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Long Island Geologists

"Geology of Long Island and Metropolitan New York"

Saturday April 22, 1995

Earth and Space Sciences Building
SUNY Stony Brook

PROGRAM WITH ABSTRACTS

Long Island Geologists

"Geology of Long Island and Metropolitan New York"

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DELINEATION OF THE SALTWATER-FRESHWATER INTERFACE AT SELECTED LOCATIONS IN KINGS AND QUEENS COUNTIES, LONG ISLAND, NEW YORK, THROUGH USE OF BOREHOLE GEOPHYSICAL TECHNIQUES

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ABSTRACT

Kings and Queens Counties, in western Long Island, N.Y., are underlain by a southeastward-dipping sequence of unconsolidated aquifers and confining units. Many public-supply wells in several parts of Kings and Queens Counties have been adversely affected by saltwater intrusion. In 1994, sixteen observation wells were drilled to locate boundaries between major hydrogeologic units and delineate the saltwater-freshwater interface. Borehole geophysical logging was used at six of these wells and one previously installed well to augment the data in the absence of sufficient core and filter-press samples.

Results indicate saltwater has intruded five of the seven areas studied. The saltwater wedges range from 215 to 5 ft in thickness, and chloride concentrations range from 110 to more than 18,000 milligrams per liter. Borehole geophysical logs provided data on the depth of lithologic contacts and of changes in salinity. Spontaneous potential, single-point-resistance, and short-normal-resistivity logs provided reliable supplements to natural-gamma and electromagnetic-induction logs.

INTRODUCTION

Kings and Queens Counties, on western Long Island (fig. 1), have undergone rapid population growth during this century, and the demand for fresh drinking-water supplies has increased proportionately. During the first half of this century, most public-supply water came from wells in Kings and Queens counties. Overpumping in some areas caused saltwater intrusion in the water-supply aquifers, however, necessitating the shutdown of several public-supply wells (Lusczynski, 1952; Buxton and others, 1981). At present, most of the public-supply water for Kings and Queens Counties is obtained from upstate surface-water reservoirs.

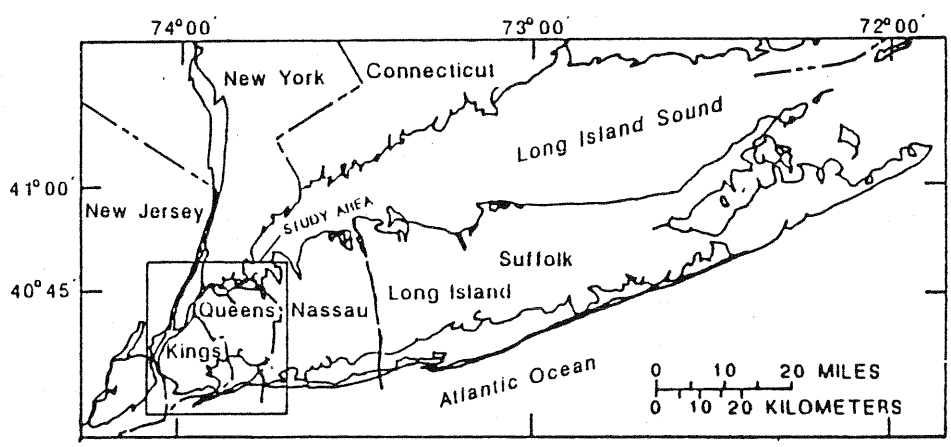


Figure 1. Location of Kings and Queens Counties, Long Island, N.Y.

In 1994, the U.S. Geological Survey, in cooperation with the New York City Department of Environmental Protection, drilled 16 observation wells to collect geologic and geochemical samples for delineation of (1) the contacts between major hydrogeologic units, and (2) the location of the saltwater-freshwater interface. Borehole geophysical logs were used at selected sites to augment the data obtained from drilling.

This report presents (1) a brief summary of the historical trends in pumpage and saltwater intrusion, (2) the borehole geophysical techniques used, and (3) the delineation of the saltwater-freshwater interface at selected sites using borehole geophysical logs and analysis of water samples from the screen zone.

Hydrogeology

Kings and Queens counties are underlain by unconsolidated deposits that constitute three major aquifers separated by two confining units. The system is underlain by crystalline bedrock. The water-table (upper glacial aquifer of Pleistocene age) in Kings and Queens counties consists of unconsolidated sand, gravel, and clay, and is underlain throughout most of the two-county area by the Gardiners Clay of Pleistocene age (Soren, 1978). The Gardiners Clay is a gray clay that overlies and confines the Jameco aquifer throughout central and southern Kings and Queens counties. The Jameco is a sand and gravel deposit of Pleistocene age (Soren, 1978) that overlies the Magothy aquifer of Cretaceous age. The Magothy aquifer consists of sand, silt, and clay (Franke and McClymonds, 1972). Underlying the Magothy aquifer is the multicolored Raritan clay of Cretaceous age, which overlies and confines the Lloyd aquifer of Cretaceous age. The Lloyd aquifer consists of sand and gravel and overlies impermeable crystalline bedrock (Franke and McClymonds, 1972).

Historical trends in Pumpage and Salinity

Most of the public-supply water in Kings and Queens counties during 1904-16 was pumped from the upper glacial aquifer at average rates of 21 and 37 Mgal/d (million gallons per day), respectively (Johnson and Waterman, 1952). Total public- and industrial-supply pumpage from all aquifers in Kings County during that period averaged 60 Mgal/d, most of which was from the upper glacial aquifer (Lusczynski, 1952). The predevelopment chloride concentration of freshwater on Long Island was 10 mg/L (milligrams per liter) or less (Lusczynski and Swarzenski, 1966). The ambient chloride concentration of shallow ground water in urbanized areas of Long Island is less than 40 mg/L (Buxton and others, 1981; Heisig and Prince, 1993); the increase is attributed to contamination from land-surface sources. In this paper, "ambient" water is defined as groundwater with a chloride concentration less than 40 mg/L; "brackish" water has a chloride concentration of 40 to 250 mg/L chloride, and saltwater has a chloride concentration greater than 250 mg/L (Lusczynski and Swarzenski, 1966).

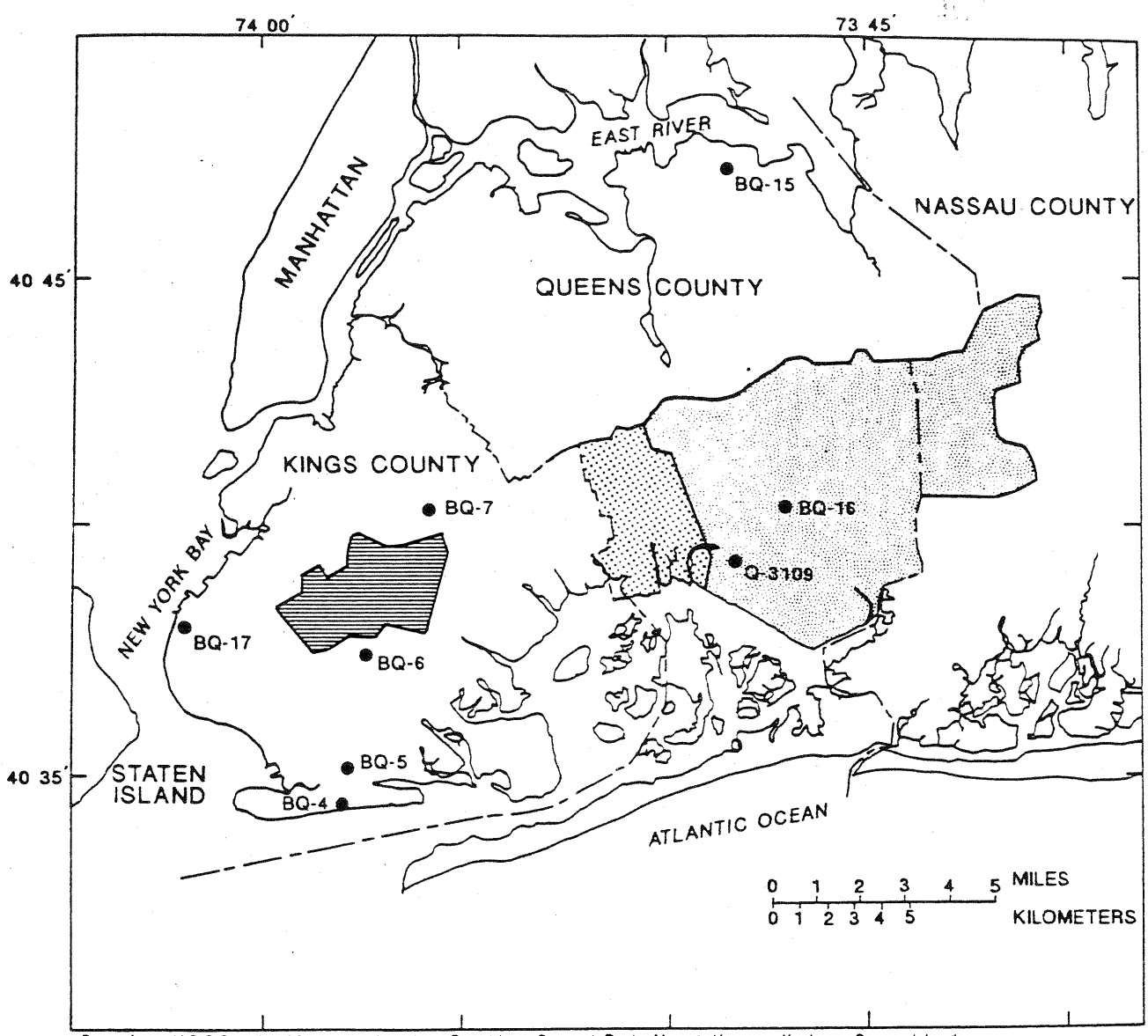
By 1936, overpumping in Flatbush in central Kings County (fig. 2) had created a major cone of depression in the water table that extended to the south shore of much of Kings County and into southwestern Queens. Maximum drawdowns in the area exceeded 35 ft (feet) below sea level. By the 1930's, chloride concentrations in Kings County had increased to more than 100 mg/L (Lusczynski, 1952; Buxton and others, 1981)(fig. 2), and, by the 1940's, chloride concentrations at inland wells exceeded 250 mg/L. The elevated chloride concentrations resulted in the shutdown of public-supply wells at Flatbush in 1947 (Lusczynski, 1952). After the shutdown, industrial pumping continued at rates of about 23 Mgal/d in northern Kings County, where ground-water levels remained below sea level into the 1960's (Buxton and others, 1981).

The cessation of pumping in Flatbush was balanced by increased pumping from the Woodhaven pumping center in southwestern Queens County (fig. 2). By 1961, however, a major cone of depression had developed at Woodhaven, and, in 1974, the attendant saltwater intrusion resulted in the shutdown of the Woodhaven wells (Buxton and others, 1981). Public-supply pumping was then shifted eastward from Woodhaven to the Jamaica pumping center in southeastern Queens (fig. 2).

Soren (1971) documented saltwater intrusion in three areas of Queens--the northwestern section, the north-central section, and the Woodhaven (southwestern) section. Lusczynski and Swarzenski (1966) delineated intermediate and deep saltwater wedges in southern Nassau and southeastern Queens from analyses of water from monitoring wells, filter-press core samples, and geophysical logs.

BOREHOLE GEOPHYSICAL TECHNIQUES

Borehole geophysical techniques can provide more information from a well than can be obtained from drilling and sampling. The geophysical-logging systems used in this study provided continuous digital records that reflect the physical properties of the sediment, the rock matrix, and the interstitial fluids. Borehole geophysical logging was selected because drilling cores and filter-press samples were insufficient for delineation of the contacts



Base from U.S.G.S. 1:24000 series: Jamaica, Brooklyn, Central Park, Mount Vernon, Yonkers, Coney Island, Flushing, The Narrows, and Far Rockaway.

EXPLANATION

● BQ-7 Location of observation well, prefix BQ indicates project well, Q indicates New York State number.

Flatbush pumping center franchise area.

Woodhaven pumping center franchise area.

Jamaica pumping center franchise area.

Figure 2. Location of observation wells and pumping center areas in Kings and Queens Counties, N.Y. (modified from Buxton and others, 1981, fig. 2).

between lithologic units and the saltwater-freshwater interface. Geophysical logging was completed at seven wells. At three of the sites, spontaneous potential (SP), single-point resistance (SPR), short-normal resistivity (R), and natural-gamma radiation (gamma) logs were collected in mud-filled open boreholes prior to casing. At each of the sites, focused electromagnetic-induction (EM) logs were collected in polyvinyl chloride (PVC) cased wells; gamma and EM logs were obtained at wells that were already cased. The SP, SPR, and R probes were calibrated to provide consistently reliable measurements. In the past, these techniques were used on Long Island to delineate salinity changes in formations but were prone to large variations in response, probably because of poor calibration technique and the limitations of the analog equipment.

Spontaneous-potential (SP) logs - These logs provide a record of the potentials, or voltages, that develop at the contacts between clay beds and sand aquifers within a borehole (Keys, 1990). This potential differs from one formation to the next and is measured in millivolts (Serra, 1984). The SP is a function of the chemical activity of the borehole fluid, the water in the adjacent sediments, the water temperature, and the type and quantity of clay. SP logs are used to determine lithology, bed thickness, and salinity of formation water (Keys, 1990).

Single-point-resistance log (SPR) - These logs provide a measure of the resistance, in ohms, between an electrode in the borehole and an electrode at land surface. The volume of surrounding material to which the SPR probe is sensitive is spherical and only 5 to 10 times the electrode diameter, and is affected by the borehole fluid (Keys, 1990). SPR logs are used to obtain high-resolution lithologic information.

Normal-resistivity (R) logs - This technique uses two electrodes typically spaced 16 or 64 inches apart in the borehole, called short- and long-normal logs, respectively. Normal-resistivity logs measure apparent resistivity in ohm-meters and are used to determine lithology and water quality (salinity) (Keys, 1990). The volume of surrounding material to which normal resistivity probes are sensitive is spherical with a diameter about twice the electrode spacing (Serra, 1984; Keys, 1990). In this study, only short-normal resistivity logs were used.

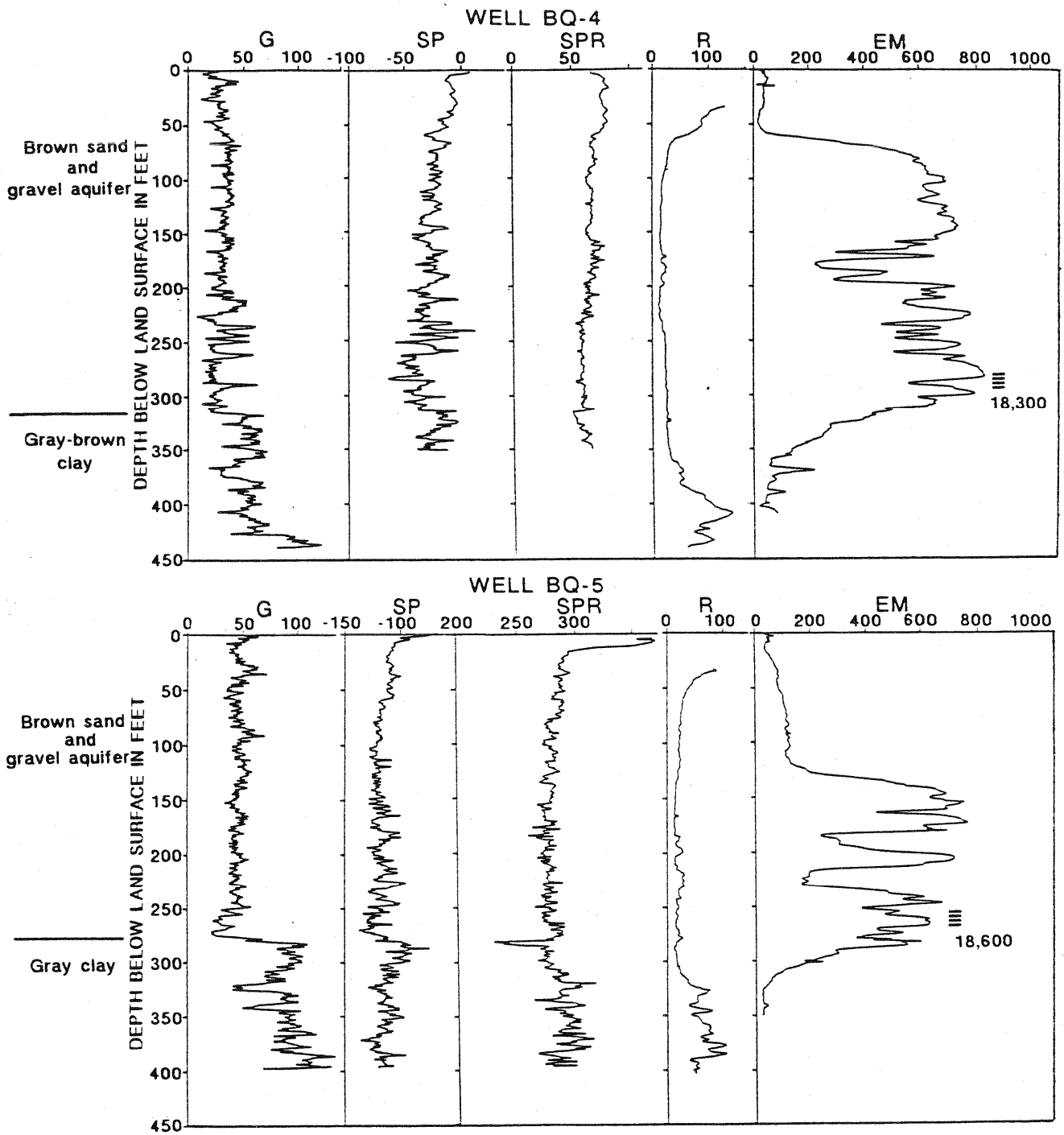
Natural-gamma (gamma) logs - Gamma logs are a record of the total gamma radiation detected in a borehole (Keys, 1990). Clays and fine-grained sediments tend to be more radioactive than the quartz sand that forms the bulk of the deposits on Long Island. Gamma logs are most commonly used for lithologic and stratigraphic correlation.

Focused electromagnetic induction (EM) logs - This technique uses an electromagnetic emitter coil that induces current loops within the surrounding formation to generate a secondary electromagnetic field. The intensity of the secondary field received by the receiver coil is proportional to the formation conductivity (Keys, 1990; Serra, 1984; Keys and MacCary, 1971). EM logs are measured in units of millisiemens per meter (mS/m) and are inversely related to the ohm-meter of normal-resistivity logs (Keys, 1990; Serra, 1984; Keys and MacCary, 1971). The normally low conductivity of Long Island's hydrogeologic deposits is advantageous in the application of induction logging in the delineation of highly conductive fluids such as saltwater. For this reason, EM logging has been used on Long Island to delineate (1) the saltwater-freshwater interface (Stumm, 1993; Stumm and Lange, 1994; Stumm, 1994), (2) ground-water contamination by road salt (Church and Friesz, 1994), landfill leachate (Mack, 1993), and septage effluent (DeSimone and Barlow, 1994).

DELINEATION OF THE SALTWATER-FRESHWATER INTERFACE

Five areas of saltwater intrusion in Kings and Queens Counties were identified from borehole geophysical logs taken at the seven well sites (fig. 2). At three sites, geophysical logs (SP, SPR, R, and gamma) were used in open boreholes in conjunction with EM logs after casing; the remaining wells had been previously cased with PVC and logged by gamma and EM probes. Chloride concentration and specific conductance data from screen-zone water samples obtained during development or sampling were also used for delineation.

Wells BQ-4 and BQ-5. - The gamma and SP logs indicated two major hydrogeologic units at well BQ-4, on the southern shore of Kings County--an unconfined aquifer (sand and gravel) underlain by a clay confining unit (fig. 3). The increasingly negative potential with depth in the SP log suggests an increase in salinity. A similar trend is seen in the SPR curve, in which the lack of a strong right deflection in the SPR curve within the aquifer above the clay suggests conductive (salty) ground water. Three distinct zones of resistivity are indicated in the R log--two within the aquifer and one within the clay. Water in the upper 60 ft of the aquifer is moderately conductive (moderate resistivity), whereas that in the deeper part is highly conductive (low resistivity). The clay has typically higher conductivity (lower resistivity) than sand or gravel. The upper part of the clay has slightly higher conductivity than its lower part as a result of saltwater intrusion from the overlying aquifer. The EM log correlates closely with the R log and indicates two zones of saltwater intrusion within the unconfined aquifer--one above 60 ft, and one below 60 ft (below land surface). The upper, moderately conductive zone had a response of about 50 mS/m; the zone beneath the contact contains the highest conductivity values measured (about 825 mS/m). Geophysical logs from well BQ-5, about 1 mi inland of BQ-4, indicate a similar pattern (fig. 3). The saltwater wedge in this area is 215 ft thick at well BQ-4 and 155 ft thick at well BQ-5, and the maximum chloride



EXPLANATION

G- Gamma log (counts per second)

SP- Spontaneous Potential log (millivolts)

SPR- Single-Point-Resistance log (ohms)

R- Short-Normal-Resistivity log (ohm-meters)

EM- Electromagnetic Induction log (millisiemens per meter)

≡110 Well screen-zone sample location, number is chloride concentration (milligrams per liter)

Figure 3. Geophysical and geologic logs of wells BQ-4 and BQ-5.

concentration (BQ-5 screen-zone sample) was 18,600 mg/L.

Well BQ-15 - Gamma and SP logs from well BQ-15 indicated three major hydrogeologic units--an unconfined aquifer, a clay confining unit, and a confined aquifer that extends to bedrock (fig. 4). The SP curve within the unconfined aquifer shows a slightly greater response in positive potential than in the confined aquifer. The SPR log shows a similar pattern; the low resistance in the unconfined aquifer suggests slightly conductive (brackish) ground water. The R log correlates with the SP and SPR logs and is nearly an inverse curve of the EM log. Both the R and EM logs indicate slightly more conductive (brackish) ground water in the unconfined aquifer than in the confined aquifer and indicate that a wedge of brackish water 60 ft thick has intruded the unconfined aquifer. Within the wedge, the peak EM response was about 25 mS/m, and the screen-zone water sample had a chloride concentration of 110 mg/L. The confined aquifer had the highest resistivity (lowest conductivity) of any unit and a low chloride concentration of 8.9 mg/L as sampled from a screen zone at a depth of 165 to 185 ft.

Wells Q-3109 and BQ-16 - Gamma logs from wells Q-3109 and BQ-16 (which were cased), in southern Queens County, indicated three major hydrogeologic units--an unconfined aquifer, a clay confining unit, and a confined aquifer (fig. 4). The EM log from well Q-3109 indicates two separate wedges of saltwater--one in the unconfined aquifer, the other in the confined aquifer. At well BQ-16, 2 mi.to the northeast, a wedge is indicated in the unconfined aquifer, but not in the confined aquifer. The wedge in the unconfined aquifer ranges in thickness from 70 ft at well Q-3109 to about 5 ft at well BQ-16 and had a peak EM response of about 625 mS/m; the estimated chloride concentration was 6,000 mg/L. The wedge in the confined aquifer at well Q-3109 is about 80 ft thick and had a peak EM response of about 300 mS/m; the chloride concentration of a water sample from the screen zone at a depth of 290 to 300 ft, was 3,200 mg/L.

Well BQ-7 - The gamma log from well BQ-7, in north-central Kings County near the defunct Flatbush pumping center, indicates two major hydrogeologic units--an unconfined aquifer and a clay confining unit (fig. 5). The EM log delineated a wedge of conductive ground water about 130 ft thick that had a peak EM response of 25 mS/m. No water samples were obtained from the unconfined aquifer, but the chloride concentration is estimated from the EM log to be about 200 mg/L.

Well BQ-17 - The gamma log of well BQ-17, along the southwestern shore of Kings County, indicated two major hydrogeologic units--a clay confining unit and a confined aquifer that extends to bedrock (fig. 5). The EM log indicates brackish water throughout the confined aquifer and a 10-ft-thick wedge of saltwater at its base. The wedge had a peak EM response of about 50 mS/m. A water sample from a screen zone in the wedge had a chloride concentration of 213 mg/L.

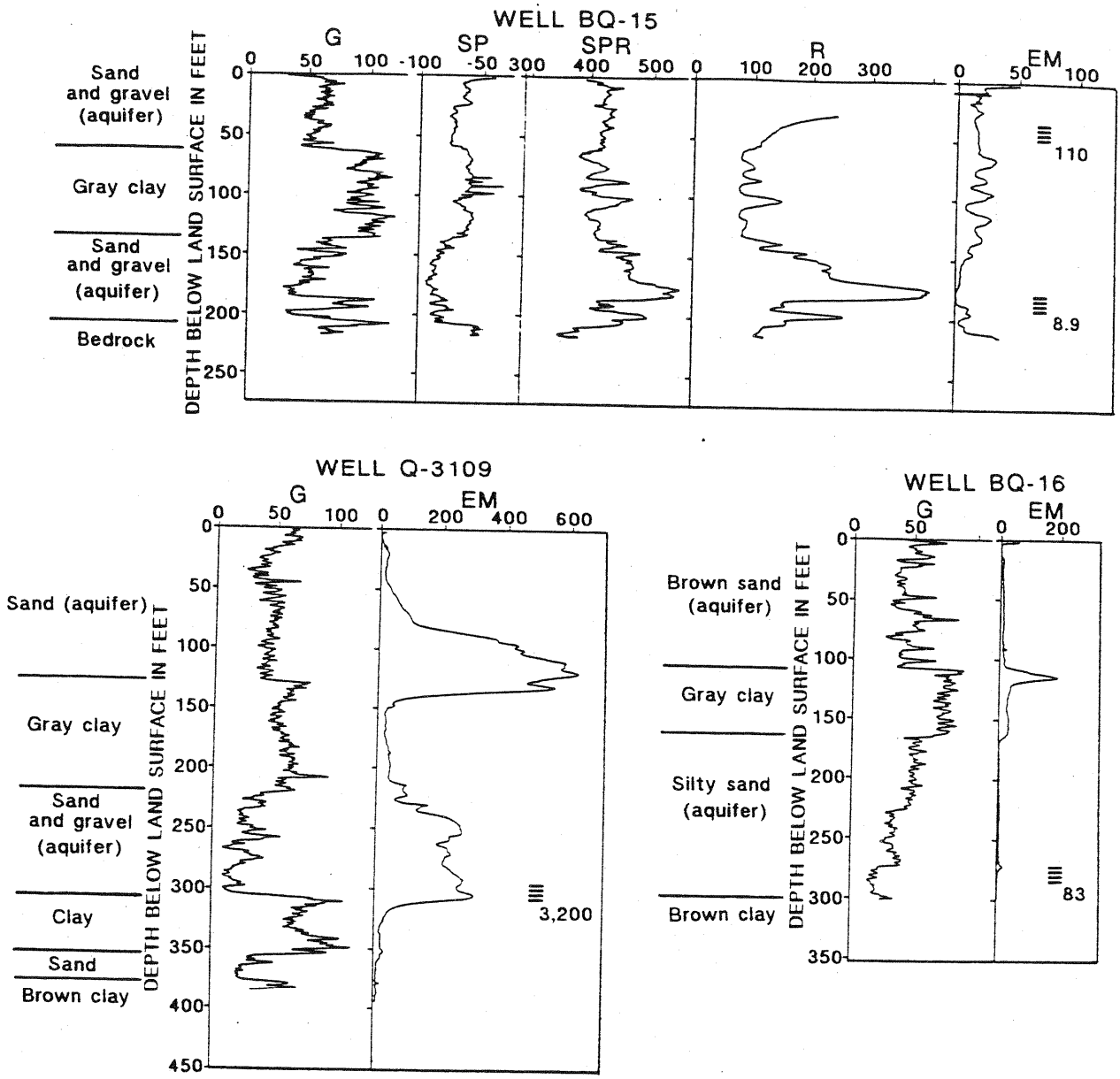
CONCLUSIONS

Seven observation wells at five locations in Kings and Queens Counties were logged with borehole geophysical techniques to delineate lithologic contacts and the saltwater-freshwater interface. A full suite of borehole geophysical logs was completed during the drilling of three of the wells to compensate for the lack of cores and filter-press samples. The SP, SPR, and R logs were used in conjunction with (1) EM logs to delineate the saltwater-freshwater interface, and (2) gamma logs to determine lithologic contacts.

Results indicate that saltwater has intruded into all five locations. A wedge of saltwater was delineated in the unconfined aquifer at wells BQ-4 and BQ-5, in southwestern Kings County; the wedge ranges from 215 to 155 ft in thickness and had a maximum EM response of 825 mS/m. The chloride concentration at screen zones exceeded 18,000 mg/L.

A wedge of saltwater 70 to 5 ft thick was delineated in the unconfined aquifer at wells Q-3109 and BQ-16, in southern Queens. The wedge at Q-3109 had a peak EM response of 625 mS/m and an estimated chloride concentration of 6,000 mg/L. A second wedge 80 ft thick was delineated within the deeper (confined) aquifer at this well; it had a peak EM response of 300 mS/m and a chloride concentration of 3,200 mg/L at the screen zone. A wedge of brackish ground water at well BQ-7, in north-central Kings County, has intruded most of the thickness of the confined aquifer. A saltwater wedge at well BQ-17, along the southwestern shore of Kings County, is about 10 ft thick at the base of the confined aquifer had a peak EM response of 50 mS/m and a chloride concentration of 213 mg/L.

In the absence of sufficient core samples from some of these wells, borehole geophysical logs provided essential information on lithologic contacts and changes in salinity with depth at the well sites. Results indicate that SP, SPR, and R logs, if properly calibrated, can provide additional lithologic and ground-water-quality information in conjunction with gamma and EM logs.



EXPLANATION

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SPR- Single-Point-Resistance log (ohms)

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EM- Electromagnetic Induction log (millisiemens per meter)

110 Well screen-zone sample location, number is chloride concentration (milligrams per liter)

Figure 4. Geophysical and geologic logs of wells BQ-15, Q-3109, and BQ-16.

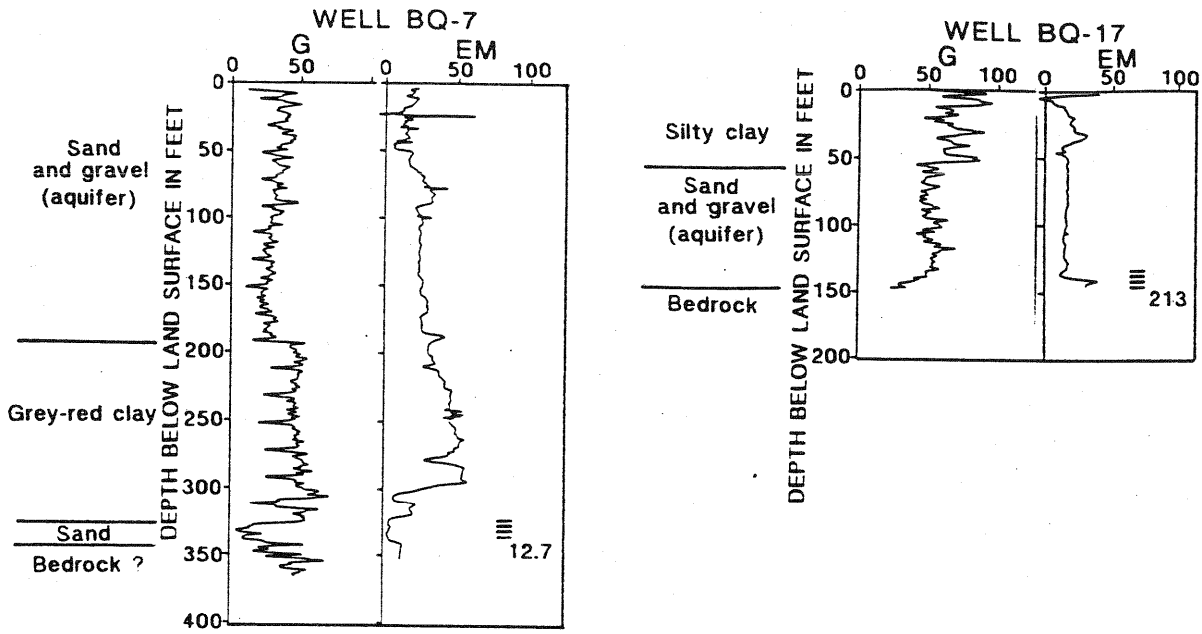

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Figure 5. Geophysical and geologic logs of wells BQ-7 and BQ-17.

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