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Selected Hydrogeologic and Water-quality Data from Jones Beach Island, Long Island, New York

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CONVERSION FACTORS, ABBREVIATIONS AND VERTICAL DATUM

Multiply	*By*	*To obtain*
	Length	
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	2.59	square kilometer
	Flow	
foot per day (ft/d)	0.3048	meter per day
	Density	
pound per cubic foot (lb/ft^3)	16.02	kilogram per cubic meter
	Pressure	
pound per square foot (lb/ft^2)	4.887	kilogram per square meter

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 the United States and Canada, formerly called Sea Level Datum of 1929.

SELECTED HYDROGEOLOGIC AND WATER QUALITY FROM JONES BEACH ISLAND, LONG ISLAND, NEW YORK

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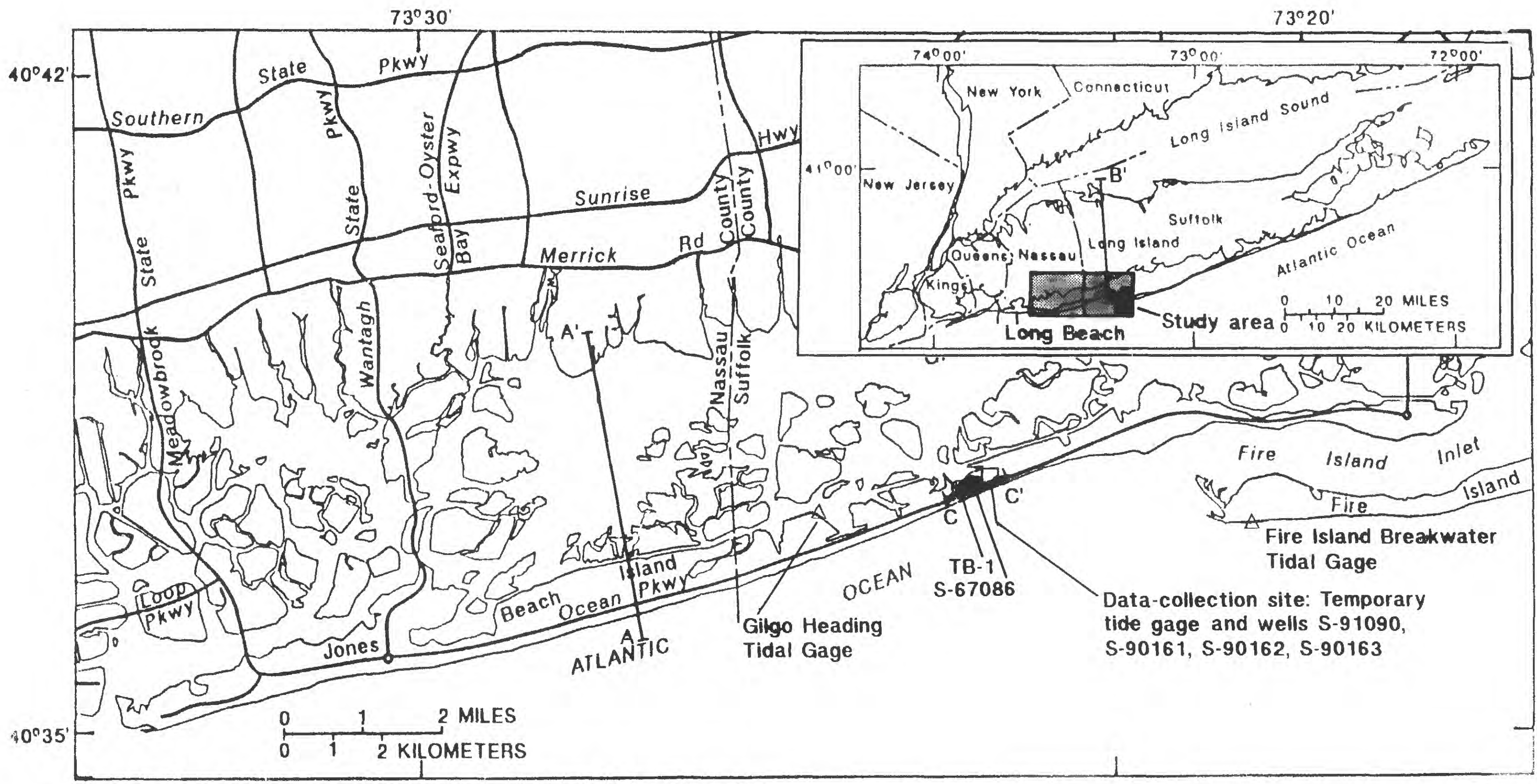
Abstract

A data-collection site was instrumented on Jones Beach Island, a barrier island south of Long Island, N.Y., to study local freshwater/saltwater relations in the shallow ground-water system. A geologic test boring revealed about 88 feet of well-sorted glacial outwash sand above about 15 feet of Gardiners Clay, which directly overlies silty sand of the Magothy Formation. Tidal effects on water levels in Great South Bay, the upper glacial aquifer, and the Magothy aquifer were observed and quantified with a tidal gage in the bay and analog water-level recorders in the wells. Chloride concentrations in the upper Magothy aquifer were higher than expected--about 270 mg/L (milligrams per liter), and those in the upper glacial aquifer were 17,000 to 19,000 mg/L, about the same as in Great South Bay. Estimates of pressure and freshwater equivalent heads indicate that, at the data-collection site, freshwater is discharging upward from the Magothy aquifer into the salty upper glacial aquifer, but dilution by this freshwater is undetectable. The reason for the elevated chloride concentration in the Magothy aquifer cannot be determined from available hydrogeologic information.

INTRODUCTION

Long Island, N.Y., and its southern barrier islands consist of unconsolidated sediments of Cretaceous and Pleistocene age and are surrounded by salty surface-water bodies that include Long Island Sound, the Atlantic Ocean, and the southern bays (fig. 1). The presence of these saltwater bodies, together with the stratigraphy of the unconsolidated sediments, strongly affect the distribution of salty ground water in near-shore areas. The unconfined (upper glacial) aquifer, which is in direct contact with Great South Bay and contains salty ground water, is separated from the underlying Magothy aquifer, which contains freshwater, by a confining unit (Gardiners Clay). The Gardiners Clay is a major control on local and regional ground-water flow on this island. The transition between fresh and salty ground water in the unconfined aquifer is landward of the southern shore of Long Island, but this transition in the unconfined aquifer is seaward of Jones Beach Island. If the ground-water system is near equilibrium, the presence of fresh ground water below the confining unit, and of salty ground water (of greater density) above it, indicates that fresh ground water discharges upward through the confining unit into the salty water in the overlying unconfined aquifer and, thus, decreases its salinity.

The interaction between fresh and salty ground water in nearshore areas is a subject of concern because it affects the availability of freshwater for use by the Long Island community. Because neither this intersection



Base from U.S. Geological Survey 1:24,000, 1954 and 1955 quadrangle.

Figure 1.--Location of study area and data-collection site.

between fresh and salty ground water, nor their flow patterns in this hydrogeologic setting, are well defined (Reilly, 1990), the U.S. Geological Survey (USGS), in cooperation with the New York State Department of Environmental Conservation and the Suffolk County Department of Health Services, began a 6-month study in 1988 to determine whether fresh ground water discharging upward through the Gardiners Clay from the Magothy aquifer to the salty upper glacial aquifer discernibly dilutes water in the upper glacial aquifer. The distribution of fresh and salty ground water near Jones Beach Island and the southern shore of Long Island is shown in a generalized south-north hydrogeologic section in figure 2.

Purpose and Scope

This report describes the hydrogeology and chemical quality of ground water in the upper glacial aquifer, Gardiners Clay, and upper part of the Magothy aquifer on the southern shore of Long Island. It also documents and discusses heads and selected water-quality data from a site on Jones Beach Island in relation to tidal fluctuations in the adjacent Atlantic Ocean and Great South Bay.

Study Area

The study area encompasses about 162 mi^2 of the south-shore area of Long Island and includes Jones Beach Island (fig. 1). The data-collection site was selected after a review of published reports that indicated that the stratigraphy beneath the site would be appropriate for installation of a well cluster. The site is near the main highway on the northern edge of Jones Beach Island and was selected to provide access to Great South Bay for monitoring of tidal water-level fluctuations.

Previous Studies

Comprehensive studies of Long Island's geology were conducted by Veatch and others (1906), Fuller (1914), Suter and others (1949), and Jensen and Soren (1974). The thickness and extent of shallow subsurface formations along a part of Long Island's southern shore and barrier islands were investigated by Doriski and Wilde-Katz (1983).

HYDROGEOLOGY

Long Island is underlain by unconsolidated sediments that thicken to the south and east and overlie bedrock. Sediment thickness ranges from 0 ft in northwestern Long Island to 2,000 ft along Fire Island (fig. 1) and is estimated to be about 1,800 ft at the data-collection site (Jensen and Soren, 1974).

Water levels in aquifers beneath coastal areas and barrier islands are strongly affected by tides. Tidal magnitude and sequence in the ocean and Great South Bay, and their effect on water levels in two aquifers beneath the data-collection site, are summarized further on.

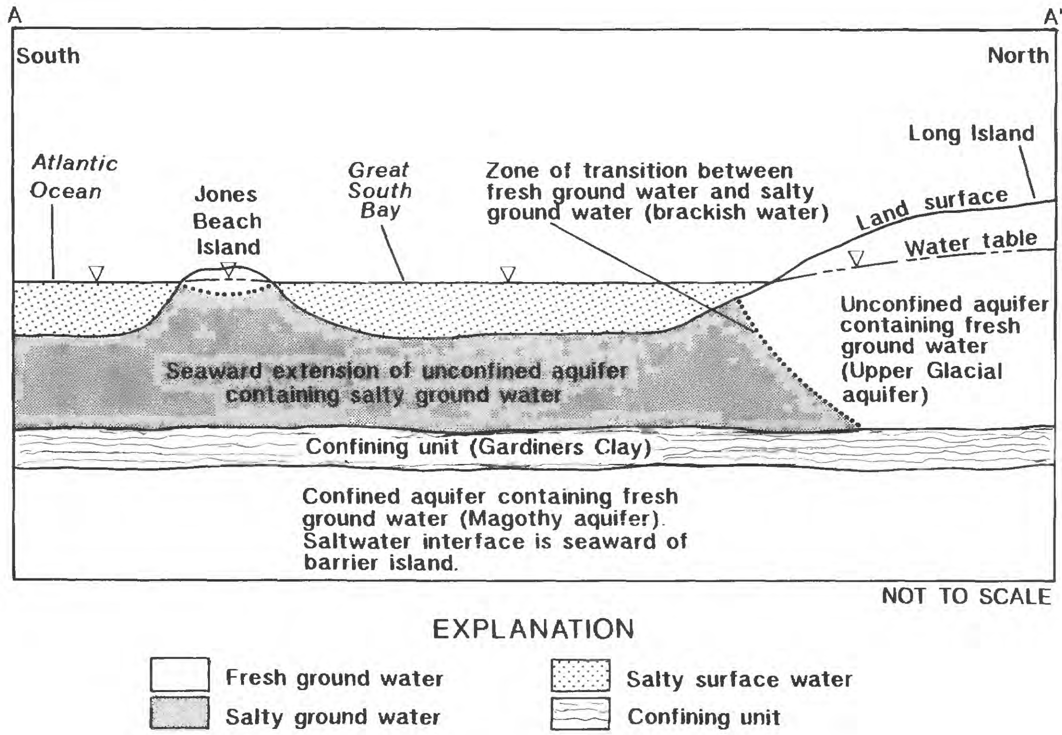


Figure 2.--Generalized distribution of fresh and salty ground water near Long Island's southern shore and barrier island. (General location is indicated in fig. 1.)

Regional Stratigraphy

A generalized north-south hydrogeologic section of the Long Island aquifer system (Jensen and Soren, 1974) near the study site is shown in figure 3. Principal hydrogeologic units within the area are described in table 1.

The upper Pleistocene deposits along the southern half of Long Island are glacial outwash consisting of well-sorted sand and gravel. The abundant sediment supply along the southern shore of Long Island, together with tidal action, longshore drift, and a low-relief coastal plain adjacent to a low-gradient continental shelf (Reinson, 1984) have produced an extensive series of barrier islands. Long Beach, Jones Beach Island, and Fire Island (fig. 1 inset) are part of this system. A chronology of morphological changes of Jones Beach Island during the last 150 years is presented by Wolff (1975).

In Suffolk County, the 20-foot clay of upper Pleistocene age is present within the outwash deposits of the barrier islands (Doriski and Wilde-Katz, 1983). It is lithologically similar to the underlying Gardiners Clay (Perlmutter and Geraghty, 1963) and is generally 10 to 40 ft thick. Its upper surface altitude is 20 to 40 ft below sea level. The 20-foot clay probably was formed during an interstadial period of the Wisconsin glaciation. Although this unit was not encountered beneath the data-collection site, Doriski and Wilde-Katz (1983) report it to be present in other parts of the study area.

The Gardiners Clay of Pleistocene age, where present along Jones Beach Island, underlies the upper Pleistocene deposits and overlies the Monmouth greensand or the Matawan Group and Magothy Formation, undifferentiated, both of Cretaceous age (fig. 3). Doriski and Wilde-Katz (1983) describe the Gardiners Clay as grayish-green to gray clay with sand layers containing quartz, glauconite, and muscovite.

The Monmouth Group, of Late Cretaceous age, consists of dark green, dark gray, or black glauconitic and lignitic clay, silt, and silty sand. It extends locally beneath the barrier islands and parts of the extreme southern shore of Long Island but was not encountered beneath the data-collection site.

The Matawan Group and Magothy Formation, undifferentiated, of Cretaceous age, is composed mainly of deltaic sand with interbedded clays and is estimated to be 950 ft thick in the study area. The sand layers consist mostly of gray, fine- to coarse-grained quartz with muscovite, lignite, and interstitial clay and silt. The underlying Raritan clay and Lloyd aquifer (table 1) do not affect the flow patterns investigated in this study and thus are not discussed further.

Doriski and Wilde-Katz's (1983) interpretation of the stratigraphy beneath the barrier island was based on a review of drillers' logs and geologic data collected from a few borings drilled as a part of their study of Long Island's southern shore and barrier islands. They suggested that, within the study area, the Monmouth Group directly underlies the Gardiners Clay, but indicated that it is absent from just east of the data-collection site to about 1.8 mi west of it and that the Gardiners Clay is absent from about 1 mi west of the data-collection site to 1.8 mi west of it. Thus, the Gardiners Clay is present at the data-collection site and directly overlies the Matawan Group and Magothy Formation.

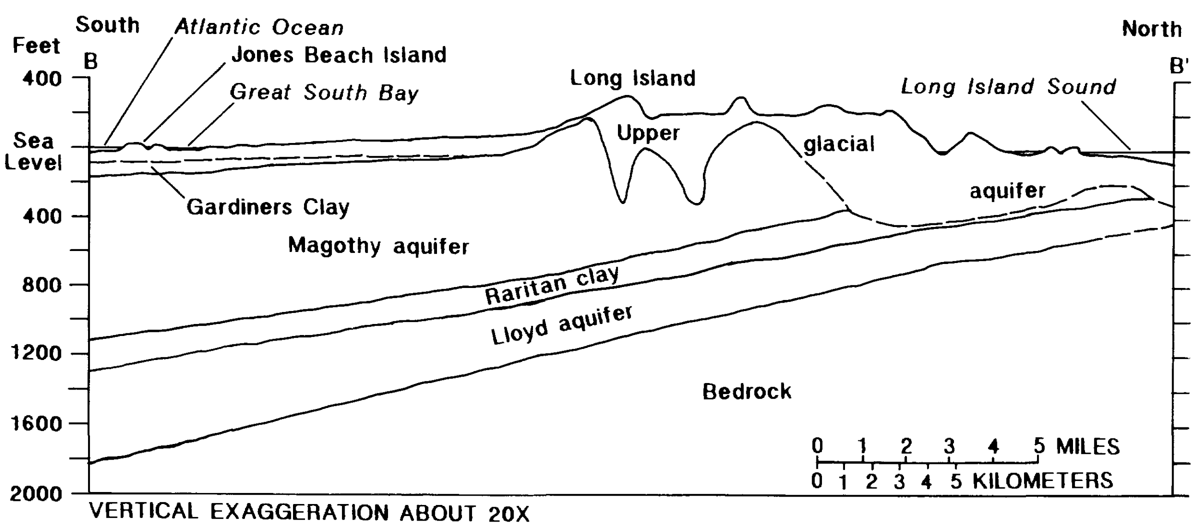


Figure 3.--Relative positions of major hydrogeologic units on Long Island. (Modified from Jensen and Soren, 1974, sheet 1. Line of section B-B' is shown in fig. 1 inset.)

Table 1.--Generalized description of Long Island's principal hydrogeologic units

[Modified from Jensen and Soren, 1971, table 1, and Franke and Cohen, 1972, table 1. Ft/d, feet per day]

Hydrogeologic unit	Geologic unit	Description and water-bearing character
Upper glacial aquifer	Upper Pleistocene deposits	Mainly brown and gray sand and gravel deposits of glacial moraine and outwash origin with moderate to high horizontal hydraulic conductivity (270 ft/d); also includes deposits of clayey till and lacustrine clay of low hydraulic conductivity. A major aquifer.
"20-foot" clay[1]	"20-foot" clay	Grayish-green clay, silt, and sand; generally underlain and overlain by outwash deposits. Unit has lower hydraulic conductivity than outwash deposits and tends to confine water in underlying aquifer.
Gardiners Clay	Gardiners Clay	Green and gray clay, silt, clayey and silty sand, and some interbedded clayey and silty gravel. Unit has low vertical hydraulic conductivity (0.001 ft/d) and tends to confine water in underlying aquifer.
Monmouth greensand[1]	Monmouth Group, undifferentiated	Interbedded marine deposits of dark gray, olive-green, dark greenish-gray, and greenish-black glauconitic and lignitic clay, silt, and clayey and silty sand. Unit has low vertical hydraulic conductivity and tends to confine water in underlying aquifer.
Magothy aquifer	Matawan Group and Magothy Formation,	Gray and white fine to coarse sand of moderate horizontal hydraulic conductivity (50 ft/d). Generally contains sand and gravel beds of low to high hydraulic conductivity in basal 100 to 200 ft. Contains much interstitial clay and silt and beds and lenses of clay of low hydraulic conductivity. A major aquifer.
Raritan clay	Unnamed clay member of the Raritan Formation	Gray, black, and multicolored clay and some silt and fine sand. Unit has low vertical hydraulic conductivity (0.001 ft/d) and confines water in underlying aquifer.
Lloyd aquifer	Lloyd Sand Member of the Raritan Formation	White and gray fine-to-coarse sand and gravel of intermediate horizontal hydraulic conductivity (40 ft/d) and some clayey beds of low hydraulic conductivity. Aquifer is developed to a small degree.
Bedrock	Undifferentiated crystalline rocks	Mainly metamorphic rocks of low hydraulic conductivity; surface generally weathered; considered to be the bottom of the ground-water system.

[1] Not shown in figure 3.

Stratigraphy of Data-Collection Site

In 1986, test boring TB-1 was drilled 0.5 mi west of the data-collection site (fig. 1) with an auger rig and was logged with a gamma-ray geophysical logger (fig. 4). The first well to be installed at the site (S-91090) was drilled in October 1987 by the cable-tool method and was screened between 111 and 117 ft below land surface (99 to 105 ft below mean sea level). The gamma-ray log, the driller's log, and descriptions of selected bailer samples from this well are presented in figure 4. Vertical section B-B', which runs east-west through the site, includes the gamma-ray logs from well S-91090 and borings from TB-1 and S67086 (locations shown in fig. 1). The stratigraphy at well S-91090 is consistent with the interpretation by Doriski and Wilde-Katz (1983) for this area.

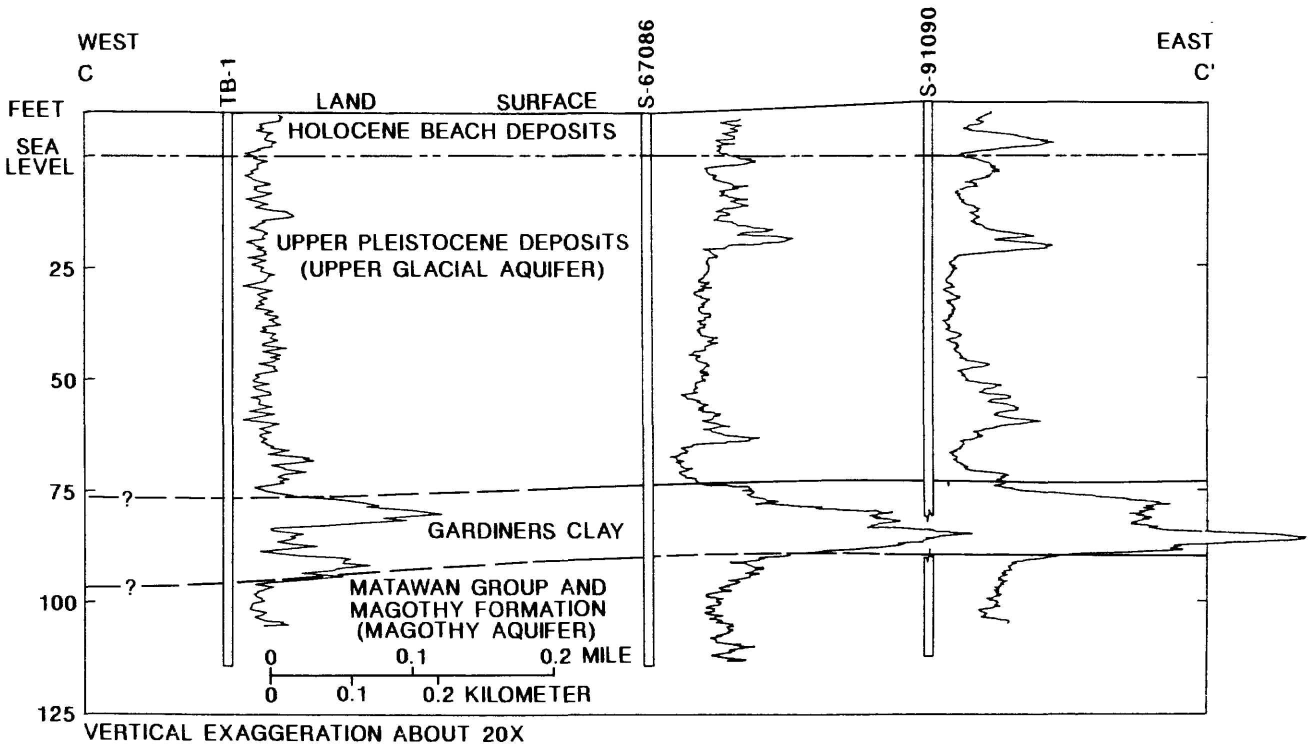
The glacial outwash deposits at well S-91090 consist mostly of gray, fine to coarse sand that is mainly quartz with trace minerals and scattered pelecypod (clam and oyster) shell fragments. The sand is fairly well sorted and contains little interstitial silt. The upper few feet of sand are light brown, which is typical of mainland Long Island's glacial outwash. The gray color of most of the sand below the water table is probably due to the dissolution of iron oxide coatings from sand grains in the chemically reducing conditions along the barrier island.

Below the outwash deposits at the data-collection site is the Gardiners Clay, which is 15 to 20 ft thick. Examination of selected cable-tool bailer samples from the upper 6 ft of Gardiners Clay by binocular microscope showed that this interval consists of several facies that include (1) dark-green clay with some sand, (2) dark brownish-gray cemented sand with a few tabular pores that probably represent dissolved shells, and (3) light grayish-green sand that contains about 15 percent glauconite. (See fig. 4.)

All three borings whose gamma-ray logs are shown in figure 4 penetrated the Matawan Group and Magothy Formation, undifferentiated, directly beneath the Gardiners Clay. Bailer samples showed this unit to consist of gray, fine to medium quartz sand with lignite grains, muscovite, and interstitial silt and clay. The samples and gamma-ray logs from the three borings are generally similar. At all three borings, the 20-foot clay is absent, and the Gardiners Clay is about 20 ft thick and directly overlies the Matawan Group and Magothy Formation.

Monitoring Wells and Tidal-Stage Gage

In March 1988, three wells cased with 4-in. inside-diameter solvent-welded polyvinyl chloride were installed with a hollow-stem auger drill rig in the upper glacial aquifer near the previously installed well S-91090 in the Magothy aquifer. The shallow well was screened at 40 to 45 ft below land surface, below any shallow freshwater lens associated with freshwater recharge on the island. The intermediate-depth well was screened 65 to 70 ft below land surface, and the deepest well at 80 to 85 ft below land surface, close to the top of the Gardiners Clay. Pertinent data on wells drilled at the data-collection site and on nearby wells are given in table 2.



DRILLER'S LOG OF WELL S-91090

Altitude, in feet above or below(-) sea level	Material
12 to 5	Beach sand
5 to -21	Fine black sand
-21 to -54	Gray medium-grained sand
-54 to -76	Fine brown sand
-76 to -95	Black clay
-95 to -108	Fine black sand, bottom of boring

DESCRIPTIONS OF SELECTED BAILER SAMPLES FROM WELL S-91090

A few samples were collected from the cable-tool bailer and examined with a microscope

Three samples of the upper part of the Gardiners Clay were collected from 72 to 78 feet below sea level. Three facies were noted:

1. Clay, dark green mixed with some medium to coarse sand, mostly quartz with traces of glauconite and other minerals.
2. Sand, dark brownish gray, fine to medium grained, indurated, mostly quartz with about 2 percent glauconite and traces of other minerals; a few tabular pores.
3. Sand, light grayish green, fine grained, mostly quartz with about 15 percent glauconite.

One sample of Matawan Group and Magothy Formation, undifferentiated, was collected at about 98 feet below sea level:

1. Sand, gray, medium grained, mostly quartz with lignite and some muscovite.

Figure 4.--Hydrogeologic section C-C' through data-collection site as inferred from three gamma-ray logs. (Line of section shown in fig. 1.)

Table 2.--Physical description of wells on Jones Beach Island used in the study

[°, degrees; ', minutes; ", seconds; --, test boring only, no well installed; UPG, upper glacial; MGTY, Magothy; PVC, polyvinyl chloride. Locations are shown in fig. 1.]

Well number	Latitude ° ' "	Longitude ° ' "	Land surface altitude (feet above sea level)	Aquifer	Total depth (feet)	Depth to screen from land surface (feet) Top	Bottom	Screen length (feet)	Diameter (inches)	Casing material
S90161	403741	732152	12	UPG	48	40	45	5	4	PVC
S90162	403741	732152	12	UPG	73	65	70	5	4	PVC
S90163	403741	732152	12	UPG	88	80	85	5	4	PVC
S91090	403741	732152	12	MGTY	117	111	117	6	4	Steel
S67086	403739	732201	10	MGTY	125	--	--	--	--	--
S67087.1	403657	732421	10	MGTY	184	179	184	5	2	Steel

A temporary stand pipe was installed in shallow water in Great South Bay, 200 ft north of the well site, to serve as a tidal-stage gage. The pipe was screened only above the bay bottom and was surrounded by a baffle to dampen waves. Water levels in the four wells and the stand pipe were measured on April 26, 1988, and January 24 and 27, 1989, with a steel tape at 20-minute intervals through one tidal cycle. The times and dates for measurements were selected from a review of tide tables published by the National Oceanic and Atmospheric Administration (NOAA) (1987, 1988).

Analog-type water-level recorders were operated with weekly charts in the four wells at the data-collection site from November 1988 through April 1989 to provide continuous records of water-level fluctuations resulting from tides. Recorders were set to a daily chart when measurements were being made at the temporary tidal-stage gage in the bay to give precise temporal measurements.

Because no nearby permanent ocean-tide gage was available, the tide tables published by NOAA (1987, 1988) were used to estimate Atlantic Ocean tides at designated nearby sites. The estimated times and heights of the ocean tide were based on the correction factors given for Fire Island Breakwater, and the datum used for height was at Long Beach (fig. 1 inset). Tidal predictions for Great South Bay at Gilgo Heading (fig. 1) were also calculated. Although NOAA (1987, 1988) states that the tide tables are not precise, they were assumed to provide a usable approximation of tidal fluctuations in time and height.

Water Levels

A 17-day hydrograph for wells S-91090, screened in the Magothy aquifer, and S-90161, screened in the upper glacial aquifer, is shown in figure 5. The peaks and troughs in the upper glacial aquifer occurred about 2 hours later than those in the Magothy. During the period of record (November 1988 through April 1989), the average tidal range (difference between water-level extremes at successive high and low tides) was 1.41 ft in the Magothy aquifer and 0.95 ft in the upper glacial aquifer. The maximum tidal range recorded in the Magothy aquifer was 2.42 ft, and that in the upper glacial aquifer was 1.96 ft.

The 15- to 20-ft thick Gardiners Clay produces confined conditions in the underlying Magothy aquifer, and the potentiometric surface in the Magothy is higher than the water table in the upper glacial aquifer (fig. 5). Static saltwater with a density of 64.0 lb/ft^3 (the weight density of ocean water) at a depth of 102 ft below sea level (the middle of the screen for well S91090 in the Magothy aquifer) produces a pressure of 6,528 lb/ft^2. The pressure of freshwater at well S-91090, calculated from recorded head measurements (fig. 5), exceeds this value and usually exceeds the 6,552 lb/ft^2 calculated for a water level of 3 ft above sea level in this well. Therefore, the freshwater pressure in the Magothy aquifer is sufficient to move the saltwater interface seaward and to cause upward seepage of freshwater from the Magothy aquifer through the Gardiners Clay into the upper glacial aquifer.

Hydrographs of water levels measured by steel tape at the four wells and in Great South Bay through one tidal cycle on April 26, 1988 and January 23-24, 1989, are presented in figures 6A and 6B, respectively, along with calculated water levels in Great South Bay and the Atlantic Ocean. A summary of selected water levels is presented in table 3. The Magothy well (S-91090) consistently shows the highest water levels, which are about 3 ft higher than those in the

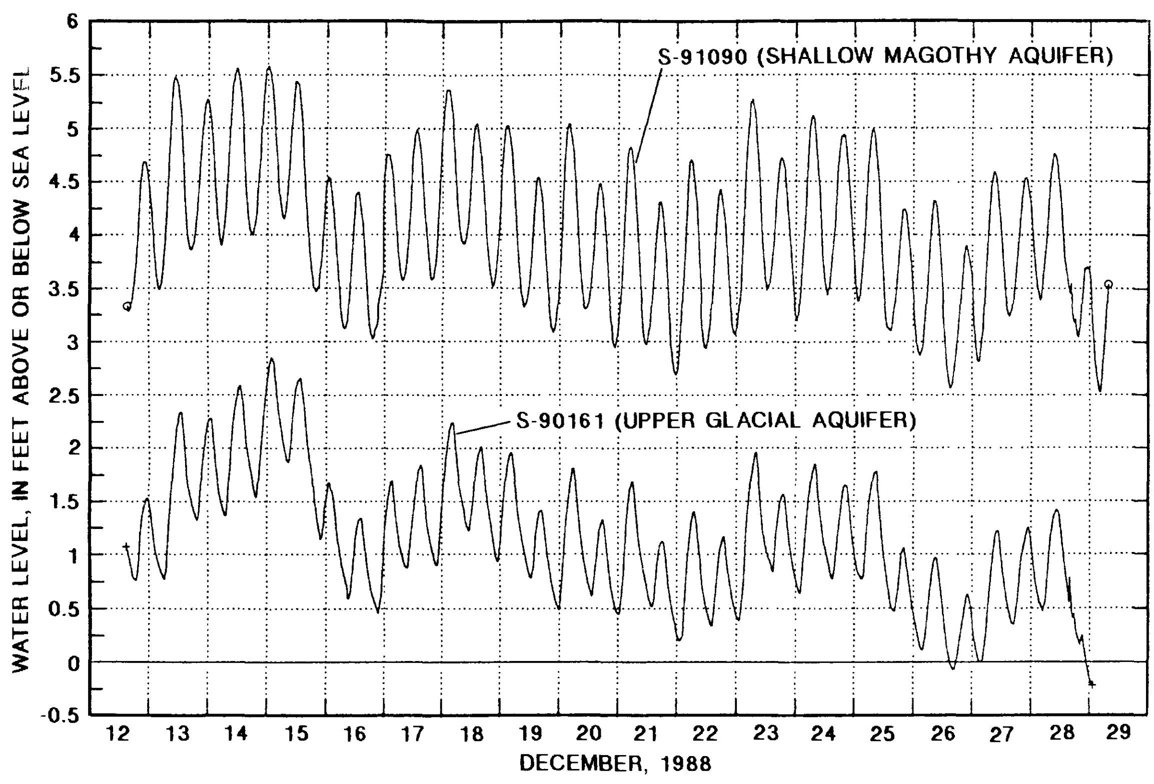


Figure 5.--Water levels in wells screened in the upper glacial and Magothy aquifers at data-collection site, December 12-29, 1988.

three upper glacial wells. The upper glacial wells are screened in salty water; therefore the water levels are not directly comparable to those in the Magothy well.

At all times of measurement, water levels in the three wells screened in the upper glacial aquifer were almost equal; any differences among them probably were the result of (1) small differences in density of ground water due to local differences in chemical concentrations, (2) measurement error (small differences in recorder consistency, observer procedure, or round-off), and (or) (3) minor circulation of salty ground water in response to ground-water movement within the overlying shallow freshwater flow system of the barrier island, or from beneath the bay floor to beneath the ocean floor, or the reverse.

The short-term hydrographs of water levels in April 1988 and January 1989 (figs. 6A, 6B) show a close correlation between water levels in the upper glacial wells and that in Great South Bay. The closest match between water levels in the three upper glacial wells and that in Great South Bay was during high tide (about 0.2 ft); the difference at low tide increased to about 0.5 ft.

The predicted bay tide (from tide tables) and the measured bay tides differed somewhat in height and timing. The measured bay level was higher than that predicted for high tide and lower than that predicted for low tide. The predicted ocean tide had a range of 3 ft on April 26, 1988, and 4.5 ft on January 24, 1989.

April 26, 1988

The tidal sequence on April 26, 1988 (fig. 6A) began with the predicted ocean low tide. The lag time before water levels in the Magothy well reached a minimum was about 1 hour, and the lag time for the three upper glacial wells was 2 hours 38 minutes to 2 hours 58 minutes. The measured low tide in the Bay reached its minimum 3 hours 20 minutes after the predicted ocean minimum. The predicted bay low tide was about 3 hours 47 minutes after ocean low tide. This came 27 min earlier than was predicted for low tide in the bay.

The sequence of maximum water levels in the bay and wells at high tide on April 26, 1988, was about the same as at low tide, although it differed slightly among the three upper glacial wells, and the measured lag times in those wells and the bay were somewhat shorter than at low tide. The lag time between the ocean high-tide crest and the bay's high-tide crest was 3 hours 7 minutes--5 minutes later than its predicted lag time.

January 23-24, 1989

A similar relation between ocean tides and ground-water levels was observed on January 24, 1989 (fig. 6B). Water levels in the Magothy aquifer reached their minima less than 1 hour after the predicted ocean low tide, and those in the three upper glacial wells reached their minima between 2 hours 0 minutes and 2 hours 58 minutes after the predicted ocean low tide. The lag time between measured low tide in the bay and the predicted low tide in the bay was 47 minutes.

The sequence of high water levels at high tide on January 24, 1989 was similar to that of low tide on the same day; the lag time between the Magothy

Table 3.--Selected high-water levels and associated low-water levels at data-collection site, Jones Beach Island, April 1988 and January 1989

[Times refer to Eastern Standard. Water levels are in feet above sea level. Locations are shown in fig. 7. Complete data set is plotted in fig. 6. Dashes indicate no measurement at or very near crest or trough of tidal cycle]

Site	April 26, 1988						January 23, 1989				January 24, 1989			
	Maximum		Minimum		Maximum		Minimum		Maximum		Minimum		Maximum	
	Time	Water level	Time	Water level	Time	Water level	Time	Water level	Time	Water level	Time	Water level	Time	Water level
Wells														
S90161	[1]0610	1.46	1143	0.67	1743	1.62	1703	0.21	2249	1.13	0430	0.49	1100	1.85
			1203	.67	1803	1.62	1730	.21	2329	1.13	0510	.49	1120	1.85
S90162	--	--	1205	.71	1825	1.68	1709	.12	2356	1.04	0430	.40	1100	1.76
							1731	.12	[2]0020	1.04	0501	.40	1116	1.76
S90163	[1]0612	1.42	1145	.61	1803	1.57	1714	.13	2302	1.03	0415	.42	1106	1.76
							1752	.13	2335	1.03	0528	.42	1130	1.76
S91090	--	--	1001	3.61	1641	4.82	--	--	--	--	0255	3.24	0950	4.97
			1021	3.61							0313	3.24		
Great South Bay														
Measured	[1]0637	1.26	1223	.11	1823	1.39	--	--	--	--	0510	-.03	1043	1.74
			1245	.11	1843	1.39					0520	-.03		
Predicted	0544	1.17	1254	.37	1828	1.17	1805	.175	2324	1.28	0607	.25	1133	1.40
Atlantic Ocean														
Predicted[3]	--	--	0907	-1.59	1526	1.31	1418	-2.56	2022	1.49	0220	-2.29	0832	1.93

[1] Measurement made very near maximum of tidal cycle
[2] January 24, 1989
[3] Predicted ocean tide height is that calculated for Long Beach. Predicted ocean tide time is that calculated for Fire Island Breakwater.

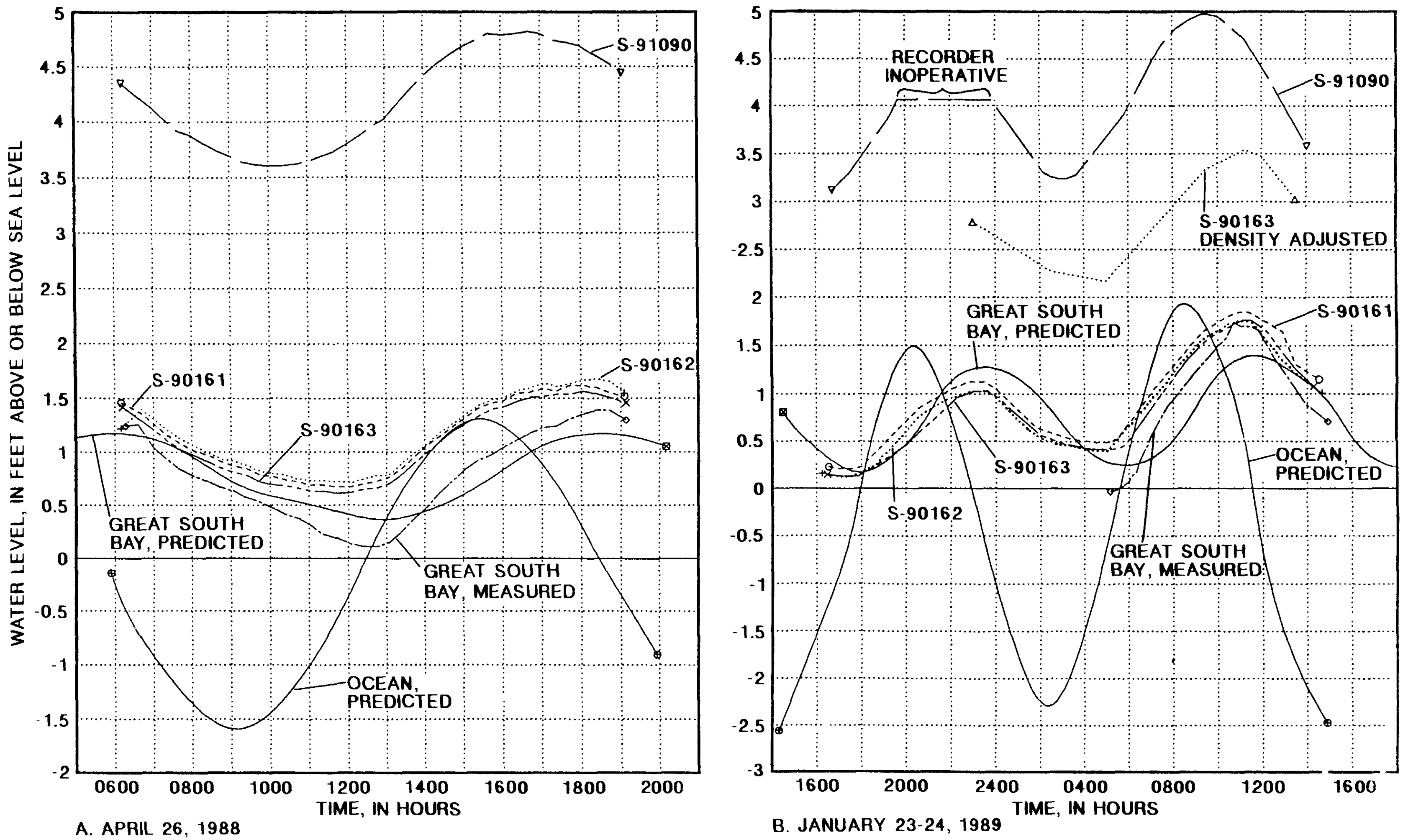


Figure 6.--Water levels in Great South Bay and in observation wells at data-collection site, April 26, 1988 (A) and January 23-24, 1989 (B). (Locations are shown in fig. 1. Predicted ocean tide height is that calculated for Long Beach; predicted ocean tide time is that calculated for Fire Island Breakwater.)

well's maximum water level and the predicted ocean crest was about 1 hour. The sequence of high water levels in the three upper glacial wells differed slightly from the low-tide sequence, as did the measured lag times between high tide in the bay and maximum water levels in those wells.

Heads in the Upper Glacial (Density-Adjusted) and Magothy Aquifers

Density-adjusted freshwater heads on January 24, 1989 in well S-90163, which is screened in the upper glacial aquifer, were calculated (fig. 6B). Although freshwater-equivalent heads cannot be used to determine vertical flow in a fluid of variable density, they provide information on the local ground-water flow field.

Equivalent freshwater heads are calculated by adding the elevation head to a modified pressure head that is calculated from an hypothetical column of freshwater. To perform this calculation, the water pressure at a point representing the elevation of the well screen is calculated as:

$$P = \rho_w g l, \tag{1}$$

where P = fluid pressure,
ρ_w = density of fluid in well,
g = acceleration due to gravity, and
l = vertical height of fluid in well above the point representing the well screen.

The equivalent freshwater head (h_f) is calculated as

$$h_f = z + \frac{P}{\rho_f g}, \tag{2}$$

where z = elevation above datum of the point representing the well screen,
P = fluid pressure at the point as calculated in equation (1), and
ρ_f = density of freshwater.

Substituting equation (1) into (2) gives a concise equation

$$h_f = z + \frac{\rho_w}{\rho_f} l. \tag{3}$$

The screen in well S-90163 is just above the top of the Gardiners Clay confining unit, and the screen of well S-91090 is just beneath the bottom of the unit. If the confining unit is assumed to contain freshwater, the difference in freshwater head between the bottom of the unit and the equivalent freshwater head at the top of the unit, based on data from well S-90163, provides a measure of the upward freshwater gradient through the confining unit. These measurements and calculated freshwater-equivalent heads (S-90163, adjusted in fig. 6B), indicate that fresh ground water flows vertically upward at this site and is discharging through the Gardiners Clay into the salty upper glacial aquifer.

WATER QUALITY

Ground-water samples were collected at the data-collection site after evacuation of three casing volumes of water in May 1988, September 1988, and April 1989; field values of specific conductance, temperature, and pH were measured and are summarized in table 4. All samples were analyzed for dissolved chloride and dissolved-solids concentrations by the USGS National Water Quality Laboratory in Denver, Colo.

Upper Glacial Aquifer and Great South Bay

Water from the three wells screened in the upper glacial aquifer was salty; chloride concentrations ranged from 17,000 to 19,000 mg/L, and the dissolved-solids concentrations ranged from 31,400 to 33,200 mg/L (table 4). Field-measured pH of water from upper glacial wells ranged from 7.5 to 7.7.

The estimated density of saltwater, based on dissolved-solids concentrations within this range, is between 1.021 and 1.025 times the weight density of distilled (pure) water (62.4 lb/ft^3). A weight density of 64 lb/ft^3 was used, as discussed previously, to calculate the freshwater equivalent head in upper glacial well S-90163.

The two water samples collected from Great South Bay in 1988 had chloride concentrations of 17,000 and 19,000 mg/L and dissolved-solids concentrations of 32,400 and 32,900 mg/L. These concentrations agree with published values of salinity in Great South Bay. A field-measured pH value of the bay in September 1988 was 8.0.

The chloride concentrations in samples from the three upper glacial wells were nearly the same as in Great South Bay. As mentioned previously, the presence of freshwater in the Magothy aquifer, and its inferred upward movement through the confining unit, indicate that freshwater is probably discharging into the upper glacial aquifer, but the results of sample analyses give no indication of dilution at the top of the confining unit (well S-90163). This indicates that the amount of freshwater discharged either is negligible or is effectively mixed in the upper glacial aquifer through tidal fluctuations and flow at the base of the aquifer.

Magothy Aquifer

Well S-91090, screened in the upper part of the Magothy aquifer, was sampled three times. Samples collected in May and September 1988 had chloride concentrations of 270 and 260 mg/L and field-measured pH of 5.9 and 5.8, respectively. Because the chloride concentrations of the water were higher than expected from published values (Lusczynski and Swarzenski, 1966), a third sample was collected in April 1989. About 20 casing volumes of water were evacuated from the well before sampling, and, again, the chloride concentration was 270 mg/L.

Water-quality data bases of the USGS and Nassau County Department of Health Services were reviewed to ascertain whether water from other wells screened in the Magothy aquifer in the study area had chloride concentrations

Table 4.--Selected chemical analyses of water samples collected at the data-collection site and a nearby well on Jones Beach Island

[Deg C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, no data available. Locations are shown in fig. 7]

Local identifier	Date m -d -y	Time	Temperature (Deg C)	Specific conductance (µS/cm) Field	Specific conductance (µS/cm) Laboratory	Dissolved solids, residue at 180 Deg C (mg/L)	Chloride, dissolved (mg/L as Cl)	pH (standard units) Field	pH (standard units) Laboratory
Great South Bay	05-06-88	1150	--	45,800	45,200	32,400	19,000	--	7.6
	09-30-88	1340	18.4	47,900	46,100	32,900	17,000	8.0	7.7
S-91090	05-06-88	1220	14.2	908	904	470	270	5.9	6.2
	09-30-88	1411	13.4	955	931	462	260	5.8	6.6
	04-17-89	1405	12.8	887	915	467	270	--	6.3
S-90161	09-30-88	1313	12.3	45,400	44,400	31,400	17,000	7.7	7.4
S-90162	05-06-88	1020	12.1	47,200	46,500	33,100	18,000	7.5	7.6
	09-30-88	1347	12.4	48,800	46,300	33,200	18,000	7.7	7.3
S-90163	05-06-88	1103	12.1	47,600	46,400	32,600	19,000	7.5	7.4
	09-30-88	1135	12.5	46,900	46,100	32,800	17,000	7.5	7.5
S-67087.1	04-19-89	1350	12.6	928	1,000	500	260	--	7.6

similar to that at S-91090. Records from wells screened in shallow, intermediate, and deep Magothy zones were examined, but the data were too limited in number, areal distribution, and period of record to enable conclusions. (Selected Magothy-well locations are shown in fig. 7, which also lists the screened interval, highest chloride value in the data bases, and year of sample collection.) No similarly high chloride concentrations were found in any other wells.

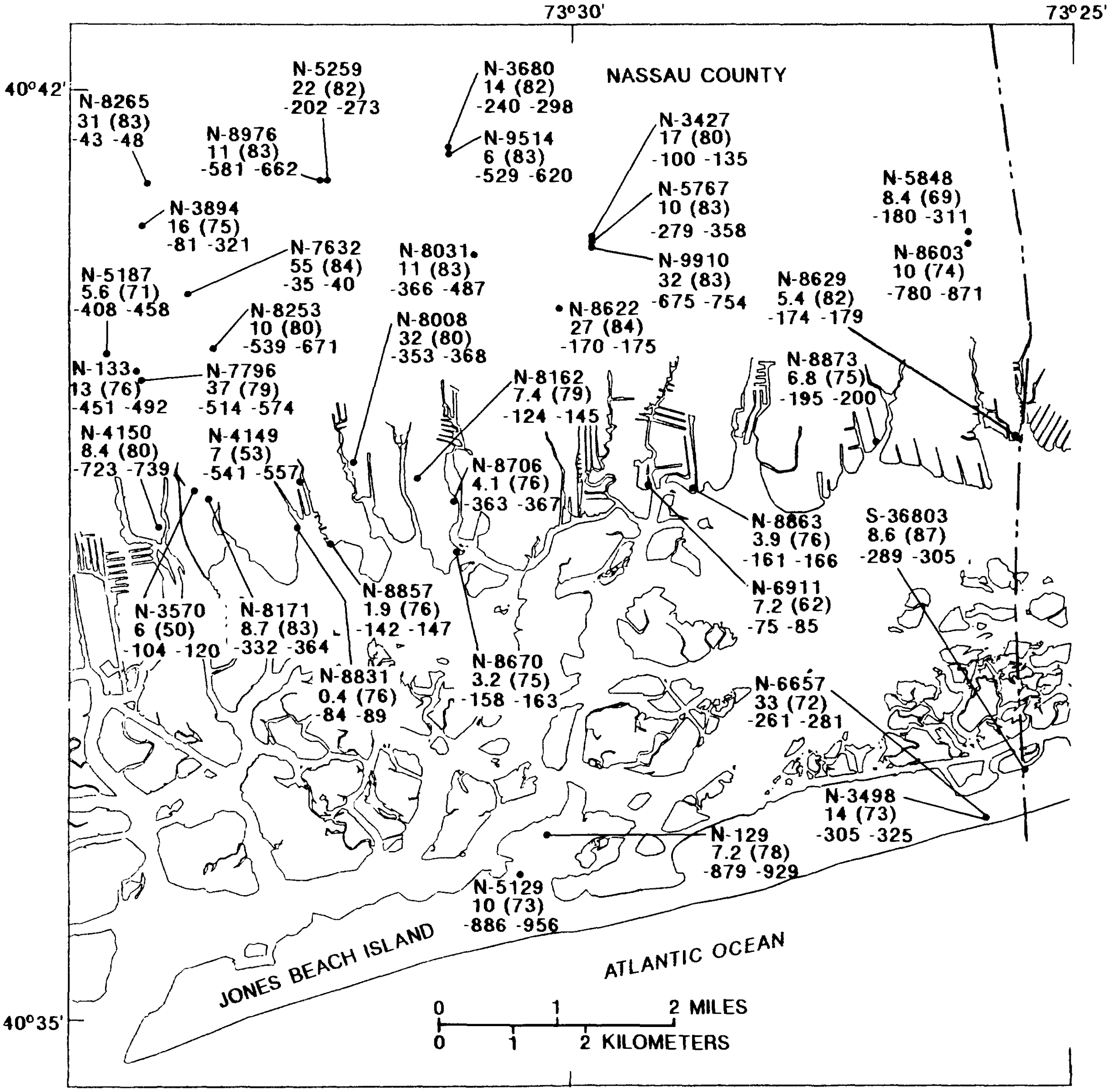
Well S-67087.1 (fig. 7) is the closest USGS observation well to the data-collection site, and its screened interval is in the upper part of the Magothy aquifer. This well is about 2 mi west of the site and is screened about 70 ft deeper than well S-91090. Water samples from S-67087.1 were not expected to contain elevated chloride concentrations, but a sample collected in April 1989 had a chloride concentration of 260 mg/L, virtually the same as at well S-91090. Although this value is within the freshwater range, it is unexpectedly high. The dissolved-solids concentration at S-67087.1 (500 mg/L) also was similar to that at well S-91090, but the laboratory pH (7.6) was higher than the range at S-91090 (6.2 to 6.6). This local difference in pH indicates that geochemical conditions in the Magothy aquifer differ between these two sites, despite the consistent chloride concentrations.

The reason for unexpectedly high chloride concentrations of about 260 mg/L in the upper part of the Magothy aquifer at the data-collection site is unknown. The barrier islands are considered to be part of the discharge area for the Magothy aquifer, as indicated by the natural upward hydraulic gradient from the Magothy aquifer to the upper glacial aquifer; therefore, the salty upper glacial water would not be expected to enter the Magothy aquifer.

Although hydrologic conditions indicate no explanation for these higher-than-expected chloride concentrations, geologic conditions suggest a reason. Doriski and Wilde-Katz (1983) indicate that the Monmouth greensand and the Gardiners Clay are absent west of the data-collection site; thus, if past or present hydraulic conditions favored mixing or dispersion of salty water from this adjacent area into the data-collection site, saltwater contamination could result. This cannot be substantiated, however, because the drillers' logs from which the absence of confining units was inferred are few and give poor lithologic descriptions, and other researchers (Smolensky and others, 1989) have interpreted the same logs in other ways. Thus, the hydrologic and geologic information available does not explain the elevated chloride concentrations in the upper part of the Magothy aquifer at the data-collection site.

SUMMARY AND CONCLUSIONS

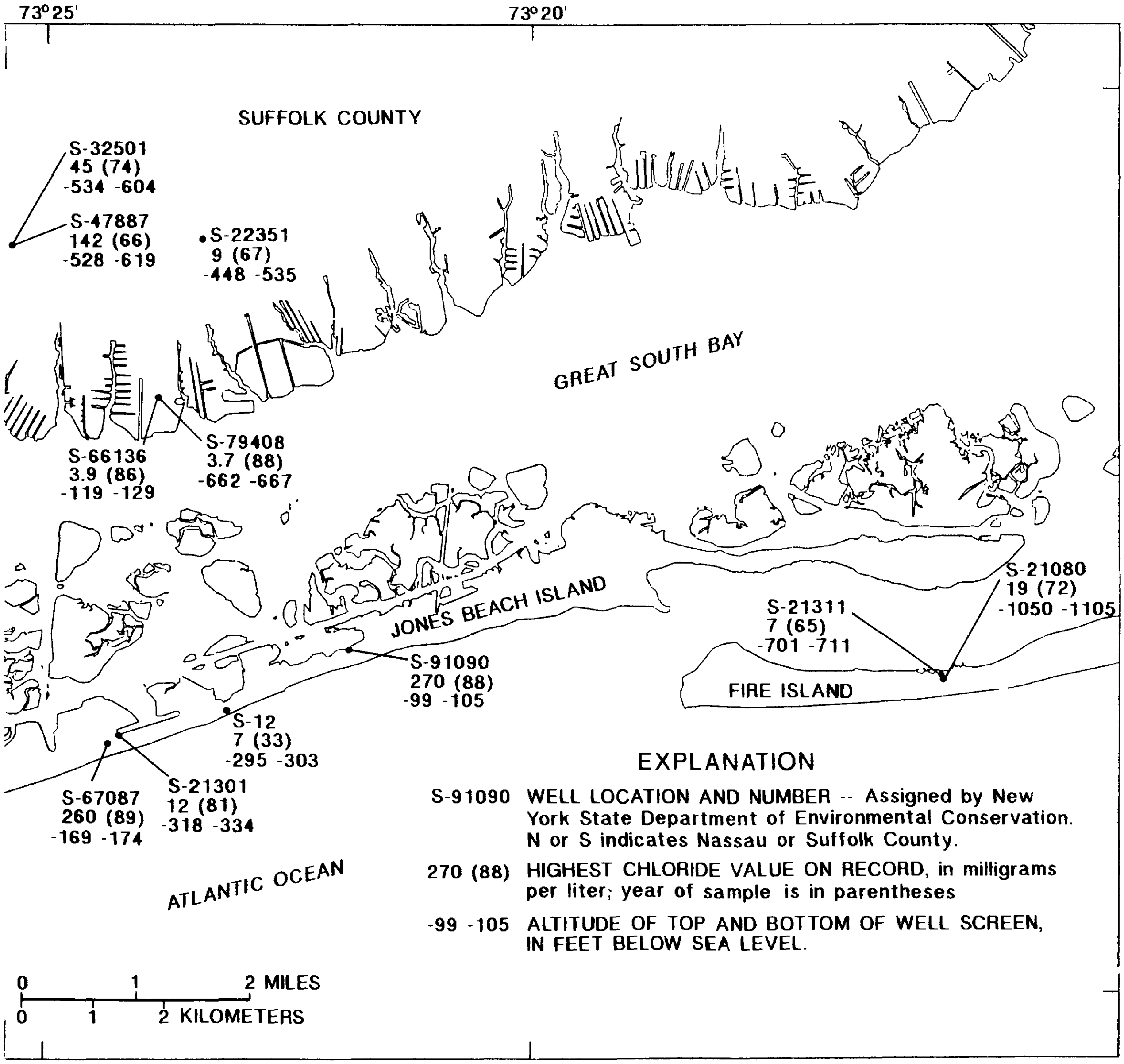
Four wells were installed at a site on Jones Beach Island, a barrier island south of Long Island. The deepest well (S-91090), drilled to a depth of 117 feet below land surface, penetrated the Gardiner's Clay and was screened in the top of the Magothy aquifer. The remaining three wells were installed in the upper glacial aquifer with screen bottoms at 45, 70, and 85 ft below land surface.



Base from U.S. Geological Survey 1:24,000, 1966,1967 and 1969 quadrangle.

Figure 7.--Maximum recorded chloride concentrations in water samples Island, and on mainland Long Island, N.Y., with year of

Chloride analyses of water from the four wells indicated that the Magothy aquifer contains freshwater (270 mg/L as Cl), whereas the three upper glacial wells have salty water with about the same chloride concentrations (17,000 to 19,000 mg/L) as Great South Bay to the north. Calculations of pressure and freshwater equivalent heads indicate that freshwater is discharging from the deeper Magothy aquifer into the salty upper glacial aquifer at the data-collection site. Vertical changes in chloride concentrations in the salty upper glacial aquifer, which would reflect upward movement of fresh ground water from the Magothy aquifer, were not observed. Ground-water levels in the upper glacial aquifer are strongly affected by tides, and this cyclical move-



from wells screened in the Magothy aquifer on Jones Beach Island, Fire sampling and screened interval.

ment could cause the small amount of fresh ground water entering the upper glacial aquifer through the confining unit to mix rapidly with the salty water in the upper glacial aquifer and thereby obscure its presence.

Chloride concentrations (260 to 270 mg/L) in the Magothy aquifer at the site, although low compared to that of sea water, are much higher than expected. A chloride concentration similar to those measured at the site was observed in water from another well screened in the Magothy aquifer (S-67087.1) 2 mi west of the site. The reason for these elevated concentrations is unknown, and to identify their cause would require further study.

REFERENCES CITED

Doriski, T.P., and Wilde-Katz, Franceska, 1983, Geology of the "20-foot" clay and Gardiners Clay in southern Nassau and southwestern Suffolk Counties, Long Island, New York: U.S. Geological Survey Water-Resources Investigations Report 82-4056, 17 p.

Franke, O.L., and Cohen, Philip, 1972, Regional rates of ground-water movement on Long Island, New York, *in* Geological Survey Research 1972: U.S. Geological Survey Professional Paper 800-C, p. C271-277.

Fuller, M.L., 1914, The geology of Long Island, New York: U.S. Geological Survey Professional Paper 82, 231 p.

Jensen, H.M., and Soren, Julian, 1971, Hydrogeologic data from selected wells and test holes in Suffolk County, Long Island, New York: Hauppauge, N.Y., Suffolk County Department of Environmental Control, Long Island Water Resources Bulletin LIWR-3, 35 p.

_____ 1974, Hydrogeology of Suffolk County, Long Island, New York: U.S. Geological Survey Hydrologic Investigation Atlas HA-501, 2 sheets, scale 1:250,000.

Lusczynski, N.J., and Swarzenski, W.V., 1966, Salt-water encroachment in southern Nassau and southeastern Queens Counties, Long Island, New York: U.S. Geological Survey Water-Supply Paper 1613-F, 76 p.

National Oceanic and Atmospheric Administration, 1987, Tide tables 1988--high and low water predictions, east coast of North and South America including Greenland: U.S. Department of Commerce, 289 p.

_____1988, Tide tables 1989--high and low water predictions, east coast of North and South America including Greenland: U.S. Department of Commerce, 289 p.

Perlmutter, N. M., and Geraghty, J. J., 1963, Geology and ground-water conditions in southern Nassau and southeastern Queens Counties, Long Island, N.Y.: U.S. Geological Survey Water-Supply Paper 1613-A, 205 p.

Reilly, T. E., 1990, Summary of dispersion in layered coastal aquifer systems: Journal of Hydrology, v. 114, p. 211-228.

Reinson, G. E., 1984, Barrier-island and associated strand-plain systems, in Walker R. G. (ed.), Facies models (2d ed.): Geological Association of Canada, Geoscience Canada Reprint Series 1, p. 119-140.

Smolensky, D. A., Buxton, H. T., and Shernoff, P. K., 1989, Hydrologic framework of Long Island, New York: U.S. Geological Survey Hydrologic Investigations Atlas HA-709, 3 sheets, scale 1:250,000.

Suter, Russell, de Laguna, Wallace, and Perlmutter, N. M., 1949, Mapping of geologic formations and aquifers of Long Island, New York: New York State Water Power and Control Commission Bulletin GW-18, 212 p.

REFERENCES CITED (continued)

Veatch, A. C., Slichter, C. S., Bowman, Isaiah, Crosby, W. O., and Horton, R. E., 1906, Underground water resources of Long Island, New York: U.S. Geological Survey Professional Paper 44, 394 p.

Wolff, M. P., 1975, Natural and man-made erosional and depositional features associated with stabilization of migrating barrier islands, Fire Island Inlet, N.Y., *in* Wolff, M. P. (ed.), Guidebook to 47th Meeting of the New York State Geological Association: Hempstead, N.Y., p. 213-258.