and was probably about 20 Mgal/d (estimated by the authors) in Queens.

1930-46.—Pumping for public supply during this period was relatively constant in Kings County but ranged from more than 60 to less than 40 Mgal/d in Queens. In 1936, tunnel 2 was completed and increased the capacity to supply upstate surface water to Kings and Queens. The effect is not evident in ground-water pumping data for Kings and may have caused only a minor decrease in Queens (fig. 4). Much of the imported water probably was used for conversion of new areas to public supply.

The 1930's brought a noticeable decline in industrial pumpage (fig. 4) for two major reasons:

1. Concern over the extensive use of ground water by industry prompted the adoption of the New York State Water Conservation Law of 1933, which required that water pumped at a rate greater than 70 gal/min (0.1 Mgal/d) be reinjected into the source aquifer after use. (Ground water pumped for industrial use and returned to the source aquifer is not included in the net pumpage shown in fig. 4.) Leggette and Brashears (1938, p. 413) estimate that only one recharge well was operating in western Long Island at the end of 1933, but by 1937, the number had increased to 105. The average daily rate of recharge reached a high of 22 Mgal/d in the air-conditioning season during these years but maintained an average annual rate of about 12 Mgal/d.
2. The widespread adoption of electric refrigeration severely reduced the quantity of water pumped for ice making. Lusczynski (1952,

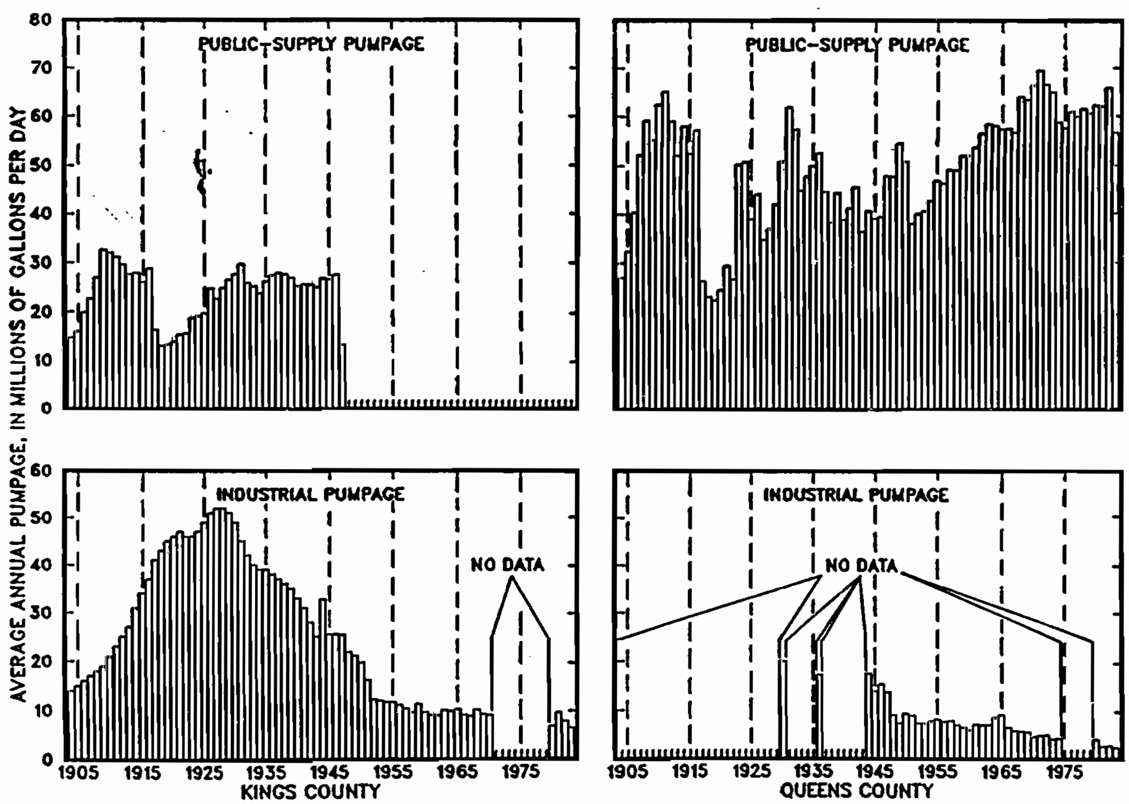


Figure 4. Annual average pumpage for industrial and public supply in Kings and Queens Counties, 1904-83. (Compiled from Johnson and Waterman, 1952; Thompson and Leggette, 1936, Suter, 1937, and New York State Department of Environmental Conservation.)

p. 4) states that the quantity of water pumped for ice-making during 1936-47 decreased from 18 Mgal/d to 4 Mgal/d.

During World War II (1940-45), industrial pumpage increased slightly in Kings County; a similar increase was likely in Queens County.

1947 to 1983.—In 1947, New York City stopped all public-supply pumping in Kings County, primarily because of saltwater intrusion, but pumping for public supply continued in Queens, where it increased from 45 Mgal/d in 1950 to more than 60 Mgal/d in the 1970's (fig. 4). The trend of pumping in Queens has been to abandon wells showing contamination and to install new ones eastward and farther inland, where water levels are higher.

Pumpage declined in 1974 (fig. 4), when all pumping for public supply (10 Mgal/d) in the Woodhaven franchise area (fig.6A) of the New York Water Service Corporation (NYWSC) was halted as a result of saltwater intrusion. Industrial pumpage declined gradually in both counties and fell below 10 Mgal/d in Kings and 3 Mgal/d in Queens.

Development of Individual Aquifers

Annual average pumpage for public supply in Kings and Queens during 1904-83 is plotted by aquifer in figure 5. Such a breakdown for industrial pumpage is unavailable, but most pumping for industrial purposes probably has been from the upper glacial (water-table) aquifer.

Early in this century (1904-17), most ground-water pumpage was derived from the upper glacial aquifer; it attained a maximum of 70 Mgal/d in 1910 (24.1 Mgal/d in Kings and 46.0 Mgal/d in

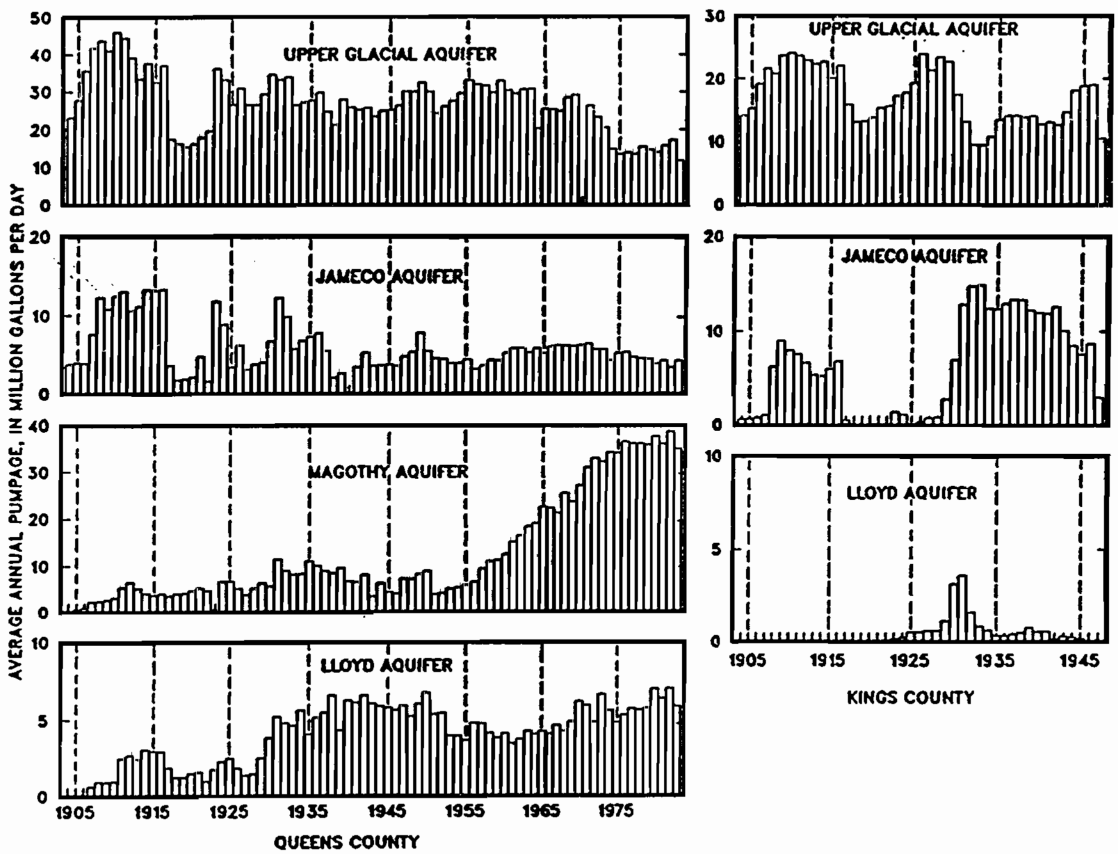


Figure 5. Annual average public-supply pumpage from individual aquifers in Queens County (left) and Kings County (right), 1904-83. (Compiled from Johnson and Waterman, 1952, and New York State Department of Environmental Conservation; pumpage records obtained from the New York Water Service Corporation and Jamaica Water Supply Company.)

Queens). At the same time, pumping from the Jameco was 20.5 Mgal/d (8 Mgal/d in Kings and 12.5 Mgal/d in Queens), and pumping from the Magothy aquifer was about 5 Mgal/d. (No water was pumped from the Magothy aquifer in Kings County throughout 1904-83 because this aquifer is not extensive there.) Pumping from the Lloyd aquifer started as early as 1905 but reached a maximum of only about 3 Mgal/d during 1904-17.

Pumping from the upper glacial and Jameco aquifers decreased substantially in 1917 with the completion of the first water tunnel to bring upstate surface water to the city, but in the following years, pumping from all aquifers gradually increased. A distinct shift in pumping from the upper glacial to the Jameco aquifer in Kings County is evident during 1928-33 (fig. 5); pumpage from the upper glacial aquifer decreased from 23.4 Mgal/d in 1928 to 9.5 Mgal/d in 1933, while pumping from the Jameco aquifer increased from 0.8 Mgal/d to 14.9 Mgal/d. This shift was in response to saltwater intrusion, which by 1947 had caused the cessation of all public-supply pumping in Kings County.

A similar shift from the upper glacial aquifer to the Magothy aquifer occurred in Queens County during 1955-76, when pumping from the upper glacial aquifer decreased from 33.0 Mgal/d to 13.9 Mgal/d, and pumping from the Magothy aquifer increased from 5.9 Mgal/d to 36.5 Mgal/d. This shift also was due, at least in part, to saltwater intrusion, which ultimately caused the shutdown of pumping in the Woodhaven Franchise area of the NYWSC. (See fig. 6A.)

Pumping from the Lloyd and Jameco aquifers in Queens County has remained relatively stable since the 1930's, and pumping from the Lloyd in Kings County has been almost negligible—it exceeded 1 Mgal/d only during 1929-32, with a maximum of 3.6 Mgal/d in 1931.

Declines in Water Levels

The most marked effect of urbanization on the hydrologic system of western Long Island has been a decline in the water table and in the potentiometric surface of the deeper aquifers. The configuration of the water table before development was discussed previously (see fig. 3); water-table maps for subsequent years (figs. 6A-6E) depict the changes resulting from urbanization and related stresses during the 20th century.

By 1936, the water table showed severe declines resulting from heavy pumping and loss of recharge. (Compare figs. 3 and 6A.) An asymmetric cone of depression in northern Kings County, an area of extensive industrial pumping at that time, reached a depth of 35 ft below sea level and extended into western Queens County.

The decline in industrial pumping that started around 1930 (fig. 4) resulted in some recovery of the water table by 1943 (fig. 6B). (Note that the water table in northern Queens County was not contoured, possibly because, at that time, Jacob (1945) was uncertain whether anomalous high water levels were perched or were the actual water-table surface.) The water-table configuration of 1943 showed a partial recovery in northern Kings and western Queens Counties.

After the cessation of pumping for public supply in Kings in 1947, the water table recovered further. The water-table configuration of 1951 (fig. 6C) shows a rise in the southern half of Kings County to altitudes above sea level, and the cone of depression in the north is smaller and shallower than in 1936 (fig. 6A).

By 1961, the water table (fig. 6D) had risen to above sea level throughout Kings County except in a small area in the north. Perlmutter and Soren (1962, p. 128) report that the dewatering rates at several subway stations in Flatbush increased from less than 20 gal/min in 1947 to as much as 1,000 gal/min by 1961.

A sizable cone of depression is evident in the Woodhaven franchise area in Queens County, where pumping increased in response to a continuing rise in demand. The cone of depression extended into Jamaica, where pumpage by the Jamaica Water Supply Company in 1961 was nearly 50 Mgal/d. Although the cone of depression in 1961 was not as deep as that in Kings County in the 1930's (fig. 6A), the initial water levels in Queens County were 20 ft higher than in Kings, so that the respective declines represent similar losses in ground-water storage.

By 1974, the water table had recovered further in Kings County (fig. 6E), and the cone of depression in Queens had shifted from Woodhaven, where pumping stopped in 1974, eastward to Jamaica, where the Jamaica Water Supply Company was pumping about 60 Mgal/d. Water levels in this cone of depression represent a regional drawdown of about 35 ft from water levels in 1903 (fig. 3).

Similar declines in the potentiometric surface of the deeper aquifers have resulted from increased pumping and urbanization. Historical data on the potentiometric surface of these aquifers are sparse, but recent water-level records for wells screened in the deeper aquifers confirm that drawdown propagates rapidly from one aquifer to the next in areas where confining units are absent. Pumping confined parts of the deeper aquifers produces a cone of depression within the pumped aquifer that is broader than the one in the water-table aquifer. Because confined storage coefficients are typically much lower than the specific yield of the water-table aquifer, the transient response to stress is more rapid in the deeper aquifers. Also, the absence of local stream and surface-water boundaries in confined aquifers forces propagation of drawdown to more distant boundaries.

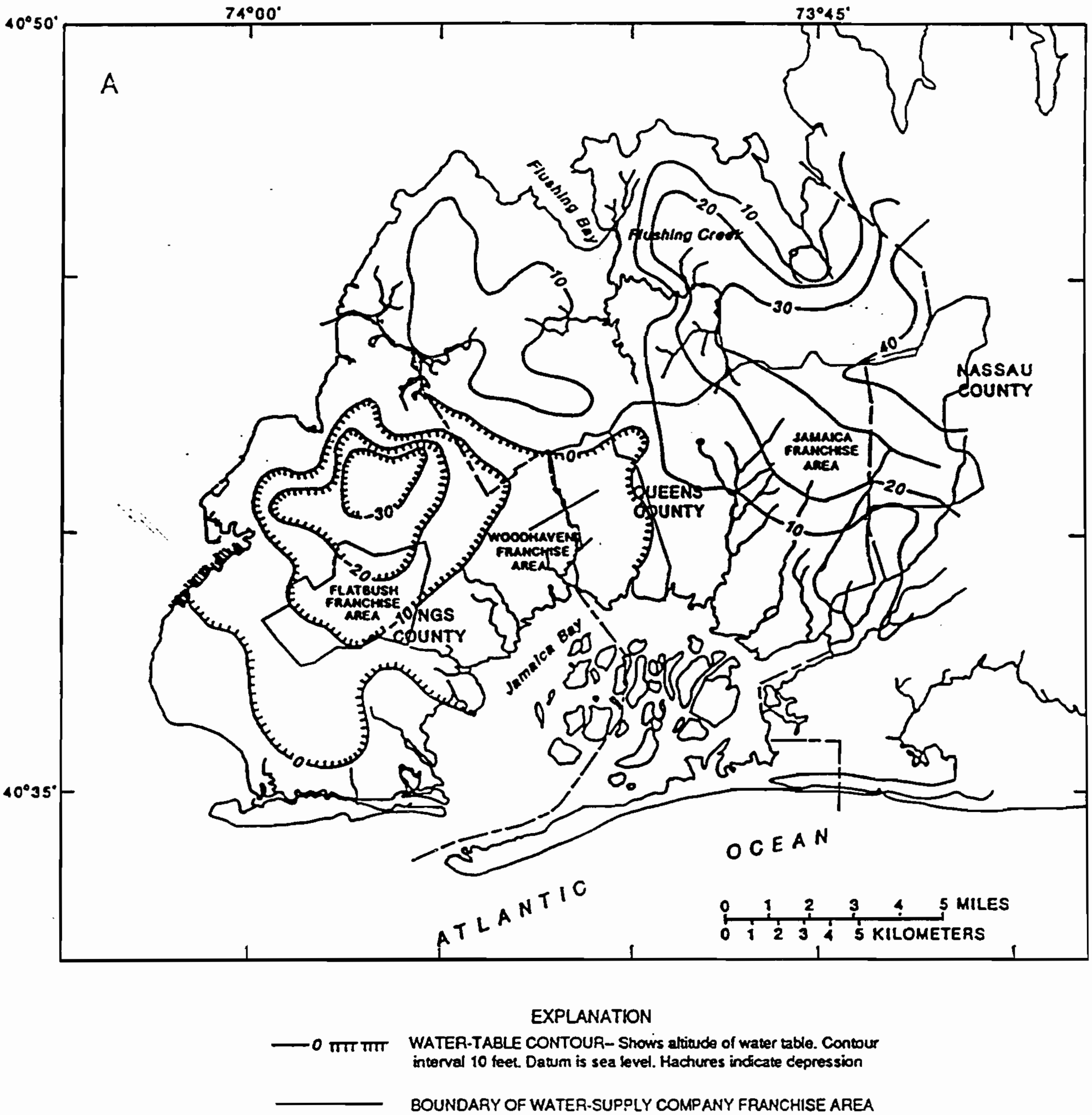


Figure 6A. Water-table configuration in 1936. (Modified from Suter, 1937, fig. 26.)

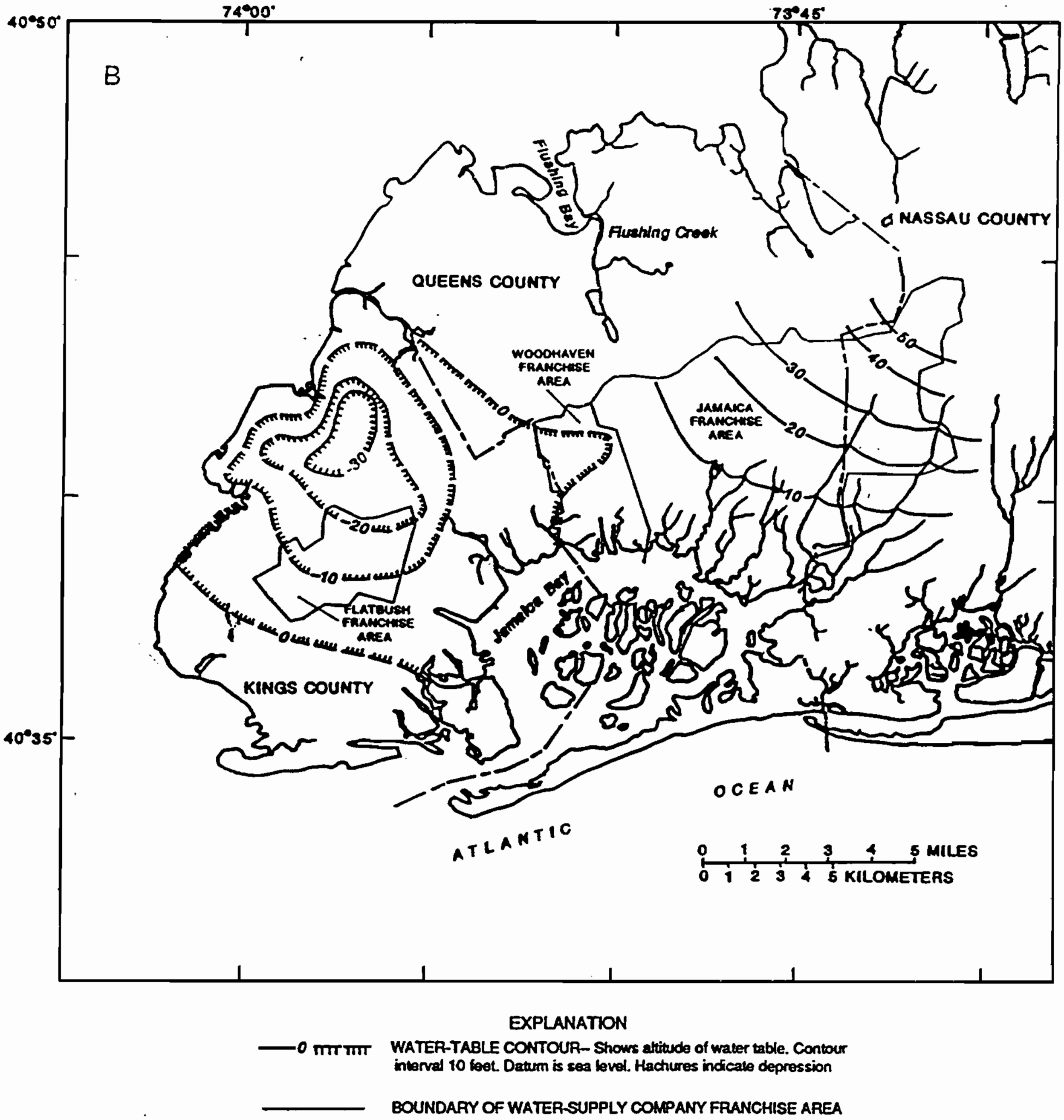
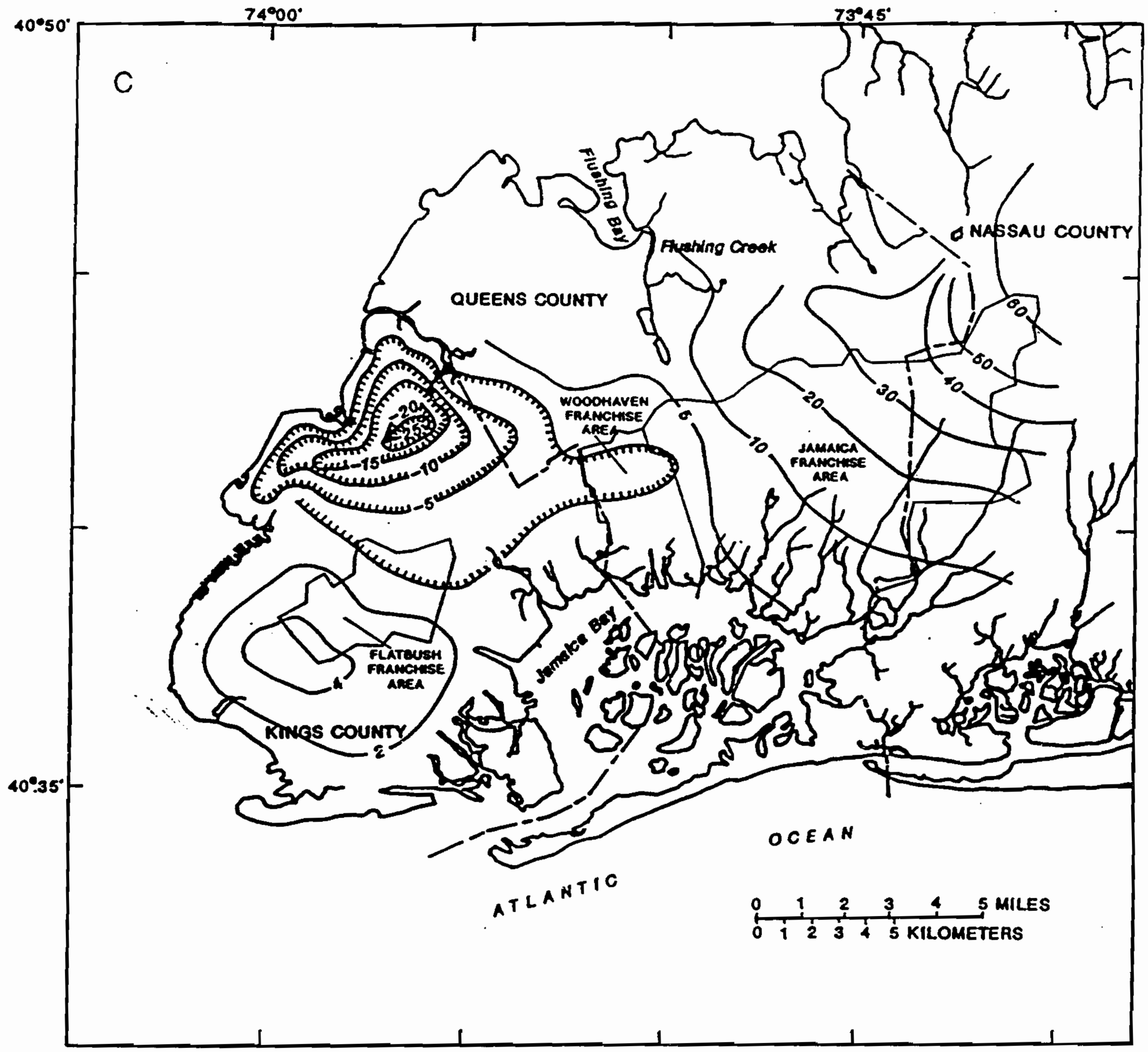


Figure 6B. Water-table configuration in 1943. (Water levels were measured in late May.). (Modified from Jacob, 1945, pl. 1.)

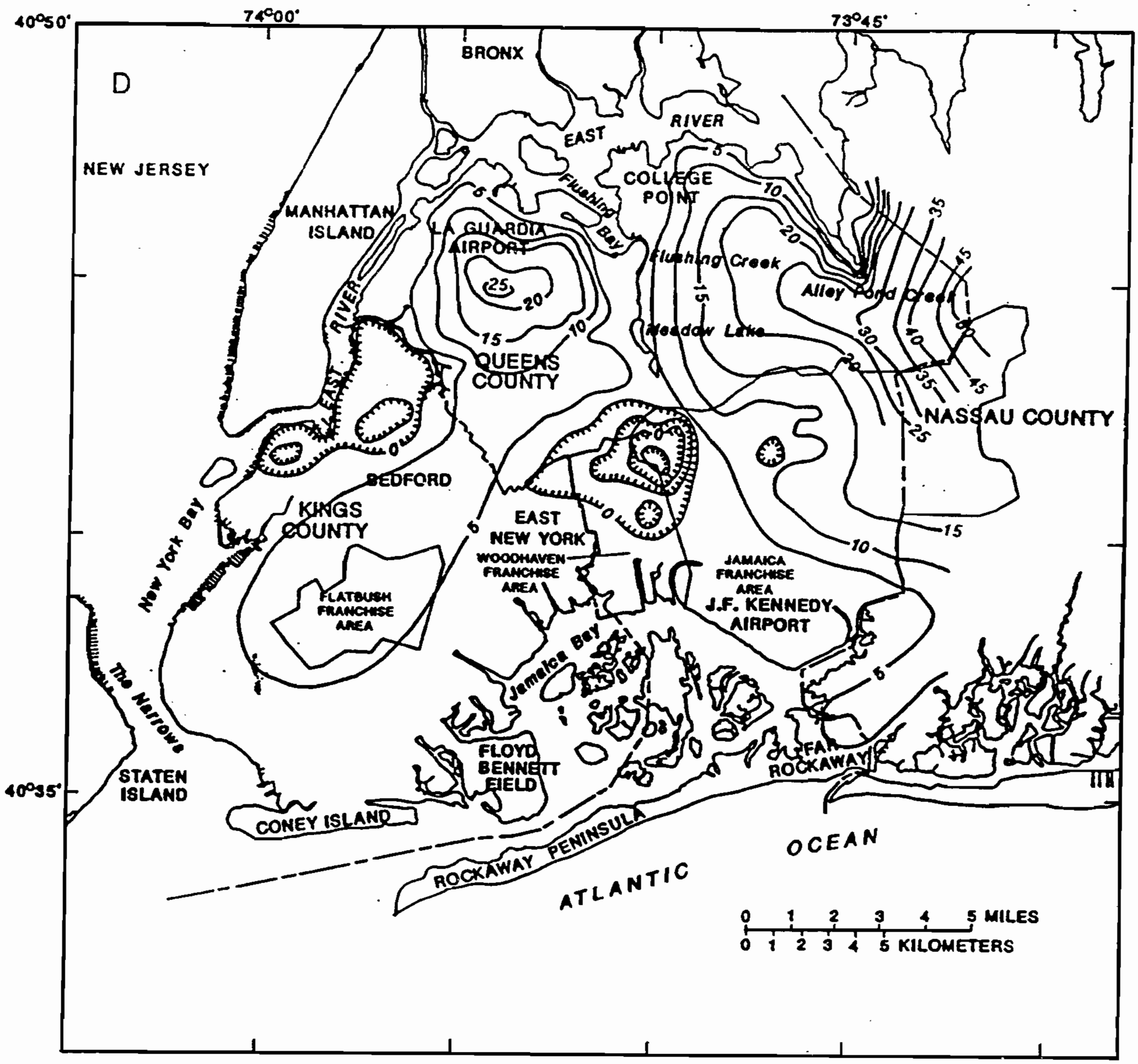


EXPLANATION

—0 ╥╥╥ WATER-TABLE CONTOUR– Shows altitude of water table. Contour interval 10 feet. Datum is sea level. Hachures indicate depression

——— BOUNDARY OF WATER-SUPPLY COMPANY FRANCHISE AREA

Figure 6C. Water-table configuration in 1951. (Water levels were measured in January. Modified from Lusczynski and Johnson, 1951, pl. 1.).



EXPLANATION

—0 ┬┬┬ WATER-TABLE CONTOUR— Shows altitude of water table. Contour interval 10 feet. Datum is sea level. Hachures indicate depression

——— BOUNDARY OF WATER-SUPPLY COMPANY FRANCHISE AREA

Figure 6D. Water-table configuration in 1961. (Water levels were measured in December. Modified from Perlmutter and Soren, 1962, fig. 1B.)

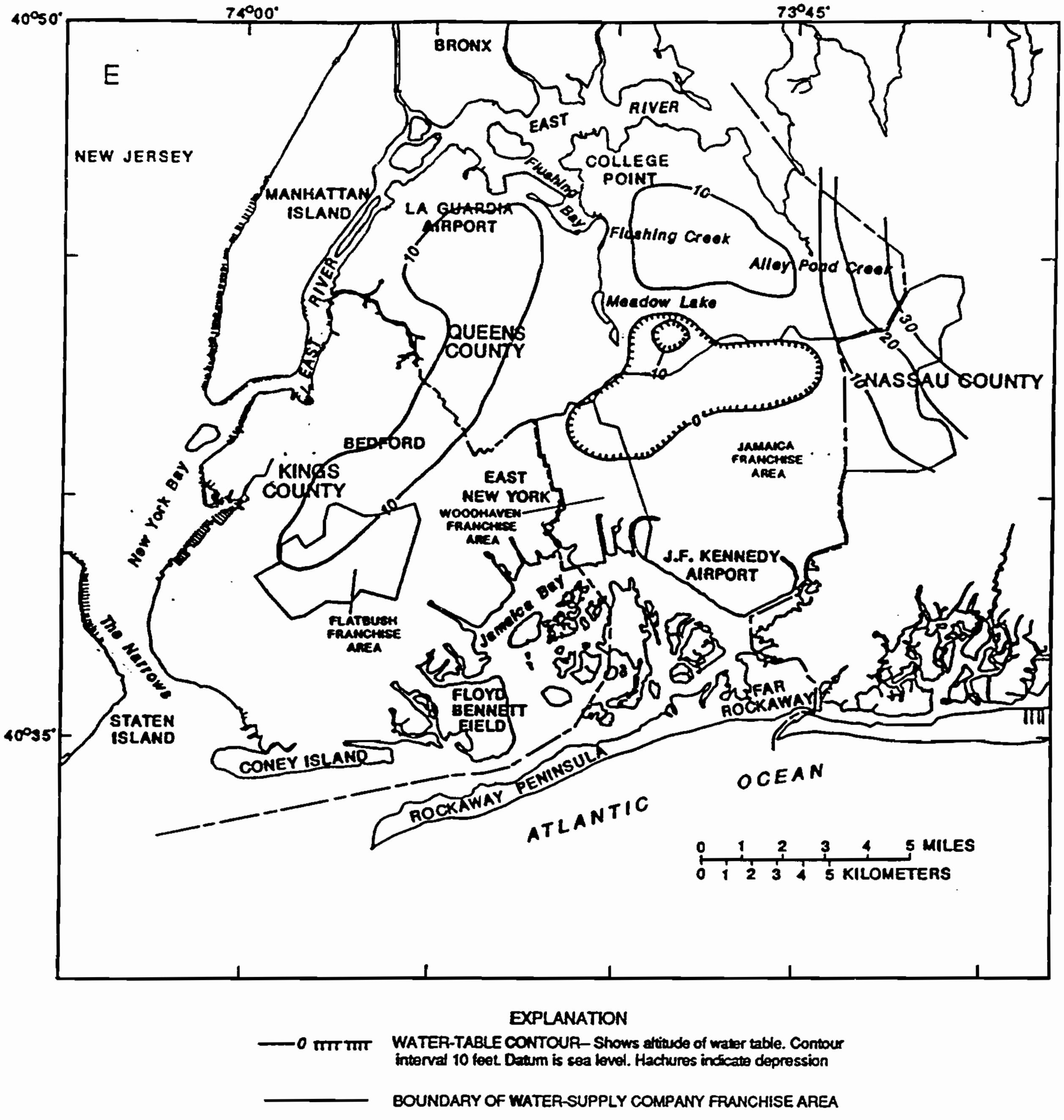


Figure 6E. Water-table configuration in 1974. (Water levels were measured in March. Modified from Koszalka, 1975, pl. 3.)

Deterioration of Ground-Water Quality

In addition to lowering ground-water levels in Kings and Queens Counties, urbanization and development of the ground-water resources have caused serious deterioration of ground-water quality. The most striking example has been the encroachment of saltwater from surrounding saltwater boundaries in response to excessive drawdown. Other sources of contamination, some of which were present from the early stages of development, include fertilizers, underground sewage-disposal systems, landfills, large cemeteries, road salts, leaking sewers, chemical spills at land surface, and industrial and other wastewater impoundments.

Historical water-quality data are sparse, but chloride and nitrate data were collected as far back as 1900 and are used here to give an indication of changes in ground-water quality during this century. Elevated chloride concentrations accompanied by very low nitrate concentrations are indicative of seawater encroachment, whereas elevated nitrate and chloride together are considered to indicate contamination from land surface.

Nitrate and chloride are among the earliest contaminants to be introduced to the ground-water system. They first entered the system on a widespread basis about 200 years ago as fertilizers and domestic wastes and are considered indicators of water that has been affected by human activities.

Chloride

Encroachment of saline ground water has affected public-supply wells in western Long Island since the turn of this century. Spear (1912) shows the increase in chloride in water pumped from driven wells at the Shetucket pumping station near Jamaica Bay during 1897-1905 (fig. 7). Chloride concentrations rose to 500 mg/L in these 9 years. Once saline ground water was drawn into the area of the pumping wells, even a significant reduction in pumping rate did little to improve water quality.

Later, pumping wells were installed inland to avoid the saline ground water. By the early 1930's, however, high pumping rates had caused saltwater intrusion even in inland areas. A sharp increase in chloride concentration in water from two public-supply wells screened in the upper glacial aquifer in the Flatbush franchise area occurred during the 1940's (fig. 8A). Saline ground water probably was drawn this far inland from beneath surrounding tidal waters by the expanding cone of depression that extended to shore areas. The migration of saltwater so far inland during this period probably

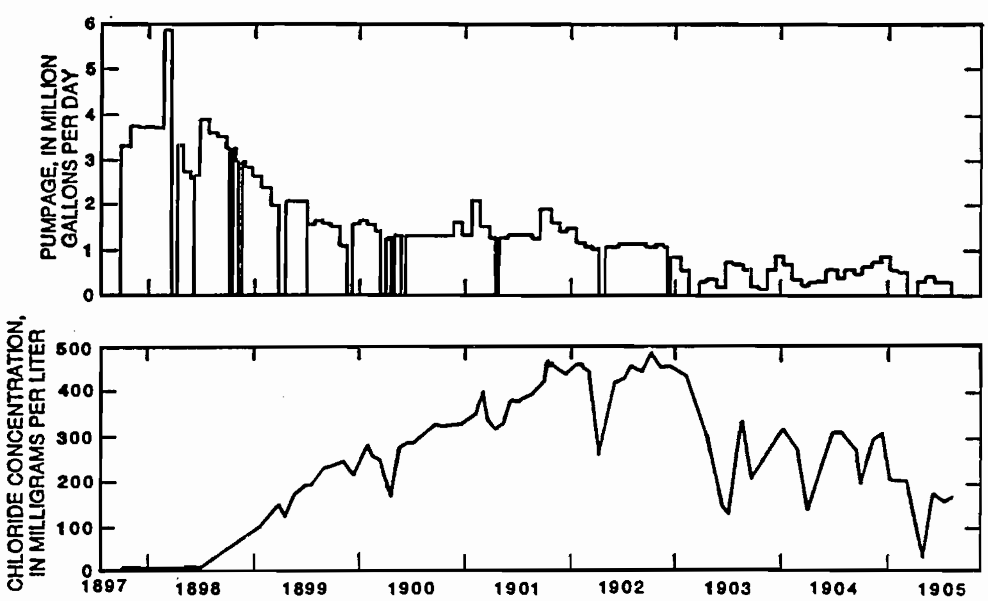


Figure 7. Average chloride concentration and total pumpage from eight driven wells at the Shetucket pumping station, 1897-1905. (From Spear, 1912, sheet 12.)

indicates that saline ground water moved through preferential and highly conductive pathways. The water-table configuration of 1903 (fig. 3) shows seaward gradients; that of 1936 (fig. 6A) indicates a change to flat or slightly landward gradients near much of the shore in Kings County, which would accelerate saltwater encroachment. Pumping was stopped in Flatbush wells in 1947 (see fig. 8A).

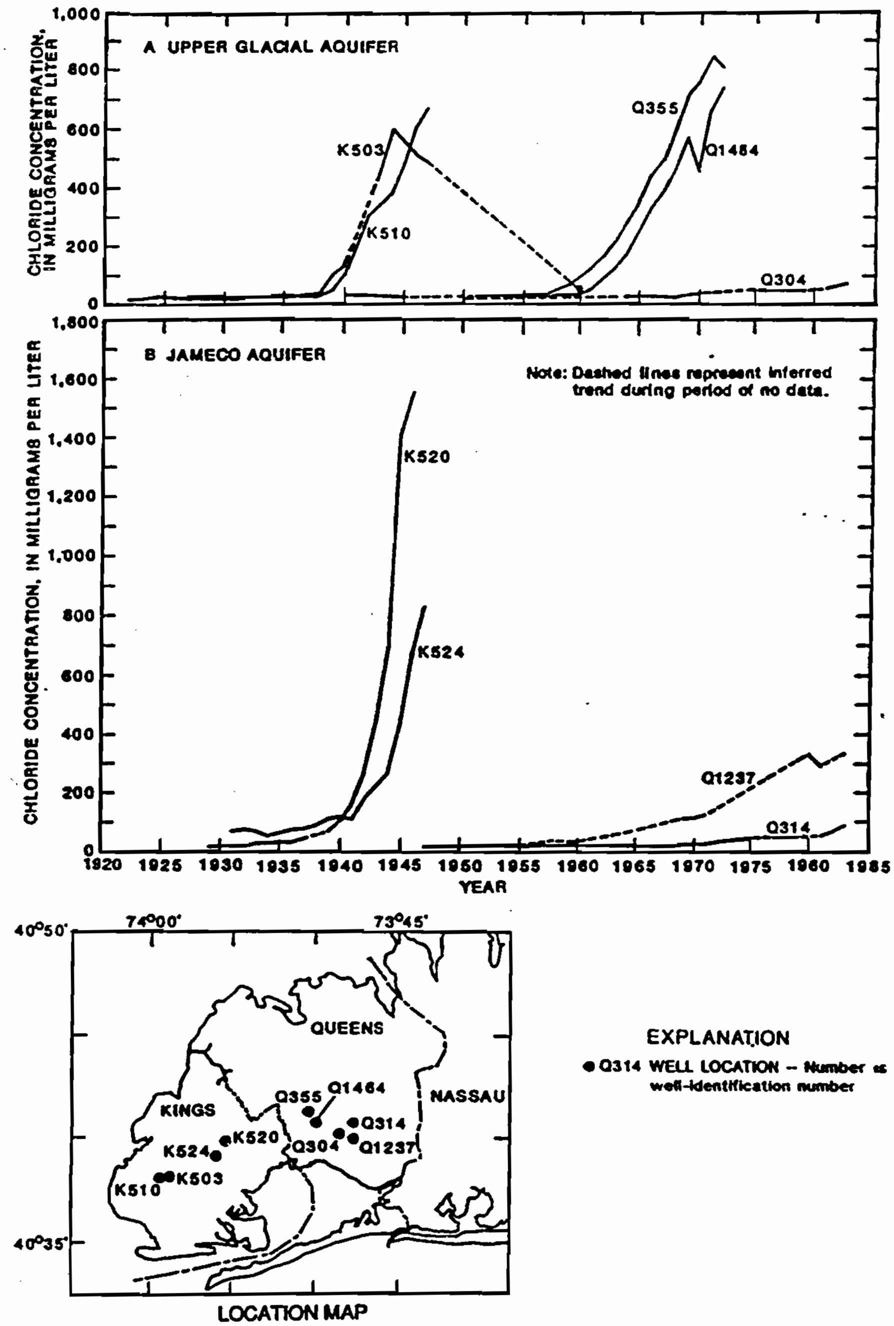


Figure 8. Chloride concentration in water from selected wells in Kings and Queens Counties: (A) Wells screened in the upper glacial aquifer. (B) Wells screened in the Jameco aquifer. (Data from U.S. Geological Survey files, Lusczynski, 1952, and selected annual reports of the Bureau of Water Supply, City of New York.)

When the chloride concentration of water from the upper glacial aquifer began to increase, pumping was shifted eastward and to deeper aquifers, but a similar increase in chloride concentration in the deeper aquifers soon followed (fig. 8B). The transient response of water levels in the confined aquifers to pumping is quicker than that in the water-table aquifer; that is, changes in hydraulic head are transmitted more rapidly, and saltwater intrusion follows. Lusczynski (1952, p. 5-6) indicates that, during the 1930's and 1940's saltwater intrusion into the Jameco aquifer was more rapid than in the upper glacial aquifer and extended farther inland and caused higher chloride concentrations. The rise in chloride concentration at two wells screened in the Jameco aquifer is more rapid than at corresponding wells screened in the upper glacial aquifer. (Compare figs. 8A and 8B.)

The Lloyd aquifer shows no evidence of saltwater intrusion, most likely because it is tapped by only a few wells. Pumpage from the Lloyd in Kings County began in 1920 and, until 1940, averaged less than 1 Mgal/d (fig. 5). Well K464, on the western shore of Jamaica Bay and screened in the Lloyd aquifer (pl. 1), had chloride concentrations of 6 to 10 mg/L during 1937-50. High chloride concentrations were measured in water from this well in 1950, but because this was immediately after repair work had been done on these wells, it is probably a result of a damaged well casing that allowed shallow saline ground water to contaminate the well.

The maximum recommended concentration of chloride in community water systems is 250 mg/L (New York State Department of Health, 1977)—the approximate taste threshold for most people. By 1940, public-supply water in Kings County had begun to exceed this amount, and, by 1947, chloride contamination in the upper glacial aquifer was widespread (fig. 9A). Although background chloride concentrations are probably 10 mg/L or less (see previous section), much of the shallow ground water in Kings County had been affected to some degree by chloride contamination from land surface (fig. 9A). Therefore, 40 mg/L has been used as a background level for chloride in shallow ground water (Soren, 1971).

Chloride concentrations at wells near the shore had reached 1,000 to 8,000 mg/L by 1947, and the concentrations inland were as high as 700 mg/L. At the same time, chloride concentrations in the Jameco aquifer in Kings County were as high as 1,500 mg/L. Queens County in 1947 had only traces of chloride in the upper glacial aquifer, however (figs. 8A and 9A).

Pumping in Queens County increased sharply in the early 1950's (figs. 4 and 5) and was accompanied by an increase in chloride concentrations. Water from two wells that tap the upper glacial aquifer in the Woodhaven franchise area (fig. 8A) showed a marked increase in chloride concentration from the late 1950's until 1974, when pumping for public supply (which was entirely from the upper glacial aquifer) in that area was stopped.

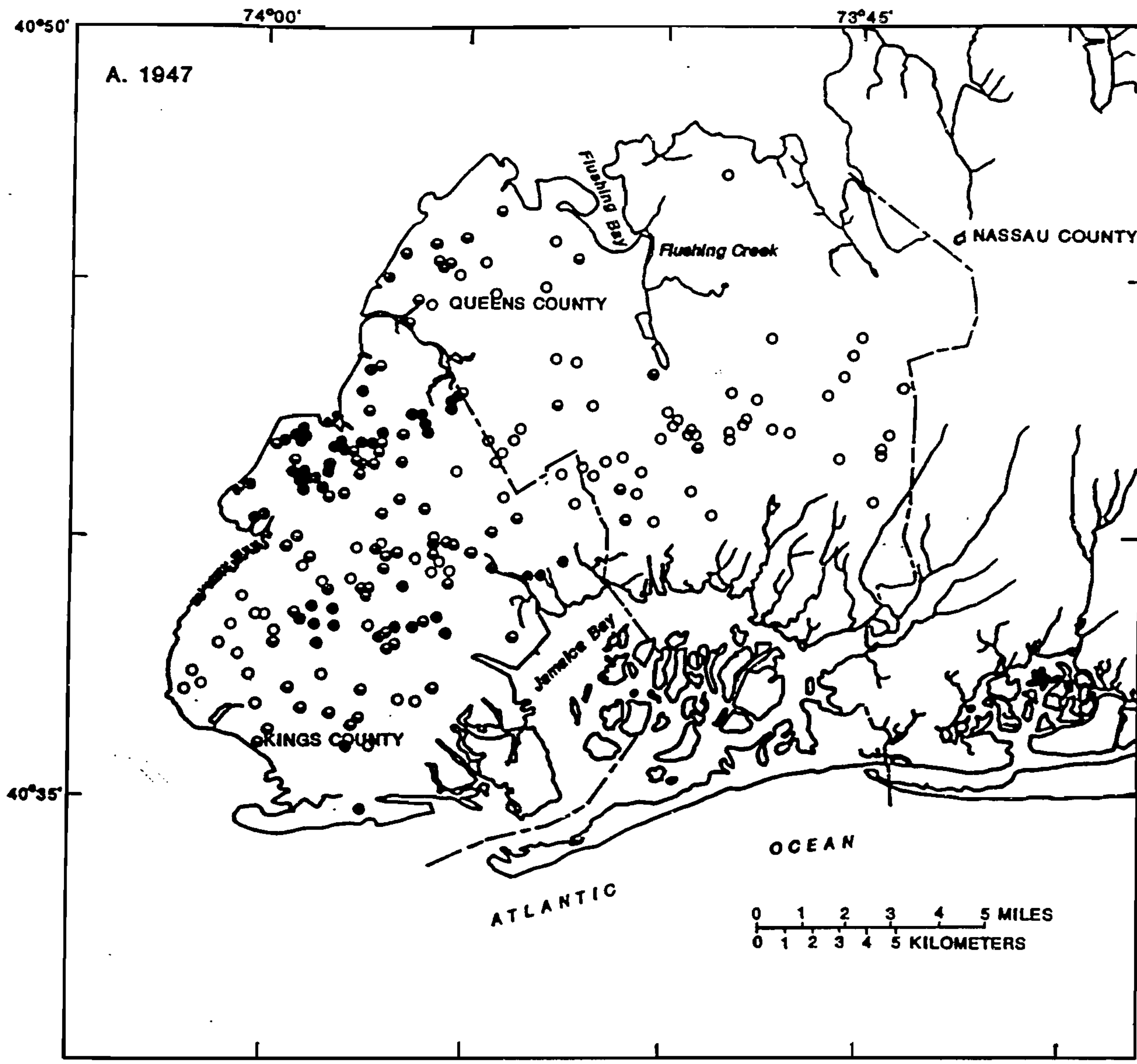
The map in figure 9B indicates that, in 1960, water from much of the upper glacial aquifer in western Queens County had chloride concentrations greater than 40 mg/L. Chloride contamination appears to be greatest in shore areas and in the cone of depression around pumping centers in the Woodhaven franchise area (fig. 6D) and is largely the result of saltwater intrusion.

Some of the chloride contamination in Queens County is undoubtedly derived from inland surface sources, especially in northwestern Queens, which has been extensively developed since the 19th century and where water-table gradients indicate that saltwater intrusion is unlikely.

Chloride concentrations in Kings County in 1960 (fig. 9B) appear to show a decrease since the cessation of pumping in 1947 through dilution and the gradual recovery of ground-water levels (fig. 6). Water at well K503 in 1960 (fig. 8A) shows a considerable decrease in chloride concentration since 1947.

By 1970, chloride contamination in the Woodhaven franchise area had become even more extensive (figs. 6 and 9C), and, by 1974, pumping for public supply had been stopped because of saltwater intrusion. Chloride contamination in the Jamaica area in 1970 was still virtually negligible (fig. 9C).

Wells in the Jamaica Water Supply Company area (southeastern Queens County)—Q304 in the upper glacial aquifer and Q1237 and Q314 in the Jameco aquifer (fig. 8)—all show a steady increase in chloride concentration since the 1960's. This could be a forewarning of sharp increases similar to those that occurred in western Queens in the 1960's and in Kings in the 1940's.

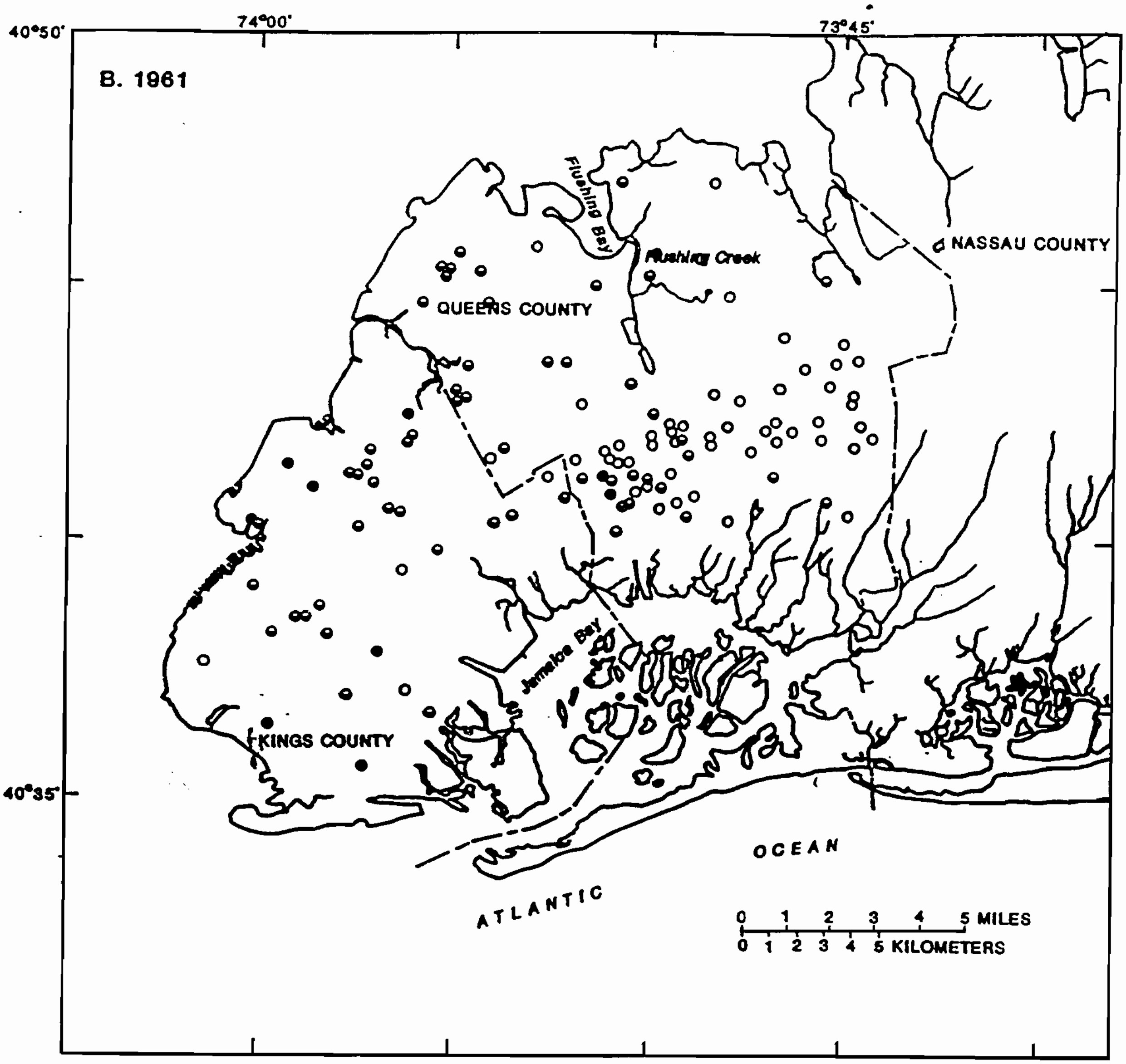


EXPLANATION

CHLORIDE CONCENTRATION, IN MILLIGRAMS PER LITTER

- LESS THAN 40
- 40 TO 250
- MORE THAN 250

Figure 9A. Chloride concentrations in the upper glacial aquifer in Kings and Queens Counties in 1947. (Data from U.S. Geological Survey files, Lusczynski, 1952, and selected annual reports of the Bureau of Water Supply, New York City, 1948, 1962, and 1971.)



EXPLANATION

CHLORIDE CONCENTRATION, IN MILLIGRAMS PER LITTER

- LESS THAN 40
- 40 TO 250
- MORE THAN 250

Figure 9B. Chloride concentrations in the upper glacial aquifer in Kings and Queens Counties in 1961. (Data from U.S. Geological Survey files, Lusczynski, 1952, and selected annual reports of the Bureau of Water Supply, New York City, 1948, 1962, and 1971.)

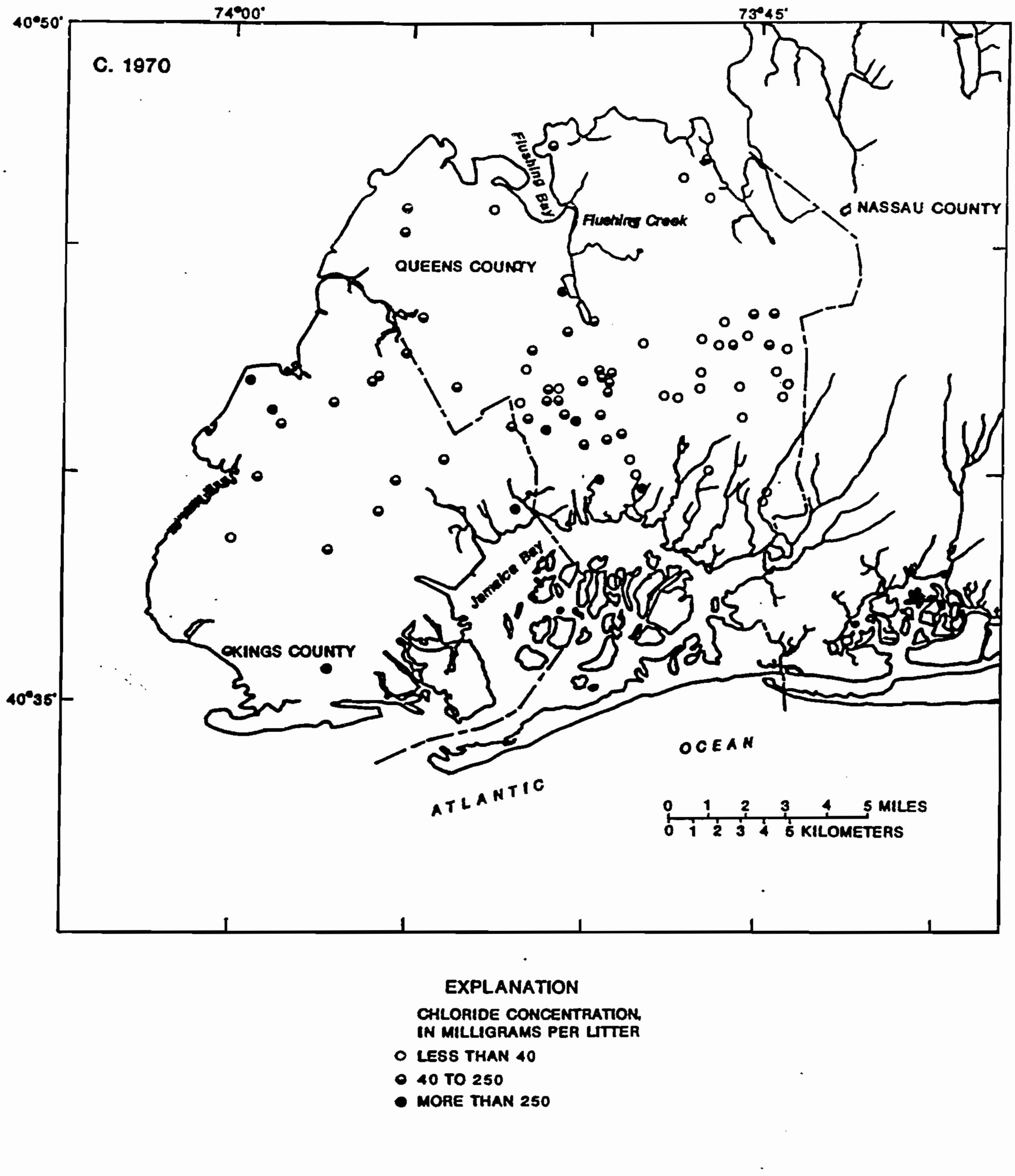


Figure 9C. Chloride concentrations in the upper glacial aquifer in Kings and Queens Counties in 1970. (Data from U.S. Geological Survey files, Lusczynski, 1952, and selected annual reports of the Bureau of Water Supply, New York City, 1948, 1962, and 1971.)

Nitrate

Nitrate is the predominant form of nitrogen found in ground water. After introduction at the water table, it has been found to be a persistent indication of contamination from land surface. The first introduction of nitrate to ground water resulted from domestic waste disposal and agricultural sources, which became widespread about 200 years ago. Other sources of nitrate are leaking sewer lines and leachate from landfills. Because elevated nitrate concentrations in water can be harmful, a limit of 10 mg/L nitrate (as nitrogen) is defined as drinking-water standard (New York State Department of Health, 1977). Data on nitrate concentrations in the upper glacial aquifer in Kings County during 1897-1916 (Kimmel, 1972) indicate that ground water in developed areas was already contaminated by the turn of this century. Nitrate concentrations (as nitrogen) in 13 of 14 wells in Kings sampled in 1942 ranged from 6 to 25 mg/L (Kimmel, 1972); the concentration in the remaining well was 2 mg/L.

Data on nitrate contamination of the deeper aquifers in Kings County are scant. The amount of denitrification in deeper aquifers is undetermined, however, elevated concentrations in deep aquifers as early as 1929 indicate some downward migration of nitrate from the water-table aquifer (Kimmel, 1972, p. D202).

Veatch and others (1906) state that 8 of 13 private wells or pumping stations in Queens County sampled before 1903 had nitrate concentrations greater than 1 mg/L as N and as high as 34 mg/L. Additional data on nitrate in Queens County are summarized in Soren (1971, table 1), which includes analyses of water from 38 wells (10 in the Lloyd aquifer, 15 in the Jameco-Magothy aquifer, and 13 in the upper glacial aquifer) that were sampled during the 1950's and 1960's. Nitrate (as N) concentrations were above 10 mg/L in water from only four of the wells, but many samples, including several from the Magothy aquifer, had concentrations higher than 0.2 mg/L (predevelopment level), which indicates some contamination in the upper glacial aquifer and local downward movement to the deeper aquifers. These data indicate that nitrate contamination in Queens County is not as advanced as Kings County.

RECENT (1983) HYDROLOGIC CONDITIONS

Hydrologic data collected in 1983 indicate that the ground-water reservoir in eastern Queens County is still severely stressed. The following paragraphs refer to maps and hydrogeologic sections that: (1) represent the current three-dimensional distribution of hydraulic head, (2) indicate the patterns of ground-water movement, (3) define the distribution of ground-water quality on western Long Island, and (4) quantify the effects of the stresses of urbanization on the ground-water-system budget.

Water-Table and Potentiometric-Surface Altitudes

Routine water-level measurements made by USGS throughout Long Island are used to monitor changes in the ground-water reservoir that result from natural hydrologic fluctuations or continued development by man. Water-level measurements in 194 wells in Kings, Queens, and western Nassau County from January through April 1983 were used to construct a set of maps showing the configuration of the water table and the potentiometric surfaces in the confined aquifers of western Long Island (pl. 4, 5, and 6). Table 8 (at end of report) lists all observation wells, their location by latitude-longitude, and their screened interval.

Measurements were made in all available observation wells and industrial or public-supply wells that were not pumped during or immediately before the measurement period. The distribution of these wells is summarized by aquifer and county in table 4. The deeper aquifers have fewer wells, especially in Kings County, primarily because installation expenses are greater, and many wells in Kings County, abandoned since the 1940's or earlier, have been destroyed.

Plates 4, 5, and 6 show the distribution of hydraulic head in the upper glacial (water table) aquifer, the Jameco-Magothy aquifer, and the Lloyd aquifer, respectively. As described previously, the Jameco and Magothy aquifers are presented as one hydrogeologic unit.

Construction of these maps entailed overlaying maps of successive aquifers to verify that vertical gradients consistently represented the three-dimensional pattern of ground-water flow. Hydrologic sections presented on plate 7 show the vertical distribution of head throughout the entire thickness of unconsolidated deposits. Together, the sections and maps give an indication of the three-dimensional distribution of hydraulic head throughout the ground-water system and the pattern of ground-water flow. Most vertical gradients occur within confining units (except in the water-table aquifer near streams), enabling a set of maps and sections to be used effectively to represent three-dimensional flow patterns.

Additional information on hydrologic factors that affect the distribution of hydraulic head and movement of ground water within the system can be useful in constructing such maps. The location and average pumping rate during the measurement period of 103 industrial and public-supply wells are shown on plates 5 and 6; plate 7 shows the screened interval of each well on a cross section. These data help define the configuration of the cones of depression that are centered at the screens of the pumping wells. Other hydrogeologic characteristics that affect the head distribution and are shown on these maps include: (1) hydrogeologic-unit geometry, particularly the extent of confining layers, which affect vertical head relations and patterns of flow between aquifers; (2) locations of permeability boundaries, that is, the boundary between zones that differ considerably in hydraulic conductivity; and (3) natural hydrologic boundaries such as gaining-stream channels and the saltwater-freshwater interface in the confined aquifers.

Water-Table Configuration

The configuration of the water table in western Long Island, shown on plate 4, was constructed from water levels measured in 132 observation wells screened in the upper glacial aquifer (table 4) in March and April 1983. The water table shows anomalous mounds along the north shore. The water level in well Q2791 in northeastern Queens was more than 50 ft above sea level and has been comparably high in recent years. These features are not perched ground water because they are hydraulically connected with the water table, as indicated by the fact that well Q2791 is screened from 11 to 19 ft above sea level. Rather, this mounding is attributed to two causes. The first is that the upper glacial material on the north half of Long Island consists of moraine deposits that, on the average, have a hydraulic conductivity 2 to 10 times lower than the outwash deposits on the south shore and locally could be several orders of magnitude lower. This contrast in hydraulic conductivity is a major reason for the north-to-south asymmetry of the water table throughout Long Island. The water-table divide is much closer to the northern

Table 4.—Number of observation wells in which water levels were measured, January through April 1983.

County	Aquifer				
	Upper glacial	Jameco[1]	Magothy[1]	Lloyd	Total
Kings	31	2	0	1	34
Queens	48	5	13	11	77
Nassau[2]	53	1	21	8	83
Total	132	8	34	20	194

[1] The Jameco and Magothy aquifers are considered one hydrogeologic unit for purposes of mapping the distribution of hydraulic head.

[2] That part of Nassau County adjacent to the Queens County border.

shore than the southern shore throughout Kings and Queens Counties.

The second reason for the anomalous high ground-water levels along the north shore is the configuration of the base of the water-table aquifer. This aquifer is underlain by either bedrock or confining-unit material overlying bedrock, either of which forms a virtually impermeable bottom boundary to the aquifer at a shallow depth (fig. 10). The Raritan confining unit is above sea level in northeast Queens, and bedrock crops out in northwest Queens (fig. 10 and sections B-B′ and D-D′ on pl. 7), which further restricts ground-water discharge to the north shore and results in the steep northward gradients (pl. 4).

Locations of 38 wells pumped for either industrial supply or public supply are shown on plate 4. Two major cones of depression caused primarily by pumping (during the measurement period) of 13.8 Mgal/d for public supply are evident in southern Queens County, where water levels have been drawn down to below sea level. A considerable increase in gradients from Nassau into Queens County since the predevelopment period indicates that the amount of ground water flowing across the county line has increased significantly. The western (smaller) cone of depression has no discharging wells at its center in the upper glacial aquifer. Comparison of the water-table map with the potentiometric-surface map of the Jameco-Magothy aquifer (pl. 5) indicates, however, that the larger cone of depression in the water table is caused by pumping in the Jameco-Magothy aquifer. This occurs in an area where the Gardiners Clay is absent and the aquifers have substantial hydraulic connection.

Potentiometric Surface of the Jameco-Magothy Aquifer

The potentiometric-surface altitude in the Jameco-Magothy aquifer is shown on plate 5. Water levels measured in 42 wells screened in this aquifer in March and April 1983 were used to construct the map. The number of available observation wells decreases westward rapidly in the area; only two are available in Kings County (table 4). Plate 5 also shows the northern extent of

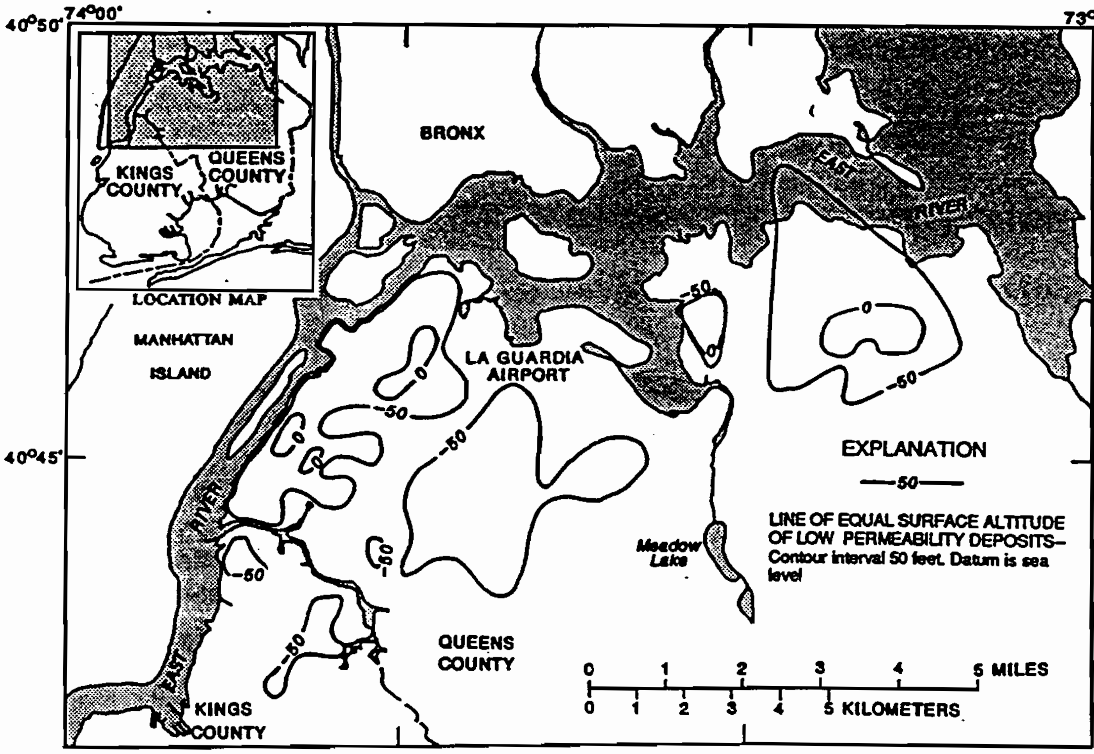


Figure 10. Upper surface altitude of deposits with low permeability at base of water-table aquifer in northern Kings and Queens Counties.

this aquifer unit and the Gardiners Clay. (The Gardiners Clay, where present, separates the Jameco-Magothy aquifer from the overlying upper glacial aquifer.) The Gardiners Clay overlaps the Jameco-Magothy aquifer throughout Kings County; thus, all ground water that moves vertically between the Jameco-Magothy and upper glacial aquifers must move through the confining unit. In Queens County, the aquifer extends farther north, and the confining unit recedes southward. In areas where the aquifer is not overlain by the Gardiners Clay, the Jameco-Magothy aquifer is in direct contact with the upper glacial aquifer.

Careful consideration was given to the extent of the confining unit in plotting the head relations between the Jameco-Magothy and upper glacial aquifers. Vertical head differences between the aquifers are greater, and flow rates lower, where the confining unit is present. The resulting distribution of head in both aquifers (pls. 4, 5) indicates vertical gradients consistent with the three-dimensional patterns of ground-water flow. For example, ground-water gradients are downward beneath the water-table mound in northeast Queens County, but to the east, under Alley Pond Creek, seepage to the creek results in upward gradients.

Head distribution in the Jameco-Magothy in Kings County indicates that water enters the aquifer vertically from the upper glacial aquifer by downward seepage through the Gardiners Clay and then flows southward to near the shore, where it discharges by upward seepage back through the Gardiners Clay.

Ground-water flow patterns in Queens County are more complex than in Kings County. A deep erosional channel through the Cretaceous deposits trends north-south through Queens County. (The origin of this channel is discussed in a previous section; a map of the configuration of the Cretaceous surface is shown in Smolensky and others, 1989). This channel also cuts through the Raritan confining unit and was subsequently filled with upper glacial deposits, which act as a conduit for ground-water flow between all aquifer units (sections C-C' and E-E', pl. 7). The area in which these glacial deposits are laterally contiguous with the Jameco-Magothy aquifer is shaded on plate 7 to identify this pathway for ground-water flow; this is a significant factor in the three-dimensional pattern of ground-water movement in this area. The Jameco-Magothy aquifer is underlain everywhere by the Raritan confining unit except in this eroded channel.

Well Q2410 taps the eroded channel in north-central Queens; it is screened in upper glacial deposits but at a depth equivalent to the Jameco-Magothy aquifer. The hydraulic head in this well is similar to that in the overlying glacial deposits, which is consistent with the contention that the channel acts as a direct pathway for water from the upper glacial aquifer to pumping wells in the Jameco-Magothy aquifer.

Pumping for public supply in the Jameco-Magothy aquifer in Queens County during the measurement period was 31.26 Mgal/d; most pumping wells are in the east-central part of the county, and ground-water levels have been drawn down below sea level in an extensive cone of depression. The Gardiners Clay is absent throughout most of this area, and the effects of pumping have propagated into the water-table aquifer (pl. 4). A concentration of pumping in southwestern Nassau County has drawn ground-water levels down to below sea level in that area.

An important lateral hydrologic boundary in the Jameco-Magothy aquifer is the interface between fresh and saline ground water. This interface is actually a zone of diffusion in which chloride concentrations increase from the typical concentration in the fresh ground-water system (less than 40 mg/L) to that of seawater, about 19,000 mg/L. Under undisturbed conditions, this zone of diffusion probably does not exceed several hundred feet in width, but nearby pumping can cause considerable mixing and expansion of this zone. Chloride concentrations in water samples from wells near the shore were used as a guide to estimate the approximate position of the interface; results are discussed in greater detail in the section "Saltwater Intrusion" (p. 42).

The configuration of the saltwater-freshwater interface is controlled by the distribution of head within the ground-water system and tends toward an equilibrium state in which the pressures in saltwater and freshwater balance. The interface typically extends farther landward with increasing depth (pl. 7). The interface in southern Kings and Queens extends several miles inland in the Jameco-Magothy aquifer. Two holes in the Gardiners Clay along the south shore (pl. 5) probably partly explain the extreme landward position of the interface in this part of the Jameco-Magothy aquifer. Before development, these holes permitted discharge upward, lowering head in the Jameco-Magothy aquifer; during pumping, they provide a pathway for intrusion downward into the aquifer.

The altitude of the base of the Jameco-Magothy aquifer at the edge of the interface ranges from 300 to 600 ft below sea level across south-western Long Island. Freshwater heads of 7.5 to 15 ft are required to balance static saline ground water at these depths. Hydraulic heads along the edge of the freshwater system range from 1 to 5 ft (pl. 5), indicating that the interface is not in an equilibrium position and is moving landward.

Water levels at several wells in southwestern Nassau County have been below sea level (fig. 11) and are depicted as a separate cone of depression in several published potentiometric-surface maps of the Magothy aquifer. This area has no known stress that could cause such a local cone of depression, however. An inspection of recent water-quality analyses shows that the dissolved-solids concentrations at these wells are elevated by sea water and are high enough to significantly increase the density of water in the well. This would cause the measured hydraulic head to be lower than if freshwater were in the well casing. Thus, the observed depressions in this area do not indicate converging flow patterns, but are rather an artifact of pressure-head measurement in terms of a fluid that is denser than freshwater.

Evaluation of horizontal gradients and flow rates in a system of dilute seawater such as this require adjustment of head measurements to the calculated head of a common fluid (freshwater). These head data are referred to as freshwater or equivalent-freshwater head. The equation for freshwater head (h_f) is given as:

$$h_f = (h_s - z)\frac{\rho_s}{\rho_f} + z$$

where: h_s is measured head of saline ground water,
ρ_s is density of saline ground water,
ρ_f is density of fresh ground water, and
z is altitude of the well screen.

The density of the water in the casing (the measurment fluid) was estimated assuming a proportional mixture of freshwater and seawater determined by the measured chloride concentration. The chloride concentration, estimated density, and freshwater and saltwater heads, in pertinent wells are presented in table 5. Corrections to freshwater head resulted in changes of as much as 12 ft (well N6702). The distribution of head in wells in southern Queens and southwestern Nassau County, both as actually measured and as equivalent-freshwater head, is shown in figure 11. The measured heads in wells N3861, N6510, and N6702 were below sea level as a result of saline water in the well casings. The distribution of equivalent freshwater head does not show a cone of depression. Hydraulic gradients in freshwater head indicate a landward movement of ground water toward pumping centers to the north.

Ground-water levels shown on plates 4, 5, and 6 were made as part of an islandwide synoptic measurement; water samples were not collected at the time of measurement. Estimates of fluid density were made from chloride concentrations in the most recent sampling of these wells; the dates of these analyses are included in table 5. A more accurate estimate of the effects of local differences in fluid density would be possible if sampling and chemical analyses were included with future water-level measurements. Thus, if a well is expected to be affected by saltwater, it would first be pumped to ensure that the water in the casing is indicative of the local ground water; then a sample would be taken for chemical analysis, and finally the recorded static water level would be measured.

The rate of movement of the saltwater-freshwater interface is difficult to estimate. To obtain an approximation, Darcy's law was applied along a transect trending from the center of Jamaica Bay north-northeastward toward the center of pumping. Estimates of the horizontal component of velocity based on published values of water-transmitting coefficients ranged from 0.5 to 1.0 ft/d. Although this rate may seem slow, at a rate of 1.0 ft/d, the interface would advance 1 mi in 15 years, a distance of major consequence to long-range resource management, especially because intrusion could be more rapid near well screens or in local zones with high permeability or low porosity.

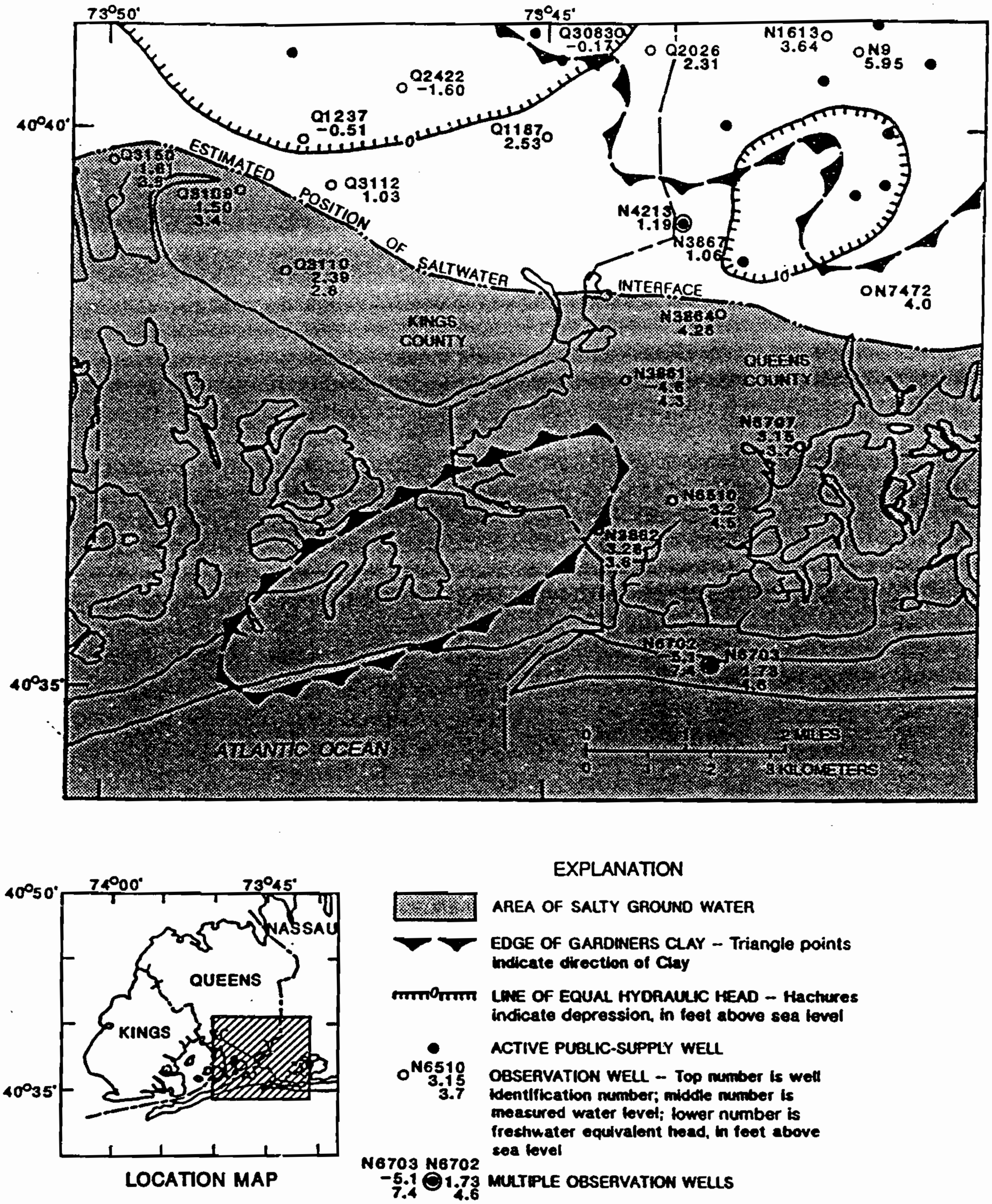


Figure 11. Distribution of hydraulic head in southern Queens and southwestern Nassau County, as measured and converted to freshwater equivalent head.

Table 5.—Equivalent freshwater head at wells affected by saline water in the Jameco-Magothy aquifer.

[Well locations are shown in fig. 11.]

Well no.	Date of sample collection	Average screen altitude (feet below sea level)	Chloride concentration (milligrams per liter)	Density[1] (grams per cubic centimeter)	Saltwater head (feet above or below (-) sea level)	Freshwater head (feet above sea level)
N6703	10/5/83	-460	5,800	1.0061	1.7	4.6
N6702	8/6/81	-672	15,000	1.0187	-5.1	7.4
N6510	4/10/62	-447	14,000	1.0173	-3.2	4.5
N3861	9/1/81	-517	14,000	1.0173	-4.6	4.3
N6707	9/28/83	-492	1,900	1.0010	3.2	3.7
N3862	8/26/81	-294	1,900	1.0010	3.3	3.6
Q3110	7/18/83	-306	2,300	1.0014	2.4	2.8
Q3109	8/18/83	-278	6,400	1.0069	1.5	3.4
Q3150	6/21/83	-119	15,000	1.0187	1.6	3.8

[1] Estimated from a relation between chloride concentration and density in dilute seawater solutions (Weast, 1981, p. D229).

Potentiometric Surface of the Lloyd Aquifer

The potentiometric-surface altitude of the Lloyd aquifer measured in January 1983 is shown on plate 6. Only 20 wells that tap the Lloyd aquifer were available for measurement, and only one is in Kings County. The Raritan confining unit overlaps the Lloyd aquifer throughout Kings and western Queens. In central Queens, where the ancestral Hudson River channel eroded the Raritan confining unit away (shaded on pl. 6), upper glacial sediments lie either directly on bedrock or on deposits of the Lloyd aquifer and thus afford a direct pathway for ground-water exchange among all three aquifers.

The potentiometric-surface map (pl. 6) shows four public-supply wells, all in Queens County, that tap the Lloyd aquifer. Together they pumped at a rate of 5.94 Mgal/d during the measurement period. The cone of depression created by these wells is deeper and more extensive than that in the overlying Jameco-Magothy aquifer (pl. 5), where pumping is more than six times greater. No observation wells are near the center of the cone of depression; thus, the shape of the potentiometric surface near these wells is only estimated. Water levels measured in the pumping wells after they had been temporarily shut down for several hours were still more than 20 ft below sea level. Although these data are difficult to interpret and are not used to indicate absolute head values, they are considered to indicate the maximum ground-water level in an area immediately surrounding the pumping wells during their operation.

The configuration of the potentiometric surface near the eroded channel indicates that water flows downward through the channel-fill deposits from the overlying aquifers to recharge the Lloyd aquifer. Head contours in the Lloyd aquifer indicate that water is diverging from this source area.

The Lloyd aquifer is expected to be more sensitive to pumping than the overlying aquifers for two reasons. First, probably only about 5 percent of the total volume of water in the system moves through the Lloyd because it is the deepest aquifer and is almost everywhere separated from the rest of the system by the Raritan confining unit. Second, even though pumping in the Lloyd aquifer would increase the downward hydraulic gradients between the overlying Jameco-Magothy aquifer and the Lloyd aquifer and would increase the downward flow of water into the Lloyd, the considerable pumping in the overlying aquifer has caused a significant drawdown in that aquifer; thus, even a small amount of pumping from the Lloyd would lower the hydraulic head to below that in the overlying aquifer. The result is that any pumping causes a more extensive and deeper cone of depression in the Lloyd aquifer than in the overlying aquifer, as seen through comparison of plates 5 and 6.

Pumping for public supply from the Lloyd aquifer occurs at two locations in Nassau County, near the Queens County line. One is near the north shore, where the Lloyd aquifer is fairly close to land surface; the other is at Long Beach on the south-shore barrier island, where it is the only source of fresh ground water.

The saltwater-freshwater interface in the Lloyd aquifer is estimated to lie just off the south shore (pl. 6). Here the base of the Lloyd ranges from 600 to 1,200 ft below sea level. Freshwater heads of 15 to 30 ft would be needed to balance static seawater at these depths, but water-level measurements along the interface indicate that head in the Lloyd aquifer does not exceed a few feet. Thus, data indicate that, as in the overlying Jameco-Magothy aquifer, the interface is not in an equilibrium position and is moving landward.

Darcy's Law was used to estimate the rate of landward movement on a transect due north through the center of Jamaica Bay (pl. 6). Estimates of the horizontal velocity are from 0.02 to 0.05 ft/d—much lower than in the overlying Jameco-Magothy aquifer and consistent with the smaller ground-water gradients observed in the Lloyd (pl. 5, 6).

Distribution of Hydraulic Head Along Selected Vertical Sections

The five hydrogeologic sections shown on plate 7 depict the vertical variations in hydraulic head within the system. All pumping wells and observation wells that lie along or close to the sections are indicated with their screened intervals; the observed head values shown are considered the average head over the screened interval. Equipotential lines are near vertical in each aquifer unit, where ground-water gradients are generally horizontal, but refract toward the horizontal where they enter the confining units because here, the vertical gradients are much larger than in the aquifers.

In the interpretation of head maps (plan view), ground-water flow paths are assumed to be aligned with the direction of the steepest hydraulic gradient. In the interpretation of hydrologic sections, however, this is not always true. In vertical sections, flowlines generally are not perpendicular to equipotential lines because the aquifer units are anisotropic, and the section is drawn with extreme vertical exaggeration.

The estimated configuration of the saltwater-freshwater interface is also indicated; it typically extends landward with depth and is near vertical within confining layers. It could contain more irregularities than are shown as a result of extensive clay lenses within the aquifer units or local drawdown from pumping.

Section A-A′ (pl. 7) trends north-south in Kings County. The water table along this profile is asymmetric because the ground-water divide is close to the north shore. The water-table mound at the divide is probably caused by a local zone of low permeability in the moraine deposits. Low head in the Jameco-Magothy aquifer, caused by pumping in Queens County, has caused the saltwater-freshwater interface in this aquifer to move inland. As a result, subsea discharge upward through the Gardiners Clay has probably ceased.

Freshwater in the Lloyd aquifer extends considerably farther seaward than in the Jameco-Magothy, but, as stated previously, head in the freshwater system is inadequate to balance sea water at the depths of the Lloyd aquifer. Thus, saline ground water in the Lloyd probably is moving slowly landward.

Section B-B′ (pl. 7) trends from northwestern Queens County southward to near the Kings-Queens County line. The extreme thinning of the upper glacial aquifer at the north shore is evident in the section. Within the north-central part of the section is a large area in which the bedrock is overlain by confining-unit material; as a result, the bottom boundary of the aquifer system is less than 50 ft below sea level locally. This is considered a major cause of high ground-water levels along the north shore.

Freshwater in the Jameco-Magothy aquifer is limited along this section. The hole in the overlying Gardiners Clay, which is evident in this section, provides a pathway for intrusion of saline ground water. Ground water in the Lloyd aquifer at section B-B' flows generally eastward toward the major pumping center.

Section C-C' (pl. 7) trends southward from Flushing Bay and crosses the ancestral Hudson River channel, which has eroded through all Cretaceous deposits and forms a pathway for water to the Lloyd aquifer from above. Water at well Q2418 has attained a chloride concentration as high as 550 mg/L (1981), which may indicate that saltwater from Flushing Bay and its estuary was drawn into the ground-water system, possibly by intensive pumping during the 1960 World's Fair or from public-supply wells screened in the Jameco-Magothy and Lloyd aquifers to the south. The latter possibility warrants concern for potential saltwater intrusion from the north shore toward the major pumping centers in central Queens.

Section D-D' (pl. 7) trends north-south near the Queens-Nassau County border. Only small traces of the Jameco Gravel have been found this far east. This section indicates that the high pumping rates in southeastern Queens County have caused landward gradients in the Lloyd and Jameco-Magothy aquifers. Flow in small zones along the north and south shores in the upper glacial aquifer is seaward, though.

Saline ground water probably is migrating downward into the Lloyd aquifer from the overlying Jameco-Magothy aquifers. Darcy's Law for fluids of variable density was used with data from wells N6703 and N8011 to estimate the vertical velocity and traveltime for saline ground water to cross the Raritan confining unit. Darcy's Law is given as:

$$V_z = -\frac{k_z}{n\mu}\left(\frac{\Delta P}{\Delta Z} + \rho g\right)$$

where:
- V_z is vertical velocity component,
- k_z is vertical intrinsic permeability,
- n is porosity,
- is viscosity,
- P is change in pressure across the confining unit,
- ρ is density, and
- Z is thickness of confining unit, and
- g is the gravitational constant

Conservative values for aquifer properties were assumed, including $n = 0.2$, and k_z is calculated from a vertical hydraulic conductivity of 0.002 ft/d for freshwater. A density of 1.019 g/cm^3 was used for ground water overlying the Raritan confining unit. The resulting velocity was about 0.2 ft/yr, and the traveltime across the confining unit was about 1,250 years. This indicates that lateral intrusion of saltwater within the Lloyd aquifer poses a greater threat than intrusion from the overlying aquifer.

Section E-E' (pl. 7) runs east-west through Kings and Queens Counties. This section shows the severe effects of pumping in Queens County. Large westward gradients indicate movement of ground water from Nassau County into Queens and downward into the Lloyd aquifer. The vertical pathway for water to the Lloyd aquifer through the ancestral Hudson River channel is also evident in this section. Sections D-D' and E-E' show a larger cone of depression in the Lloyd than in the overlying aquifers despite the lower pumpage.

Water Budget

Even though much of the ground-water system in Kings County is recovering from previous stress, and water levels now approach those of 1903, some severe, perhaps irreversible, deviations from the predevelopment flow patterns persist. Under predevelopment conditions, ground water was replenished entirely by recharge from precipitation and discharged solely by seepage to streams and as subsea outflow to the surrounding saltwater bodies. Urbanization and pumping have altered recharge and discharge patterns and introduced new components to the water budget. The estimated quantities of inflow and outflow in 1983 are compared with predevelopment values in table 6. The water budget was developed through evaluation of hydrologic data and through calibration of a three-dimensional ground-water flow model of the Long Island ground-water system (H. T. Buxton and D. A. Smolensky, U.S. Geological Survey, written commun., 1988), which was being developed concurrently with this project.

Inflow

The large expanses of paved, impervious surfaces in Kings and Queens Counties have caused increased runoff and evaporation, which in turn have led to a major reduction in recharge from precipitation. Analysis of land use in Kings and Queens by the City of New York (New York City

Department of Environmental Protection, 1979) indicates that Kings County has been the most severely affected by development and that Queens, although also affected, still has areas of permeable land surface such as parks, cemeteries, and low-density residential communities. About 15 percent of precipitation, 24 Mgal/d countywide or 0.32 (Mgal/d)/mi² in Kings County, and about 35 percent of precipitation, 83 Mgal/d countywide or 0.73 (Mgal/d)/mi² in Queens County, is estimated to enter the ground-water system as recharge, a considerable decrease from that which reached the aquifers before development, 1.1(Mgal/d)/mi² (table 6). Recharge in neighboring Nassau County continues to equal about 50 percent of precipitation, even under present urban conditions, because an extensive recharge-basin system captures runoff and returns it to the ground.

A large volume of water is returned or added to the ground-water system as leakage from artificial structures, which include water-supply lines and sewer lines, and as infiltration of water used for purposes such as lawn sprinkling. In areas where the water was pumped from the ground, such infiltration would constitute only a partial return to the system. In 1983, 57 Mgal/d of water was pumped from local aquifers to supply about 500,000 people and 7,600 commercial and industrial users in southeastern Queens. All of Kings County and most of Queens County are supplied with water totaling almost 700 Mgal/d from upstate surface-water reservoirs, however (New York City Bureau of Water Supply, written commun., 1983). Infiltration of water leaking from this source constitutes artificial recharge from an external and potable source. In all, a total of about 760 Mgal/d (450 Mgal/d in Kings and 310 Mgal/d in Queens) is transmitted through the water-supply system, which contains 4,270 mi of supply lines (1,900 mi in Kings County and 2,370 mi in Queens) and has 613,000 service connections (313,000 in Kings County and 300,000 in Queens) (New York City Department of Environmental Protection, 1981, and Jamaica Water Supply Co., oral commun., 1984). Although many water-main breaks are tabulated annually by the New York City Bureau of Water Supply, constant leaking of the aging water-supply system is the largest source of recharge from artificial sources.

The total volume of leakage from artificial sources is difficult to estimate but undoubtedly constitutes a major part of the present ground-water budget. The total rate of infiltration from these sources is estimated to be about 70 Mgal/d, although it could be larger. The distribution of this recharge corresponds to water-supply and sewer networks. About 30 Mgal/d is estimated to infiltrate in Kings and 40 Mgal/d in Queens.

Table 6. Water budgets for predevelopment and recent (1983) conditions.

[Values are in million gallons per day]

Budget component	Predevelopment (pre-1900) conditions	Recent (1983) conditions
INFLOW		
Recharge from precipitation	209	107
Leakage from water-supply lines and other infiltration	0	70
Ground-water inflow from Nassau	6	9
Total	215	186
OUTFLOW		
Base flow to streams	62	11
Pumpage		
Public supply	0	57
Private (net)	0	17
Subsea discharge	153	101
Total	215	186

The final component of inflow to western Long Island is ground-water flow from Nassau County. Large hydraulic gradients in all aquifer units indicate that a significant amount of water enters from Queens County as subsurface flow. A flow-model analysis indicated that about 9 Mgal/d of ground water flows across the Nassau-Queens border, a 50-percent increase from pre-development conditions as a result of the steeper gradients induced by current pumping rates.

Total inflow to the western Long Island ground-water system from the above sources is 186 Mgal/d. This is less than the total amount of water entering before development. Even the significant inflow from leakage of imported surface water is insufficient to compensate for the loss of natural recharge through urbanization.

Outflow

Water is discharged from the ground-water system in three ways—as stream base flow, through pumpage, and as subsea outflow. Under predevelopment conditions, base flow constituted a significant outflow from the ground-water system. Today, however, only two major streams remain in Kings and Queens (Flushing Creek and Alley Creek). These, along with several smaller creeks, receive a total of about 11 Mgal/d in ground-water seepage (base flow).

As stated earlier, ground water that is pumped and either lost by evaporation or discharged to the sea is considered consumptive (net) pumpage and represents a net draft on the ground-water system. In 1983, pumpage for public supply from Queens aquifers was 57 Mgal/d. Of the 57 Mgal/d of public-supply pumpage in Queens County, 11.8 Mgal/d was pumped from the upper glacial aquifer, 39.3 Mgal/d from the Jameco-Magothy aquifer (35 Mgal/d from the Magothy aquifer and 4.3 Mgal/d from the Jameco aquifer), and 5.9 Mgal/d from the Lloyd aquifer (Jamaica Water Supply Company, written commun., 1984).

Private pumping includes pumping for industrial purposes and for dewatering in areas of ground-water flooding. The water pumped for these purposes is discharged to sewers with ocean outfall and is assumed consumptive. Net industrial pumpage in 1983 is estimated to have been 2.3 Mgal/d in Queens and 6.6 Mgal/d in Kings (New York State Department of Environmental Conservation, written commun., 1984). In 1983, subway dewatering in the Flatbush area of Kings County averaged 4 Mgal/d (New York City Transit Authority, oral commun., 1984). Fourteen additional wells with a maximum pumping capacity of 20 Mgal/d are planned in the East New York and Bedford sections of Kings County (New York City Transit Authority, oral commun., 1985). Undoubtedly homes, businesses, and institutions are dewatering also. Temporary dewatering is often required for the construction of underground structures, but no information is currently available. A total of about 8 Mgal/d is pumped for dewatering purposes in western Long Island (6 Mgal/d in Kings and 2 Mgal/d in Queens) (New York City Department of Environmental Protection, oral commun., 1984). Therefore, a total of about 17 Mgal/d is pumped for private purposes in Kings and Queens Counties.

The remaining discharge component of the ground-water budget, subsea outflow to the surrounding saltwater bodies, is considerably smaller than under predevelopment conditions but is still the largest discharge component. Because subsea discharge is impossible to measure, it is typically estimated as the flow rate required to balance the ground-water budget. Subsea outflow from the upper glacial and Jameco-Magothy aquifers at present is estimated to be 101 Mgal/d; this value is corroborated by ground-water-flow model analysis (H. T. Buxton and D. A. Smolensky, U.S. Geological Survey, written commun. 1988). Subsea outflow from the Lloyd is negligible because pumping has lowered hydraulic heads throughout that aquifer in Kings and Queens, producing landward gradients.

Ground-Water Quality

The present quality of the ground water of western Long Island has been affected by more than 200 years of development and urbanization. The natural quality of Long Island's ground water (before man's influence) was the product of chemical constituents introduced with recharge from precipitation and natural geochemical reactions that occur between the ground water and the aquifer material. Present ground-water quality is affected further by contaminants introduced by human activities as well as by additional geochemical reactions.

This study used the results of analyses of ground-water samples collected in 1983 to describe the present quality of ground water on western Long Island. An earlier, preliminary study by Buxton and others (1981) used results from a network of 77 observation wells supplemented by concurrent data from 67 public-supply wells provided by the Jamaica Water Supply Company. These samples were collected in 1981. In 1983, the network of observation wells sampled by the USGS was expanded to 107 wells (locations are shown on pl. 8). Samples were collected from June through October 1983; results are presented in table 10 (at end of report; 1981 data are included where available). Concurrent data from 84 public-supply wells sampled during 1983 and analyzed by the Jamaica Water Supply Company are presented in table 11 (at end of report).

Chloride and nitrate concentration data are used to indicate the extent to which contamination from land surface and saltwater intrusion has propagated within the ground-water system. A brief summary of the distribution of other major inorganic constituents is provided in support of this analysis. In addition, concentrations of selected organic compounds detected in public-supply wells of the Jamaica Water Supply Company are used to indicate the effect of these chemicals and related human activities on the ground-water system.

Extent of Human-Induced Contamination

In the following discussion, maps and vertical sections are used to provide a three-dimensional representation of (1) the extent to which land-surface contamination has migrated through the ground-water system, and (2) the extent to which the saltwater-freshwater interface has moved landward in all three major aquifers. Chloride and nitrate are used as indicators as described in the section "Deterioration of ground-water quality" (p. 24). Background concentrations of both are low, less than 10 mg/L and 0.2 mg/L as N, respectively, compared to concentrations observed in 1983. The maps (figs. 12-14, p. 44-49) and cross sections (fig. 15, p. 50) can be evaluated in conjunction with the corresponding potentiometric maps (pl. 4, 5, and 6) and hydrogeologic sections (pl. 7), to indicate the extent of contamination in relation to the patterns of ground-water movement.

Contamination from land surface.—Nitrogen, in the form of nitrate, was one of the first contaminants to be introduced to the ground-water system; it entered as fertilizers and domestic waste dissolved in natural recharge. Even today, nitrate continues to enter the system through leakage from New York City's extensive combined-sewer network (Kimmel, 1972).

The shaded areas on the sections in figure 15 indicate the extent of ground water that has been affected by contamination from land surface. This area is defined on the assumption that nitrate has entered the system at the water table uniformly and consistently over the years and has migrated along natural ground-water flow paths through the system. Only three wells in the shaded area (Q2978, section D-D'; Q2418, section C-C'; and Q2137, section E-E') had nitrate concentrations less than 1.0 mg/L, and Q2418, one of these wells, is affected by seawater intrusion. This format is used to indicate areas with a high expectation of contamination from land-surface sources and to provide a means to assess further migration of contaminated ground water.

Nitrate concentrations throughout the upper glacial aquifer indicate severe contamination that appears to decrease eastward (figs. 12B and 15). Concentrations in 19 of 35 samples from Kings County exceeded the public health standard of 10 mg/L, and concentrations in 27 of the 35 samples were greater than 5 mg/L (as N). In Queens County, 8 of 39 samples had concentrations greater than 10 mg/L (as N), and 24 exceeded 5 mg/L (as N). Of 11 samples from Nassau County, only 1 exceeded the public health standard, but 8 had concentrations of 3.7 mg/L (as N) or higher.

Nitrate concentrations in samples from only 2 of 72 wells in the Jameco-Magothy aquifer were greater than 10 mg/L (as N). The distribution of these values is plotted in figure 13B (p. 47). Of 69 samples from wells in Queens and Nassau Counties that were not affected by seawater, 12 were from wells in the area where the Gardiners Clay separates the Jameco-Magothy and upper glacial aquifers. The highest nitrate concentration in these wells was 0.79 mg/L, and all but two wells had concentrations of 0.28 mg/L or less. Of the 47 samples taken from inland wells where the Gardiners Clay is absent, 34 had nitrate concentrations greater than 2 mg/L (as N).

The Gardiners Clay slows the downward movement of ground water, which suggests that water in the Jameco-Magothy aquifer beneath this confining unit is older than in areas where the unit is absent. Section D-D′ (fig. 15) illustrates the difference between nitrate concentrations in the part of the Jameco-Magothy aquifer that is confined and protected by the Gardiners Clay and those in the part that is in good hydraulic connection with the upper glacial aquifer. Sections C-C′ and E-E′ (fig. 15) both show large areas where the confining unit is absent, and nitrate concentrations in the Jameco-Magothy aquifer indicate contamination from land-surface sources.

The Jameco-Magothy aquifer in Kings County is completely overlain by the Gardiners Clay. As noted previously, however, the Gardiners Clay is much sandier in Kings than in Queens and would inhibit vertical flow much less. Samples from four of six wells that tap the Jameco-Magothy in Kings County had nitrate concentrations ranging from 6 mg/L to more than 10 mg/L, which suggests that, as expected, flow rates through the Gardiners Clay are more rapid in Kings County than in Queens.

Of the 14 samples from the Lloyd aquifer, 12 had nitrate concentrations ranging from less than 0.1 to 0.72 mg/L in 1983; this indicates little, if any, contamination from land surface. The absence of land-surface contamination in the Lloyd aquifer is attributed to the aquifer's greater depth and to separation from overlying aquifers by the Raritan confining unit. Franke and Cohen (1972) estimated that the age of water in the Lloyd aquifer was 1,000 to 10,000 years—1 or 2 orders of magnitude older than water in the shallower aquifers. Therefore, this water entered the ground-water flow system (at the water table) long before the contamination from land surface appeared.

Two factors suggest that water in the Lloyd aquifer in western Long Island could be younger than that farther east, however. The first is the erosional channel that cuts through the Raritan confining unit in central Queens County and forms a pathway for more rapid vertical movement of ground water downward to the Lloyd aquifer. (The area where Raritan and Lloyd deposits were eroded away and subsequently replaced by glacial material is shaded in figs. 14A and 14B; the erosional channel also is indicated in the sections in fig. 15.) The second factor is that the Lloyd aquifer in Kings and Queens Counties has been pumped since the turn of this century, and the increased downward gradients caused by this pumping have probably accelerated vertical ground-water movement. The sections in figure 15 indicate that, even though water affected by man has not yet reached the Lloyd aquifer, the pathway for downward movement through the eroded channel in the Raritan confining unit could allow it to reach there within decades rather than the millennia it could take to move through the confining unit.

Saltwater intrusion.—Ground water that has been affected by seawater is readily identified by elevated chloride along with other principal constituents of seawater (sodium, sulfate, and hardness) and low nitrate concentrations. Total nitrogen concentration (as nitrate, nitrite, ammonia, and nitrogen gas) in seawater is 0.5 mg/L (as N) (Hem, 1970, p. 11). Concentrations of chloride and nitrate and the other principal constituents of seawater were used to define the general position of the zone of diffusion of the saltwater-freshwater interface.

A history of intense pumping in Kings and western Queens Counties has caused the zone of diffusion in western Long Island to become more dispersed than anywhere else on Long Island. In some areas, the residue of past seawater intrusion extends far inland and undoubtedly contributes to contamination that, when combined with elevated nitrate concentrations, appears to be solely of land-surface origin. Delineation of areas that have been affected by both seawater and land-surface contaminants was beyond the scope of this study, however.

Chloride concentrations in the upper glacial aquifer ranged from 13 to 9,000 mg/L in 1983 (fig. 12A). Chloride concentrations in inland areas of Kings and southwestern Queens County differ locally in an erratic fashion—concentrations of less than 20 mg/L can be found close to concentrations well over 200 mg/L. This probably indicates a combination of past saltwater intrusion and land-surface-derived contamination. In contrast, chloride concentrations in inland parts of eastern Queens and Nassau Counties range from 16 to 86 mg/L and do not indicate saltwater intrusion. Most samples with chloride concentrations above 250 mg/L were from nearshore areas and indicate the landward extent of the zone of diffusion of the saltwater interface. The saltwater interface, as a lateral boundary to the fresh ground-water system and as mapped in figures 13A and 14A, is assumed to coincide with a chloride concentration of about 1,000 mg/L.

The three sections in figure 15 show that the saltwater interface in the upper glacial aquifer is close to shore. The elevated chloride concentration at well Q2418 (section C-C') indicates that it possibly is being drawn landward from Flushing Bay (fig. 12A, p. 44).

The distribution of chloride in samples from the Jameco-Magothy aquifer is shown in figure 13A (p. 46). The interface configuration is based on the average values for the entire thickness of the aquifer and gives a general indication of the extent of saline ground water in plan view. The vertical configuration of the interface is shown in the hydrogeologic sections in figure 15 (p. 50). The interface is expected to advance landward with depth, but data on chloride concentrations at the base of the Magothy aquifer are too sparse to indicate the landward extent of the toe of the interface. Additional monitoring wells at the base of the Jameco-Magothy aquifer would be needed to ensure that saltwater intrusion has not progressed significantly farther inland there than in the shallower parts of the aquifer. The interface is estimated to have migrated inland in southern Queens and southwestern Nassau Counties in response to the extensive pumping in southeastern Queens and Nassau Counties during recent years. Elevated concentrations in wells K2510 and K2511, in the extreme south of Kings County (pl. 8 and fig. 13A), indicate that the saltwater interface in the Jameco-Magothy aquifer is inland in Kings County as well. Chloride concentrations as high as 500 mg/L in samples from inland wells in Kings County indicate a residue of past saltwater intrusion.

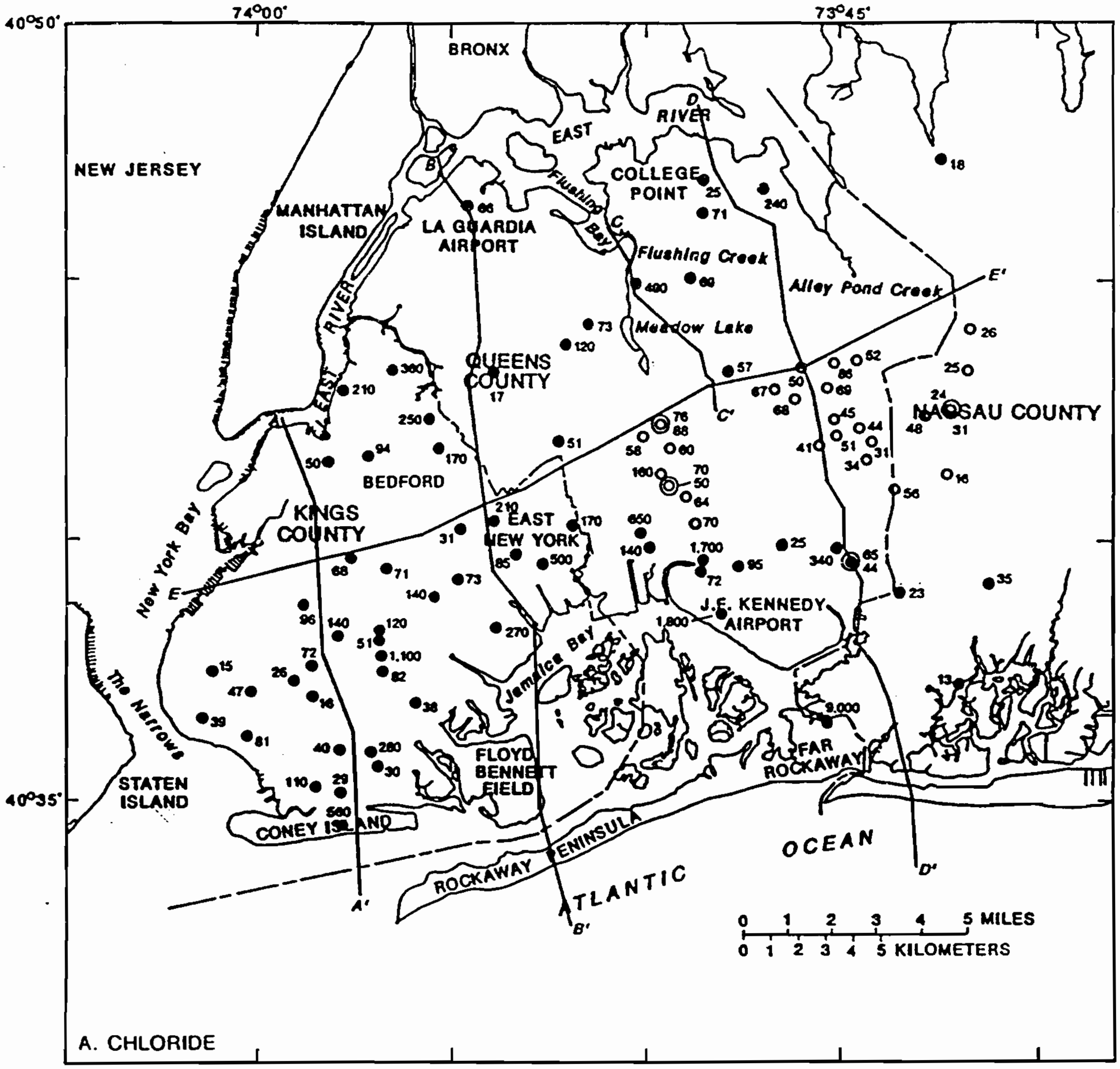
Chloride concentrations at inland wells in Queens County are much lower than in Kings. Only eight Queens wells had chloride concentrations exceeding 100 mg/L, probably because pumping has been continually shifted eastward to avoid severe saltwater intrusion locally. Except at three wells screened near the saltwater-freshwater interface, chloride concentrations in Nassau County wells were less than 50 mg/L.

The Jameco-Magothy aquifer could have a potential for saltwater intrusion from the north shore near Flushing Bay, where the aquifer is close to land surface and glacial deposits form a good hydraulic pathway for saltwater intrusion (fig. 15, section C-C').

In the Lloyd aquifer, chloride concentrations in samples from inland wells range from 3 to 16 mg/L, within the predevelopment range. Three samples taken along the south shore of Kings and Queens Counties had chloride concentrations between 50 and 100 mg/L, which probably indicates the farthest landward extent of the saltwater-freshwater interface. These data are insufficient to indicate how rapidly the chloride concentrations increase seaward, however. The configuration of the interface, as shown in figure 14A (p.48) is estimated.

As shown in the sections in figure 15, the interface in the Lloyd aquifer on the north shore is close to the northern edge of the Raritan confining unit, which in this area is close to the shore. Several wells on the north shore have elevated chloride concentrations, indicating possible saltwater intrusion. Well Q1373 in College Point (pl. 8) had a chloride concentration of 1,200 mg/L in 1983. This well, along with well Q1374 (not sampled) at the same location and depth, were industrial pumping wells drilled in 1946. This pumping induced the saltwater to move into the College Point area. Soren (1971) reports that Q1374 had a chloride concentration of 1,718 mg/L in 1955.

The extensive regional cone of depression in the Lloyd aquifer could be sufficient to induce saltwater intrusion from the north as well as the south shore. Saline ground water could affect the Lloyd aquifer (fig. 15) either by lateral movement of the interface from its current position in the Lloyd or by vertical migration through the channel in the Raritan confining unit. Well Q3134 (figs. 14A and section C-C' in fig. 15), in the erosional channel in the Raritan confining unit near Flushing Bay, had a chloride concentration of 500 mg/L in 1983. Saline ground water probably was drawn into the Flushing area during the 1964-65 World's Fair, when large-scale ground-water withdrawals occurred (Soren, 1971, p. A32). Additional discussion of the movement of the saltwater-freshwater interface is given in the earlier section, "Water-Table and Potentiometric-Surface Altitudes."



EXPLANATION

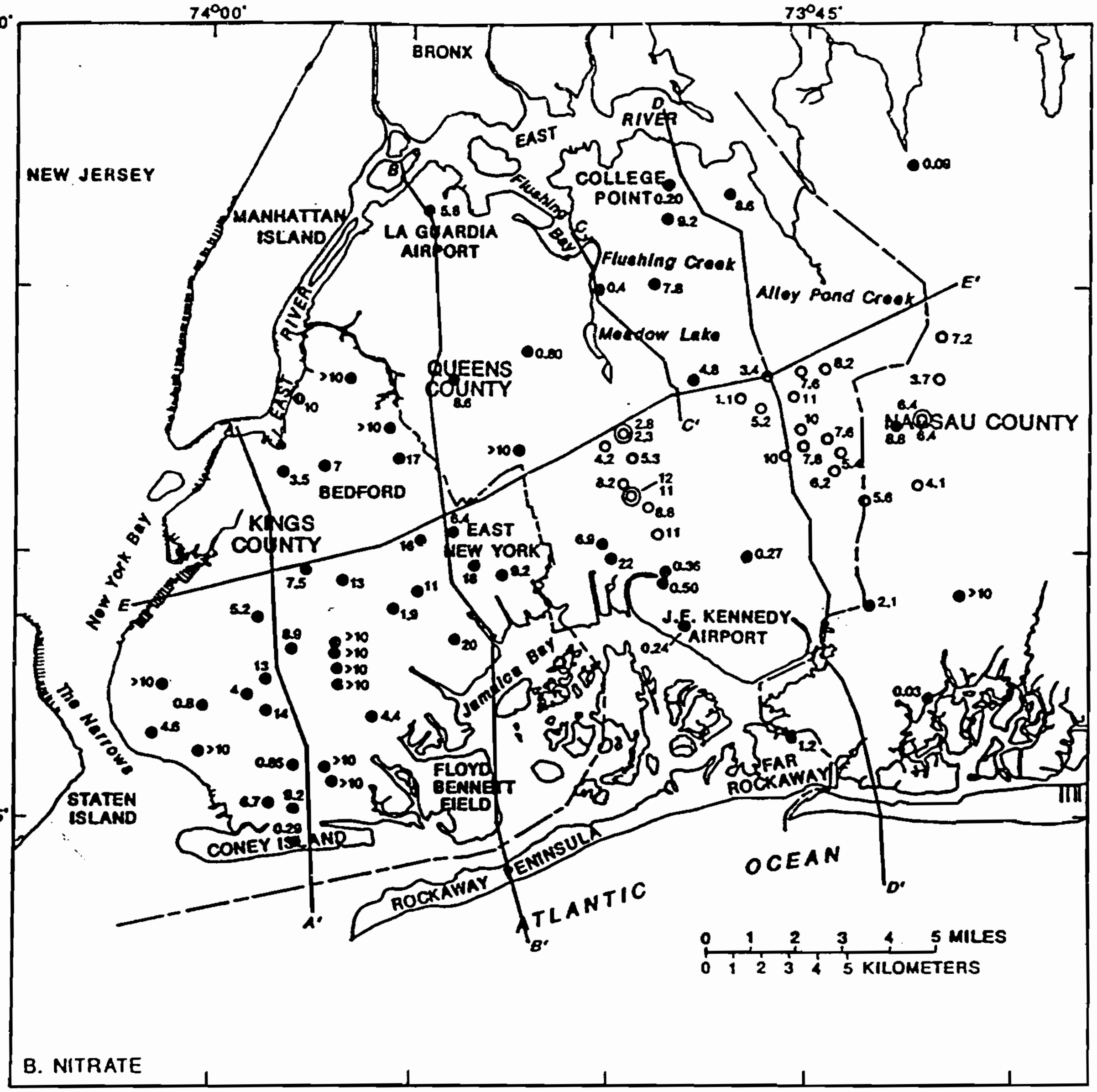
A——A' TRACE OF HYDROGEOLOGIC SECTION SHOWN IN FIGURE 15

●30 WELL SAMPLED BY U.S. GEOLOGICAL SURVEY AND ANALYZED BY NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION–Number is chloride concentration, in milligrams per liter

○70 WELL SAMPLED AND ANALYZED BY JAMAICA WATER-SUPPLY COMPANY–Number is chloride concentration, in milligrams per liter

◎70/50 MULTIPLE-WELL SITE–Upper and lower numbers refer to shallow and deep screens, respectively

Figure 12A. Chloride concentrations in the upper glacial aquifer, 1983.



EXPLANATION

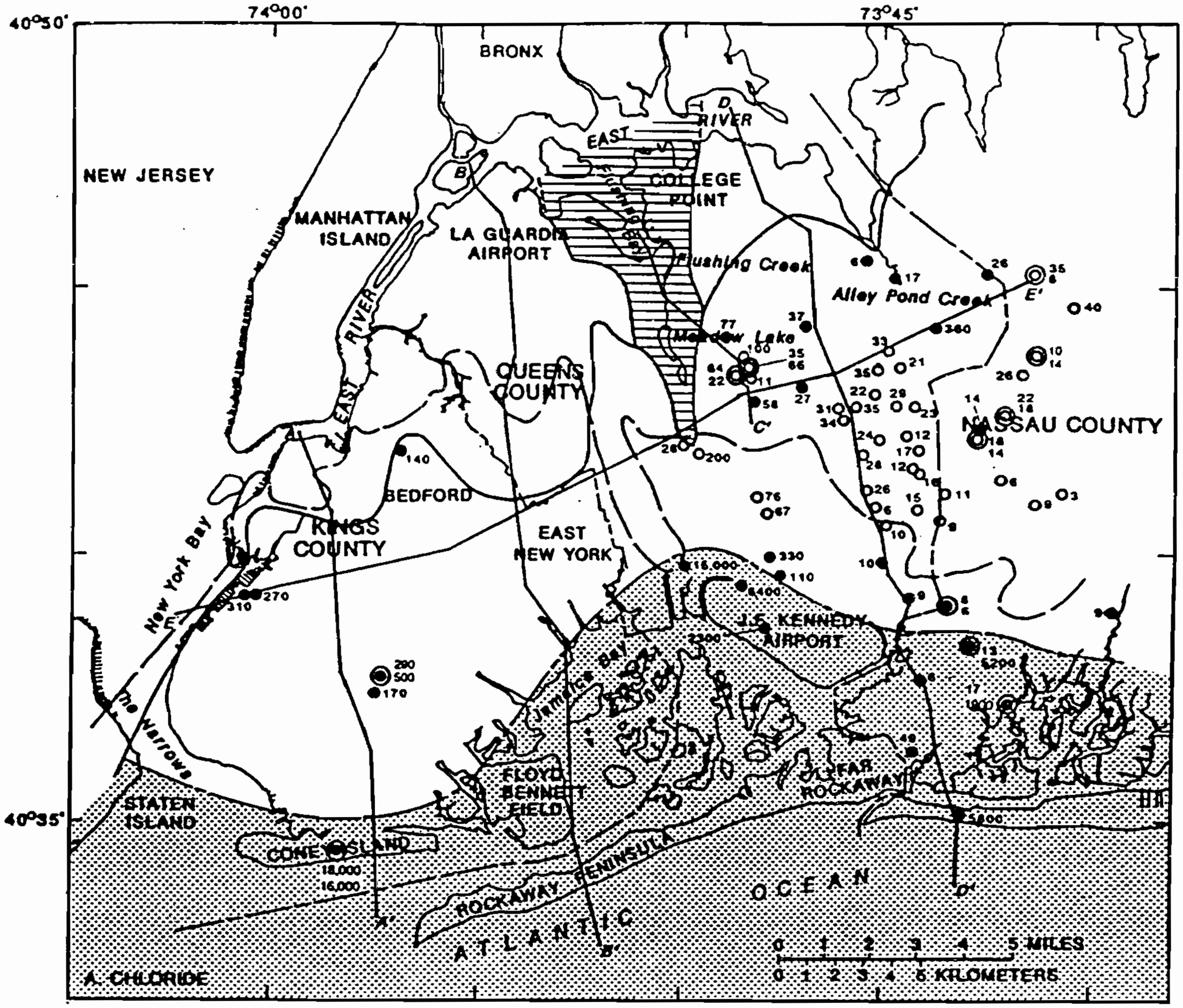
A——A' TRACE OF HYDROGEOLOGIC SECTION SHOWN IN FIGURE 15

● 9.2 WELL SAMPLED BY U.S. GEOLOGICAL SURVEY AND ANALYZED BY NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION–Number is chloride concentration, in milligrams per liter

○ 11 WELL SAMPLED AND ANALYZED BY JAMAICA WATER-SUPPLY COMPANY–Number is chloride concentration, in milligrams per liter

◎ 2.8/2.3 MULTIPLE-WELL SITE–Upper and lower numbers refer to shallow and deep screens, respectively

Figure 12B. Nitrate concentrations in the upper glacial aquifer, 1983.



EXPLANATION

GLACIAL DEPOSITS LATERALLY CONTIGUOUS WITH JAMECO-MAGOTHY AQUIFER

SALTY GROUND WATER

NORTHERN LIMIT OF THE JAMECO-MAGOTHY AQUIFER

NORTHERN LIMIT OF GARDINERS CLAY

ESTIMATED POSITION OF TOE OF SALTWATER INTERFACE

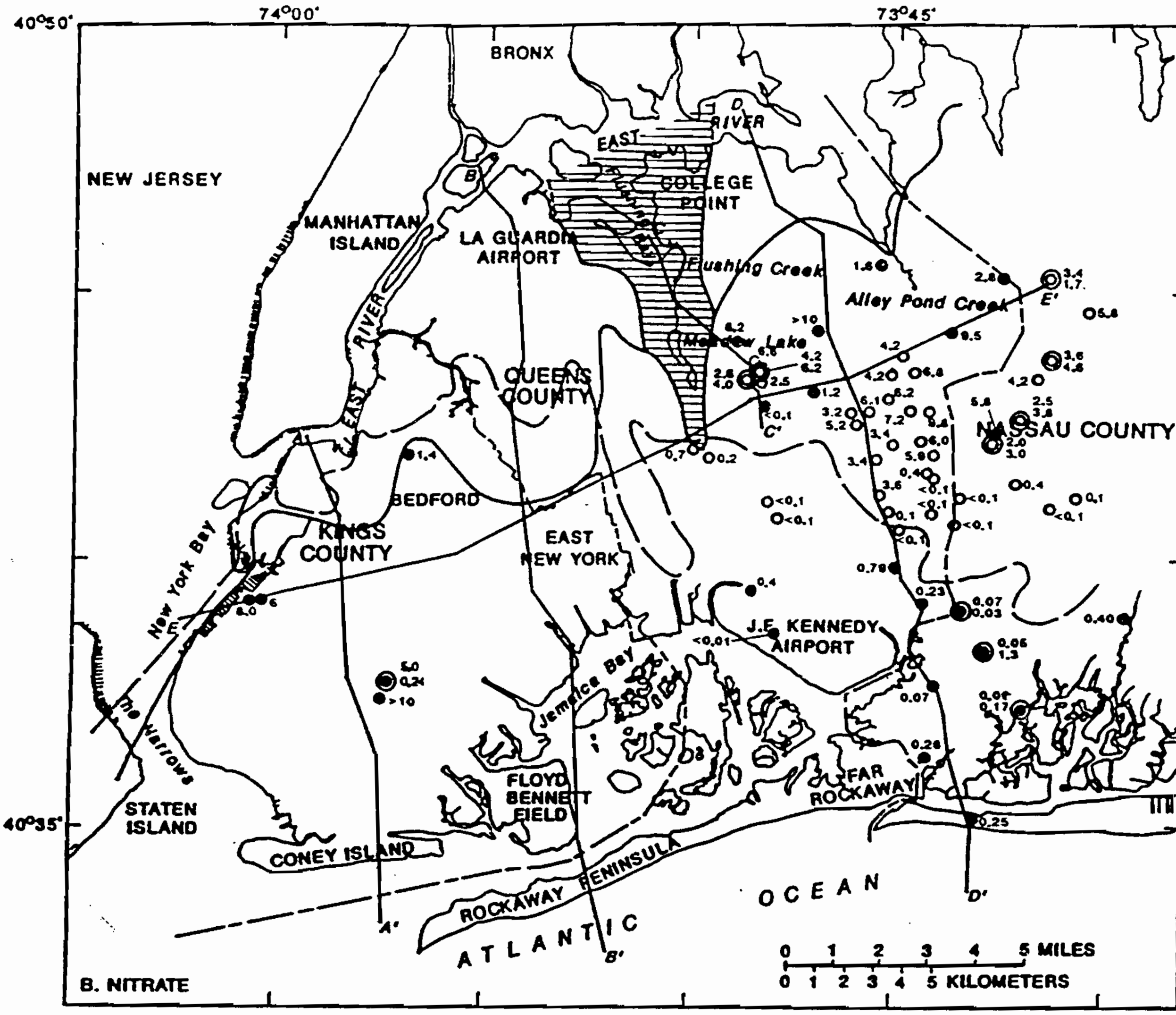
A———A' TRACE OF HYDROGEOLOGIC SECTION SHOWN IN FIGURE 15

●170 WELL SAMPLED BY U.S. GEOLOGICAL SURVEY AND ANALYZED BY NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION—Number is chloride concentration, in milligrams per liter

○67 WELL SAMPLED AND ANALYZED BY JAMAICA WATER-SUPPLY COMPANY—Number is chloride concentration, in milligrams per liter

◎18/14 MULTIPLE-WELL SITE—Upper and lower numbers refer to shallow and deep screens, respectively

Figure 13A. Chloride concentrations in the Jameco-Magothy aquifer, 1983.



EXPLANATION

GLACIAL DEPOSITS LATERALLY CONTIGUOUS WITH JAMECO-MAGOTHY AQUIFER

NORTHERN LIMIT OF JAMECO-MAGOTHY AQUIFER

NORTHERN LIMIT OF GARDINERS CLAY

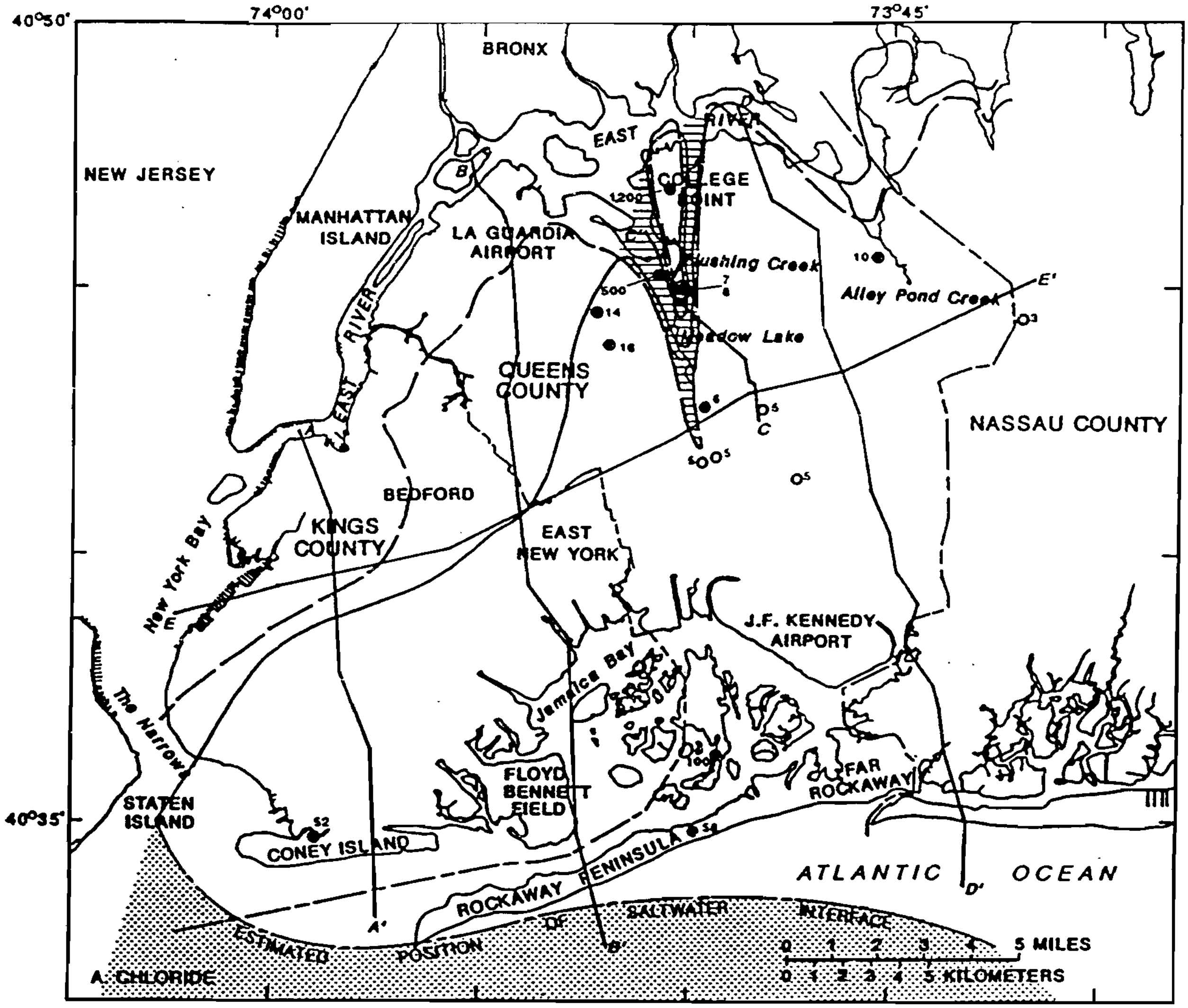
A——A' TRACE OF HYDROGEOLOGIC SECTION SHOWN IN FIGURE 15

●>10 WELL SAMPLED BY U.S. GEOLOGICAL SURVEY AND ANALYZED BY NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION--Number is chloride concentration, in milligrams per liter

O3.4 WELL SAMPLED AND ANALYZED BY JAMAICA WATER-SUPPLY COMPANY--Number is chloride concentration, in milligrams per liter

◎2.0 3.0 MULTIPLE-WELL SITE--Upper and lower numbers refer to shallow and deep screens, respectively

Figure 13B. Nitrate concentrations in the Jameco-Magothy aquifer, 1983.



EXPLANATION

GLACIAL DEPOSITS LATERALLY CONTIGUOUS WITH LLOYD AQUIFER

SALTY GROUND WATER

NORTHERN LIMIT OF THE LLOYD AQUIFER

NORTHERN LIMIT OF THE RARITAN FORMATION OF THE CLAY MEMBER

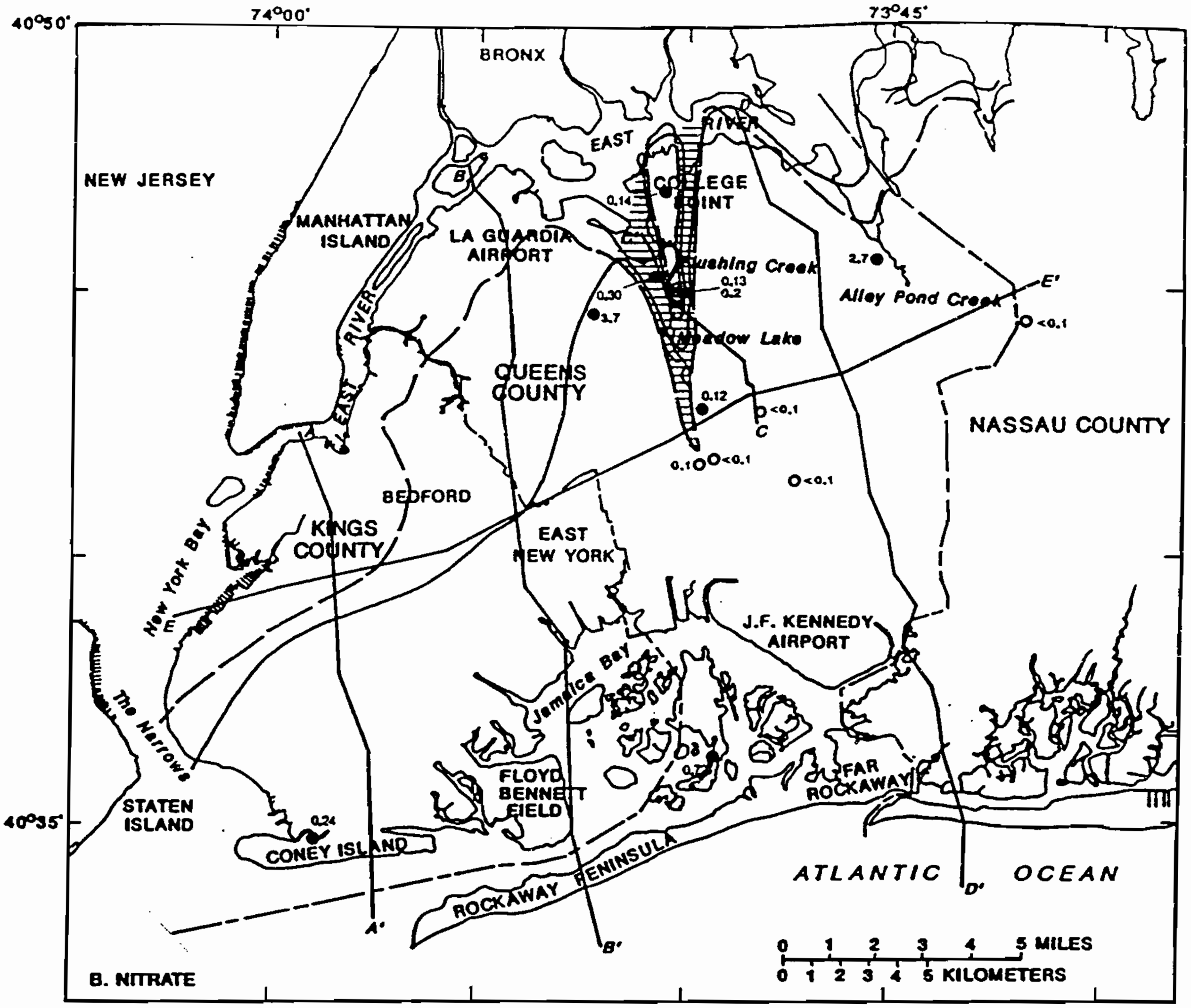
A—A' TRACE OF HYDROGEOLOGIC SECTION SHOWN IN FIGURE 15

●52 WELL SAMPLED BY U.S. GEOLOGICAL SURVEY AND ANALYZED BY NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION--Number is chloride concentration, in milligrams per liter

○5 WELL SAMPLED AND ANALYZED BY JAMAICA WATER-SUPPLY COMPANY--Number is chloride concentration, in milligrams per liter

◉ 7/6 MULTIPLE-WELL SITE--Upper and lower numbers refer to shallow and deep screens, respectively

Figure 14A. Chloride concentrations in the Lloyd aquifer, 1983.



EXPLANATION

GLACIAL DEPOSITS LATERALLY CONTIGUOUS WITH LLOYD AQUIFER

NORTHERN LIMIT OF THE LLOYD AQUIFER

NORTHERN LIMIT OF THE RARITAN FORMATION OF THE CLAY MEMBER

A——A' TRACE OF HYDROGEOLOGIC SECTION SHOWN IN FIGURE 15

●24 WELL SAMPLED BY U.S. GEOLOGICAL SURVEY AND ANALYZED BY NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION--Number is chloride concentration, in milligrams per liter

O0.1 WELL SAMPLED AND ANALYZED BY JAMAICA WATER-SUPPLY COMPANY--Number is chloride concentration, in milligrams per liter

MULTIPLE-WELL SITE--Upper and lower numbers refer to shallow and deep screens, respectively

Figure 14B. Nitrate concentrations in the Lloyd aquifer, 1983.

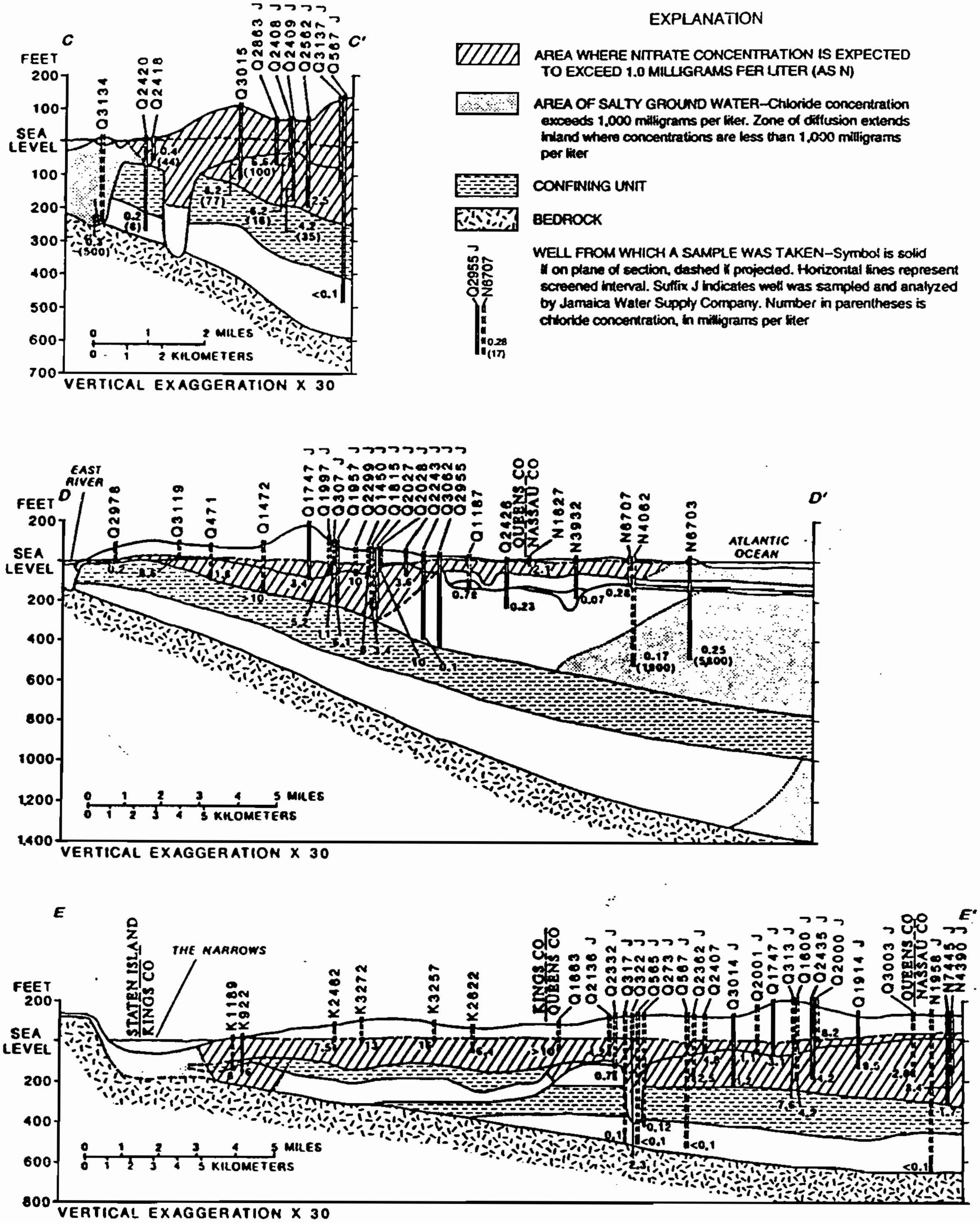


Figure 15. Nitrate and chloride concentrations along sections C-C', D-D', and E-E'. (Trace of sections is shown on pl. 7.)

Inorganic Constituents

As described in the previous section, two general trends are observed in the concentrations of human-induced inorganic constituents in ground water in western Long Island. Concentrations tend to decrease eastward in each aquifer and also with depth at any location. These trends reflect the facts that (1) development began in western Kings County and progressed eastward, and (2) land use today ranges from intense urbanization in Kings to mixed residential-industrial use in western Nassau. These trends in individual aquifers are discussed in the following paragraphs.

Upper Glacial Aquifer.—The analyses of samples from 96 wells in the upper glacial aquifer during 1983 (table 10, at end of report) indicate that human activities have altered the ground water's natural chemical composition. The dissolved-solids concentration, a measure of all chemical constituents dissolved in ground water, is elevated throughout the upper glacial aquifer in Kings and Queens; all samples had concentrations greater than 100 mg/L. Under natural conditions, the dissolved-solids concentration is extremely low, generally below 35 mg/L (table 3). These data indicate that the public-health standard of 500 mg/L is exceeded at 33 wells—18 in Kings and 15 in Queens.

Hardness values have risen since development (table 3). Predevelopment concentrations in Kings and Queens Counties were less than 25 mg/L (as $CaCO_3$), but 1983 values ranged from 42 to 3,100 mg/L (except one sample, which had 20 mg/L). Except for five wells that were considered to be significantly affected by seawater (chloride and hardness concentrations 650 mg/L or above), hardness values ranged from 20 to 740 mg/L in Kings County, from 42 to 440 mg/L in Queens, and from 54 to 250 mg/L in Nassau. Higher concentrations in Kings are caused at least in part by a residue of saltwater intrusion from the 1940's.

Fluoride concentrations are extremely low in ground water throughout Kings and Queens Counties. Natural concentrations are 0.5 mg/L or less and are probably derived from dissolution of amphibole, hornblende, and mica (Hem, 1970). Most ground-water contaminants (manmade waste and saltwater) do not contain significant concentrations of fluoride. Seven wells in Kings and Queens had fluoride concentrations ranging from 0.8 to 1.0 mg/L. Fluoride is added to the drinking-water supply of New York City at an average concentration of 0.93 mg/L (New York City Department of Environmental Protection, written commun., 1984). Therefore, these concentrations could indicate leakage from water-supply lines.

Sulfate concentrations are considerably higher than in predevelopment times, when they were less than 12 mg/L (table 3). Only 3 of 67 wells in Kings and Queens in 1983 had sulfate concentrations less than 12 mg/L, the maximum observed value in samples representative of predevelopment conditions. Samples from the remaining wells, excluding two affected by seawater, ranged from 15 to 200 mg/L and averaged about 75 mg/L. No distinct east-west trend is evident from these data.

Jameco-Magothy Aquifer.—Analyses of samples from 80 wells screened in the Magothy-Jameco aquifer are available. Eight of these are in Kings County (all are screened in the Jameco), 47 are in Queens, and 25 are in Nassau.

The dissolved-solids concentrations of almost all samples from the Jameco-Magothy aquifer exceed predevelopment levels. The eight samples from Kings County had the highest concentrations—all were above the 500-mg/L public-health standard. The dissolved-solids concentrations in 39 of 44 samples from Queens County were below the public health standard, and 28 were below 250 mg/L. Wells in Nassau County showed still lower dissolved-solids concentrations. Except for two samples that were affected by seawater, concentrations in 17 samples ranged from 32 to 224 mg/L.

The hardness of samples ranged from a low of 8 mg/L (as $CaCO_3$) in Nassau County to a high of 14,000 mg/L in a well affected by seawater in southern Queens. Except for nine wells affected by seawater (chloride and hardness concentrations of 1,100 mg/L or above), values ranged from moderately hard to hard, averaging 330 mg/L in Kings County, 140 mg/L in Queens, and 38 mg/L in western Nassau.

Sulfate concentrations in the Jameco-Magothy aquifer were slightly above predevelopment concentrations but were lower than those in the upper glacial aquifer. Except for the same nine wells that were affected by seawater, sulfate concentrations were less than 100 mg/L in Kings County, less than 110 mg/L in Queens, and less than 63 mg/L in Nassau.

Lloyd Aquifer.—Analyses are available from only 15 wells screened in the Lloyd aquifer (which has only a few wells because drilling to that depth is costly, and water is generally available from the other aquifers.) Of these wells, 13 are in Queens County, 1 is in Kings, and 1 is in western Nassau. One well (Q1373, pl. 8), on the north shore of Queens County, where the Lloyd aquifer is close to land surface, is affected by seawater; at the remaining 14 wells, the total dissolved-solids concentration was 265 mg/L or less and, at 7 wells, was 100 mg/L or less. Hardness at those 14 wells was less than 65 mg/L, and sulfate concentrations were less than 35 mg/L; in 10 wells they were less than 20 mg/L.

Organic Constituents

The widespread use of a variety of organic compounds in highly industrialized and urbanized areas of western Long Island has created concern over the potential for ground-water contamination. Even though the toxicity of many organic compounds is unknown, their distribution is a critical factor in decisions as to where ground water is safe for drinking.

No extensive ground-water-sampling effort has been undertaken in Kings or Queens Counties to date to document the presence of organic compounds; only ground water pumped in southeastern Queens by the Jamaica Water Supply Company is routinely monitored for organic compounds. This monitoring began in 1979 and is under the auspices of the New York City Department of Health. Results indicate contamination by organic compounds. During the fall and winter of 1983, when 54 wells of the Jamaica Water Supply Company were sampled for total volatile organic compounds, 42 showed detectable levels (detection limit 0.1 parts per billion, ppb) (New York City Department of Health, 1984.) Of these 42 wells, two exceeded the recommended guidelines set by the New York City Department of Health (1984) and were ordered closed by that department. Since the Department of Health began monitoring in 1979, it has ordered 14 wells closed for exceeding the guidelines; 12 of these wells are screened in the upper glacial aquifer, and the remaining two in the Magothy aquifer. The closed wells could be monitored and reopened if the concentrations of organic compounds drop below the recommended guidelines.

Detectable levels of organic contamination have been found mostly in the upper glacial and Magothy aquifers, where most of the pumping occurs. The New York City Department of Health (1984) reports that, in 1983, detectable levels of contamination were found at 22 of 23 wells screened in the upper glacial aquifer, at 19 of 25 wells screened in the Magothy aquifer, and at 1 of 4 wells screened in the Lloyd aquifer. Two wells screened in the Jameco aquifer showed no contamination.

The New York City Department of Health (1984) also reports that samples from 28 contaminated wells contained more than one organic compound; a total of 16 different volatile organic compounds were detected in 1983.

Data from southeastern Queens County indicate that organic compounds have migrated through the upper glacial aquifer and into the Jameco-Magothy aquifer. Many of the organic compounds enter the ground-water system from sporadic, dispersed point sources, which makes correlation extremely difficult. In fact, some wells found not to have detectable levels of organic compounds at one sampling may contain detectable levels at a subsequent sampling as sporadic and irregular plumes pass the well screen. These data are few, however, and whether the conclusions drawn from them can be applied to the rest of western Long Island is uncertain. Yet, ground water that contains other indicators of land-surface contamination, as described in the previous section, would have the highest probability of containing organic compounds as well.

GROUND-WATER-RESOURCE CONCERNS

The hydrologic conditions observed in 1983 indicate that pumping has caused an extensive cone of depression in all three major aquifers. Whether current pumping exceeds the safe yield of the aquifer system is difficult to determine until unacceptable levels of specific undesirable hydrologic effects of development have been identified and measured. Undesired results of ground-water development on western Long Island include severe water-level declines, intrusion of saline ground water, downward migration of land-surface contamination into confined aquifers, and flooding of underground structures. The first three are closely related in that extreme drawdown that results from pumping of deep aquifers will increase the rate of landward movement of the saltwater-freshwater interface and the rate of downward movement of contaminants (introduced at the water table) into confined aquifers. The major result of these undesired effects is that the potable ground-water supply would be continually diminished.

The data in this report indicate that the saltwater-freshwater interface is moving landward and that contaminants in shallow aquifers are moving into the confined aquifers. Any increase in pumping will accelerate these effects to some extent, however, a realistic resource-management strategy could include location of wells in inland areas beyond the threat of saltwater intrusion, and beneath the extent of migration of land-surface contaminants which would prolong the period until treatment is needed to maintain an adequate supply of potable water.

With the liklihood of additional decreases in ground-water pumping,flooding of underground structures by rising water levels is another serious concern . Such flooding is already occurring in areas where pumping has been curtailed and could extend farther if present pumping rates are reduced. Reducing ground-water pumpage while increasing the use of upstate surface water would require monitoring of ground-water levels, especially near shores and buried stream channels, where depths to water are smallest. Redistribution of pumping for public supply can provide a means to mitigate both severe drawdown in the east and excessive water levels farther west, but significant financial, institutional, and water-quality considerations would need to be resolved first.

Ground-water quality is worst in the westernmost and shallowest parts of the aquifer system but improves eastward and with depth. Potable ground water is still largely available in eastern Queens, even from the upper glacial aquifer, but probably not in areas farther west. The Lloyd aquifer, which is still uncontaminated, cannot greatly supplement the supply because it is sensitive to pumping and is expected to yield only small volumes of water without incurring excessive drawdown. Therefore, redistribution of ground-water pumping, even at current rates, would probably require some treatment to ensure potable quality.

In 1983, only about 60 Mgal/d, or 8 percent, of the 750 Mgal/d used for public supply in Kings and Queens Counties was derived locally from ground water; the remainder was supplied from an upstate surface-water-reservoir system. A conjunctive-resource-development strategy that takes advantage of the inherent differences in the nature of ground-water and surface-water systems could enable a reduction in the harmful effects of the present development strategy. At present, water is developed continuously from both sources and used in separate areas. The use of ground water as a periodic supplement to the surface-water supply could result in a combined system with greater productivity than the separate ground- and surface-water-supply systems as they are operated at present.

SUMMARY

The aquifers underlying Kings and Queens Counties supplied an average of about 120 Mgal/d during 1904-47. Intensive pumping in Kings County during the 1930's lowered ground-water levels and caused intrusion of saline ground water into the upper glacial and Jameco-Magothy aquifers until 1947, when all pumping for public supply in the county was stopped. Subsequently, pumping in Queens County has been increased. A severe cone of depression that developed in southwestern Queens County during the 1960's also caused intrusion of saline ground water; as a result, pumping for public supply in the Woodhaven franchise area of the New York Water Supply Company was halted in 1974. Pumping for public supply has persisted in eastern Queens County, where the Jamaica Water Supply Company has pumped an average of about 60 Mgal/d since 1974.

Since the cessation of pumping in Kings and southwestern Queens, ground-water levels have been recovering steadily. In 1983, ground-water levels in Kings were close to predevelopment levels, and contamination by saltwater had partly dispersed and become diluted. An extensive cone of depression remains in all three major aquifers in eastern Queens County, however. The saltwater-

freshwater interface in the Jameco-Magothy aquifer, which is already inland, is moving toward the center of pumping. Available data indicate that saline ground water in the Lloyd aquifer is not far offshore and is also moving landward.

At present, elevated nitrate and chloride concentrations throughout the upper glacial aquifer indicate widespread contamination from land surface. Some contamination in the Jameco-Magothy aquifer is attributed to downward migration in areas of substantial hydraulic connection between aquifers (where the Gardiners Clay is absent). A channel eroded through the Raritan confining unit provides a pathway for migration of contaminants to the Lloyd aquifer. The cone of depression in the Lloyd has increased the downward gradients through this channel, which could cause contaminants to enter the Lloyd sooner than anticipated.

Although chloride and nitrate have been used as the principal indicators of ground-water contamination, other constituents introduced from point sources also may affect ground-water quality locally. The extent to which nitrate and chloride from the land surface have moved through the ground-water system indicates that treatment eventually could be needed to ensure the quality of water pumped from the upper glacial or Jameco-Magothy aquifers. Ground water in the Lloyd aquifer is still largely uncontaminated, but present pumpage and ground-water levels indicate that this aquifer is much more sensitive to withdrawals than the overlying aquifers and could be more susceptible to contamination from land-surface sources in western Long Island than in other areas.

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TABLES OF WELL AND CHEMICAL DATA

Table 7.--Wells and test borings plotted on plate 2 that occupy a multiple well site.

Well number shown with asterisk on plate 2	Other wells at same site or nearby
KINGS COUNTY	
K320	K259, K277
K531	K526
K533	K520
K640.4	K640.1, K640.2, K640.3
K642.2	K642.1
K656	K290
K725	K694
K731	K676
K898	K673
K920	K916
K1010	K639
K1030	K930, K956
K1031	K887
K1073	K660
K1091	K720
K1112	K49
K1130	K893, K955
K1148	K167
K1191	K1190
K1283	K724
K1286	K538
K1332	K638
K1340	K1313, K1319
K1346	K1343
K1360	K1355
K1490	K37
K1548	K82, K1015, K1018, K1288, K1488
K1558	K178
K1641	K1287
K1977	K675
K2069	K33
K2070	K944, K1012
K2136	K1153, K1273, K1336
K2262	K1303
K2513	K2512
K2533	K637
K3132	K3129, K3130, K3131
K3133	K64.2, K64.5, K64.6, K1160, K1274, K1275, K1305, K1344, K1600, K1629, K2286, K2434
K3184	K3151, K3176, K3177, K3178, K3179, K3180, K3181, K3182, K3183
RICHMOND COUNTY	
R80	RD (tunnel boring d)
R94	R93

Well number shown with asterisk on plate 2	Other wells at same site or nearby
QUEENS COUNTY	
Q268	Q64
Q276	Q275
Q283	Q282
Q455	Q33
Q484	Q460, Q461, Q462, Q464, Q466, Q468, Q480
Q453	Q425
Q495	Q490, Q491, Q492, Q493, Q494
Q564	Q563
Q566	Q317
Q571	Q324, Q556
Q584	Q572, Q273
Q602	Q386
Q634	Q340
Q678	Q224
Q1027	Q1026
Q1028	Q440, Q444
Q1037	Q985, Q1036
Q1053	Q1048, Q1049
Q1057	Q278, Q1041, Q1042, Q1043, Q1045, Q1056
Q1071	Q542
Q1098	Q453
Q1175	Q339, Q680
Q1197	Q333
Q1241	Q1086, Q1087
Q1274	Q437
Q1305	Q334
Q1379	Q1376
Q1507	Q557, Q1932
Q1516	Q127
Q1532	Q1063, Q1291
Q1542	Q1373, Q1374, Q1497, Q1498
Q1620	Q978
Q1629	Q1535
Q1730	Q451
Q1736	Q1695
Q1747	Q1536
Q1812	Q1787
Q1815	Q1450
Q1839	Q306, Q561, Q572
Q1876	Q336, Q1861
Q1914	Q581, Q582
Q1932	Q111, Q1929, Q1930, Q1931
Q1957	Q1311, Q1923
Q1965	Q1035, Q1239, Q1275
Q2001	Q1985
Q2028	Q2003

Well number shown with asterisk on plate 2	Other wells at same site or nearby
QUEENS COUNTY (cont'd)	
Q2137	Q318, Q567
Q2148	Q364, Q1978, Q1979
Q2188	Q1982, Q2000
Q2189	Q2140
Q2243	Q2205
Q2276	Q2259, Q2275
Q2300	Q2255, Q2299
Q2332	Q2122, Q2138, Q2325
Q2333	Q1258
Q2343	
Q2356	Q1423
Q2374	Q2364, Q2373
Q2384	Q350, Q2289
Q2394	Q2273, Q2390, Q2393
Q2400B	Q447, Q2386, Q2400A
Q2402	Q2377
Q2409	Q2361, Q2408
Q2413	Q586
Q2420	Q441, Q2416, Q2419
Q2432	Q2405
Q2435	Q2404
Q2443	Q310, Q1924, Q1958, Q2430
Q2592	Q2144, Q2309
Q2955	Q2765
Q3000	Q1472
Q3003	Q1850, Q1909, Q2987
Q3012	1372, Q1384
Q3014	Q2991
Q3034	Q3026
Q3036	Q3030
Q3062	Q3029
Q3083	Q3056
Q3156	Q311, Q1449
Q3157	Q314
QBWS2	Q1502, Q1638
QBWS4	Q206
NASSAU COUNTY	
N3327	N2578
N4243	N3905
N4266	N2749
N5110	N1618
N5576	N1686, N1687
N6581	N3864
N6701	N4405
N8456	N8375
N8840	N8821
N9110	N23, N8342
N9151	N11
N9308	N2

Table 8.—Observation wells whose records were used to produce maps of water-table and potentiometric-surface altitudes

Well no.	Aquifer[1]	Screened interval[2] (ft above sea level)	Date measured (1983)	Water level (ft above sea level)
K 19	Upglac	Bot at -34	3/25	8.83
K 30	Upglac	+8 to +3	3/25	5.36
K 508	Upglac	-23 to -66	3/25	9.14
K 522	Jam	-188 to -248	3/25	8.51
K 631	Upglac	+16 to -9	3/25	5.28
K 889	Upglac	-41 to -51	3/25	3.96
K1194	Upglac	-23 to -26	3/22	7.92
K1265	Upglac	Bot at -21	3/23	7.39
K1301	Upglac	-27 to -49	3/25	5.33
K1494	Upglac	-140 to -161	3/25	4.21
K2859	Lloyd	-464 to -480	4/21	1.09
K3132	Jam	-234 to -285	3/25	7.22
K3245	Upglac	+9 to +6	3/25	9.36
K3246	Upglac	-1 to -4	3/25	8.62
K3247	Upglac	-3 to -6	3/25	4.06
K3248	Upglac	-7 to -10	3/25	4.96
K3249	Upglac	-11 to -14	3/25	4.34
K3250	Upglac	-12 to -15	3/25	1.93
K3251	Upglac	-10 to -13	3/25	3.04
K3252	Upglac	-11 to -14	3/25	1.72
K3253	Upglac	-6 to -9	3/25	5.27
K3254	Upglac	+1 to -2	3/25	5.56
K3255	Upglac	-2 to -5	3/25	4.70
K3256	Upglac	-1 to -4	3/22	5.37
K3257	Upglac	+3 to 0	3/25	12.07
K3259	Upglac	+3 to 0	3/25	12.38
K3260	Upglac	-7 to -10	3/25	10.29
K3261	Upglac	+23 to +20	3/25	25.81
K3271	Upglac	-9 to -11	3/22	5.20
K3272	Upglac	0 to -3	3/25	10.39
K3273	Upglac	-3 to -6	3/25	7.99
K3274	Upglac	-4 to -7	3/25	5.25
K3275	Upglac	-6 to -9	3/25	4.47
K3276	Upglac	-13 to -16	3/25	5.98
Q 34	Lloyd	Bot at -184	3/22	4.55
Q 273	Lloyd	-281 to -411	3/22	1.51
Q 283	Lloyd	-282 to -382	3/22	-11.59
Q 287	Lloyd	Bot at -712	1/3	0.8
Q 305	Upglac	+16 to -29	3/23	-12.82
Q 306	Upglac	-16 to -46	3/29	5.79
Q 307	Upglac	+17 to -27	3/22	-7.01
Q 308	Upglac	+4 to -41	3/30	3.37
Q 313	Upglac	+34 to -9	3/22	-0.90
Q 319	Upglac	-8 to -23	3/23	0.27
Q 321	Upglac	+13 to -2	3/22	3.40
Q 324	Upglac	-13 to -33	3/23	1.93
Q 470	Lloyd	-333 to -361	3/23	-0.07
Q 471	Mag	Bot at -98	3/23	13.24
Q 560	Upglac	-18 to -48	3/29	6.08
Q 561	Upglac	-31 to -61	3/29	5.75
Q 569	Upglac	-6 to -26	3/23	0.84
Q 570	Upglac	-13 to -33	3/23	2.92
Q 577	Lloyd	-485 to -520	1/21	-4.71
Q1058	Upglac	-13 to -33	3/23	1.97
Q1071	Lloyd	-755 to -820	1/4	1.9
Q1187	Jam	Bot at -120	3/22	2.53
Q1189	Upglac	Bot at -35	3/22	1.97
Q1223	Upglac	Bot at -5	3/23	4.40
Q1237	Jam	Bot at -200	3/22	-0.51
Q1249	Upglac	-13 to -16	3/22	-5.64
Q1250	Upglac	-14 to -17	3/23	-4.90
Q1254	Upglac	-8 to -11	3/22	3.56
Q1284	Upglac	Bot at -9	3/23	4.43
Q1326	Upglac	-13 to -45	3/22	19.06
Q1373	Lloyd	-144 to -156	3/20	4.92
Q1391	Upglac	-53 to -83	3/23	14.17
Q1406	Upglac	-2 to -27	3/23	18.17
Q1416	Upglac	-2 to -27	3/23	11.68
Q1534	Upglac	-10 to -30	3/22	-4.44
Q1600	Mag	-172 to -192	3/22	-0.52
Q1812	Mag	-80 to -130	3/22	-7.74
Q1829	Upglac	+19 to -13	3/23	8.25
Q1839	Upglac	-40 to -60	3/29	5.33
Q1843	Upglac	-32 to -52	3/23	6.05
Q2006	Upglac	-36 to -56	3/30	-0.35
Q2026	Mag	-357 to -391	3/29	2.31
Q2137	Mag	-80 to -120	3/30	-5.40
Q2188	Mag	-124 to -164	3/22	3.98
Q2243	Mag	-43 to -63	3/29	-3.45
Q2275	Upglac	-31 to -51	3/29	-6.85
Q2299	Upglac	-42 to -62	3/23	-9.35
Q2300	Mag	-125 to -165	3/22	-9.78
Q2321	Upglac	-45 to -61	3/22	-1.63
Q2324	Upglac	Bot at -69	3/23	2.98
Q2343	Mag	-125 to -165	3/22	-1.00
Q2346	Upglac	-15 to -17	3/22	13.43
Q2410	Upglac	-145 to -187	3/22	6.69
Q2416	Lloyd	-218 to -263	1/6	5.07
Q2418	Upglac	-42 to -54	3/22	-0.18
Q2420	Lloyd	-218 to -268	3/22	5.05
Q2422	Mag	-300 to -320	3/22	-1.60
Q2442	Upglac	-42 to -52	3/29	-4.41
Q2791	Upglac	+20 to +12	3/22	53.53
Q2993	Upglac	Bot at -56	4/7	7.16
Q2994	Upglac	Bot at -56	3/23	3.38
Q2995	Upglac	Bot at -73	3/23	3.30
Q3015	Mag	-71 to -111	3/22	1.76
Q3036	Lloyd	-229 to -249	1/6	-7.86
Q3083	Mag	-259 to -307	3/29	-0.17
Q3109	Mag	-268 to -288	3/22	[3]1.50
Q3110	Jam	-296 to -316	3/22	[3]2.39
Q3112	Jam	-199 to -209 -279 to -289	3/21	1.03
Q3114	Upglac	-7 to -9	3/23	3.36
Q3115	Upglac	Bot at -16	3/23	4.05
Q3117	Upglac	Bot at -12	3/23	3.08
Q3118	Upglac	-10 to -13	3/23	2.68
Q3119	Upglac	+4 to +0.5	3/22	18.87
Q3121	Upglac	+6 to +3	3/22	22.99
Q3122	Upglac	-3 to -6	3/22	11.73

Table 8.—Observation wells whose records were used to produce maps of water-table and potentiometric-surface altitudes (continued)

Well no.	Aquifer[1]	Screened interval[2] (ft above sea level)	Date measured (1983)	Water level (ft above sea level)
Q3123	Upglac	+1 to -2	3/22	6.68
Q3150	Jam	Bot at -119	4/21	[3]1.61
N 9	Mag	-74 to -114	3/22	5.95
N 22	Mag	-110 to -130	3/3	0.01
N 24	Lloyd	-347 to -407	1/12	1.32
N 700	Upglac	+4 to -20	3/18	11.6
N1102	Upglac	+23 to +18	3/23	28.99
N1106	Upglac	+16 to +13	4/6	24.63
N1108	Upglac	+4 to +1	4/6	16.61
N1110	Upglac	Bot at -4	4/6	7.90
N1111	Upglac	Bot at -7	4/6	8.06
N1112	Upglac	-7 to -10	4/4	6.18
N1114	Upglac	-2 to -5	4/4	9.44
N1115	Upglac	+7 to +3	4/4	9.89
N1116	Upglac	-9 to -12	4/4	4.97
N1298	Lloyd	-271 to -321	1/6	-0.15
N1328	Lloyd	-475 to -565	1/12	0.09
N1422	Upglac	Bot at -13	4/4	8.09
N1427	Upglac	Bot at +9	4/8	12.99
N1429	Upglac	Bot at -8	4/4	8.16
N1453	Upglac	+27 to +24	4/6	23.85
N1455	Upglac	+18 to +15	4/6	19.48
N1458	Upglac	+10 to +7	4/6	18.02
N1459	Upglac	+10 to +7	4/5	14.82
N1472	Upglac	Bot at +19	4/6	28.76
N1475	Upglac	+19 to +16	4/6	27.44
N1613	Mag	Bot at -471	3/21	3.64
N1625	Upglac	+2 to -1	4/8	2.85
N1626	Upglac	-4 to -7	4/8	4.54
N1628	Upglac	-10 to -14	4/4	3.03
N1682	Upglac	-18 to -21	4/8	15.55
N1683	Upglac	Bot at +25	4/8	32.40
N1802	Lloyd	-509 to -559	1/12	-4.91
N2413	Mag	-427 to -457	3/29	7.65
N3707	Upglac	-7 to -9	4/4	2.41
N3708	Upglac	-10 to -13	4/4	1.11
N3710	Upglac	-0 to -12	4/4	1.71
N3861	Mag	-512 to -523	3/22	-[3]4.60
N3862	Mag	-288 to -299	3/28	[3]3.28
N3864	Mag	-456 to -467	3/28	4.28
N3867	Mag	-497 to -509	3/23	1.06
N3905	Mag	-80 to -120	3/9	33.00
N4213	Jam	-125 to -129	3/28	1.10
N4266	Lloyd	-317 to -337	3/23	0.90
N5156	Mag	-220 to -260	3/29	16.20
N6242	Upglac	-3 to -5	3/28	3.15
N6510	Mag	-444 to -450	3/28	-3.21[3]
N6702	Mag	-655 to -666	3/22	-5.19[3]
N6703	Mag	-456 to -467	3/22	1.73[3]
N6707	Mag	-487 yo -497	3/28	3.20[3]
N7235	Upglac	-18 to -20	4/4	5.73
N7445	Mag	-263 to -323	3/30	33.29
N7472	Mag	-112 to -116	3/21	4.23
N7493	Mag	-274 to -278	3/23	4.08
N7512	Mag	-202 to -252	3/9	36.00
N7720	Mag	-366 to -437	3/8	29.16
N7855	Mag	-493 to -563	3/10	6.02
N8011	Lloyd	-1199 to -1259	1/5	0.66
N8038	Mag	-61 to -85	3/9	33.40
N8052	Upglac	-78 to -82	3/18	3.38
N8195	Mag	-426 to -486	3/10	-7.33
N8374	Upglac	-9 to -12	4/8	1.99
N8599	Upglac	-11 to -15	4/4	3.65
N8638	Upglac	-21 to -24	4/4	3.50
N8644	Upglac	-3 to -6	4/4	7.17
N8646	Upglac	-14 to -16	4/4	2.73
N8655	Upglac	-17 to -20	4/4	1.98
N8964	Upglac	-38 to -43	3/18	14.8
N8970	Upglac	-34 to -39	4/6	23.22
N9098	Upglac	-8 to -13	4/5	16.74
N9099	Upglac	-6 to -11	3/23	15.37
N9188	Upglac	-30 to -35	4/6	25.49
N9208	Upglac	-73 to -78	3/23	13.75
N9309	Upglac	-11 to -16	3/23	8.40
N9468	Upglac	-14 to -18	4/4	5.38
N9476	Upglac	-14 to -19	4/8	3.13
N9776	Lloyd	-237 to -248	1/6	-1.77
N9820	Lloyd	-239 to -244	1/6	7.58
N9892	Upglac	-3 to -13	3/18	9.8
N9893	Upglac	-1 to -11	3/18	3.50
N9895	Upglac	+3 to -7	3/18	17.50
N9947	Upglac	-19 to -24	4/8	12.02
N9979	Upglac	Bot at -19	4/8	5.39
N9982	Upglac		4/6	32.82
N9983	Upglac	+16 to +11	4/6	32.39
N10005	Upglac	-10 to -15	4/8	8.17

[1] Upglac = Upper glacial
Jam = Jameco Gravel
Mag = Magothy

[2] Bot = Bottom

[3] Freshwater equivalent head listed in table 5, p. 36.

Table 9.--*Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties.*

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks[2]
B 1	404826	735000	2							-63		
B 2	404817	734958	0							-98		
B 3	404852	734909	9							-50		
B 4	405130	734616	10							-2		
B 39	404831	735005	2	-90						-63		
B 59	404820	735249	8	-80						-70		
B 69	404845	735210	0	-76						-71		
M 41	404240	740029	30	-46						-46		
M 114	404236	740037	30	-47						-47		
M 160	404705	735635	3	-146						-139		
M 161	404432	735915	30	7						16		
R A	403614	740310	0	-210	-124	-170				-190		Bridge boring
R B	403609	740326	90	-216	-99					-163		Bridge boring
R C	403834	740413								-115		Tunnel boring
R D	403831	740440								100	R80	Tunnel boring
R 7	403753	740437	10	-40								
R 14	403734	740445	25	-18								
R 18	403659	740416	45	-97								
R 22	403700	740358	15	-162						-162		
R 65	403506	740538	10	-77				-75				
R 66	403529	740518	12	-87				-84				
R 73	403730	740449	50	-30						-30		
R 79	403815	740519	120	76						110		
R 80	403830	740441	110	73						106		
R 81	403831	740433	40	-9						6		
R 82	403443	740316	5	-1000			NR	NR	NR	-450		
R 89	403659	740409	25	-11								
R 91	403652	740404	25	-15								
R 93	403646	740359	25	-27							R94	
R 94	403643	740357	25	-34								

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks[1,2]
R 95	403638	740353	35	-33								
R 98	403628	740331	55	-88								
R 99	403632	740325	0	-114								
R 100	403639	740307	0	-122								
K A	403630	740220	0	-275	-105	-170		-183		-270		
K 1	403441	735917	5	-745	-150	-163	-229	-393	-471	-625		
K 9	404027	735945	4	-155	-91	-125				-145		
K 12	404150	735912	49	-50						-50		
K 15	404148	735852	15	-99						-93		
K 20	404054	735824	40	-96	-94							
K 23	404055	735759	57	-186						-186		
K 33	404204	735708	14	-162	-82	-131					K2069	
K 36	404208	735602	28	-80	-77							
K 37	404228	735623	25	-105	-92						K1490	
K 45	404048	735411	61	-223	-155							
K 49	404317	735725	18	-315	-82					-114	K1112	
K 50	404314	735728	16	-141	-75					-141		
K 64.2	404201	735654	10	-158	-85	-99					K3133	
K 64.5	404202	735655	10	-155	-58	-90					K3133	
K 64.6	404202	735655	10	-164	-67	-130					K3133	
K 82	404147	735802	20	-100						-100	K1548	NR 20 TO -99
K 110	404154	735943	72	-88						-88		
K 167	403918	740038	13	-137	-73	-82					K1148	
K 178	403420	735925	5	-113							K1558	
K 247	403813	735351	15	-164								
K 249	404132	735643	40	-135	-133							
K 255	404150	735613	54	-69	-69							
K 256	404126	735725	50	-156	-124					-156		
K 259	404120	735859	40	-73	-73						K320	
K 261	404126	735916	35	-60						-60		

[1]PRES - Unit present but surface altitude not discernible.
NR - No record; no record near altitudes indicated under remarks.
[2]Veatch - Well number from numbering system employed in Veatch and others, 1906.

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Altitude of well: Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks[1,2]
K 277	404118	735854	37	-109	-86					-109	K320	
K 283	403432	735855	7	-147								
K 285	403804	735946	63	-149	-144							
K 290	404117	735900	39	-65						-65	K656	
K 316	403747	740121	65	-129	-125							
K 320	404119	735857	38	-76	-65					-75		
K 329	403952	735555	75	-158	-90	-128						
K 426	404231	735633	38	-102	-64							
K 458	404253	735802	5	-1048	-115					-173		
K 464	403643	735452	5	-489	-159	-202	-245	-284	-443			
K 465	404411	735706	10	-390						-55		
K 514	403830	735545	26	-534	-149	-167		-198	PRES	-441		
K 515	403819	735624	20	-323	-146	-180		-197	-278			
K 517	403950	735709	78	-225	-100	-165		PRES				
K 518	403815	735617	13	-317	-157	-184		-215	-287			
K 519	403936	735613	29	-221	-131	-157		PRES				
K 520	403951	735525	42	-376	-98	-131		-268	-288	-358	K533	
K 521	403849	735547	34	-396	-136	-179		-223	-323			
K 522	403857	735721	50	-250	-91	-145		-240				
K 523	403754	735813	47	-488	-123	-153		-204	-248	-384		
K 524	403920	735551	33	-357	-146	-198		-254	-331	-349		
K 525	403818	735847	47	-353	-173	-217		-260	-288			
K 526	403949	735737	82	-318	-146	-211				-289	K531	
K 528	403921	735708	61	-310	-172	-195		-237		-310		
K 529	403839	735847	62	-158	-151							
K 530	403818	735810	33	-127	-112							
K 531	403950	735740	82	-296	-146	-214				-291		
K 532	403819	735654	11	-454	-146	-178		-199	-264	-409		
K 533	403954	735523	42	-353	-98	-131		-268	-288	-342		
K 534	403819	735644	17	-452	-150	PRES		PRES	-273	-404		

Table 9.--*Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)*

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks[2]
K 537	403851	735452	19	-194	-128	-164						
K 538	404015	735227	10	-162	-60	-112					K1286	
K 543	404107	735259	63	-222	-154	-218						
K 569	404304	735600	15	-175	-33			PRES				Veatch 65
K 579	404351	735635	7	-75						-75		
K 584	403742	740126	60	-85	-70							
K 611	404215	735805	10	-120	-92							Veatch 55
K 619	403929	735357	25	-426	-101	-120		-206	-349	-426		
K 637	404226	735641	35	-177	-55			-114		-168	K2533	
K 638	404022	735937	9	-166	-135	-136				-166	K1332	
K 639	404009	735940	28	-162	-122	-142					K1010	
K640.1	404209	740021								-33	K640.4	NR TO -33
K640.2	404202	740015								-46	K640.4	NR TO -46
K640.3	404200	740013								-50	K640.4	NR TO -50
K640.4	404157	740010								-68		NR TO -68
K 641	404210	740009								-64		NR TO -64
K642.1	404211	735957								-92	K642.2	NR TO -92
K642.2	404218	740003								-92		NR TO -92
K 646	404021	735909	25	-169	-82	-129						
K 648	404019	735915	38	-159	-112	-114						
K 650	404015	735918	40	-155	-81	-122						
K 654	404102	735933	25	-133						-100		
K 655	404109	735859	39	-175						-147		
K 656	404115	735856	43	-116						-90		
K 657	404055	735838	44	-183						-162		
K 658	404135	735809	61	-140	-103					-120		
K 659	404111	735846	38	-132						-106		
K 660	404119	735853	35	-90						-67	K1073	
K 661	404130	735840	54	-94	-71					-74		
K 662	404216	735924	0	-108						-98		

[1]PRES - Unit present but surface altitude not discernible.
NR - No record; no record near altitudes indicated under remarks.
[2]Veatch - Well number from numbering system employed in Veatch and others, 1906.

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks[1,2]
K 663	404152	735813	14	-181	PRES					-161		
K 664	404207	735748	17	-162	-104					-142		
K 665	404147	735831	12	-157	-108					-140		
K 666	404217	735733	55	-159						-139		
K 668	404054	735947	57	-142						-123		
K 669	404049	740001	48	-134						-114		
K 670	404228	735718	30	-135				-75		-115		
K 671	404209	735906	37	-98						-76		
K 672	404238	735715	20	-150				-74		-130		
K 673	404249	735708	14	-182				-98		-161	K898	
K 675	404307	735545	13	-209				PRES		-190	K1977	
K 676	404108	735910	28	-135						-127	K731	
K 677	404300	735613	19	-196	-30			-69		-176		
K 678	404253	735635	39	-182				-46		-162		
K 679	404321	735628	35	-183				-47		-163		
K 680	403959	735220	5	-429	-105	-151	-211	-229	-408			
K 682	404400	735737	10	-43						-43		
K 684	404212	735940	5	-99						-98		
K 685	404216	735913	7	-84						-73		
K 686	404241	735810	0	-146						-146		
K 687	404212	735739	43	-157						-142		
K 688	404315	735757	0	-111						-107		
K 689	404333	735608	31	-129				-44		-109		
K 690	404307	735651	10	-184						-163		
K 691	404258	735700	18	-177						-149		
K 692	404407	735644	3	-85						-82		
K 694	404105	735918	16	-101						-88	K725	
K 698	403937	740040	0	-100	-73							
K 699	403753	740130	75	-66	-62							
K 700	404031	740015	6	-110	-51	-99				-110		

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks[1]
K 701	404006	740027	0	-83	-50							
K 702	404058	735936	28	-112						-88		
K 703	404041	740014	16	-122	-93	-104				-125		
K 704	404035	740030	7	-123	-51	-121						
K 705	404044	740100	10	-141						-110		
K 708	404132	740008	6	-114						-82		
K 709	404156	735909	56	-83						-62		
K 710	404401	735719	13	-41						-28		
K 711	404359	735628	0	-74						-74		
K 715	404233	735644	36	-84	-49							
K 717	404223	735716	45	-157						-141		
K 718	403721	740121	80	-355	NR			NR		-294		NR 80 TO -293
K 720	404029	740006	13	-90	-55						K1091	
K 723	404202	735914	57	-84						-72		
K 724	404239	735633	48	-89							K1283	
K 725	404104	735922	14	-101						-80		
K 728	404147	735906	36	-96						-79		
K 729	404141	735826	45	-130						-108		
K 730	404136	735902	36	-98						-68		
K 731	404107	735914	23	-187						-160		
K 887	404201	735556	49	-76	-46						K1031	
K 893	404225	735607	20	-98	-61						K1130	
K 894	404215	735555	30	-252	-57			-148				
K 898	404248	735709	-3	-71								
K 910	404010	735444	45	-137	-126							
K 916	404019	735921	13	-149	-118						K920	
K 917	404028	735906	10	-96								
K 920	404020	735922	13	-151	-117	-122						
K 921	404038	735741	118	-213	NR	NR				-213		NR 118 TO -212
K 922	403919	740027	12	-138	-87	-102						

[1]PRES - Unit present but surface altitude not discernible.
NR - No record; no record near altitudes indicated under remarks.

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks[1,2]
K 930	404037	735904	20	-160	-123	-129				-160	K1030	
K 944	403912	740052	18	-139	-84	-102					K2070	
K 952	404146	735602	67	-55	-55							
K 955	404225	735610	18	-54	-47						K1130	
K 956	404037	735905	22	-160	-96	-130				-160	K1030	
K 1010	404009	735941	20	-161	PRES	-136						
K 1012	403912	740052	16	-159	-100	-124					K2070	
K 1015	404146	735807	20	-72	-72						K1548	
K 1018	404146	735807	18	-98	-44						K1548	
K 1020	403420	735942	5	-108								
K 1021	403428	735859	10	-110								
K 1030	404037	735905	20	-162	-123	-132				-162		
K 1031	404204	735554	49	-56	-56							
K 1051	404150	735803	20	-66	-60							
K 1054	404029	735230	26	-64	-63							
K 1056	403452	735248	7	-733		-123	-213	-493	-683			Veatch 130
K 1057	403503	735251	13	-711		-127	-217	-487	-693			Veatch 131
K 1073	404117	735848	32	-88						-62		
K 1091	404030	740007	11	-113	-38	-88						
K 1112	404314	735723	7	-48								
K 1130	404225	735613	18	-71	-63							
K 1148	403916	740036	11	-139	-86	-95						
K 1153	404206	735605	40	-61	-61						K2136	
K 1160	404201	735656	10	-125	-69	-101					K3133	
K 1190	404056	740025	10	-55	-54						K1191	
K 1191	404055	740026	1	-59	-59							
K 1192	404055	740011	30	-82								
K 1271	403920	740048	5	-1498	-90	-134				-207		Veatch 5
K 1273	404206	735605	40	-235	-65			PRES			K2136	Veatch 35
K 1274	404202	735655	10	-155	-55	-140					K3133	Veatch 37

[1]PRES - Unit present but surface altitude not discernible.
[2]Veatch - Well number from numbering system employed in Veatch and others, 1906.

Table 9.--*Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)*

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Altitude: Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks[1,2]
K 1275	404202	735655	10	-165	PRES	-129					K3133	Veatch 38
K 1283	404239	735632	45	-195				PRES				Veatch 62
K 1286	404012	735229	10	-154	-60	-108						Veatch 135
K 1287	403903	735734	50	-111							K1641	
K 1288	404143	735809	30	-78	-78						K1548	
K 1303	404256	735734	16	-74	-40						K2262	
K 1305	404200	735701	10	-156	-82	-112					K3133	
K 1309	403940	735458	30	-201	-124	-133						
K 1313	404146	735756	31	-130	-72					-129	K1340	
K 1319	404145	735757	31	-114	-72						K1340	
K 1322	403423	735954	5	-180	-119	-150	-180					
K 1332	404022	735937	10	-158	-121	-158						
K 1336	404204	735602	50	-113	-52						K2136	
K 1339	403941	735541	40	-129	-119							
K 1340	404145	735757	25	-120	-82					-120		
K 1343	403934	735539	39	-129	-123						K1346	
K 1344	404200	735701	10	-161	-85	-101					K3133	
K 1346	404232	735532	39	-129	-123							
K 1354	403911	735832	70	-110	-95							
K 1355	403905	735628	46	-129	-74						K1360	
K 1359	403908	735526	28	-177	-112							
K 1360	403904	735628	45	-90	-70							
K 1363	403923	735527	33	-137	-131							
K 1370	404338	735555	27	-50				-48				
K 1488	404147	735805	25	-83	-75						K1548	
K 1490	404229	735623	35	-100	-70							
K 1494	403841	740051	80	-164	-162							
K 1504	403928	735738	64	-116	-114							
K 1508	403912	735545	28	-118	-103							
K 1510	404003	735517	52	-153	-113							

[1]PRES - Unit present but surface altitude not discernible.
NR - No record; no record near altitudes indicated under remarks.
[2]Veatch - Well number from numbering system employed in Veatch and others, 1906.

Table 9.--*Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)*

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Altitude of well: Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks
K 1536	404033	735950	14	-142	-109	-122						
K 1548	404145	735804	38	-78	-78							
K 1558	403420	735925	5	-113								
K 1560	404334	735552	30	-71				-71				
K 1561	404111	740020	5	-55	-55							
K 1575	404211	735534	30	-55	-55							
K 1578	404058	735808	74	-129	-129							
K 1600	404202	735657	10	-147	-70	-101					K3133	
K 1629	404201	735656	10	-160	-60	-90					K3133	
K 1641	403900	735728	50	-154								
K 1662	404205	735740	6	-141	PRES					-122		
K 1713	404046	735644	50	-132	-128							
K 1857	404014	735533	100	-118	-108							
K 1900	404028	740049	10	-125	-119							
K 1932	403831	735611	26	-125								
K 1977	404308	735547	15	-148				-95				
K 1990	404234	735536	15	-55								
K 2044	404135	735919	48	-92						-92		
K 2056	404120	740006	10	-75	-52	-61						
K 2059	403709	735923	38	-184	-139	-158						
K 2069	404202	735710	10	-167	-75	-123				-165		
K 2070	403913	740053	18	-151	PRES	PRES						
K 2136	404204	735610	50	-62	-55							
K 2172	404144	735919	50	-66								
K 2173	404215	735816	5	-110						-110		
K 2204	403634	735729	19	-171	-148	-154						
K 2227	404413	735726	10	-40						-40		
K 2262	404257	735737	8	-53	-53							
K 2286	404158	735653	15	-175	-68	-98					K3133	
K 2326	403630	735519	15	-185	-181							

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks
K 2342	403641	735510	5	-149	-149							
K 2434	404200	735659	10	-186	-72	-102					K3133	
K 2450	404033	735730	10	-91								
K 2488	403421	735826	10	-214	-148	-176						
K 2512	404009	735953	10	-142	-120	-129					K2513	
K 2513	404009	735953	10	-120	-109							
K 2533	404228	735639	30	-62	-49							
K 2556	404047	735716	65	-100								
K 2568	404223	735527	20	-80	-77							
K 2582	403732	735737	10	-186		-140						
K 2859	403451	735856	10	-490	-160	-198	-292	-360	-458			
K 2860	403822	735255	10	-206	-163	-183						
K 3129	403748	735721	30	-240	PRES	-204					K3132	
K 3130	403748	735719	30	-258	-172	-206					K3132	
K 3131	403749	735716	30	-261	-160	-200					K3132	
K 3132	403750	735717	30	-280	-180	-215						
K 3133	404158	735658	15	-188	-83	-107				0		
K 3151	403921	735450	29	-232	-66	-103	-170	-220			K3184	
K 3176	403920	735446	29	-146	-47	-136					K3184	
K 3177	403921	735447	29	-146	-46	-131					K3184	
K 3178	403922	735448	29	-146	-43	-131					K3184	
K 3179	403923	735448	29	-146	-43	-136					K3184	
K 3180	403921	735446	29	-173	-56	-133	-143				K3184	
K 3181	403922	735446	29	-146	-54	-133					K3184	
K 3182	403923	735447	29	-146	-57	-138					K3184	
K 3183	403925	735449	29	-173	-56	-133	-143				K3184	
K 3184	403924	735447	29	-174	-42	-134	-142					
Q 13	404506	735554	24	-65						-65		
Q 17	404427	735656	17	-158						-11		
Q 27	404435	735221	57	-244			-10	-60	-190	-244		

[1]PRES - Unit present but surface altitude not discernible.

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well[3]	Remarks[1,2]
Q 29	404229	735202	80	-145			-96					
Q 31	404224	735133	70	-421	-84		-120	-200	-360	-421		
Q 33	404701	735049	27	-183				-66	-126	-179	Q455	
Q 37	404401	734659	72	-71			-28					
Q 52	404207	735341	80	-70	-70							
Q 62	404502	735510	38	-91						-91		
Q 64	404429	735257	35					-80			Q268	
Q 65	404500	735106	20	-264				-69	-190	-241		
Q 95	404526	735611	20	-72						-70		
Q 111	403635	734539	9	-1005			-160	-597	-808		Q1932	
Q 122	404428	735557	42	-83								
Q 123	403503	734952	8	-952	-197	-242	-348	-455	-751			
Q 127	404539	734954	40	-160				-50			Q1516	
Q 161	404507	735711	5	-145						-9		
Q 165	404529	735649	5	-200						0		
Q 171	404442	735618	46	-454						-10		
Q 183	404646	735058	5	-165				5	-131			
Q 184	404414	735452	90	-492				-49		-114		
Q 192	404337	735331	100	-73				0				
Q 206	404443	735409	47	-170				-95		-170	QBWS4	NR -50 TO -95
Q 224	403953	734526	15	-473	-109		-199	-423			Q678	
Q 237	404113	735109	36	-541		-108	-177	-262	-400	-520		
Q 262	404527	735403	10	-217				-28		-128		Veatch 162
Q 263	404500	735458	38	-87				-47		-80		Veatch 99
Q 268	404421	735255	27	-270				NR		-266		NR 27 TO -265
Q 272	404302	734934	13	-482				PRES	-313	-457	Q584	
Q 273	404257	734937	26	-462				-131	-282		Q584	
Q 274	404447	734759	20	-387			-25	-148	-284	-387		
Q 275	404543	734450	5	-451			-75	-231	-355		Q276	
Q 276	404511	734433	25	-506			-25	-191	-371	-504		

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks
Q 278	404524	734438	16	-520			-59	-196	-336	-498	Q1057	
Q 282	404448	734743	30	-433			-38	-133	-277		Q283	
Q 283	404450	734750	27	-420			-41	-123	-283	-383		
Q 287	403624	734916	5	-712	-150	-230	-315	PRES	-655			
Q 290	403354	735326	5	-723	-195	-215	-280	-485	-680			
Q 301	404214	734935	67	-43	-43							
Q 306	404147	734718	26	-71	-47						Q1839	
Q 310	404141	734413	47	-64			-58				Q2443	
Q 311	404107	734805	28	-232	-100	-177					Q3157	
Q 312	404044	734552	22	-254	-48	-148	-242					
Q 314	404049	734752	35	-275	-81	-160		-275			Q3156	
Q 317	404154	734937	61	-539	-62	-202		-234	-392		Q566	
Q 318	404254	734813	131	-119			-79				Q2137	
Q 324	404155	734638	32	-91	-33						Q571	
Q 332	403943	734437	8	-367	-111		-132					
Q 333	403958	734502	12	-128	-49	-64					Q1197	
Q 334	403952	734535	8	-182	-67		-103				Q1305	
Q 335	404004	734620	13	-322	-70	-147	-284					
Q 336	404016	734716	10	-163	-85	-135					Q1876	
Q 337	404000	734742	8	-214	-106	-163						
Q 338	403957	734805	10	-220	-91	-195						
Q 339	404002	734830	10	-197	-103	-174					Q1175	
Q 340	404026	735135	9	-153	PRES	-71	-121				Q634	
Q 341	404243	735134	70	-176			-58					
Q 344	403959	735005	10	-326		-110	-178					
Q 345	404006	735040	10	-209		-143	-189					
Q 350	404020	735007	33	-622		-103	-208	-265	-453	-577	Q2384	
Q 364	404449	735333	63	-126				-27			Q2148	
Q 369	404438	735520	80	-72						-61		
Q 374	404632	735530	33	-31						-17		

[1]PRES - Unit present but surface altitude not discernible.
NR - No record; no record near altitudes indicated under remarks.
[2]Veatch - Well number from numbering system employed in Veatch and others, 1906.
[3]BWS - New York City Bureau of Water Supply Well

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks
Q 375	404633	735558	15	-43						-41		
Q 376	404518	735521	43	-79						-59		
Q 377	404539	735503	64	-23						-3		
Q 378	404549	735455	75	-28						-8		
Q 379	404529	735512	52	-95						-74		
Q 380	404559	735447	78	-30						-10		
Q 381	404647	735354	19	-76						-56		
Q 382	404617	735429	58	-69						-51		
Q 386	404451	735534	75	-147						-73	Q602	
Q 387	404425	735539	64	-112						-88		
Q 388	404433	735536	70	-133						-106		
Q 389	404508	735529	35	-49						-28		
Q 390	404351	735605	23	-188				-56		-171		
Q 391	404357	735557	62	-135						-115		
Q 392	404403	735549	65	-101						-85		
Q 393	404345	735557	17	-153				-59		-133		
Q 394	404411	735542	48	-127				-42		-107		
Q 395	404422	735704	7	-67						-67		
Q 398	404437	735642	2	-65								
Q 399	404447	735653	13	-55								
Q 403	403352	735440	5	-865	-192	-206	-237	-486	-643	-865		
Q 404	404652	735517	43	-3						8		
Q 405	404702	735347	0	-95						-69		
Q 406	404646	735514	53	-29						-24		
Q 407	404623	735521	22	-28						-23		
Q 408	404610	735608	6	-51						-42		
Q 411	404609	735435	64	-61						-41		
Q 412	404549	735424	66	-62						-42		
Q 413	404612	735510	56	-55						-38		
Q 414	404618	735352	21	-102						-71		

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks
Q 415	404629	735342	8	-102						-82		
Q 416	404646	735325	0	-143						-89		
Q 417	404522	735447	46	-75						-54		
Q 422	404430	735728	7	-59						-49		
Q 423	404435	735706	17	-52						-42		
Q 425	404444	735535	75	-84						-64	Q453	
Q 426	404446	435500	63	-84				-32		-64		
Q 427	404436	735502	91	-136				-37		-121		
Q 428	404415	735507	98	-169				-86		-149		
Q 429	404407	735529	64	-170				-31		-150		
Q 431	404409	735503	104	-139				-71		-118		
Q 432	404401	735509	115	-187				-68		-167		
Q 434	404353	735508	89	-174				-30		-147		
Q 435	404346	735511	63	-196				-78		-176		
Q 436	404313	735526	8	-209	-57			-155		-187		
Q 437	404320	735501	5	-255	-97			-131		-207	Q1274	
Q 438	404325	735514	4	-204	-95			-113		-184		
Q 439	404513	735056	10	-118								
Q 440	404446	735041	27	-94							Q1028	
Q 441	404500	735023	2	-83							Q2420	
Q 442	404459	734959	10	-84								
Q 443	404439	735049	27	-76								
Q 444	404435	735036	2	-80							Q1028	
Q 446	404414	735047	2	-88								
Q 447	404402	735039	2	-89							Q2400B	
Q 448	404320	735014	7	-53								
Q 449	404337	735017	1	-90								
Q 450	404545	735022	10	-72								
Q 451	404518	735038	17	-142							Q1730	
Q 452	404504	735037	4	-87								

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks[1,2]
Q 453	404446	735535	68	-79						-77	Q1098	
Q 455	404701	735048	37	-63				-15				
Q 460	404541	734529	11	-446			-2	-146	-297	-399	Q484	
Q 461	404541	734529	11	-366			-2	-146	-297		Q484	
Q 462	404541	734529	7	-398			-4	-162	-275	-393	Q484	
Q 464	404541	734529	6	-361			-4	-145	-272		Q484	
Q 466	404541	734529	7	-384			3	-130	-305		Q484	
Q 468	404541	734529	2	-398			-19	-138	-300		Q484	
Q 480	404541	734529	9	-381			-28	-183	-278		Q484	
Q 484	404541	734529	7	-384			-3	-154	-259			
Q 490	404704	734939	5	-219				-45	-135	-219	Q495	
Q 491	404704	734939	9	-205				-53	-143		Q495	
Q 492	404704	734939	6	-222				-59	-171		Q495	
Q 493	404704	734939	7	-212				-44	-168	-208	Q495	
Q 494	404704	734939	5	-213				-59	-153	-208	Q495	
Q 495	404704	734939	4	-189				-57	-170			
Q 542	403453	734959	6		-191	-237	-291	-455	-684		Q1071	
Q 556	404200	734644	32	-391	-32		-106	PRES			Q571	
Q 557	404223	734800	58	-139			-56				Q1507	
Q 558	404054	734917	33	-130	-127							
Q 559	404021	734839	16	-281	-97	-161	-198	-256				
Q 561	404139	734715	25	-65	-65						Q1839	
Q 562	404140	734716	23	-658	-67		-120	-238	-458	-649		
Q 563	404302	734513	70	-68			-24				Q564	
Q 564	404302	734513	70	-229			-24					
Q 565	404202	734916	65	-495	-51	-249		-351	-415			
Q 566	404154	734937	61	-231	-84	-202						
Q 567	404254	734813	131	-504			-79	PRES	-410		Q2137	
Q 568	404200	734403	50	-819			-55	-354	-554	-811		
Q 571	404200	734644	30	-602				NR	-480	-600		NR 30 TO -479

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks
Q 572	404150	734719	25	-758				NR	NR	-650	Q1839	NR 25 TO -649
Q 580	404425	734341	115	-553			15	-293	-469			
Q 581	404420	734340	112	-570			0	-272	-466		Q1914	
Q 582	404418	734339	110	-591			16	-280	-461		Q1914	
Q 584	404257	734937	10	-620				-120	-320	-440		
Q 586	404347	735025	15	-420				-135	-325	-414	Q2413	
Q 595	404458	734810	20	-427			PRES	-115	-235			
Q 597	404325	735001	0	-89								
Q 601	404524	735022	0	-156				-89				
Q 602	404453	735533	50	-109						-85		
Q 603	404351	735558	69	-133					-53	-110		
Q 633	404004	735022	11	-180		-117						
Q 634	404024	735135	10	-139	-87	-131						
Q 669	404748	735028	10	-149				-66				Veatch 186
Q 676	403909	734739	0	-203	-140	-200						
Q 678	403953	734526	10	-261	-99		-120					
Q 680	403957	734831	10	-182	-105	-175					Q1175	
Q 681	403958	734715	5	-151	-84	-137						
Q 682	404001	734653	7	-251	-76	-147						
Q 683	404001	734602	10	-283	-62	-202	-250					
Q 684	403959	734553	10	-410	-68	-160	-183					
Q 689	404116	734822	40	-82	-71							
Q 690	404119	734736	20	-180	-75	-169						
Q 710	404605	734643	75	11			14					
Q 720	403955	734446	18	-388	-45	-81	-127					
Q 721	403950	734358	22	-390			-80					
Q 722	403956	734344	17	-373			-41					
Q 724	404049	734501	27	-330			-53					
Q 952	404425	735523	29	-28								
Q 954	404536	735626	12	-289						-15		

[1]PRES - Unit present but surface altitude not discernible.
NR - No record; no record near altitudes indicated under remarks.
[2]Veatch - Well number from numbering system employed in Veatch and others, 1906.

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks[1]
Q 957	404208	734810	45	-137			-49					
Q 962	404506	735642	20	-175						-25		
Q 964	404546	735243	20	-105								
Q 966	404440	735724	8	-192						-37		
Q 978	404443	735423	60	-110				-42			Q1620	
Q 985	404207	734832	35	-143			-61				Q1037	
Q 1026	404446	735011	8	-287				-72	-234		Q1027	
Q 1027	404446	735013	8	-275				-82	-232			
Q 1028	404438	735039	5	-419						-316		NR 5 TO -315
Q 1030	403451	735004	6	-1043	-192	-240	-336	-467	-731	-974		
Q 1032	404459	735138	40	-223				-21	-182	-211		
Q 1035	404215	734752	62	-215			-89				Q1965	
Q 1036	404209	734831	55	-128			-40				Q1037	
Q 1037	404209	734831	51	-145			-23					
Q 1041	404528	734441	5	-188			-76				Q1057	
Q 1042	404530	734442	5	-199			-76				Q1057	
Q 1043	404532	734442	5	-120			-73				Q1057	
Q 1045	404537	734443	5	-181			-61				Q1057	
Q 1048	404520	734437	6	-177			-93				Q1053	
Q 1049	404519	734439	6	-154			-109				Q1053	
Q 1053	404518	734440	12	-190			-132					
Q 1056	404523	734437	5	-166			-125				Q1057	
Q 1057	404527	734439	9	-38			-38					
Q 1063	404132	734540	32	-112			-29				Q1532	
Q 1064	404156	734826	35		-55							
Q 1071	403454	734956	12	-851	-188	-240	-268	-468	-737			
Q 1085	404348	735531	6	-164	-78			PRES		-158		
Q 1086	404445	735210	52	-297				-38	-206	-227	Q1241	
Q 1087	404444	735211	52	-66				-38			Q1241	
Q 1093	404631	735449	53	11						11		

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks[1,2]
Q 1095	404359	734741	38	-14			-14					
Q 1098	404439	735534	72	-143						-62		
Q 1175	404002	734834	10	-206	-113	-176						
Q 1197	403958	734502	15	-119	-47	-90	-117					
Q 1221	404522	735624	17	-161						-21		
Q 1230	403539	734626	10	-154								
Q 1239	404218	734751	50	-150			-33				Q1965	
Q 1241	404445	735211	52	-265				-8	-204			
Q 1246	404520	735553	42	-178						-21		
Q 1257	404548	735542	30	-120						-17		
Q 1258	404446	735547	55	-8						-8	Q2333	
Q 1272	404525	735640	10	-185						8		
Q 1274	404326	735449	15	-65	-40							
Q 1275	404217	734754	50	-111			-33				Q1965	
Q 1278	404313	735044	56	-114			-37					
Q 1291	404132	734537	42	-29			-27				Q1532	
Q 1293	404424	734350	115	-565			-23	-255	-475			
Q 1304	403952	734916	14	-140	-121	-132						Veatch 195
Q 1305	403948	734538	12	-166	-66		-111					Veatch 196
Q 1311	404250	734538	58	-349			-40				Q1957	Veatch 220
Q 1314	404210	734803	38	-177			-100					
Q 1328	404456	735303	53	-62				-59				
Q 1352	404618	735157	13	-195						-169		
Q 1353	404756	734942	0	-162				-74	-92	-142		
Q 1372	404308	734357	80	-142			-31				Q3012	
Q 1373	404656	735029	50	-212				13	-144	-195	Q1542	
Q 1374	404653	735030	55	-200				20	-151	-195	Q1542	
Q 1376	404152	735109	83	-128		-103	-114				Q1379	
Q 1378	404120	735112	42	-170		-111						
Q 1379	404154	735107	83	-127		-103	-114					

[1]PRES - Unit present but surface altitude not discernible.
NR - No record; no record near altitudes indicated under remarks.
[2]Veatch - Well number from numbering system employed in Veatch and others, 1906.

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Altitude of well, in feet above or below (-) sea level: Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well[3]	Remarks
Q 1383	403610	734514	26	-224			-114					
Q 1384	404308	734357	80	-152			-26				Q3012	
Q 1392	404227	734750	60	-301			-72	-260			Q1507	
Q 1400	404401	735229	20	-282				-58	-238	-281		
Q 1412	404259	735427	42	-98				-78				
Q 1423	404233	734630	55	-247			-85				Q2356	
Q 1447	404148	734847	45	-90	-84							
Q 1449	404107	734805	28	-108	-103						Q3157	
Q 1450	404207	734459	55	-77			-62				Q1815	
Q 1465	404604	735025	12	-115				-59				
Q 1472	404415	734657	70	-184			-75				Q3000	
Q 1477	404050	735022	34	-144	-82	-111						
Q 1483	404055	735118	25	-159		-120	-143					
Q 1493	404140	735041	45	-98								
Q 1497	404653	735030	55	-169				25	-130	-169	Q1542	
Q 1498	404653	735030	55	-169				25	-130	-169	Q1542	
Q 1502	404426	735614	15	-78						-76	QBWS2	
Q 1503	404316	734837	75	-32			-32					
Q 1507	404222	734750	58	-99			-94					
Q 1511	404139	735105	48	-97								
Q 1516	404539	734957	35	-77								
Q 1521	404029	734553	20	-162	-44	-126						
Q 1528	404137	735158	70	-118		-114						
Q 1532	404134	734542	40	-414			-21	-334				
Q 1535	404249	734435	70	-380			-39	-356			Q1629	
Q 1536	404324	734554	190	-83			-73				Q1747	
Q 1542	404653	735030	53	-171				23	-132	-171		
Q 1600	404330	734503	98	-356			-12	-283				
Q 1619	404554	735558	15	-28						-27		
Q 1620	404439	735413	60	-173				-42		-170		

Table 9.--*Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)*

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well[3]	Remarks
Q 1629	404249	734435	70	-242			-35					
Q 1630	403518	734827	7	-168		-119						
Q 1632	404435	735608	18	-45						-45		
Q 1635	404510	735553	3	-37						-37		
Q 1638	404424	735615	13	-60						-60	QBWS2	
Q 1640	404617	734404	80	-56			-20					
Q 1678	404541	735032	12	-258				-137	-169	-255		
Q 1695	404615	734409	85	-84			-4				Q1736	
Q 1730	404516	735035	10	-260								
Q 1736	404617	734410	88	-30			-6					
Q 1738	404446	735635	15	-131						-26		
Q 1747	404323	734553	180	-93			-83					
Q 1787	404303	734816	110	-138			-67				Q1812	
Q 1789	404552	734621	80	-9			25					
Q 1802	404338	735115	90	-72								
Q 1811	404151	734921	50	-97	-95							
Q 1812	404303	734816	110	-145			-69					
Q 1815	404207	734459	58	-248			-56					
Q 1823	404057	734854	40	-242	-85	-183		-232				
Q 1835	404145	734734	35	-313	-57		-155	-297				
Q 1839	404150	734719	25	-61	-61							
Q 1841	404423	734337	115	-242			-20					
Q 1850	404516	734230	132	-71			1				Q3003	
Q 1851	404341	735122	80	-223			-43	-88				
Q 1861	404019	734717	9	-176	-68	-130					Q1876	
Q 1876	404019	734717	8	-172	-84	-140						
Q 1909	404515	734231	132	-118			26				Q3003	
Q 1912	404516	735600	40	-360						-30		
Q 1914	404418	734342	120	-138			-14					
Q 1918	404332	735517	15	-67	-63							

[3]BWS - New York City Bureau of Water Supply Well

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identi-fication number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks
Q 1922	404550	735338	30	-103				-44		-102		
Q 1923	404250	734538	65	-246			-22	-225			Q1957	
Q 1924	404141	734413	47	-442			-56	-384			Q2443	
Q 1926	404620	734740	90	-200				0	-160			
Q 1929	403631	734542	9	-1036			-123	-579	-777		Q1932	
Q 1930	403633	734545	8	-122			-118				Q1932	
Q 1931	403634	734544	8	-132			-124				Q1932	
Q 1932	403635	734542	8	-126			-118					
Q 1933	404443	735307	77	-178				-47		-175		
Q 1937	404540	734609	68	-15			5					
Q 1941	404341	734850	78	-36			-29					
Q 1957	404250	734538	65	-236			-58	-221				
Q 1958	404141	734413	47	-395			-82	-387			Q2443	
Q 1965	404212	734753	36	-227			-91					
Q 1978	404451	735336	65	-144				-5		-144	Q2148	
Q 1979	404451	735335	65	-25				-19			Q2148	
Q 1982	404332	734429	90	-303			-9	-274			Q2188	
Q 1983	404217	734915	70	-371	-53		-204	-243				
Q 1984	404137	734522	45	-356			-35	-336				
Q 1985	404306	734637	145	-155			-62				Q2001	
Q 1999	404156	734613	35	-366	-40		-144	-305				
Q 2000	404332	734429	90	-28			-20				Q2188	
Q 2001	404259	734634	123	-84								
Q 2003	404156	734526	55	-281			-49				Q2028	
Q 2025	404648	735425	25	-42						-31		
Q 2026	404042	734337	40	-410			-48					
Q 2028	404156	734526	54	-261			-32					
Q 2080	404600	735518	45	9						9		
Q 2122	404205	735000	60	-355	-60	-151	-180	-208	-310		Q2332	
Q 2137	404254	734813	130	-120			-80					

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks
Q 2138	404208	735002	60	-63							Q2332	
Q 2140	404124	734930	48	-274	-76	-183		-253			Q2189	
Q 2144	404601	735011	12	-134							Q2592	
Q 2148	404452	735337	65	-20				-16				
Q 2149	404126	734646	25	-75	-71							
Q 2188	404332	734429	90	-192			-19					
Q 2189	404124	734930	48	-83	-80							
Q 2195	404546	734949	25	-67				-58				
Q 2202	404312	735424	52	-193				-95		-193		
Q 2205	404117	734522	45	-351			-26				Q2243	
Q 2206	404036	734436	25	-108	-48	-89	-105					
Q 2227	404056	734627	20	-399	-59	-208	-232					
Q 2243	404117	734522	45	-62			-3					
Q 2255	404224	734503	63	-290			-62				Q2300	
Q 2259	404216	734423	55	-319			-45				Q2276	
Q 2261	404404	735103	30	-54			-48					
Q 2266	403626	734457	22	-110								
Q 2272	404241	735359	95	-52								
Q 2273	404434	735156	30	-247				-154	-202	-234	Q2394	
Q 2274	404740	734832	20	-148				-9	-109			
Q 2275	404216	734423	55	-50							Q2276	
Q 2276	404216	734423	55	-319			-45					
Q 2280	404622	735129	8	-194						-192		
Q 2282	404733	734747	9	-188				-31	-129	-188		
Q 2289	404012	735006	30	-132		-103					Q2384	
Q 2299	404224	734503	63	-100			-62				Q2300	
Q 2300	404224	734503	63	-220			-62					
Q 2309	404602	735013	5	-123							Q2592	
Q 2321	404245	734406	65	-309			-82				Q2343	
Q 2325	404208	735002	60	-180	-76	-149	-180				Q2332	

Table 9.--*Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)*

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks
Q 2329	404159	734629	30	-79								
Q 2331	404703	734905	65	-40				-38				
Q 2332	404208	735002	60	-192	-71	-151	-165					
Q 2333	404443	735601	25	-12						-12		
Q 2343	404245	734406	65	-175			-77					
Q 2349	403935	734515	10	-80	-70							
Q 2356	404234	734629	50	-165			-97					
Q 2361	404329	734827	74	-262			-33	-198			Q2409	
Q 2362	404320	734818	82	-244			-63	-205				
Q 2363	404343	734831	64	-366			-30	-184	-347			
Q 2364	404323	734838	74	-264			-32	-177			Q2374	
Q 2366	404559	735512	45	2						2		
Q 2373	404323	734838	74	-193			-31	-181			Q2374	
Q 2374	404323	734838	74	-193			-31	-181				
Q 2377	404510	735005	20	-250						-248	Q2402	
Q 2378	404718	734622	12	-162								
Q 2384	404022	734957	27	-126		-111						
Q 2385	404343	735008	5	-99								
Q 2386	404411	735042	5	-130				-120			Q2400B	
Q 2390	404434	735159	35	-252				-134	-232		Q2394	
Q 2392	404349	735009	5	-160								
Q 2393	404434	735159	35	-130				-129			Q2394	
Q 2394	404434	735158	35	-115								
Q2400A	404404	735040	13	-104				-88			Q2400B	
Q2400B	404404	735040	18	-121								
Q 2402	404509	735011	20	-253						-253		
Q 2404	404352	734449	160	-250			-30	-250			Q2435	
Q 2405	404248	734602	62	-288			-75	-224			Q2432	
Q 2408	404329	734827	74	-85			-32				Q2409	
Q 2409	404329	734827	74	-207			-32	-183				

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Altitude of well: Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks
Q 2410	404411	735019	5	-195								
Q 2413	404336	735028	8	-127				-122				
Q 2416	404504	735018	7	-266				-54	-200		Q2420	
Q 2417	404455	735052	10	-293								
Q 2419	404503	735019	7	-264				-71	-213		Q2420	
Q 2420	404503	735020	7	-267				-73	-216			
Q 2422	404025	734638	20	-361	-63	-163	-300					
Q 2426	403919	734420	6	-238	-44		-124					
Q 2430	404135	734402	47	-413			-53	-383			Q2443	
Q 2432	404248	734602	62	-230			-89	-225				
Q 2435	404352	734449	160	-202			-34					
Q 2437	404329	735214	80	-118			-87	-92				
Q 2443	404135	734402	47	-319			-64					
Q 2445	404500	735606	26	-84						-84		
Q 2468	404627	735024	10	-165				10	-140			
Q 2588	404512	734456	90	-67			-18					
Q 2592	404603	735008	12	-238						-238		
Q 2600	404506	734613	65	-25			-11					
Q 2685	404412	734538	105	-41			-28					
Q 2706	404245	735017	110	-66			-66					
Q 2712	404450	734402	185	-53			18					
Q 2721	404507	735620	35	-265						15		
Q 2765	404038	734450	25	-425			-40				Q2955	
Q 2791	404624	734835	80	-60				0				
Q 2837	404237	735136	60	-120	-80							
Q 2955	404040	734451	25	-430			-41	-425				
Q 2987	404515	734231	132	-327			3	-274			Q3003	
Q 2988	404402	734858	104	-360			-55	-140	-249			
Q 2990	404129	734849	50	-264	-115	-164	-224					
Q 2991	404310	734700	110	-404			-45	-215	-400		Q3014	

Table 9.--*Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)*

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks
Q 3000	404413	734701	70	-209			-66	-200				
Q 3002	404610	734621	70	-47			1					
Q 3003	404515	734231	140	-183			21					
Q 3012	404310	734359	84	-42			-20					
Q 3014	404310	734700	110	-227			-37	-211				
Q 3020	404340	734231	95	0								
Q 3026	404237	734554	60	-275			-85	-257			Q3034	
Q 3029	404059	734508	25	-410			-44	-401			Q3062	
Q 3030	404356	735151	18	-320			-42	-68	-235	-288	Q3036	
Q 3036	404354	735200	20	-279			PRES	-40	-225			
Q 3034	404237	734554	60	-228			-85					
Q 3056	404054	734403	40	-429			-86	-425			Q3083	
Q 3062	404059	734508	25	-405			-44	-401				
Q 3083	404056	734406	40	-323			-49					
Q 3109	403933	734829	22	-427	-109	-202	-234	-376				
Q 3110	403845	734757	10	-461	-104	-186	-346	-431				
Q 3111	403850	734648	14	-486	-112	-198	-295	-447				
Q 3112	403939	734728	11	-418	-99	-145	-293	-381				
Q 3156	404050	734755	35	-278	-80	-159		-278				
Q 3157	404107	734805	28	-259	-102	-173	-244	-257				
Q [d]BWS2	404424	735610	25	-29						-29		
Q BWS3	404338	735414	29	-158				-86		-158		
Q BWS4	404446	735406	49	-127				PRES		-127		
Q BWS5	404612	735233	23	-159						-159		
Q BWS7	404429	734632	61	-535			-32	-151	-302	-482		
Q BWS9	404233	734940	115	-537					-388	-498		
QBWS10	404612	734611	61	-411			-21	-99	-274	-381		
QBWS12	404442	734850	16	-406			-52	-86	-276	-332		
QBWS13	404308	735257	102	-296	-148			-254		-294		
QBWS14	404303	734914	85	-490			-55	-185	-330	-450		

[1]PRES - Unit present but surface altitude not discernible.
'20ft - "20 foot" clay may be present.

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks*
QBWS15	404612	734834	97	-299				-45	-185	-258		
QBWS16	404530	735231	60	-172				-96		-172		
QBWS17	404431	735258	38	-242	-67			-82		-222		
QBWS18	404227	735106	77	-429			-66	-166	-366	-429		
QBWS19	404655	734813	65	-297				-5	-137	-225		
N 3	403931	734234	5	-460	-61		-107					
N 6	403953	734316	10	-328			-52					
N 10	404229	734246	51	-351			-79	-351				
N 11	404224	734238	50	-390			-30	-358			N9151	
N 23	404642	734405	18	-449			-54	-178	-280	-416	N9110	
N 24	404735	734242	12	-448				-171	-261	-416	N9308	
N 216	404955	734524	30	-482						-200		
N 248	403946	734252	14	-176			-41					
N 559	403713	734333	20	-109	-64		-109					20 ft -25, -41
N 687	404743	734444	8	-362					-272	-312		
N 914	403932	734243	10	-104	-60		-88					
N 1298	404655	734445	15	-370			-70	-132	-243	-325		
N 1346	403850	734238	5	-143	-50		-142					
N 1618	404631	734215	+83	-502			-52	-184	-324	-502	N5110	
N 1686	404723	734349	95	-255			30	-125			N5576	
N 1687	404723	734349	95	-130			PRES	-113			N5576	
N 1802	404512	734210	132	-618			9	-284	-427	-616		
N 1818	404532	734209	141	-94			21					
N 1835	404519	734210	122	-148			1					
N 1926	404841	734533	51	-235					-160	-235		
N 1958	404426	734148	116	-641			16	-296	-491	-639		
N 2203	403806	734412	5	-177	-70	-142	-158					
N 2214	404826	734504	47	-245					-173	-243		
N 2413	404126	734209	51	-475			-41	-458				
N 2578	404033	734312	25	-478			-57	-434			N3327	

[1]PRES - Unit present but surface altitude not discernible.
*20ft - "20 foot" clay may be present.

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level[1]: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks[2,*]
N 2749	404751	734405	56	-389				-194	-250	-342	N4266	
N 2597	403532	734034	6	-1246	-103	-117	-137	-786	-945			
N 3327	404033	734312	25	-545			-67	-432				
N 3443	404815	734345	124	-347			-32	-136	-256	-339		
N 3448	403511	734150	7	-1243	-83		-123	-715	-990			20ft -47
N 3705	403824	734159	24	-166	-49	-136	-150					20ft -16, -49
N 3734	403711	734443	12	-130			-130					20ft -16
N 3851	404727	734355	82	-105			17					
N 3861	403751	734401	5	-616	-59	-133	-203	-545				20ft -23
N 3862	403621	734418	8	-787	-111	-123	-156	-646				20ft -36
N 3864	403827	734250	4	-632	-65	-133	-206	-576			N6581	20ft -19, -37
N 3866	403816	734142	6	-446	-88	-130	-180					20ft -22, -33
N 3867	403912	734320	6	-543	-51	-78	-144	-513				20ft -30, -51
N 3905	404544	734151	134	-636			41	-254	-431	-611	N4243	
N 4077	404324	734139	85	-453			PRES	-351				
N 4173	404526	734159	130	-130			12					
N 4243	404541	734152	132	-128			41					
N 4266	404752	734403	57	-419				-155	-233	-348		
N 4405	403515	734305	9	-1108	-84	-120	-141	-709	-865		N6701	20ft -35, Veatch 272
N 4714	403802	734444		-228		-150						
N 5076	404238	734203	71	-392			-31	-392				
N 5079	403742	734052	15	-138	-97		-122					
N 5099	404647	734235	189	-245			-50	-199				
N 5110	404629	734213	82	-324			-63	-188				
N 5576	404722	734348	95	-171			29	-110				
N 5731	403944	734319	15	-87			-58					20ft -34, -48
N 5884	404756	734258	68	-160			36	-95				
N 6455	403942	734245	15	-69			-46					
N 6467	403810	734331	4	-694	-55	-132	-191	-571				20ft -21, -36
N 6468	403840	734330	5	-699	-52	-134	-230	-530				20ft -29, -33

Table 9.--Hydrogeologic units penetrated by wells and test holes in Kings, Queens, Nassau, Bronx, New York, and Richmond Counties (continued)

[Well locations are shown on pl. 1]

Well-identification number	Lat.	Long.	Altitude of well, in feet above or below (-) sea level: Top	Bottom	Hydrogeologic unit penetrated and altitude of unit surface, in feet above or below (-) sea level: Gardiners Clay	Jameco Gravel	Magothy aquifer	Raritan confining unit	Lloyd aquifer	Bedrock	Located near well	Remarks
N 6469	403810	734313	6	-597	-66	-131	-150	-569				20ft -7, -26
N 6581	403827	734250	8	-612	-61	-131	-207	-579				
N 6610	403641	734331	9	-235	-79	-100	-121					20ft -24, -40
N 6701	403517	734306	11	-846	-77	-133	-149	-716				
N 6706	403713	734159	6	-737	-68	-125	-155	-628				20ft -19, -33
N 6813	403936	734309	10	-228			-69					
N 6925	404750	734446	11	-274				-159	-190			
N 7445	404515	734122	120	-333			16	PRES				
N 7613	404814	734518	38	-197					-147			
N 7770	404827	734454	43	-267					-178			
N 8109	403844	734233	5	-148	-52		-147					20ft -28
N 8221	404922	734500	75	-215					-155			
N 8342	404642	734405	18	-425			-81	-179	-277	-421	N9110	
N 8375	404654	734223	110	-454			-66	-174	-325		N8456	
N 8455	404940	734446	55	-224						-205		
N 8456	404656	734226	105	-519			-73	-182	-342	-510		
N 8466	403803	734142	11	-463	-69		-129					20ft -20
N 8821	404533	734154	133	-107			18				N8840	
N 8840	404532	734151	122	-118			22					
N 8964	404635	734356	47	-188			-143	-173				
N 9110	404640	734410	15	-371			-90	-174	-281			
N 9151	404224	734238	50	-386			-24	-383				
N 9308	404735	734240	12	-431				-144	-243	-419		
N 9532	403948	734218	10	-130	-70		-88					
N 9567	403846	734029	25	-115	-43		-63					

[1]PRES - Unit present but surface altitude not discernible.
[2]Veatch - Well number from numbering system employed in Veatch and others, 1906.
[3]20ft - "20 foot" clay may be present.

Table 10.--Selected chemical analyses of ground water samples from observation wells in Kings, Queens, and eastern Nassau Counties,[1] *N.Y.* µS/cm, microsiemens per centimeter at 25 degrees celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; deg C, degrees celsius; --, analysis not available; <, less than NTU, Nephelometric turbidity unit; Neg, negligible.]

Well no	Lat	Long	Screened interval (ft above or below (-) sea level)	Aquifer[1]	Date sampled[2]	Specefic conductance (µS/cm)	pH (units)	Field temp (deg C)	Color (unit)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Calcium, total (mg/L as Ca)	Magnesium, total mg/L as Mg)
K922	403919	740027	-117 to -138	Jameco	6/14/83	1,370	7.6	12	4	0.4	380	97	46
K1189	403918	740043	-119 to -140	Jameco	3/11/81	1,400	7.7	15	6	2.0	280	60	31
					6/14/83	1,470	7.6	15	60	5.9	340	88	42
K1673	403849	735852	-14 to -19	Upglac	2/18/81	890	7.3	15.5	2	.3	400	--	--
					9/19/83	611	7.1	15.5	--	.3	360	90	22
K1678	403549	735701	-99 to -109	Upglac	4/ 7/81	4,560	7.6	13	220	>25	880	300	32
					8/ 3/83	3,690	7.7	16	10	.9	740	120	74
K1689	403742	735839	-18 to -26	Upglac	2/25/81	860	7.3	19.5	3	.3	96	--	50
					9/ 6/83	164	7.0	--	5	.3	340	53	52
K2040	404146	735713	-66 to -77	Upglac	4/ 9/81	490	7.3	15	18	5.3	170	29	24
					6/14/83	920	7.1	15	5	.4	390	110	35
K2407	403524	735834	-19 to -45	Upglac	2/12/81	1,210	6.9	7	4	.4	160	--	--
					8/25/83	1,600	6.6	17	9	.8	160	98	70
K2412	403643	740131	-42 to -53	Upglac	4/28/81	600	7.6	15	3	1.2	290	77	24
					8/ 9/83	610	7.4	15	--	--	300	90	19
K2482	403945	735742	-35 to -50	Upglac	3/19/81	720	7.4	14	7	.4	280	62	30
					8/11/83	726	7.6	17	4	.4	290	50	34
K2510	403426	735832	-173 to -199	Jameco	3/23/81	>8,000	7.2	13	5	2.1	5,200	320	1,100
					6/22/83	>9,000	7.2	13	12	3.6	5,300	320	980
K2511	403427	735833	-159 to -185	Jameco	6/22/83	>9,000	7.3	--	11	2	5,700	350	1,200
K2582	403732	735737	-153 to -184	Jameco	9/22/83	980	7.8	18	8	.6	340	65	49

1 Upglac — upper glacial aquifer
Jameco — Jameco aquifer
Lloyd — Lloyd aquifer
Mag — Magothy aquifer
Rar — Raritan confining unit

2 Wells were sampled by the U.S Geological Survey and ranged from 2 to 32 inches in diameter Generally, the smaller diameter wells are Geological Survey observation wells; those of larger diameter are industrial or abandoned public-supply wells. Sample-collection procedures were determined mainly by well diameter and depth to water. Normally, where the depth to water was 25 ft or less, a centrifugal pump was used; otherwise a submersible pump was used. In places where both centrifugal and submersible pumps were impractical, the samples were bailed. The volume of water standing in the well casing was evacuated at least three times, and specific conductance was monitored until stable before sampling was begun.

All samples were stored and preserved with appropriate chemical reagents as described by the Bureau of Water Supply Laboratory (New York City Department of Environmental Protection, written commun., 1983). Samples were analyzed by the Bureau of Water Supply Laboratory according to methods prescribed by the American Public Health Association (1976).

Table 10.--Selected chemical analyses of ground water sampled from observation wells in Kings, Queens, and eastern Nassau Counties (continued)

Well no.	Date sampled	Sodium, total (mg/L as Na)	Potassium, total mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Total dissolved solids (mg/L)	Nitrogen, as nitrate, total (mg/L as N)	Nitrogen as ammonia, total (mg/L as N)	Arsenic, total (µg/L as As)	Cadmium, total (µg/L as Cd)
K 922	6/14/83	130	10	190	97	270	0.2	936	6.0	0.04	<50	<10
K1189	3/11/81	200	10	180	95	250	--	822	14.0	.06	--	<10
	6/14/83	160	13	170	94	310	.2	996	8.0	.01	<50	<10
K1673	2/18/81	--	--	220	86	130	--	616	8.4	.09	<50	<10
	9/19/83	40	4	270	48	96	.3	562	5.2	<.02	<50	<10
K1678	4/ 7/81	700	14	96	260	1300	.1	--	9.0	<.03	--	<10
	8/ 3/83	510	9	100	190	30	.2	2460	>10	--	<50	<10
K1689	2/25/81	40	3	240	65	84	--	560	.6	.03	<50	<10
	9/ 6/83	45	6	220	38	72	.3	555	13	<.03	<50	<10
K2040	4/ 9/81	38	2	98	50	80	.1	--	12	.18	--	<10
	6/14/83	110	4	230	87	94	.2	619	7	.01	<50	<10
K2407	2/12/81	--	--	200	7	230	--	798	6.3	.05	<50	<10
	8/25/83	110	7	38	<50	110	.3	--	6.7	<.03	<50	<10
K2412	4/28/81	15	--	400	--	21	.2	--	4	.05	--	<10
	8/ 9/83	13	3	180	70	39	.1	419	4.6	<.03	<50	<10
K2482	3/19/81	41	3	180	88	70	.2	478	5.6	<.03	--	<10
	8/11/83	40	4	200	60	68	.3	496	7.5	<.03	<50	<10
K2510	3/23/81	8,000	360	150	2,400	15,000	.6	29,200	.3	.03	<20	<10
	6/22/83	7,000	400	150	2,300	16,000	.6	40,100	--	.01	<50	<10
K2511	6/22/83	8,200	400	150	2,300	18,000	.7	42,000	--	.05	ND	<10
K2582	9/22/83	43	3	120	95	170	.3	634	>10	<.03	<50	<10

Well no.	Date sampled	Chromium, total µg/L as Cr)	Copper, total (µg/L as Cu)	Iron, total (µg/L as Fe)	Lead, total (µg/L as Pb)	Manganese total (µg/L as Mn)	Mercury, total (µg/L as Hg)	Selenium, total µg/L as Se)	Silver, total (µg/L as Ag)	Zinc, total (µg/L as Zn)	Linear alkyl sulfonate
K 922	6/14/83	<30	30	190	<30	10	<1	<10	<50	40	neg
K1189	3/11/81	<40	60	2,600	<10	300	<1	--	<30	40	neg
	6/14/83	<30	50	230	<30	300	<1	<10	<50	30	neg
K1673	2/18/81	<40	10	30	<10	30	<1	<10	<30	40	neg
	9/19/83	<30	10	140	<30	10	--	<10	<50	40	neg
K1678	4/ 7/81	<50	30	100	<30	30	<1	--	<10	40	neg
	8/ 3/83	<30	10	150	40	30	<1	<10	<50	90	neg
K1689	2/25/81	<50	40	100	<10	<10	<1	<10	<30	50	neg
	9/ 6/83	<30	120	80	80	30	<1	<10	<50	380	neg
K2040	4/ 9/81	<50	10	690	<30	40	<1	--	<10	2,000	neg
	6/14/83	<30	20	70	<30	10	<1	<10	<50	40	neg
K2407	2/12/81	<40	10	40	<10	440	<1	<10	<30	60	neg
	8/25/83	<30	230	160	190	60	<1	<10	<50	90	neg
K2412	4/28/81	<50	20	180	<30	30	--	--	<10	50	--
	8/ 9/83	<30	10	60	<30	20	<1	<10	<50	30	neg
K2482	3/19/81	<50	10	100	<30	<10	<1	--	<20	10	--
	8/11/83	<30	40	100	<30	20	<1	<10	<50	20	neg
K2510	3/23/81	<50	50	320	<30	900	<1	--	50	40	neg
	6/22/83	<30	60	410	80	3,600	<1	<10	<50	70	neg
K2511	6/22/83	60	70	380	70	3,500	<1	<10	<50	50	neg
K2582	9/22/83	<30	10	750	120	20	<1	<10	<50	80	neg

Table 10.--Selected chemical analyses of ground water sampled from observation wells in Kings, Queens, and eastern Nassau Counties (continued)

Well no.	Lat	Long	Screened interval (ft above or below (-) sea level)	Aquifer[1]	Date sampled[2]	Specific conductance (µS/cm)	pH (units)	Field temp (deg C)	Color (unit)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Calcium, total (mg/L as Ca)	Magnesium, total mg/L as Mg)
K2591	404301	735753	-22 to -37	Upglac	4/13/81	1,400	6.7	17	6	1 8	410	100	36
					9/20/83	1,200	6.6	17.5	300	>25	350	28	18
K2598	404230	735537	-37 to -48	Upglac	3/31/81	1,030	7.2	16	23	.3	400	110	33
					7/13/83	750	7.0	16	60	>20	240	65	19
K2610	403938	735237	-35 to -52	Upglac	2/12/81	4,300	6.9	16	6	.6	1,100	--	--
					6/ 8/83	4,000	6.5	14.5	6	.2	470	180	10
K2622	404028	735354	-40 to -50	Upglac	4/ 7/81	650	6.9	11.5	5	1.5	270	29	22
					9/15/83	1,250	7.1	14	5	.6	480	140	58
K2859	403451	735856	-464 to -480	Lloyd	3/27/81	500	8.0	15	18	30	40	4.6	6.8
					7/26/83	280	7.1	16	70	45	36	3.8	15
K3130	403748	735721	-207 to -258	Jameco	7/28/83	1,260	7.3	17	2	.5	240	120	61
K3132	403750	735717	-234 to -280	Jameco	7/28/83	4,890	7.0	14	65	.6	14,000	280	140
K3133	404158	735658	-145 to -175	Jameco	3/ 4/81	1,700	7.4	12	6	.4	460	180	4.5
					6/29/83	950	7.6	15	5	.6	350	76	32
K3151	403921	735450	-20 to -70	Upglac	9/ 1/83	783	7.5	15	8	.4	330	85	35
K3214	403813	735654	-26 to -49	Upglac	7/12/83	875	6.9	17	2	.2	310	80	37
K3216	403755	735652	-24 to -47	Upglac	7/12/83	2,600	7.2	15	8	.4	1,200	140	70
K3218	403824	735656	-23 to -46	Upglac	4/14/81	780	7.4	16.5	4	.3	300	65	34
					7/12/83	800	7.1	17	7	2.4	290	48	36
K3242	403608	735757	-33 to -53	Upglac	9/20/83	573	6.5	17	5	.2	190	100	13
K3245	404155	735521	+9 to +6	Upglac	2/25/81	1,000	6.9	--	40	19	190	--	--

Well no	Date sampled	Sodium, total (mg/L as Na)	Potassium, total mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Total dissolved solids (mg/L)	Nitrogen, as nitrate, total (mg/L as N)	Nitrogen as ammonia, total (mg/L as N)	Arsenic, total (µg/L as As)	Cadmium, total (µg/L as Cd)
K2591	4/13/81	150	12	190	90	250	0.2	--	6.7	0.01	--	<10
	9/20/83	29	5	150	190	210	.4	805	10	<.03	<50	<10
K2598	3/31/81	62	4	210	130	100	.1	508	16	.12	<1	<10
	7/13/83	62	7	44	97	250	.3	535	>10	.03	<50	<10
K2610	2/12/81	--	--	200	98	1,300	--	3,320	8.7	.03	<50	<10
	6/ 8/83	340	13	230	--	500	1	2,700	9.2	.11	<50	<10
K2622	4/ 7/81	20	1	96	85	95	.2	--	7.5	<.03	--	<10
	9/15/83	94	5	250	82	210	.4	864	6.4	<.03	<50	<10
K2859	3/27/81	70	6	52	10	110	.4	260	.3	.03	--	<10
	7/26/83	45	5	44	21	52	--	193	.24	.03	<50	<10
K3130	7/28/83	70	3	120	78	290	.2	866	5	<.03	<50	<10
	7/28/83	480	12	100	180	500	.1	3,470	.24	<.03	<50	<10
K3133	3/ 4/81	180	4	180	130	340	--	455	2.6	.21	<50	<10
	6/29/83	71	4	180	1	140	.2	707	1.4	.02	<50	<10
K3151	9/ 1/83	26	5	160	<50	73	.2	--	11	--	<50	<10
K3214	7/12/83	55	6	120	--	51	.2	612	>10	.03	<50	<10
K3216	7/12/83	160	10	110	--	1,100	.2	1,640	>10	.03	<50	<10
K3218	4/14/81	38	3	140	57	93	.1	--	15	.01	--	<10
	7/12/83	50	5	120	--	120	.2	565	>10	.03	<50	<10
K3242	9/20/83	107	4	94	85	40	.8	348	.85	<.03	<50	<10
K3245	2/25/81	--	--	80	160	160	--	615	10	.12	<50	<10

Table 10.--*Selected chemical analyses of ground water sampled from observation wells in Kings, Queens, and eastern Nassau Counties (continued)*

Well no.	Date sampled	Chromium, total µg/L as Cr)	Copper, total (µg/L as Cu)	Iron, total (µg/L as Fe)	Lead, total (µg/L as Pb)	Manganese total (µg/L as Mn)	Mercury, total (µg/L as Hg)	Selenium, total µg/L as Se)	Silver, total (µg/L as Ag)	Zinc, total (µg/L as Zn)	Linear alkyl sul-fonate
K2591	4/13/81	350	50	6,100	<30	1,900	<1	--	<10	30	neg
	9/20/83	<30	30	200	<30	180	--	<10	<50	80	neg
K2598	3/31/81	600	10	60	<10	30	<1	--	<10	20	neg
	7/13/83	1600	10	120	<30	40	<1	<10	<50	130	neg
K2610	2/12/81	150	20	60	<10	160	<1	<10	<30	60	neg
	6/ 8/83	140	90	200	--	130	2	<10	--	40	neg
K2622	4/ 7/81	<50	10	60	<30	20	<1	--	<10	20	neg
	9/15/83	<30	20	70	<30	10	--	<10	<50	70	neg
K2859	3/27/81	<50	10	1,700	<10	50	<1	--	<10	20	neg
	7/26/83	<30	30	--	<30	80	<1	<10	<50	70	neg
K3130	7/28/83	<30	20	60	<30	300	<1	<10	<50	50	neg
K3132	7/28/83	<30	10	4,300	<30	2,300	<1	<10	<50	30	neg
K3133	3/ 4/81	40	50	180	<10	360	<1	<10	<30	<10	neg
	6/29/83	<30	20	100	<30	300	<1	<10	<50	80	neg
K3151	9/ 1/83	<30	10	150	<30	50	<1	<10	<50	50	neg
K3214	7/12/83	<30	10	70	<30	50	<1	<10	<50	100	neg
K3216	7/12/83	<30	10	630	<30	120	<1	<10	<50	120	neg
K3218	4/14/81	50	20	50	<30	10	<1	--	<10	30	--
	7/12/83	<30	30	80	<30	10	<1	<10	<50	170	neg
K3242	9/20/83	<30	630	95,000	<30	18,000	--	<10	<50	160	neg
K3245	2/25/81	<40	70	50,000	<10	8,700	<1	<10	<30	25,000	neg

Table 10.--*Selected chemical analyses of ground water sampled from observation wells in Kings, Queens, and eastern Nassau Counties (continued)*

Well no.	Lat	Long	Screened interval (ft above or below (-) sea level)	Aquifer[1]	Date sampled[2]	Specific conductance (µS/cm)	pH (units)	Field temp (deg C)	Color (unit)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Calcium, total (mg/L as Ca)	Magnesium, total mg/L as Mg)
K3245	404155	735521	+9 to +6	Upglac	6/29/83	900	7.1	--	200	22	170	32	21
K3246	403902	735528	-1 to -4	Upglac	2/10/81	--	6.2	18	--	--	--	--	--
					9/15/83	284	5.7	17	6	.7	72	19	7.2
K3247	403605	735712	-3 to -6	Upglac	8/22/83	1,300	7.0	15	85	--	450	--	--
K3248	403712	740016	-7 to -10	Upglac	2/24/81	990	6.4	15	28	250	400	--	130
					7/25/83	506	6.7	16	120	41	130	12	29
K3249	403623	740021	-11 to -14	Upglac	4/22/81	800	6.2	14.5	75	14	200	--	54
					7/13/83	1,110	6.0	17	12	1.5	240	30	50
K3250	403443	735755	-12 to -15	Upglac	2/11/81	2,700	6.8	16	60	15	500	--	--
					8/30/83	2,400	6.8	16	70	75	440	50	82
K3251	403520	735755	-10 to -13	Upglac	2/11/81	470	6.7	12.5	5	22	220	--	--
					6/30/83	450	6.9	17	27	7	190	--	9.8
K3252	403702	735558	-11 to -14	Upglac	2/11/81	580	6.4	16.5	27	10	120	--	--
					6/15/83	575	5.0	16	35	3.7	84	23	5.6
K3253	403727	735908	-6 to -9	Upglac	8/22/83	460	7.4	16	4	--	20	--	--
K3254	403737	735649	+1 to -2	Upglac	5/ 1/81	800	6.6	11	60	.7	260	--	--
					8/18/83	700	6.4	17	5	4.4	200	45	21
K3255	403827	735352	-2 to -5	Upglac	2/11/81	--	--	17	--	--	--	--	--
					6/ 8/83	1,150	--	15	17	4.5	280	93	14
K3256	403949	735321	-1 to -4	Upglac	2/10/81	620	6.3	18.5	5	4.2	180	--	--
					6/ 8/83	700	6.3	18	28	12	200	52	20

Well no	Date sampled	Sodium, total (mg/L as Na)	Potassium, total mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Total dissolved solids (mg/L)	Nitrogen, as nitrate, total (mg/L as N)	Nitrogen as ammonia, total (mg/L as N)	Arsenic, total (µg/L as As)	Cadmium, total (µg/L as Cd)
K3245	6/29/83	120	4	32	100	170	0.2	686	17	0.06	<50	<10
K3246	2/10/81	--	--	--	--	--	--	--	10	--	<50	<10
	9/15/83	21	2	30	40	140	.3	195	1.9	<.03	<50	<10
K3247	8/22/83	--	--	46	93	280	.2	--	>10	<.03	--	--
K3248	2/24/81	6.6	18	100	120	200	--	610	9.4	.06	<50	<10
	7/25/83	48	4	94	--	47	.4	332	.8	.01	<50	<10
K3249	4/22/81	70	--	8.0	--	200	.2	--	12	.69	--	<10
	7/13/83	120	6	140	59	81	.3	758	>10	.01	<50	20
K3250	2/11/81	--	--	230	130	690	--	1,620	.3	.39	<50	<10
	8/30/83	320	75	180	<50	560	.2	--	.29	--	<50	<10
K3251	2/11/81	--	--	190	20	12	--	280	6.9	.06	<50	<10
	6/30/83	14	--	120	35	29	.2	346	9.2	.02	<50	<10
K3252	2/11/81	--	--	96	56	82	--	338	4.2	.75	<50	<10
	6/15/83	76	6	150	34	38	.2	342	4.4	.01	<50	<10
K3253	8/22/83	--	--	140	28	26	.2	--	4	.03	--	--
K3254	5/ 1/81	--	--	170	--	100	<.2	--	13	.12	--	<10
	8/18/83	82	6	130	40	82	.1	457	>10	.11	<50	<10
K3255	2/11/81	--	--	--	--	850	--	--	12	--	<50	<10
	6/ 8/83	82	11	24	--	270	1	822	20	.05	<50	<10
K3256	2/10/81	--	--	46	92	69	--	369	6	.15	<50	<10
	6/ 8/83	33	5	22	--	85	1	451	18	.02	<50	<10

Table 10.--Selected chemical analyses of ground water sampled from observation wells in Kings, Queens, and eastern Nassau Counties (continued)

Well no.	Date sampled	Chromium, total µg/L as Cr)	Copper, total (µg/L as Cu)	Iron, total (µg/L as Fe)	Lead, total (µg/L as Pb)	Manganese total (µg/L as Mn)	Mercury, total (µg/L as Hg)	Selenium, total µg/L as Se)	Silver, total (µg/L as Ag)	Zinc, total (µg/L as Zn)	Linear alkyl sul-fonate
K3245	6/29/83	<30	600	80,000	360	3,400	<1	<10	<50	26,000	neg
K3246	2/10/81	<40	10	600	<10	170	<1	<10	<30	1,400	neg
	9/15/83	<30	10	5,900	<30	200	--	<10	<50	1,500	neg
K3247	8/22/83	--	--	--	<30	--	<1	--	--	--	neg
K3248	2/24/81	50	2,500	56,000	<10	5,300	<1	<10	<30	14,000	neg
	7/25/83	<30	30	12,000	<30	250	<1	<10	<50	3,500	neg
K3249	4/22/81	<50	650	56,000	<30	3,800	--	--	<10	110,000	neg
	7/13/83	60	1,400	87,000	200	1,300	<1	<10	<50	38,000	neg
K3250	2/11/81	<40	10	6,700	<10	1,300	<1	<10	<30	730	neg
	8/30/83	<30	10	18,000	30	1,000	<1	<10	<50	900	neg
K3251	2/11/81	<40	20	2,100	<10	400	<1	<10	<30	1,400	neg
	6/30/83	<30	20	950	<30	80	<1	<10	<50	850	neg
K3252	2/11/81	<40	10	2,700	<10	480	<1	<10	<30	1,000	neg
	6/15/83	<30	40	440	<30	330	<1	<10	<50	200	neg
K3253	8/22/83	--	--	--	<30	--	<1	--	--	--	neg
K3254	5/ 1/81	<50	90	24,000	<30	--	--	--	--	--	neg
	8/18/83	<30	30	3,400	<30	60	54	<10	<50	3,200	neg
K3255	2/11/81	<40	10	2,100	<10	50	<1	<10	<30	1,400	neg
	6/ 8/83	<30	40	560	<30	30	<1	<10	<50	170	neg
K3256	2/10/81	<40	10	12,000	<10	160	<1	<10	<30	2,500	neg
	6/ 8/83	<30	30	2,100	<30	100	<1	<10	<50	1,300	neg

Table 10.--Selected chemical analyses of ground water sampled from observation wells in Kings, Queens, and eastern Nassau Counties (continued)

Well no	Lat	Long	Screened interval (ft above or below (-) sea level)	Aquifer[1]	Date sampled[2]	Specific conductance (µS/cm)	pH (units)	Field temp (deg C)	Color (unit)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Calcium, total (mg/L as Ca)	Magnesium, total mg/L as Mg)
K3257	404017	735445	+3 to 0	Upglac	3/20/81	1,400	5.9	14	60	35	460	73	66
					7/19/83	707	6.5	16	44	>20	300	80	32
K3260	404325	735635	-7 to -10	Upglac	2/12/81	2,000	6.8	18.5	6	2.7	540	--	--
					7/12/83	1,600	6.5	16	--	80	490	110	50
K3267	403709	735841	-10 to -14	Upglac	4/23/81	400	6.6	13	5	.4	170	1.6	40
					7/19/83	388	6.6	16	2	.2	170	18	27
K3271	404025	735151	-9 to -12	Upglac	6/21/83	1,220	7.1	15	--	65	330	120	18
K3272	403932	735645	0 to -3	Upglac	8/30/83	520	7.0	16	--	>25	160	36	12
K3273	403817	735801	-3 to -6	Upglac	9/15/83	760	6.4	17	15	1.6	72	--	--
K3275	403737	740117	-6 to -9	Upglac	8/ 3/83	861	7.3	17	>30	>25	380	200	38
K3276	404135	735840	-13 to -16	Upglac	7/25/83	241	7.5	13	90	37	100	30	7.3
Q 273	404257	734937	-281 to -411	Lloyd	4/ 8/81	160	7.0	--	120	50	72	16	8
					7/14/83	133	6.9	14	14	47	64	13	6.7
Q 277	404519	734438	-101 to -131	Mag	10/6/83	144	6.7	20	75	18	50	12	3.2
Q 287	403624	734916	to	Lloyd	7/20/83	400	6.5	18	1	32	36	5.5	2.8
Q 470	404541	734526	-333 to -361	Lloyd	4/20/81	100	6.3	13	8	>20	38	8.2	4.3
					8/31/83	90	6.4	14	27	25	16	7.1	2.5
Q 471	404541	734526	to -98	Mag	2/19/81	63	6.8	12.5	30	18	40	--	--
					7/11/83	50	6.5	13	12	6.8	28	3.5	2.1
Q1071	403453	734956	-755 to -820	Lloyd	4/29/81	275	6.7	14.5	200	65	38	13	1.6
					9/12/83	247	6.5	17	--	--	36	8.3	2.5

Well no.	Date sampled	Sodium, total (mg/L as Na)	Potassium, total mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Total dissolved solids (mg/L)	Nitrogen, as nitrate, total (mg/L as N)	Nitrogen as ammonia, total (mg/L as N)	Arsenic, total (µg/L as As)	Cadmium, total (µg/L as Cd)
K3257	3/20/81	41	6	120	210	230	0.3	872	12	0.03	--	<10
	7/19/83	29	6	100	200	31	.5	499	16	.04	<50	<10
K3260	2/12/81	--	--	250	190	380	--	1,300	9.7	.06	<50	<10
	7/12/83	140	10	210	--	360	.2	1,170	>10	.01	<50	130
K3267	4/23/81	6.5	--	100	--	13	.1	--	12	.14	--	<10
	7/19/83	7.4	2	100	9.2	16	.3	266	14	.01	<50	<10
K3271	6/21/83	120	11	260	100	170	.3	841	--	.03	<50	<10
K3272	8/30/83	50	4	40	73	71	.3	370	13	<.02	<50	<10
K3273	9/15/83	--	--	30	58	140	.3	532	8.9	<.03	<50	20
K3275	8/ 3/83	38	8	860	120	15	.2	562	>10	<.03	<50	<10
K3276	7/25/83	8.4	2	100	--	50	.9	158	3.5	.03	<50	<10
Q 273	4/ 8/81	4.6	1	74	0.0	8.0	.2	--	1.0	.30	--	<10
	7/14/83	3.9	1	62	2.7	6.0	.3	99	.12	.01	<50	<10
Q 277	10/ 6/83	9.2	3	40	15	17	.5	92	--	<.03	<50	<10
Q 287	7/20/83	64	5	30	--	100	.3	265	.72	.04	<50	<10
Q 470	4/20/81	5.4	--	34	33	8.0	<.1	--	3.1	.51	--	<10
	8/31/83	5.7	1	24	10	10	.2	--	2.7	--	<50	<10
Q 471	2/19/81	--	--	22	4.0	16	--	45	1.0	.20	<50	<10
	7/11/83	3.8	.6	18	--	6.0	.2	39	1.6	.03	<50	<10
Q1071	4/29/81	--	--	22	--	57	.1	--	.60	.54	--	<10
	9/12/83	44	12	24	5.0	58	.2	174	--	--	<50	<10

Table 10.--Selected chemical analyses of ground water sampled from observation wells in Kings, Queens, and eastern Nassau Counties (continued)

Well no.	Date sampled	Chromium, total µg/L as Cr)	Copper, total (µg/L as Cu)	Iron, total (µg/L as Fe)	Lead, total (µg/L as Pb)	Manganese total (µg/L as Mn)	Mercury, total (µg/L as Hg)	Selenium, total µg/L as Se)	Silver, total (µg/L as Ag)	Zinc, total (µg/L as Zn)	Linear alkyl sul-fonate
K3257	3/20/81	<50	360	46,000	3,000	3,800	<1	--	<20	70,000	neg
	7/19/83	<30	1,1900	84,000	700	1,500	<1	<10	<50	21,000	neg
K3260	2/12/81	<40	20	1,000	<10	60	<1	<10	<30	1,400	neg
	7/12/83	<30	1,200	76,000	380	450	<1	<10	<50	12,000	neg
K3267	4/23/81	<50	30	150	<30	30	--	--	<10	1,600	neg
	7/19/83	<30	10	70	<30	10	<1	<10	<50	460	neg
K3271	6/21/83	<30	370	13,000	650	1,700	1	<10	<50	5,500	neg
K3272	8/30/83	<30	2,400	18,000	1,400	550	--	<10	<50	9,600	neg
K3273	9/15/83	<30	10	1,600	<30	230	--	<10	<50	8,800	neg
K3275	8/ 3/83	100	3,300	60,000	1,200	5,400	<1	<10	<50	73,000	neg
K3276	7/25/83	<30	2,300	10,000	300	150	<1	<10	<50	4,500	neg
Q 273	4/ 8/81	<50	10	4,000	<30	400	<1	--	<10	20	neg
	7/14/83	<30	10	5,500	<30	400	<1	<10	<50	20	neg
Q 277	10/ 6/83	<30	30	1,300	<30	140	<1	<10	<50	100	neg
Q 287	7/20/83	<30	10	28,000	150	1,400	<1	<10	<50	60	neg
Q 470	4/20/81	<50	640	70,000	<30	130	--	--	<10	--	neg
	8/31/83	<30	80	29,000	460	30	<1	<10	<50	3,000	neg
Q 471	2/19/81	<40	20	790	<10	10	<1	<10	<30	120	neg
	7/11/83	<30	100	570	80	30	<1	<10	<50	70	neg
Q1071	4/29/81	<50	10	11,000	<30	350	--	--	--	20	neg
	9/12/83	<30	10	11,000	<30	340	--	<10	<50	30	neg

Table 10.--Selected chemical analyses of ground water sampled from observation wells in Kings, Queens, and eastern Nassau Counties (continued)

Well no	Lat	Long	Screened interval (ft above or below (-) sea level)	Aquifer[1]	Date sampled[2]	Specific conductance (µS/cm)	pH (units)	Field temp (deg C)	Color (unit)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Calcium, total (mg/L as Ca)	Magnesium, total mg/L as Mg)
Q1187	403958	734458	to -120	Jameco	7/14/83	190	6.3	14	14	5.4	52	12	5.2
Q1189	403958	734458	to -35	Upglac	2/18/81	1,650	6.2	14	27	7.0	470	--	--
					6/ 7/83	1,570	6.3	15	30	27	250	91	15
Q1237	403959	734744	to -200	Jameco	10/ 6/83	1,270	7.6	14	8	1.2	410	150	46
Q1241	404436	735218	-209 to -249	Lloyd	3/ 3/81	230	6.5	--	170	>25	60	15	5.4
					6/15/83	280	6.5	16	450	45	54	15	5.9
Q1373	404656	735037	-144 to -156	Lloyd	9/22/83	3,300	7.8	16	25	.7	380	90	28
Q1472	404415	734656	-122 to -152	Mag	9/22/83	360	6.8	16.5	3	.6	120	28	56
Q1506	403945	734825	-81 to -93	Upglac	8/ 9/83	5,000	6.9	15	--	4.5	1,100	150	150
Q1605	404357	735204	-6 to -17	Upglac	2/20/81	850	7.0	15.5	4	1.0	410	--	--
					9/ 1/83	950	7.1	--	9	.6	430	120	55
Q1663	404205	735218	-31 to -41	Upglac	2/19/81	730	7.3	9.0	9	3.9	370	--	--
					8/ 8/83	881	7.3	14	2	.7	440	110	45
Q1914	404418	734342	-112 to -138	Mag	8/25/83	550	5.9	13	7	1.2	610	31	17
Q1930	403633	734525	-91 to -111	Upglac	3/17/81	>8,000	6.8	13.5	90	>25	2,800	240	520
					6/23/83	>9,000	6.5	15	120	12	3,100	320	440
Q2289	404016	735006	-66 to -117	Upglac	7/27/83	2,340	6.8	15	8	1.0	750	140	90
Q2324	403957	734950	to -69	Upglac	2/13/81	1,030	7.4	14	5	2.8	450	--	--
					6/ 6/83	960	7.5	14	6.0	5.2	410	--	54
Q2384	404022	734957	-92 to -123	Upglac	7/27/83	2,290	7.4	14	5	.3	750	140	90
Q2407	404320	734748	-19 to -45	Upglac	9/ 7/83	500	6.3	13.5	7	1.0	190	40	28

Well no.	Date sampled	Sodium, total (mg/L as Na)	Potassium, total mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Total dissolved solids (mg/L)	Nitrogen, as nitrate, total (mg/L as N)	Nitrogen as ammonia, total (mg/L as N)	Arsenic, total (µg/L as As)	Cadmium, total (µg/L as Cd)
Q1187	7/14/83	9.9	2	36	29	10	0.2	111	.79	0.01	<50	<10
Q1189	2/18/81	--	--	86	52	470	--	1,020	1.0	.96	<50	<10
	6/ 7/83	150	11	120	90	340	1	999	--	.30	<50	<10
Q1237	10/ 6/83	68	7	90	25	330	.4	779	--	<.03	<50	<10
Q1241	3/ 3/81	22	2	74	18	12	--	120	1.2	.45	<50	<10
	6/15/83	21	4	72	34	14	.3	148	3.7	.01	<50	<10
Q1373	9/22/83	520	15	4	70	1,200	.4	2,350	.14	<.03	<50	<10
Q1472	9/22/83	15	2	68	41	37	.3	227	>10	<.03	<50	<10
Q1506	8/ 9/83	870	40	550	290	1,700	.2	3,780	.36	<.03	<50	<10
Q1605	2/20/81	--	--	210	95	62	--	560	12	.21	<50	<10
	9/ 1/83	16	6	240	49	120	.2	--	.80	--	<50	<10
Q1663	2/19/81	--	--	150	97	45	--	570	10	.09	<50	<10
	8/ 8/83	20	2	280	98	51	.1	588	>10	<.03	<10	<10
Q1914	8/25/83	44	1	170	20	360	.2	--	9.5	<.03	<50	<10
Q1930	3/17/81	5,600	120	110	1,000	500	.2	14,000	.30	.15	--	--
	6/23/83	4,500	120	120	1,070	9,000	.2	21,700	1.2	.05	<50	<10
Q2289	7/27/83	220	4	90	120	650	--	1,570	6.9	.03	<50	<10
Q2324	2/13/81	--	--	210	100	140	--	750	9.6	.06	<50	<10
	6/ 6/83	38	--	150	100	140	1	672	22	.09	--	<10
Q2384	7/27/83	200	4	92	120	640	--	1,560	7.8	.03	<50	<10
Q2407	9/ 7/83	28	3	80	40	57	.2	350	4.8	<.03	<50	<10

Table 10.--*Selected chemical analyses of ground water sampled from observation wells in Kings, Queens, and eastern Nassau Counties (continued)*

Well no.	Date sampled	Chromium, total µg/L as Cr)	Copper, total (µg/L as Cu)	Iron, total (µg/L as Fe)	Lead, total (µg/L as Pb)	Manganese total (µg/L as Mn)	Mercury, total (µg/L as Hg)	Selenium, total µg/L as Se)	Silver, total (µg/L as Ag)	Zinc, total (µg/L as Zn)	Linear alkyl sul-fonate
Q1187	7/14/83	<30	10	9,500	<30	1,400	<1	<10	<50	20	neg
Q1189	2/18/81	<40	10	22,000	<10	1,800	<1	<10	<30	90	--
	6/ 7/83	<30	20	22,000	50	1,300	<1	<10	<50	--	neg
Q1237	10/ 6/83	<30	20	1,200	<30	650	1	<10	<50	60	neg
Q1241	3/ 3/81	<40	180	16,000	<10	70	<1	<10	<30	10	neg
	6/15/83	<30	7200	14,000	<30	140	<1	<10	<50	730	neg
Q1373	9/22/83	<30	60	10,000	<30	1,200	<1	<10	<50	600	neg
Q1472	9/22/83	<30	20	80	<30	20	<1	<10	<50	90	neg
Q1506	8/ 9/83	<30	80	650	100	3,700	<1	<10	<50	120	neg
Q1605	2/20/81	<40	90	180	<10	20	<1	<10	<30	200	neg
	9/ 1/83	<30	10	800	<30	10	<1	<10	<50	150	neg
Q1663	2/19/81	<40	80	480	<10	40	<1	<10	<30	150	neg
	8/ 8/83	<30	50	60	<30	10	<1	<10	<50	100	neg
Q1914	8/25/83	<30	40	40	<30	470	<1	<10	<50	100	neg
Q1930	3/17/81	<50	60	30,000	<30	2,400	<1	--	<30	30	neg
	6/23/83	<30	130	34,000	<30	1,900	<1	<10	<50	100	neg
Q2289	7/27/83	<30	10	30	<30	30	<1	<10	<50	50	neg
Q2324	2/13/81	<40	10	850	<10	30	<1	<10	<30	950	neg
	6/ 6/83	<30	100	400	<30	10	<1	--	--	--	neg
Q2384	7/27/83	<30	200	150	<30	180	<1	<10	<50	60	neg
Q2407	9/ 7/83	<30	100	230	<30	50	<1	<10	<50	120	neg

Table 10.--Selected chemical analyses of ground water sampled from observation wells in Kings, Queens, and eastern Nassau Counties (continued)

Well no	Lat	Long	Screened interval (ft above or below (-) sea level)	Aquifer[1]	Date sampled[2]	Specific conductance (µS/cm)	pH (units)	Field temp (deg C)	Color (unit)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Calcium, total (mg/L as Ca)	Magnesium, total mg/L as Mg)
Q2418	404504	735018	-42 to -54	Upglac	3/ 3/81	2,200	6.8	14	70	>25	300	110	4.2
					8/23/83	1,500	7.1	13	>30	22	300	92	24
Q2419	404503	735019	-214 to -264	Lloyd	3/ 2/81	150	7.1	13.5	100	30	62	15	5.9
					8/10/83	145	6.2	14	11	12	64	12	5.6
Q2420	404503	735020	-218 to -268	Lloyd	2/26/81	155	6.9	14	150	4.4	70	18	6.0
					8/23/83	149	7.1	14	>30	>100	60	14	4.8
Q2426	403919	734420	-207 to -227	Mag	8/ 9/83	50	6.1	14	--	.8	30	3.7	1.0
Q2656	404324	735359	-45 to -55	Upglac	4/30/81	700	7.2	12.5	27	3.5	740	--	40
					8/ 4/83	557	6.4	14	--	.5	370	80	30
Q2791	404624	734835	+12 to +4	Upglac	5/12/81	700	7.0	15	5	.7	160	--	--
					7/28/83	690	7.0	15	5	.3	270	51	28
Q2814	404511	734852	-27 to -36	Upglac	6/15/83	700	6.2	17	50	4.7	210	48	20
Q2978	404703	734835	-2 to -13	Upglac	5/18/81	600	6.4	13	5	1.4	220	--	--
					6/28/83	480	6.6	15	13	1.4	220	46	22
Q2993	404003	734622	to -56	Upglac	2/23/81	420	6.0	16	35	16	120	--	--
					8/30/83	330	6.2	15	70	8.7	82	18	8.3
Q2994	403940	734436	to -56	Upglac	6/20/83	328	6.2	13	90	45	42	6.7	3.6
Q2995	403940	734435	to -73	Upglac	2/25/81	85	8.7	14	90	23	22	--	--
					6/20/83	300	6.3	13	100	30	44	9.5	5.2
Q3003	404515	734231	-139 to -179	Mag	9/ 7/83	167	6.3	19	5	.2	44	9.5	5.5
Q3015	404403	734858	-71 to -111	Mag	8/ 8/83	629	7.1	16	2	.3	250	38	28

Well no.	Date sampled	Sodium, total (mg/L as Na)	Potassium, total mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Total dissolved solids (mg/L)	Nitrogen, as nitrate, total (mg/L as N)	Nitrogen as ammonia, total (mg/L as N)	Arsenic, total (µg/L as As)	Cadmium, total (µg/L as Cd)
Q2418	3/ 3/81	350	2	230	4.0	550	--	1,300	0.33	0.44	<50	<10
	8/23/83	230	22	230	6.0	490	.4	--	.4	.03	<50	<10
Q2419	3/ 2/81	7.4	1	68	6.3	6.0	--	75	.16	.30	<50	<10
	8/10/83	6.8	2	78	24	7.0	.3	98	.13	<.03	<50	<10
Q2420	2/26/81	8.5	1	68	1.5	15	--	90	.08	.29	--	--
	8/23/83	7.4	2	72	3.1	8.0	.2	--	.2	.03	<50	<10
Q2426	8/ 9/83	3.8	.6	16	24	9.0	.1	--	.23	<.03	<50	<10
Q2656	4/30/81	--	--	270	--	42	.2		4.6	.30	--	<10
	8/ 4/83	13	2	280	45	17	.1	546	8.6	.2	<50	<10
Q2791	5/12/81	--	--	160		52	<.2	--	13	.03	--	--
	7/28/83	48	2	150	80	71	.2	477	9.2	.01	<50	<10
Q2814	6/15/83	28	4	54	97	69	.2	388	7.8	.04	<50	<10
Q2978	5/18/81	--	--	70	--	47	.1	--	.10	.18	--	--
	6/28/83	19	2	86	100	25	.3	332	.20	.01	<50	<10
Q2993	2/23/81	--	--	40	51	52	--	240	.20	.45	--	--
	8/30/83	38	7	40	35	25	.2	--	.27	--	<50	<10
Q2994	6/20/83	46	2	38	15	65	.2	200	--	.01	<50	<10
Q2995	2/25/81	--	--	38	2.4	6.0	--	60	.20	4.0	<50	<10
	6/20/83	36	2	48	30	44	.2	191	--	.01	<50	<10
Q3003	9/ 7/83	12	2	34	8.0	26	.2	118	2.8	<.03	<50	<10
Q3015	8/ 8/83	19	2	110	80	77	.1	410	8.2	<.03	<50	<10

Table 10.--Selected chemical analyses of ground water sampled from observation wells in Kings, Queens, and eastern Nassau Counties (continued)

Well no.	Date sampled	Chromium, total µg/L as Cr)	Copper, total (µg/L as Cu)	Iron, total (µg/L as Fe)	Lead, total (µg/L as Pb)	Manganese total (µg/L as Mn)	Mercury, total (µg/L as Hg)	Selenium, total µg/L as Se)	Silver, total (µg/L as Ag)	Zinc, total (µg/L as Zn)	Linear alkyl sul-fonate
Q2418	3/ 3/81	<40	0	32,000	<10	1,400	<1	<10	<30	30	neg
	8/23/83	<30	50	22,000	<30	880	<1	<10	<50	200	neg
Q2419	3/ 2/81	<40	70	3,600	<10	120	<1	<10	<30	40	neg
	8/10/83	<30	30	4,300	<30	130	<1	<10	<50	20	neg
Q2420	2/26/81	--	--	--	<10	--	--	--	--	--	--
	8/23/83	<30	50	3,500	<30	230	<1	<10	<50	100	neg
Q2426	8/ 9/83	<30	10	450	<30	80	<1	<10	<50	20	neg
Q2656	4/30/81	<50	140	4,800	<30		--	--	--	44,000	neg
	8/ 4/83	<30	30	220	<30	80	<1	<10	<50	120	neg
Q2791	5/12/81	--	--	90	<30	--	--	--	--	--	neg
	7/28/83	<30	50	280	<30	10	<1	<10	<50	170	neg
Q2814	6/15/83	<30	130	530	<30	50	<1	<10	<50	70	neg
Q2978	5/18/81	--	--	--	<30	--	--	--	--	--	neg
	6/28/83	<30	60	450	--	230	<1	<10	<50	130	neg
Q2993	2/23/81	--	--	--	<10	--	<1	--	--	--	neg
	8/30/83	<30	70	3,800	<30	210	<1	<10	<50	120	neg
Q2994	6/20/83	<30	160	10,000	<50	420	<1	<10	<50	130	neg
Q2995	2/25/81	<40	50	4,200	<10	10	<1	<10	<30	40	neg
	6/20/83	<30	230	12,000	<30	400	<1	<10	<50	90	neg
Q3003	9/ 7/83	<30	50	40	<30	30	<1	<10	<50	100	neg
Q3015	8/ 8/83	<30	40	160	<30	10	<1	<10	<50	40	neg

Table 10.--Selected chemical analyses of ground water sampled from observation wells in Kings, Queens, and eastern Nassau Counties (continued)

Well no.	Lat	Long	Screened interval (ft above or below (-) sea level)	Aquifer[1]	Date sampled[2]	Specific conductance (µS/cm)	pH (units)	Field temp (deg C)	Color (unit)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Calcium, total (mg/L as Ca)	Magnesium, total mg/L as Mg)
Q3036	404354	735200	-229 to -249	Lloyd	3/ 2/81	195	6.7	12.5	150	45	36	9.0	3.2
					6/21/83	270	6.9	14	55	60	34	9.5	--
Q3109	403932	734829	-268 to -288	Mag	8/18/83	10,500	6.7	15	50	61	14,000	190	230
Q3110	403845	734757	-296 to -316	Jameco	7/18/83	6,520	6.7	15	85	29	1,600	400	150
Q3112	403939	734728	-279 to -289	Jameco	8/15/83	478	7.8	14	7	1.5	160	48	13
Q3114	403932	734829	-7 to -9	Upglac	8/18/83	950	6.7	13	30	30	440	94	13
Q3115	403845	734757	to -16	Upglac	7/18/83	5,620	7.0	18	55	30	800	110	78
Q3117	403939	734728	to -12	Upglac	2/ 9/81	740	6.9	14.5	23	14	250	--	--
					8/15/83	681	6.2	15	12	3.3	290	90	12
Q3119	404654	734659	+4 to +1	Upglac	2/ 9/81	870	5.9	16.5	18	8.5	290	--	--
					8/ 8/83	1,040	5.7	15.5	28	>25	310	65	27
Q3121	404631	735439	+6 to +3	Upglac	2/27/81	1,200	7.2	15	15	>25	400	--	110
					6/13/83	1,170	--	16	100	10.3	270	120	43
Q3123	404421	735132	+1 to -2	Upglac	2/ 9/81	1,100	7.1	15	13	25	440	--	--
					6/20/83	865	7.4	15	40	16	410	100	34
Q3134	404521	735051	-223 to -233	Upglac	9/20/83	1,850	6.2	14.5	3	.5	320	50	48
Q3150	403949	734957	to -119	Jameco	6/21/83	>9,000	7.0	15	--	80	5,400	400	810
N1429	403920	734107	-5 to -8	Upglac	9/27/83	394	6.1	20	10	1.2	250	40	6.2
N1627	403908	734320	-9 to -12	Upglac	4/13/81	440	6.0	16	7	1.1	120	26	14
					7/21/83	364	6.4	16	1	3.8	170	55	8.5
N3864	403827	734250	-457 to -468	Mag	10/ 3/83	80	5.6	15	12	5.1	10	2.0	1.0

Well no.	Date sampled	Sodium, total (mg/L as Na)	Potassium, total mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Total dissolved solids (mg/L)	Nitrogen, as nitrate, total (mg/L as N)	Nitrogen as ammonia, total (mg/L as N)	Arsenic, total (µg/L as As)	Cadmium, total (µg/L as Cd)
Q3036	3/ 2/81	30	2	72	13	10	--	110	0.08	2.0	<50	<10
	6/21/83	27	3	72	11	16	.2	148	--	.02	<50	<10
Q3109	8/18/83	2,800	8	82	350	6,400	.2	8,300	.4	.04	<50	<10
Q3110	7/18/83	610	70	98	200	2,300	.3	4,520	<.01	.05	<50	<10
Q3112	8/15/83	31	4	66	12	110	.2	341	--	.1	<50	<10
Q3114	8/18/83	52	10	230	180	72	.4	644	.50	<.01	<50	<10
Q3115	7/18/83	1,000	100	330	--	1,800	--	3,900	.24	.06	<50	20
Q3117	2/ 9/81	--	--	120	96	47	--	380	.50	2.2	<50	<10
	8/15/83	29	18	180	40	95	.2	490	--	.13	<50	<10
Q3119	2/ 9/81	--	--	20	92	160	--	540	6.0	.09	<50	<10
	8/ 8/83	65	4	16	100	240	.1	682	8.6	.03	<50	<10
Q3121	2/27/81	64	2	250	14	160	--	800	17	.12	<50	<10
	6/13/83	54	6	140	100	66	.2	771	5.8	.03	<50	<10
Q3123	2/ 9/81	--	--	230	150	79	--	650	25	.90	<50	<10
	6/20/83	31	2	210	110	73	.3	580	--	.03	<50	<10
Q3134	9/20/83	210	24	120	77	500	.4	1,260	.30	<.03	<50	<10
Q3150	6/21/83	6,700	170	210	2,000	15,000	.2	34,400	--	.05	<50	<10
N1429	9/27/83	27	8	54	75	35	.3	278	>10	<.03	<50	<10
N1627	4/13/81	18	7	66	50	30	.1	--	7.2	.01	--	<10
	7/21/83	8.3	6	74	--	23	.3	259	2.1	.02	<50	<10
N3864	10/ 3/83	8.8	2	14	5.5	13	--	45	.05	<.03	<50	<10

Table 10.--Selected chemical analyses of ground water sampled from observation wells in Kings, Queens, and eastern Nassau Counties (continued)

Well no.	Date sampled	Chromium, total µg/L as Cr)	Copper, total (µg/L as Cu)	Iron, total (µg/L as Fe)	Lead, total (µg/L as Pb)	Manganese total (µg/L as Mn)	Mercury, total (µg/L as Hg)	Selenium, total µg/L as Se)	Silver, total (µg/L as Ag)	Zinc, total (µg/L as Zn)	Linear alkyl sul-fonate
Q3036	3/ 2/81	<40	40	17,000	<10	150	<1	<10	<30	260	neg
	6/21/83	<30	40	9,500	60	240	<1	<10	<50	400	neg
Q3109	8/18/83	<30	20	32,000	<30	30	<1	<10	<50	80	neg
Q3110	7/18/83	<30	20	14,000	<30	2,400	<1	<10	<50	40	neg
Q3112	8/15/83	<30	50	350	<30	170	<1	<10	<50	70	neg
Q3114	8/18/83	<30	10	4,700	<30	20	<1	<10	<50	60	neg
Q3115	7/18/83	<30	--	2,900	350	270	<1	<10	<50	90	neg
Q3117	2/ 9/81	<40	130	1,400	<10	1,600	<1	<10	<30	150	neg
	8/15/83	<30	90	3,400	40	1,600	<1	<10	<50	100	neg
Q3119	2/ 9/81	<40	10	1,300	<10	50	<1	<10	<30	1,600	neg
	8/ 8/83	<30	1,800	18,000	100	260	<1	<10	<50	5,500	neg
Q3121	2/27/81	<40	350	37,000	<10	4,200	<1	<10	<30	310	neg
	6/13/83	<30	50	1,600	<30	300	<1	<10	<50	190	neg
Q3123	2/ 9/81	<40	10	2,600	<10	120	<1	<10	<30	1,000	neg
	6/20/83	<30	70	1,200	<30	100	<1	<10	<50	380	neg
Q3134	9/20/83	<30	20	120	<30	270	<1	<10	<50	100	neg
Q3150	6/21/83	<30	70	10,000	<30	900	<1	<10	<50	200	neg
N1429	9/27/83	<30	10	350	<30	40	<1	<10	<50	2,700	neg
N1627	4/13/81	<50	10	300	<30	30	<1	--	<10	110	neg
	7/21/83	<30	30	1,400	<30	90	<1	<10	<50	120	neg
N3864	10/ 3/83	<30	30	2,800	<30	20	<1	<10	<50	50	neg

Table 10.--Selected chemical analyses of ground water sampled from observation wells in Kings, Queens, and eastern Nassau Counties (continued)

Well no.	Lat	Long	Screened interval (ft above or below (-) sea level)	Aquifer[1]	Date sampled[2]	Specific conductance (µS/cm)	pH (units)	Field temp (deg C)	Color (unit)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Calcium, total (mg/L as Ca)	Magnesium, total mg/L as Mg)
N3867	403912	734320	-499 to -511	Mag	10/ 4/83	51	6	14.5	12	6	8	1.8	2.3
N3932	403751	734401	-165 to -169	Jameco	9/29/83	40	4.8	15	23	1.3	37	2.5	0.80
N4026	403713	734159	-145 to -149	Jameco	9/28/83	61	6.4	15	40	>25	18	5.3	1.1
N4062	403621	734418	-129 to -134	Jameco	9/27/83	175	6.7	15	65	75	88	8.5	3.8
N4213	403912	734320	-125 to -129	Jameco	10/ 4/83	72	5.5	15	20	4	16	3.2	2.4
N6581	403827	734250	-566 to -576	Mag	10/ 3/83	>8,000	5.9	15	1,000	31	5,200	--	96
N6701	403517	734306	-811 to -821	Rar	10/ 5/83	2,600	7.2	17	360	>25	160	20	30
N6703	403517	734306	-456 to -467	Mag	10/ 5/83	>8,000	6.2	17	800	>25	1,200	220	450
N6707	403713	734159	-487 to -497	Mag	9/28/83	5,190	6.2	15.5	90	>25	1,500	100	120
N6792	403713	734159	-42 to -44	Upglac	9/28/83	182	7.3	15	45	4.2	76	18	3.5
N7161	403856	733926	-654 to -658	Mag	10/ 4/83	45	4.8	15	25	12	8	1.5	0.2
N8877	404730	734231	-59 to -64	Upglac	9/29/83	134	6.1	14.5	150	2.5	54	9.	6.6

Well no.	Date sampled	Sodium, total (mg/L as Na)	Potassium, total mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Total dissolved solids (mg/L)	Nitrogen, as nitrate, total (mg/L as N)	Nitrogen as ammonia, total (mg/L as N)	Arsenic, total (µg/L as As)	Cadmium, total (µg/L as Cd)
N3867	10/4/83	4.9	.9	14	8.0	6.0	<.2	32	0.03	<0.03	<50	<10
N3932	9/29/83	4.1	1	14	--	6.0	.4	--	.07	<.03	<50	<10
N4026	9/28/83	4.3	.8	26	5.5	17	.2	42	.09	<.03	<50	<10
N4062	9/27/83	17	3	34	3.5	49	.3	122	.28	<.03	<50	<10
N4213	10/ 4/83	5.7	.8	20	6.5	8.0	<.2	47	.07	<.03	<50	<10
N6581	10/ 3/83	5,100	24	96	4,000	5,200	.5	--	1.3	<.03	<50	<10
N6701	10/ 5/83	400	25	38	45	860	.4	1,710	1.4	<.03	<50	<10
N6703	10/ 5/83	2,600	60	22	950	5,800	.4	9,900	.25	<.03	<50	<10
N6707	9/28/83	780	21	6	230	1,900	.3	3,650	.17	<.03	<50	<10
N6792	9/28/83	7.5	2	90	4.5	13	.3	134	.03	<.03	<50	<10
N7161	10/ 4/83	4.5	.6	18	6.5	9.0	<.2	--	.40	.05	<50	<10
N8877	9/29/83	5.5	2	28	--	18	.4	--	.09	<.03	<50	<10

Table 10.--Selected chemical analyses of ground water sampled from observation wells in Kings, Queens, and eastern Nassau Counties (continued)

Well no.	Date sampled	Chromium, total µg/L as Cr)	Copper, total (µg/L as Cu)	Iron, total (µg/L as Fe)	Lead, total (µg/L as Pb)	Manganese total (µg/L as Mn)	Mercury, total (µg/L as Hg)	Selenium, total µg/L as Se)	Silver, total (µg/L as Ag)	Zinc, total (µg/L as Zn)	Linear alkyl sul-fonate
N3867	0/ 4/83	<30	10	3,700	<30	10	<1	<10	<50	50	neg
N3932	9/29/83	<30	40	3,300	<30	10	<1	<10	<50	70	neg
N4026	9/28/83	<30	20	12,000	<30	50	<1	<10	<50	70	neg
N4062	9/27/83	<30	10	18,000	40	330	<1	<10	<50	90	neg
N4213	10/ 4/83	<30	20	950	--	60	<1	<10	<50	30	neg
N6581	10/ 3/83	<30	50	200,000	ND	3,800	<1	<10	<50	120	neg
N6701	10/ 5/83	<30	10	260	80	300	<1	<10	<50	1,800	neg
N6703	10/ 5/83	<30	10	2,100	<30	2,200	1	<10	<50	40,000	neg
N6707	9/28/83	<30	40	42,000	130	1,400	<1	<10	<50	4,500	neg
N6792	9/28/83	<30	20	1,900	<30	70	<1	<10	<50	250	neg
N7161	10/ 4/83	<30	10	5,600	<30	20	1	<10	<50	40	neg
N8877	9/29/83	<30	10	5,700	40	70	<1	<10	<50	50	neg

Table 11.--Selected chemical analyses of ground water samples from public-supply wells in Kings, Queens, and eastern Nassau Counties (sampled and analyzed by Jamaica Water Supply Company)

[Upglac, upper glacial; Jam, Jameco; Mag, Magothy; µS/cm, microsiemens per centimeter at 25 degrees celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; deg c, degrees celsius; --, analysis not available; <, less than NTU, Nephelometric turbidity unit.]

Well no.	Lat	Long	Screened interval (ft above or below (-) sea level)	Aquifer[1]	Date sampled[2]	Specific conductance (µS/cm)	pH (units)	Field temp (deg C)	Color (unit)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Calcium, total (mg/L as Ca)	Magnesium, total mg/L as Mg)
Q 301	404214	734934	+9 to -35	Upglac	9/19/83	814	7.2	--	5	1.2	350	85	33
Q 303	404054	734917	-16 to -59	Upglac	5/16/83	737	7.0	--	<5	.3	290	70	27
Q 304	404025	734839	-28 to -52	Upglac	9/19/83	681	6.8	--	<5	2.5	240	62	21
Q 307	404302	734513	+17 to -27	Upglac	6/20/83	495	5.9	--	<5	.4	120	34	8.0
Q 308	404202	734916	+4 to -46	Upglac	7/21/83	--	--	--	--	--	--	--	--
Q 310	404140	734412	-10 to -55	Upglac	10/17/83	308	6.1	--	<5	.4	82	24	4.9
Q 311	404107	734805	-174 to -234	Jameco	9/26/83	484	7.4	--	15	1.4	180	50	11
Q 313	404330	734503	+34 to -9	Upglac	10/24/83	592	6.5	--	<5	1.0	160	36	17
Q 314	404049	734752	-209 to -269	Jameco	9/26/83	440	7.6	--	8	.8	140	40	10
Q 317	404154	734937	-429 to -489	Lloyd	9/26/83	152	6.8	--	40	9.8	48	10	5.1
Q 322	404218	734933	-27 to -47	Upglac	9/19/83	858	7.0	--	<5	2.0	390	98	34
Q 323	404200	734403	-12 to -36	Upglac	7/18/83	302	6.0	--	<5	.5	86	22	7.5
Q 558	404054	734917	-92 to -122	Upglac	9/19/83	726	7.3	--	<5	2.7	290	66	29
Q 562	404140	734716	-502 to -577	Lloyd	6/ 6/83	80	5.8	--	<5	2.5	11	2.4	1.2
Q 564	404302	734513	-171 to -221	Mag	5/23/83	286	6.0	--	5	.5	98	20	11
Q 565	404201	734916	-440 to -480	Lloyd	9/26/83	158	6.8	--	50	1.2	56	17	3.4
Q 566	404154	734937	-201 to -220	Jameco	9/19/83	820	6.8	--	50	5.3	320	75	32
Q 567	404254	734810	-407 to -487	Lloyd	9/19/83	133	6.6	--	35	23	24	8.8	0.50
Q 568	404200	734403	-241 to -302	Mag	10/24/83	226	5.9	--	<5	.9	60	15	5.3
Q1450	404207	734459	-40 to -60	Upglac	10/17/83	446	6.2	--	40	1.3	140	32	12
Q1600	404330	734503	-172 to -192	Mag	10/24/83	324	6.4	--	<5	.9	110	24	11

[1] Upglac upper glacial aquifer
Jameco Jameco aquifer
Lloyd Lloyd aquifer
Mag Magothy aquifer
Rar Raritan confining unit

[2] Wells were sampled by the U.S. Geological Survey and ranged from 2 to 32 inches in diameter Generally, the smaller diameter wells are Geological Survey observation wells; those of larger diameter are industrial or abandoned public-supply wells. Sample-collection procedures were determined mainly by well diameter and depth to water Normally, where the depth to water was 25 ft or less, a centrifugal pump was used; otherwise a submersible pump was used. In places where both centrifugal and submersible pumps were impractical, the samples were bailed. The volume of water standing in the well casing was evacuated at least three times, and specific conductance was monitored until stable before sampling was begun.

All samples were stored and preserved with appropriate chemical reagents as described by the Bureau of Water Supply Laboratory (New York City Department of Environmental Protection, written commun., 1983) Samples were analyzed by the Bureau of Water Supply Laboratory according to methods prescribed by the American Public Health Association (1976).

Table 11.--*Selected chemical analyses of ground water sampled from public-supply wells in Kings, Queens, and eastern Nassau Counties (sampled and analyzed by Jamaica Water Supply Company) (continued)*

Well no.	Sodium, total (mg/L as Na)	Potassium, total mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Total dissolved solids (mg/L)	Nitrogen, as nitrate, total (mg/L as N)	Nitrogen as ammonia, total (mg/L as N)	Arsenic, total (µg/L as As)	Cadmium, total (µg/L as Cd)
Q 301	26	--	200	110	76	.1	114	2.8	.02	<2	<1
Q 303	34	--	140	82	70	<.05	459	12	.03	<2	<1
Q 304	32	--	100	82	70	.1	412	11	.12	<2	<1
Q 307	43	--	41	49	69	.1	322	11	<.02	<2	<1
Q 308	7.4	--	--	--	--	.1	120	--	.02	<2	<1
Q 310	21	--	24	40	34	.1	218	6.2	<.02	<2	<1
Q 311	7.8	--	87	14	76	.1	354	<.1	<.30	<2	<1
Q 313	41	--	69	57	86	<.05	368	7.6	<.02	<2	<1
Q 314	15	--	81	12	67	.1	86	<.1	.03	<2	<1
Q 317	6.8	--	49	14	5	<.05	82	.1	<.02	<2	<1
Q 322	24	--	210	120	88	.1	552	2.3	<.02	<2	<1
Q 323	26	--	19	39	31	<.05	200	5.4	<.02	<2	<1
Q 558	20	--	150	100	50	.1	402	11	<.02	<2	<1
Q 562	7.5	--	10	16	5.	.1	50	<.1	<.02	<2	<1
Q 564	13	--	37	32	22	.05	182	6.2	<.02	<2	<1
Q 565	5.8	--	49	15	5.	.1	100	<.1	<.02	<2	<1
Q 566	12	--	62	40	200	<.05	472	.2	<.02	<2	<1
Q 567	8.1	--	46	17	5.	.1	80	<.1	.05	<2	<1
Q 568	12	--	23	31	17	<.05	138	5.9	<.02	<2	<1
Q1450	33	--	39	61	51	.1	298	7.8	<.02	<2	<1
Q1600	15	--	52	36	35	<.05	218	4.2	<.02	<2	<1

Well no.	Chromium, total Dµg/L as Cr)	Copper, total (µg/L as Cu)	Iron, total (µg/L as Fe)	Lead, total (µg/L as Pb)	Manganese total (µg/L as Mn)	Mercury, total (µg/L as Hg)	Selenium, total µg/L as Se)	Silver, total (µg/L as Ag)	Zinc, total (µg/L as Zn)
Q 301	<20	20	90	<2	560	<.5	<2	<20	<20
Q 303	<20	20	40	<2	<20	<.5	<2	<20	<20
Q 304	<20	440	220	<2	990	<.5	<2	<20	<20
Q 307	<20	170	30	<2	<20	<.5	<2	<20	<20
Q 308	<20	200	1,800	30	150	<.5	<2	<20	<20
Q 310	<20	20	20	<2	<20	<.5	<2	<20	<20
Q 311	<20	20	1,500	<2	880	<.5	<2	<20	<20
Q 313	<20	40	90	<2	20	<.5	<2	<20	<20
Q 314	<20	20	190	<2	80	<.5	<2	<20	20
Q 317	<20	20	1,600	<2	190	<.5	<2	80	20
Q 322	<20	20	20	<2	380	<.5	<2	<20	<20
Q 323	<20	20	20	<2	<20	<.5	<2	<20	30
Q 558	<20	20	20	<2	130	<.5	<2	<20	<20
Q 562	<20	20	20	<2	<20	<.5	<2	<20	60
Q 564	<20	20	30	<2	<20	<.5	<2	<20	<20
Q 565	<20	20	690	2	350	<.5	<2	40	<20
Q 566	<20	20	5,300	<2	580	<.5	<2	<20	<20
Q 567	<20	150	2,200	<2	140	<.5	<2	<20	40
Q 568	<20	20	390	<2	60	<.5	<2	<20	20
Q1450	<20	30	1,600	<2	370	<.5	<2	--	20
Q1600	<20	30	20	<2	<20	<.5	<2	<20	30

Table 11.--Selected chemical analyses of ground water sampled from public-supply wells in Kings, Queens, and eastern Nassau Counties (sampled and analyzed by Jamaica Water Supply Company) (continued)

Well no.	Lat	Long	Screened interval (ft above or below (-) sea level)	Aquifer[1]	Date sampled[2]	Specific conductance (µS/cm)	pH (units)	Field temp (deg C)	Color (unit)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Calcium, total (mg/L as Ca)	Magnesium, total mg/L as Mg)
Q1629	404249	734435	-166 to -206	Mag	3/28/83	264	5.9	--	25	.6	66	17	5.3
Q1747	404323	734553	-55 to -80	Upglac	10/24/83	462	6.8	--	<5	.4	180	38	19
Q1811	404151	734917	-73 to -93	Upglac	9/26/83	748	7.2	--	20	3.0	290	74	24
Q1815	404211	734500	-182 to -222	Mag	10/17/83	275	6.0	--	10	.8	72	19	5.6
Q1840	404057	734854	-52 to -72	Upglac	9/19/83	640	7.0	--	<5	1.2	240	61	21
Q1843	404145	734734	-30 to -50	Upglac	7/21/83	--	--	--	--	--	--	--	--
Q1957	404250	734538	-165 to -215	Mag	10/24/83	308	6.4	--	<5	.4	100	24	10
Q1958	404140	734412	-332 to -384	Mag	10/17/83	158	5.9	--	5	.4	45	9.6	5.1
Q1997	404248	734601	-25 to -55	Upglac	9/19/83	638	6.7	--	<5	.9	210	49	22
Q2000	404332	734429	+9 to -12	Upglac	5/23/83	515	6.4	--	<5	1.2	120	30	9.2
Q2001	404259	734634	-44 to -84	Upglac	9/19/83	712	7.0	--	5	3.7	290	66	31
Q2026	404042	734336	-357 to -391	Mag	10/17/83	165	5.7	--	10	.8	39	12	1.9
Q2027	404156	734525	-28 to -38	Upglac	10/17/83	417	6.1	--	<5	.4	110	34	5.3
Q2028	404156	734525	-196 to -236	Mag	10/17/83	253	5.9	--	5	1.4	61	18	3.9
Q2137	404254	734813	-80 to -120	Mag	9/19/83	654	6.8	--	10	21	280	62	30
Q2138	404204	735000	-51 to -71	Upglac	9/19/83	742	7.0	--	<5	.8	310	73	30
Q2188	404332	734429	- 141 to -181	Mag	10/24/83	246	6.3	--	<5	.6	64	16	5.3
Q2189	404123	734930	-72 to -118	Upglac	9/19/83	891	7.2	--	<5	1.4	410	97	40
Q2243	404116	734521	-43 to -63	Mag	10/24/83	198	6.0	--	<5	.8	66	21	2.9
Q2275	404216	734423	-31 to -51	Upglac	1/24/83	368	6.0	--	<5	.8	100	31	6.3
Q2276	404216	734423	-250 to -290	Mag	10/24/83	174	6.2	--	<5	.4	38	12	1.9

Well no.	Sodium, total (mg/L as Na)	Potassium, total mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Total dissolved solids (mg/L)	Nitrogen, as nitrate, total (mg/L as N)	Nitrogen as ammonia, total (mg/L as N)	Arsenic, total (µg/L as As)	Cadmium, total (µg/L as Cd)
Q1629	16	--	25	26	29	.1	--	7.2	<.02	<2	<1
Q1747	3	--	94	43	50	<.05	288	3.4	<.02	<2	<1
Q1811	32	--	190	85	60	.1	464	5.3	.08	<2	<1
Q1815	14	--	20	43	24	<.05	172	3.4	<.02	<2	<1
Q1840	32	--	130	85	64	.1	402	8.8	<.02	<2	<1
Q1843	36	--	--	--	--	.1	476	--	.20	<2	<1
Q1957	15	--	45	36	35	<.05	197	6.1	<.02	<2	<1
Q1958	7.6	--	28	30	12	.1	104	.4	<.02	<.2	<1
Q1997	31	--	110	70	68	.1	378	5.2	<.02	<2	<1
Q2000	30	--	84	49	52	<.02	140	8.2	.03	<2	<1
Q2001	22	--	170	85	67	.1	424	1.1	.13	<2	<1
Q2026	9.6	--	6.	36	9.	<.05	192	<.1	<.02	<2	<1
Q2027	30	--	44	53	41	.1	276	10	<.02	<2	<1
Q2028	15	--	11	48	28	.1	162	3.4	<.02	<2	<1
Q2137	14	--	150	95	58	<.05	404	<.1	<.02	<2	<1
Q2138	23	--	170	95	58	.1	196	4.2	<.02	<2	<1
Q2188	11	--	25	28	21	.1	98	6.8	<.02	<2	<1
Q2189	28	--	160	90	160	<.05	540	8.2	.03	<2	<1
Q2243	19	--	23	27	26	.1	124	3.6	<.02	<2	<1
Q2275	6	--	26	52	44	<.05	206	7.6	<.02	<2	<1
Q2276	8.5	--	21	16	12	<.05	112	6.0	<.02	<2	<1

Table 11.--Selected chemical analyses of ground water sampled from public-supply wells in Kings, Queens, and eastern Nassau Counties (sampled and analyzed by Jamaica Water Supply Company) (continued)

Well no.	Chromium, total Dµg/L as Cr)	Copper, total (µg/L as Cu)	Iron, total (µg/L as Fe)	Lead, total (µg/L as Pb)	Manganese total (µg/L as Mn)	Mercury, total (µg/L as Hg)	Selenium, total µg/L as Se)	Silver, total (µg/L as Ag)	Zinc, total (µg/L as Zn)
Q1629	<20	20	20	<2	<20	<.5	<2	<20	<20
Q1747	<20	20	20	<2	<20	<.5	<2	<20	<20
Q1811	<20	40	50	<2	490	<.5	<2	<20	<20
Q1815	<20	20	20	<2	<20	<.5	<2	<20	<20
Q1840	<20	20	20	<2	160	<.5	<2	<20	<20
Q1843	<20	20	60	<2	40	<.5	<2	<20	70
Q1957	<20	20	20	<2	70	<.5	<2	<20	<20
Q1958	<20	20	20	2	<20	<.5	<2	<20	<20
Q1997	<20	20	40	<2	<20	<.5	<2	<20	<20
Q2000	<20	90	20	<2	<20	<.5	<2	<20	<20
Q2001	<20	20	530	<2	340	<.5	<2	<20	<20
Q2026	<20	60	570	<2	120	<.5	<2	<20	20
Q2027	<20	30	60	<2	<20	<.5	<2	<20	<20
Q2028	<20	40	930	<2	160	<.5	<2	<20	<20
Q2137	<20	20	2,200	<2	570	<.5	<2	<20	<20
Q2138	<20	30	20	5	60	<.5	<2	<20	50
Q2188	<20	60	20	4	<20	<.5	<2	<20	<20
Q2189	<20	20	150	<2	160	<.5	<2	<20	<20
Q2243	<20	20	70	<2	170	<.5	<2	<20	60
Q2275	<20	40	40	<2	<20	<.5	<2	<20	<20
Q2276	<20	20	20	3	<20	<.5	<2	<20	<20

Table 11.--Selected chemical analyses of ground water sampled from public-supply wells in Kings, Queens, and eastern Nassau Counties (sampled and analyzed by Jamaica Water Supply Company) (continued)

Well no.	Lat	Long	Screened interval (ft above or below (-) sea level)	Aquifer[1]	Date sampled[2]	Specific conductance (µS/cm)	pH (units)	Field temp (deg C)	Color (unit)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Calcium, total (mg/L as Ca)	Magnesium, total mg/L as Mg)
Q2299	404225	734503	-42 to -62	Upglac	7/18/83	416	5.8	--	<5	.5	120	36	6.8
Q2300	404224	734503	-179 to -219	Mag	7/ 7/83	--	--	--	--	--	--	--	--
Q2332	404204	735000	-158 to -188	Jameco	9/26/83	522	7.2	--	<5	.7	230	54	23
Q2343	404249	734406	-125 to -165	Mag	5/23/83	274	6.0	--	5	1.2	79	17	8.5
Q2362	404320	734818	-138 to -205	Mag	10/17/83	484	7.1	--	5	.3	190	47	17
Q2363	404343	734831	-56 to -66	Mag	9/19/83	759	6.6	--	<5	1.3	260	56	29
Q2373	404323	734838	-69 to -84	Mag	9/19/83	856	7.0	--	<5	.6	370	88	37
Q2374	404323	734838	-145 to -180	Mag	10/17/83	472	7.0	--	<5	.6	190	45	18
Q2408	404329	734827	-52 to -72	Mag	9/19/83	706	6.9	--	<5	.9	270	66	25
Q2409	404329	734827	-142 to -182	Mag	10/17/83	440	6.6	--	<5	.6	160	34	18
Q2432	404247	734603	-178 to -218	Mag	10/17/83	352	6.6	--	<5	.2	120	27	12
Q2435	404351	734448	-150 to -190	Mag	6/ 6/83	292	6.2	--	<5	1.8	90	22	8.3
Q2442	404135	734402	-46 to -56	Mag	7/ 7/83	--	--	--	--	--	--	--	--
Q2443	404135	734402	-273 to -313	Mag	10/17/83	169	5.9	--	<5	.9	43	10	4.4
Q2955	404040	734450	-385 to -420	Mag	10/24/83	145	5.8	--	5	.8	28	8.0	1.9
Q3014	404309	734700	-159 to -209	Mag	10/17/83	385	7.0	--	<5	.5	140	29	16
Q3034	404234	734553	-184 to -224	Mag	10/17/83	352	6.2	--	<5	.4	110	25	10
Q3062	404059	734508	-357 to -397	Mag	10/17/83	92	6.0	--	<5	.6	27	7.2	2.2
Q3083	404056	734406	-271 to -319	Mag	7/18/83	188	5.6	--	<5	.6	110	13	19
N 11	404224	734238	-325 to -359	Mag	1/31/83	211	5.6	--	<5	.3	61	14	5.8
N 12	404219	734240	-318 to -376	Mag	6/ 6/83	151	5.8	--	<5	1.6	40	10	3.6

Well no.	Sodium, total (mg/L as Na)	Potassium, total mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Total dissolved solids (mg/L)	Nitrogen, as nitrate, total (mg/L as N)	Nitrogen as ammonia, total (mg/L as N)	Arsenic, total (µg/L as As)	Cadmium, total (µg/L as Cd)
Q2299	26	--	30	51	45	<.05	246	10	<.02	<2	<1
Q2300	12	--	--	--	--	.1	34	--	<.02	<2	<1
Q2332	10	--	140	72	28	<.05	260	.7	<.02	<2	<1
Q2343	13	--	19	26	23	.1	196	9.8	<.02	<2	<1
Q2362	14	--	110	72	11	.1	302	2.5	<.02	<2	<1
Q2363	36	--	110	90	100	.1	426	6.6	<.02	<2	<1
Q2373	22	--	210	110	84	.1	522	2.6	.07	<2	<1
Q2374	13	--	120	61	22	.1	292	4.0	<.02	<2	<1
Q2408	28	--	140	82	66	<.05	406	6.2	<.02	<2	<1
Q2409	15	--	74	47	35	.1	264	4.2	<.02	<2	<1
Q2432	16	--	63	39	31	.05	212	3.2	.11	<2	<1
Q2435	11	--	25	36	33	.1	188	4.2	<.02	<2	<1
Q2442	26	--	--	--	--	.05	136	--	<.02	<2	<1
Q2443	10	--	11	29	16	.07	112	<.1	<.02	<2	<1
Q2955	6.5	--	15	26	10	.1	176	<.1	<.02	<2	<1
Q3014	12	--	83	48	27	<.05	246	1.2	<.02	<2	<1
Q3034	18	--	41	48	34	.1	216	5.2	<.02	<2	<1
Q3062	5.8	--	11	18	6.0	<.05	72	.1	<.02	<2	<1
Q3083	11	--	11	54	15	.07	244	<.1	<.02	<2	<1
N 11	13	--	11	33	14	.1	224	5.8	<.02	<2	<1
N 12	9.7	--	25	24	14	<.05	84	3.0	<.02	<2	<1

Table 11.--Selected chemical analyses of ground water sampled from public-supply wells in Kings, Queens, and eastern Nassau Counties (sampled and analyzed by Jamaica Water Supply Company) (continued)

Well no.	Chromium, total Dµg/L as Cr)	Copper, total (µg/L as Cu)	Iron, total (µg/L as Fe)	Lead, total (µg/L as Pb)	Manganese total (µg/L as Mn)	Mercury, total (µg/L as Hg)	Selenium, total µg/L as Se)	Silver, total (µg/L as Ag)	Zinc, total (µg/L as Zn)
Q2299	<20	30	20	5	<20	<.5	<2	<20	30
Q2300	<20	30	20	<2	<20	<.5	<2	<20	70
Q2332	<20	20	560	<2	120	<.5	<2	<20	<20
Q2343	<20	80	20	<2	<20	<.5	<2	<20	<20
Q2362	<20	30	20	2	<20	<.5	<2	<20	<20
Q2363	<20	20	20	<2	<20	<.5	<2	<20	<20
Q2373	<20	20	20	<2	160	<.5	<2	<20	<20
Q2374	<20	20	30	<2	<20	<.5	<2	<20	<20
Q2408	<20	20	20	<2	<20	<.5	<2	<20	<20
Q2409	<20	20	20	<2	<20	<.5	<2	<20	<20
Q2432	<20	20	20	<2	<20	<.5	<2	<20	<20
Q2435	<20	20	20	<2	<20	<.5	<2	<20	<20
Q2442	<20	20	60	<2	<20	<.5	<2	<20	<20
Q2443	<20	20	700	<2	100	<.5	<2	<20	<20
Q2955	<20	20	460	<2	100	<.5	<2	<20	<20
Q3014	<20	40	60	<2	<20	<.5	<2	<20	<20
Q3034	<20	20	20	<2	<20	<.5	<2	<20	<20
Q3062	<20	20	40	<2	<20	<.5	<2	<20	<20
Q3083	<20	30	2,200	<2	210	<.5	<2	<20	<20
N 11	<20	30	20	<2	<20	.5	<2	<20	<20
N 12	<20	30	50	4	<20	<.5	<2	<20	<20

Table 11.--Selected chemical analyses of ground water sampled from public-supply wells in Kings, Queens, and eastern Nassau Counties (sampled and analyzed by Jamaica Water Supply Company) (continued)

Well no.	Lat	Long	Screened interval (ft above or below (-) sea level)	Aquifer[1]	Date sampled[2]	Specific conductance (µS/cm)	pH (units)	Field temp (deg C)	Color (unit)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Calcium, total (mg/L as Ca)	Magnesium, total mg/L as Mg)
N 13	404214	734241	-182 to -240	Mag	7/18/83	297	5.6	--	10	3.5	80	18	8.3
N 14	404411	734137	+14 to -7	Upglac	7/18/83	308	5.9	--	<5	.7	98	31	4.9
N 17	404437	734023	-304 to -364	Mag	1/31/83	286	5.7	--	<5	.6	61	18	3.4
N 693	404229	734244	-18 to -43	Upglac	3/28/83	420	5.8	--	<5	.6	130	32	10
N1958	404426	734148	-551 to -611	Lloyd	1/31/83	48	5.2	--	<5	.5	12	4.	--
N2115	404106	734329	-36 to -56	Upglac	7/18/83	410	5.8	--	<5	.6	96	31	4.3
N2413	404125	734210	-427 to -457	Mag	7/18/83	121	5.4	--	<5	.6	14	4.	1.0
N2414	404124	734210	-18 to -38	Upglac	3/28/83	204	5.5	--	<5	.4	52	15	3.4
N3720	404112	734041	-443 to -483	Mag	1/31/83	63	5.2	--	<5	.5	14	4.	1.0
N4077	404323	734138	+15 to -5	Upglac	3/28/83	226	5.6	--	<5	.2	58	16	3.9
N4298	404323	734138	-264 to -299	Mag	1/31/83	213	5.8	--	<5	.3	59	16	4.4
N4390	404514	734121	-137 to -172	Mag	1/31/83	308	6.0	--	<5	.4	90	25	6.6
N4512	404100	734122	-415 to -465	Mag	1/31/83	87	5.3	--	<5	.4	26	8.	1.5
N5155	404238	734203	+1 to -19	Upglac	7/18/83	336	7.1	--	<5	2.6	61	17	4.4
N5156	404238	734203	-220 to -260	Mag	6/ 6/83	152	5.5	--	<5	2.8	44	10	4.1
N6744	404238	734205	-4 to -24	Upglac	7/18/83	352	7.1	--	30	16	59	18	3.4
N6745	404239	734202	-234 to -274	Mag	7/18/83	180	5.6	--	<5	2.9	49	14	2.9
N7445	404514	734121	-268 to -328	Mag	6/ 6/83	94	6.2	--	<5	1.0	27	6.	2.4
N7482	404109	734329	-367 to -407	Mag	3/28/83	139	5.5	--	<5	.6	36	8.	3.4
N7649	404344	734121	-65 to -105	Mag	1/31/83	132	5.8	--	<5	.4	31	8.	2.7
N7650	404344	734121	-300 to -340	Mag	1/24/83	143	5.8	--	<5	.4	24	6.4	1.9

Well no	Sodium, total (mg/L as Na)	Potassium total as K)	Alkalinity (mg/L (mg/L CaCO3)	Sulfate, dissolved (mg/L as SO4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Total dissolved solids (mg/L)	Nitrogen, as nitrate, total (mg/L as N)	Nitrogen, as ammonia, total (µg/L as N)	Arsenic, total (µg/L as As)	Cadmium, total (µg/L as Cd)
N 13	14	--	13	63	18	<.05	158	2.0	<.02	<2	<1
N 14	19	--	26	43	26	.06	227	7.2	<.02	<2	<1
N 17	25	--	14	28	40	<.05	178	5.8	<.02	<2	<1
N 693	30	--	22	57	48	<.05	266	8.8	<.02	<2	<1
N1958	3.2	--	6.	6	3.	<.05	34	<.1	<.02	<2	<1
N2115	28	--	36	42	56	<.05	242	5.6	<.02	<2	<1
N2413	5.6	--	8.	24	8.	.06	62	.4	<.02	<2	<1
N2414	12	--	18	33	16	<.05	142	4.1	.03	<2	<1
N3720	4.6	--	8.	12	3.	<.05	46	.1	<.02	<2	<1
N4077	16	--	16	24	25	.1	104	3.7	<.02	<2	<1
N4298	16	--	14	25	26	<.05	144	4.2	<.02	<2	<1
N4390	19	--	39	30	35	<.05	206	3.4	<.02	<2	<1
N4512	5.8	--	6.	19	9.	<.05	52	<.1	<.02	<2	<1
N5155	44	--	62	36	24	.1	246	6.4	<.02	<2	<1
N5156	10	--	15	21	22	<.05	110	2.5	<.02	<2	<1
N6744	79	--	62	38	31	.1	72	6.4	<.02	6	<1
N6745	10	--	19	24	18	<.05	104	3.6	<.02	<2	<1
N7445	5.7	--	21	4	8.	<.05	68	1.7	<.02	<2	<1
N7482	8.4	--	25	27	11	.07	80	<.1	.08	<2	<1
N7649	7.7	--	10	6	10	<.05	86	3.6	--	<2	<1
N7650	7.6	--	10	6	14	<.05	76	4.6	<.02	<2	<1

Table 11.--Selected chemical analyses of ground water sampled from public-supply wells in Kings, Queens, and eastern Nassau Counties (sampled and analyzed by Jamaica Water Supply Company) (continued)

Well no.	Chromium, total Dμg/L as Cr)	Copper, total (μg/L as Cu)	Iron, total (μg/L as Fe)	Lead, total (μg/L as Pb)	Manganese total (μg/L as Mn)	Mercury, total (μg/L as Hg)	Selenium, total μg/L as Se)	Silver, total (μg/L as Ag)	Zinc, total (μg/L as Zn)
N 13	<20	20	140	<2	<20	<.5	<2	<20	<20
N 14	<20	30	20	<2	<20	<.5	<2	<20	<20
N 17	<20	30	40	<2	<20	<.5	<2	<20	<20
N 693	<20	20	20	<2	<20	<.5	<2	<20	<20
N1958	<20	20	20	<2	<20	<.5	<2	<20	40
N2115	<20	20	20	<2	60	<.5	<2	<20	<20
N2413	<20	20	350	<2	30	<.5	<2	<20	<20
N2414	<20	20	20	<2	<20	<.5	<2	<20	<20
N3720	<20	20	180	<2	20	<.5	<2	<20	<20
N4077	<20	170	20	3	<20	<.5	<2	<20	<20
N4298	<20	20	20	2	<20	<.5	<2	<20	<20
N4390	<20	20	20	2	<20	<.5	<2	<20	<20
N4512	<20	20	430	<2	<20	<.5	<2	<20	<20
N5155	<20	40	30	<2	<20	<.5	<2	<20	<20
N5156	<20	20	20	<2	30	<.5	<2	<20	--
N6744	<20	20	30	<2	<20	<.5	<2	<20	<20
N6745	<20	30	20	<2	<20	<.5	<2	<20	<20
N7445	<20	20	20	<2	<20	<.5	<2	<20	<20
N7482	<20	20	190	<2	60	<.5	<2	<20	<20
N7649	<20	20	20	<2	<20	<.5	<2	<20	<20
N7650	<20	20	20	<2	<20	<.5	<2	<20	<20