Saltwater Intrusion into the Old Bridge Aquifer in the Keyport-Union Beach Area of Monmouth County, New Jersey

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Prepared in cooperation with the New Jersey Department of Environmental Protection, Division of Water Resources

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By F. L. SCHAEFER and R. L. WALKER

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GLOSSARY

Aquifer. A formation of rock or soil that will yield sufficient quantities of water to wells and springs.

Artesian aquifer. An aquifer containing water under sufficient pressure to rise above the top of the aquifer when penetrated by a well.

Chloride concentration. A measure of the amount of salt in water expressed in milligrams per liter.

Cone of depression. A low in the potentiometric surface centered in the area of greatest concentration of pumping.

Confining layer. A layer of earth material that hampers the movement of water.

Diffusion zone. A zone of mixed water between fresh and salty ground water.

Discharge area. The location where ground water leaves an aquifer.

Effective porosity. The part of a rock or soil occupied by interconnected pore spaces (openings) available for fluid transmission.

Ground water. Water saturating a geologic strata (layer) beneath the land surface.

Head, static. The height of the surface of a water column that can be supported by the static pressure at a given point.

Hydraulic conductivity. A measure of the ability of a material to transmit water.

Hydraulic gradient. The change in static head per unit of distance in a given direction. If not specified, the direction generally is understood to be that of the maximum rate of decrease in head.

Milligrams per liter. (mg/L) is a unit for expressing the concentration of chemical constituents in solution, that is, the weight of constituent per unit volume of water.

Outcrop area. Regions where aquifers are exposed at land surface.

Potentiometric surface. An imaginary surface either above or below land surface, connecting levels to which water will rise from an aquifer tapped by tightly cased wells.

Recharge area. The location where water enters the aquifer.

Saltwater intrusion. Movement of saltwater so that it replaces fresh ground water.

Specific conductance. A measure of the ability of water to carry an electric current.

Water table. The top of the zone of saturation in porous, unconfined earth material that is filled with ground water.

FACTORS FOR CONVERTING INCH-POUND UNITS TO METRIC UNITS

MULTIPLY INCH-POUND UNIT	BY	TO OBTAIN METRIC UNIT
inches (in)	25.4	millimeters (mm)
inches (in)	0.0254	meters (m)
feet (ft)	0.3048	meters (m)
feet per mile (ft/mi)	0.189	meters per kilometer (m/km)
miles (mi)	1.609	kilometers (km)
gallons (gal)	0.003785	cubic meters (m^3)
million gallons per day (Mgal/d)	0.04381	cubic meters per second (m^3/s)

ABSTRACT

Lateral saltwater intrusion is occuring in a part of the Old Bridge aquifer in the vicinity of Keyport and Union Beach Boroughs in Monmouth County, N.J. Beginning about 1970, analyses of water samples from five wells tapping the Old Bridge aquifer show abnormally high chloride concentrations, indicating saltwater intrusion.

In 1977, the wells affected by saltwater were limited to near-coastal areas in Keyport and Union Beach Boroughs. By March 1977, chloride concentrations at the Union Beach Water Department well field reached 660 milligrams per liter. At Keyport, prior to the abandonment of its Myrtle Avenue plant in May 1976, chlorides ranged from about 40 to 110 milligrams per liter. It is probable that other municipal and industrial wells in adjacent coastal areas and in areas further inland will be affected in the future.

This saltwater contamination is significant since total annual pumpage from the aquifer by eight major water users in the vicinity of Keyport and Union Beach increased from 3.9 million gallons per day in 1957 to 8.0 million gallons per day in 1976.

Water-level measurements in 31 wells tapping the Old Bridge aquifer were made in 1977 to develop a map of the potentiometric (water-level) surface of the aquifer. This map shows that a cone of depression has developed in the Middlesex-Monmouth County area. This cone extends under Raritan Bay in the north and from western Middlesex County to Atlantic Highlands Borough on the east. Water levels at the center of the cone are as low as 45 feet below sea level in Hazlet Township.

The reduction in water levels has caused a reversal in the direction of ground-water flow in the Old Bridge aquifer. Prior to development, water in the aquifer flowed into Raritan Bay. However, saltwater is now flowing inland from the submerged (exposed) outcrop of the aquifer beneath Raritan Bay. The average rate of saltwater flow towards Hazlet Township was determined to be 400 feet per year (1977).

Two other potential sources of saltwater contamination are discussed and evaluated: saltwater infiltration through abandoned, unsealed wells, and contamination from excavations for sewerlines. The study shows, however, that neither source contributed significantly to the saltwater contamination of the Old Bridge aquifer.

INTRODUCTION

Technical terms when first used in the text are printed in *italics* and are defined in a glossary at the beginning of this report.

Saltwater intrusion into freshwater *aquifers* in the Coastal Plain of New Jersey has occurred at several locations and poses a threat to the potable *groundwater* supply in this region. In order to monitor this potential danger, the U.S. Geological Survey began collecting ground-water samples in some nearshore areas of the Coastal Plain as early as 1923. This basic sampling program, now called the Saltwater Monitoring Network, has been expanded to include semiannual or annual sampling of about 200 wells tapping the multilayered aquifer system of the Coastal Plain.

Saltwater intrusion was first identified in Middlesex County in the 1930's, but saltwater intrusion was not evident in Monmouth County as late as the 1960's.

However, since the early 1970's, water samples from wells tapping the Old Bridge aquifer in the Boroughs of Keyport and Union Beach, Monmouth County, have shown abnormally high *chloride concentrations,* indicating saltwater intrusion. Although the chloride concentrations did not exceed the public health standards for potable water of 250 *milligrams per liter,* the increase in concentration was considered serious enough by the New Jersey Department of Environmental Protection to warrant additional study.

Beginning in January 1977, following an intensive inventory of wells in the Keyport-Union Beach area, water levels were measured and water samples were collected for laboratory determinations of chloride concentration. These data were evaluated with other data collected since 1950. This report contains the results of that investigation.

STUDY AREA

The Boroughs of Keyport and Union Beach are located along Raritan Bay in northern Monmouth County. The study area, however, extends from Atlantic Highlands Borough on the east to Sayreville Borough in Middlesex County on the west and from Raritan Bay southward to and including parts of Old Bridge Township, Aberdeen Township, Matawan Borough, and Hazlet, Holmdel, and Middletown Townships. The area of investigation and the wells from which data were collected are shown in figure 1. A listing of these wells appears in table 1.

Table 1.-- List of wells in Monmouth and Middlesex Counties tapping the Old Bridge aquifer.

MUNICIPALITY	MAP NUMBER*	OWNER ANG LOCAL IBENTIFIER	ALTITUDE BF LAND SURFACE (FEET)	SCREENED INTERVAL (FEET)
BLB BRIBBE TWP	1	OLB BRIBBE MUNICIPAL UTILITIES AUTHORITY, ROOWNTOWN 2	95	198 - 289
	2	OLB BRIDGE TWP BOARD OF EDUCATION, CEDAR RIDGE SCHOOL	60	173 - 195
	3	BLB ROIDGE MUNICIPAL UTILITIER AUTHORITY, BROWNTOWN OBS.	45	144 - 160
	4	CLYBE BOWNE, BROWNTOWN	31	71 - 74
	5	NAPPI TRUCK CO. 2-1965	124	— - 253 **
	6	OSCHWALO BRICK 1	59	159 - 289
	7	OLD BRIDGE MUHICIPAL UTILITIES AUTHBRITY, LAWRENCE HARBOR 1	90	193 - 218
	0	OLB BRIDGE MUNICIPAL UTILITIES AUTRORITY, 1-HOPE PABK	140	107 - 177
SAYREVILLE BBRB	9	SAYREVILLE WATER DEPARTMENT 0-1973	40	78-98, 118-139
	10	SOUTH AMROY WATER BEPARTMENT 0	10	33 - 40
	11	SOUTH AMBOY WATER BEPARTMENT 10	10	39 - 40
ATLANTIC HIGHLAND BBRO	12	ATLANTIC HIGHLAND WATEB DEPARTMENT 1	28	551 - 593
	13	ATLANTIC HIGHLAND WATER DEPARTMENT 3	28	547 - 572
HAZLET TWP	14	WEST KEANSBURO WATER COMPANY 1	59	326 - 350
	15	WEST KEANSBURO WATER COMPANY 2	44	312 - 352
HOLMDEL TWP	10	WEST KEANSBURO WATER COMPANY 3	173	400 - 430
KEANSBURO BORO	17	KEANSBURG WATER DEPARTMENT 5A	10	298 - 350
	18	KEANSBURG WATER BEPARTMENT 3	12	308 - 348
KEYPBHT BBRO	19	KEYPORT BOROUGH WATER BEPARTMENT 7	35	304 - 364
	28	KEHR OLASS COMPANY, REPLACEMENT 2	20	285 - 315
HAZLET TWP	21	LEX LUCAS 1	RO	250 - 262
KEYPORT BORB	22	KEYPORT ROROUOH WATER DEPARTMENT 5	10	204 - 267
	23	KEYPORT RORBUGH WATER BEPARTMENT 1	18	211 - 271
	24	KEYPBRT BOROUBH WATER DEPARTMENT 4	18	229 - 289
	25	KEYPORT ROROUGH WATER DEPARTMENT 6	10	247 - 277
	28	INFERN-O-THERM 1	18	— - 300 **
MATAWAN BORO	27	MATAWAN ROROUGH WATER DEPARTMENT 4	90	220-238, 248-268
	28	MATAWAN ROROUGH WATER DEPABTMENT 3	90	231 - 271
ABEHBEEN TWP	29	ABERDEEN TWP MUNICIPAL UTILITIES AUTHORITY 3	94	325 - 345
	30	ABERDEEN TWP MUNICIPAL UTILITIER AUTHBRITY 2	65	318 - 364
	31	MATAWAN ROROUGH WATER BEPARTMENT 1	30	222 - 252
	32	MATAWAN ROROUOH WATER BEPARTMENT 2	39	228 - 250
MIBDLETOWN TWP	33	ENGINEERED PRECISION CASTING 1-1964	28	354 - 364
	34	SEA COAST PRODUCTS, SMITH 1	18	— - 420 **
UNION BEACH BORB	35	UNION BEACH WATER DEPARTMENT 2-1927	10	298 - 311
	39	UNION BEACH WATER DEPABTMENT 1-1962	10	235 - 299
	37	UNION BEACH WATER DEPARTMENT 2-1969	18	282 - 299
	38	UNION BEACH WATER BEPARTMENT 1-1927	18	240 - 299
	39	INTERNATIONAL FLAVORS & FRABRANCES CORP. 1	18	298 - 326
	40	INTERNATIONAL FLAVORS & FRAGRANCES CORP. 2	18	302 - 326
	41	INTERNATIONAL FLAVORS & FRAGRANCER CORP. 3-R	10	272 - 310

*Locations shown in figure 1
**Total depth

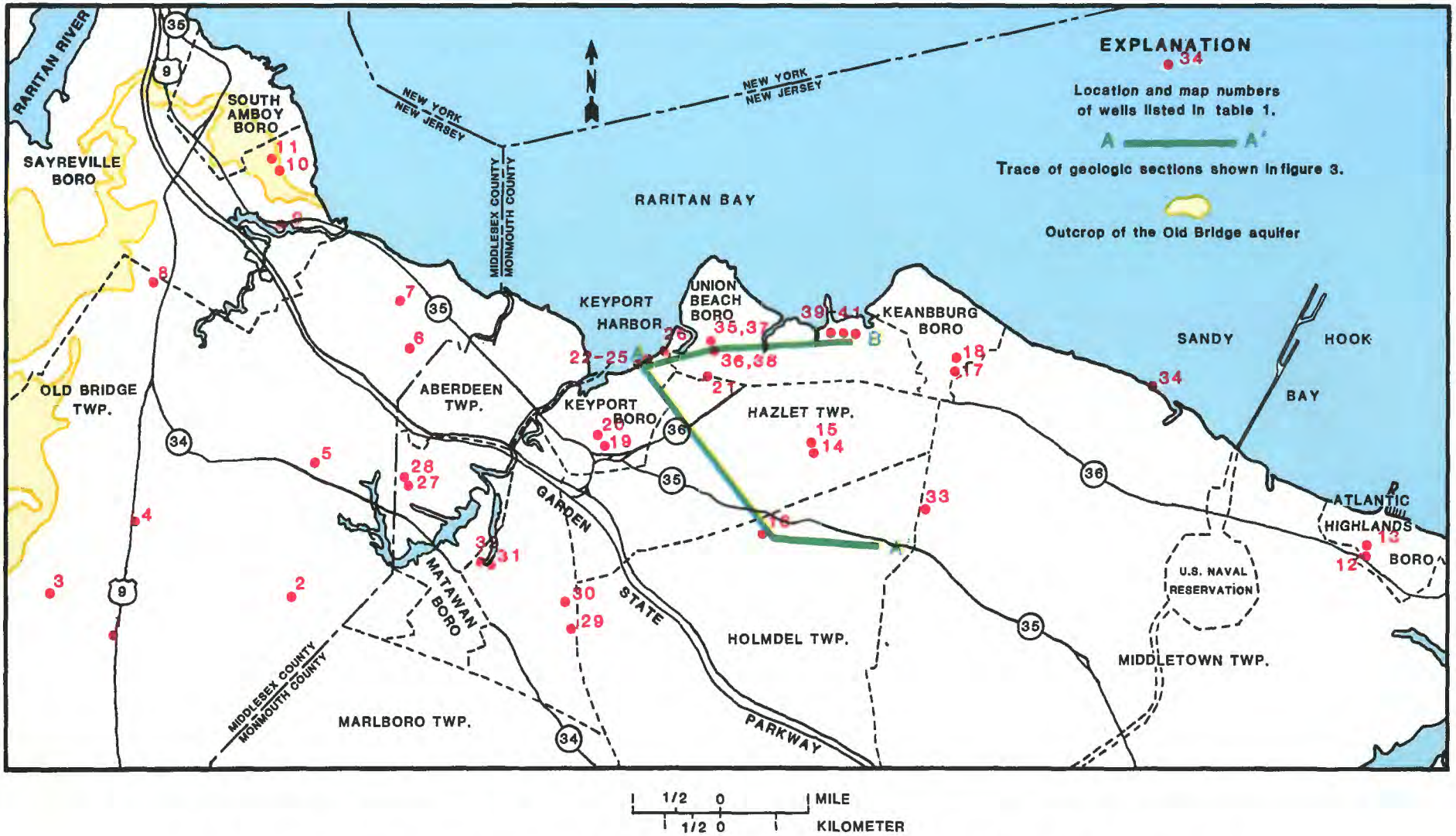

Figure 1.--Middiesex-Monmouth County study area and iocation of weiis tapping the Oid Bridge aquifer.

GEOHYDROLOGY

The most productive source of ground water in the northern part of the Coastal Plain of New Jersey is the Potomac-Raritan-Magothy aquifer system. The position of the major aquifers (the Farrington and Old Bridge aquifers) and *confining layers* within this system are shown in figure 2. This aquifer system is composed of layers of silts, clays, sands, and gravels lying on dense crystalline bedrock. The sediments are exposed at land surface in northeast-southwest trending bands. In cross section they appear as wedge-shaped layers which slope in a southeasterly direction at a rate from 10 to 60 feet per mile. The total thickness of these sediments increases from about 0 to 150 feet in Middlesex County to 1,700 feet in Monmouth County.

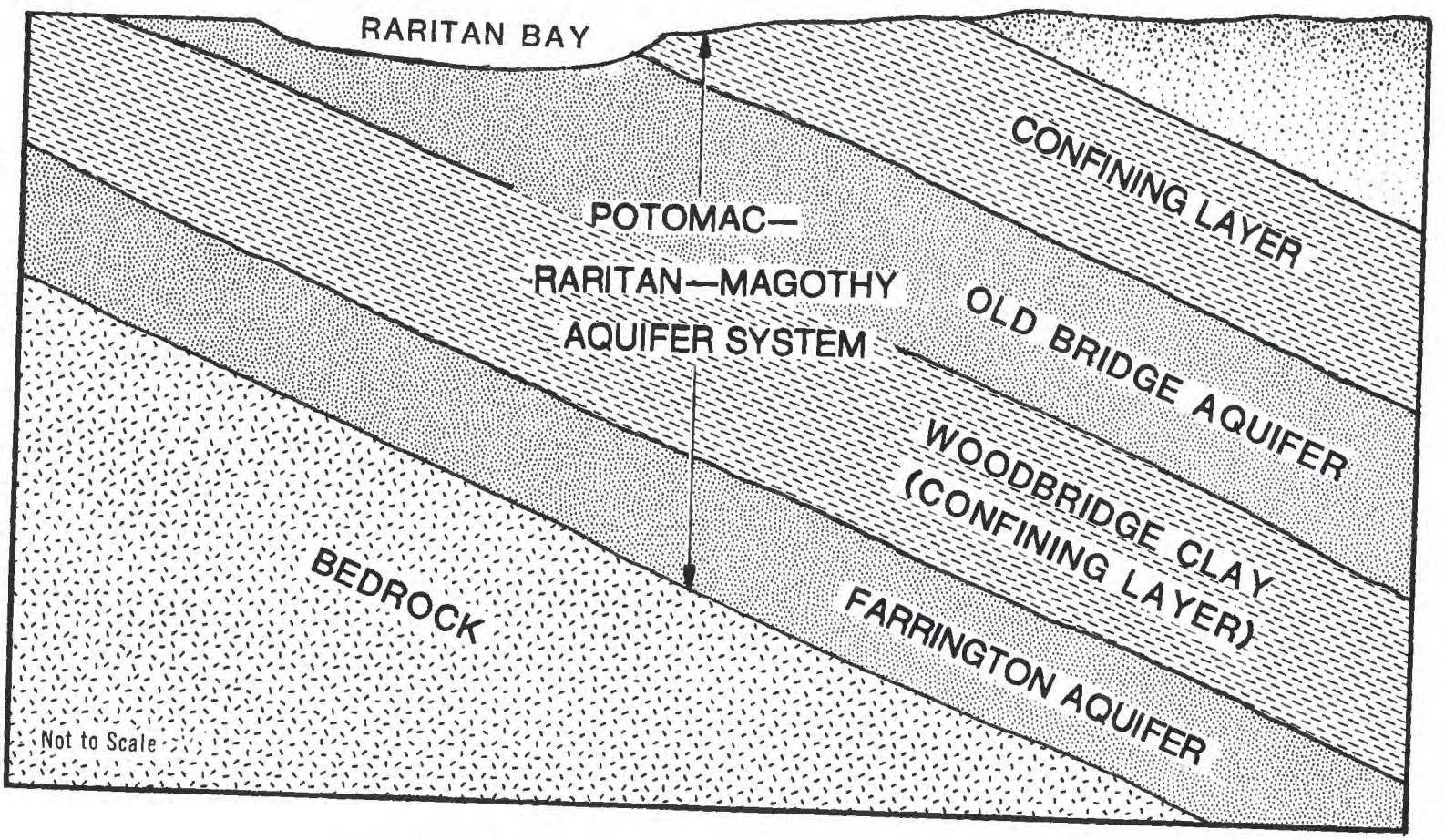

Figure 2.--Geohydrology of the northern Coastal Plain.

Old Bridge Aquifer

The Old Bridge aquifer consists primarily of sand, with locally thin, irregular clay beds. The *outcrop area* of the Old Bridge aquifer lies four to five miles northwest of Keyport. It is exposed as an irregular band that extends from beneath Raritan Bay near South Amboy to the southwest (fig. 1). Water in the outcrop area is under *water-table* conditions. To the southeast, in the Keyport-Union Beach area, the Old Bridge is an *artesian aquifer* underlain and overlain by confining layers of silt and clay. The top of the aquifer in the Keyport-Union Beach area varies in depth from about 200 to 300 feet below sea level and in thickness from 80 to 120 feet (fig. 3).

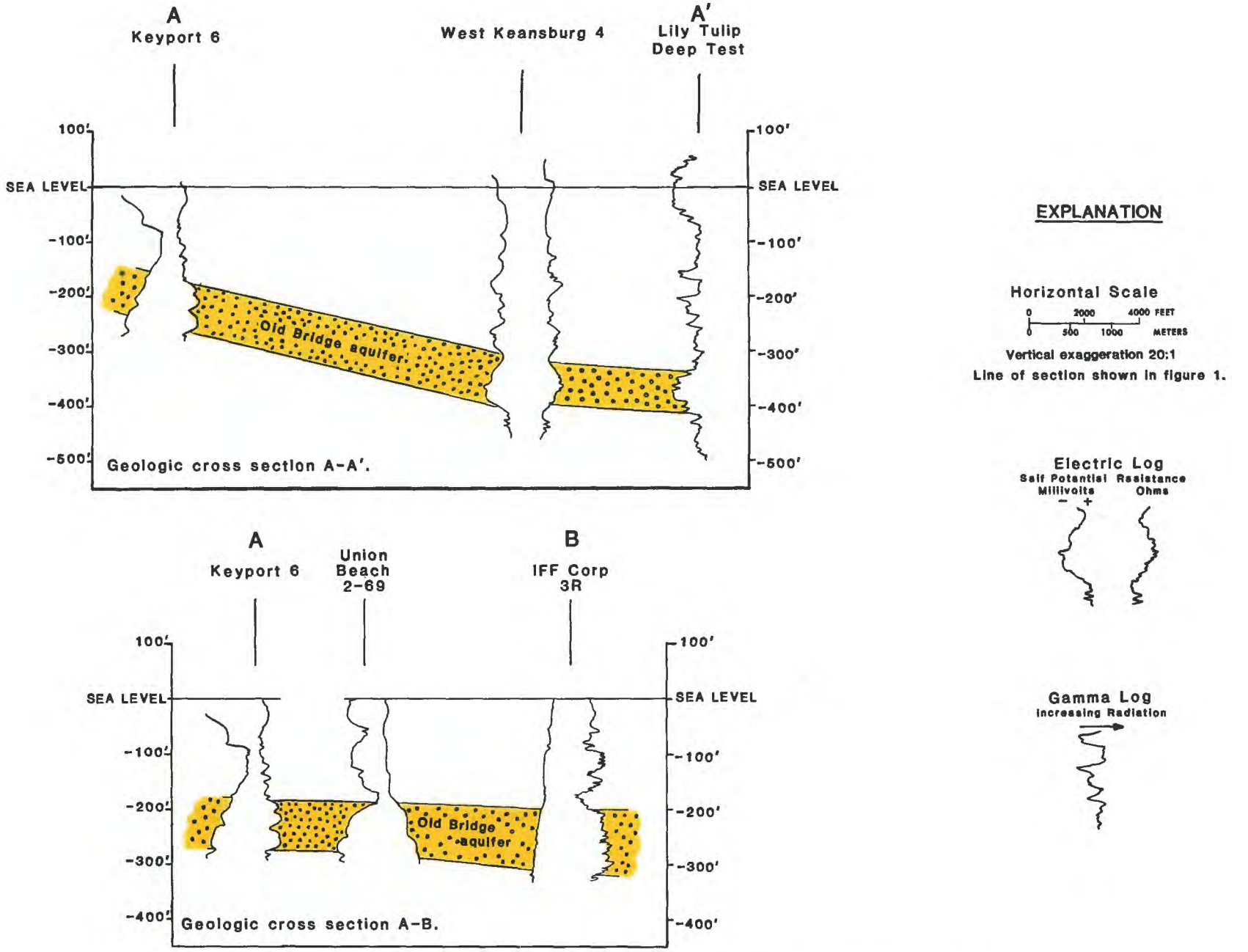

Figure 3.--Generalized geologic cross sections along lines A-A' and A-B of figure 1.

Ground-Water Movement

The Old Bridge aquifer is replenished primarily by precipitation on the outcrop area and by passage of water from surface-water bodies overlying the outcrop. These surface-water bodies include streams, ponds, and lakes, as well as Raritan Bay. Prior to well development in the northern part of the Coastal Plain, water flowed through the aquifer entirely in response to natural *hydraulic gradient* from areas of higher *head (recharge areas)* to areas of lower head *(discharge areas).* Ground water flowed in a curvilinear pattern from the high intake areas in Middlesex County through Monmouth County and then discharged into Raritan Bay.

Ground-water withdrawals (pumpage) from the Old Bridge aquifer in the Keyport-Union Beach area more than doubled between 1957 and 1976 (from 3.9 to 8.0 Mgal/d). This increased withdrawal has caused significant changes in the water level in the region (fig. 4). These changes have altered the direction of ground-water flow, particularly in the study area where a reversal in the predevelopment flow is apparent.

A *potentiometric surface* map showing water levels was made from water-level measurements of 31 wells tapping the Old Bridge aquifer in 1977 (fig. 5). A *cone of depression* centered in Hazlet Township shows water levels as low as 45 feet below sea level in 1977 as compared to 10 feet below sea level in 1957 (fig 4.). This cone of depression extends under Raritan Bay in the north and from beyond Atlantic Highlands on the east to western Middlesex County.

Potentiometric data shown in figures 5 and 6 are useful in determining the general direction of ground-water flow in a region and also in determining the rate of this flow. Ground-water flow is in the direction of lowest head and perpendicular to the potentiometric contours. Rate of flow in the Old Bridge aquifer can be determined from a series of aquifer data: a *hydraulic conductivity* of 125 ft/d, an *effective porosity* of 25 percent, and a hydraulic gradient of 13 ft/mi (along section C-C' of fig. 6). These data yield an average rate of ground-water flow of 1.2 ft/d, or about 400 ft/yr (January 1977). It should be stressed that this rate of flow is an approximation and should not be used for accurate prediction of the distance traveled or arrival time of any contaminant.

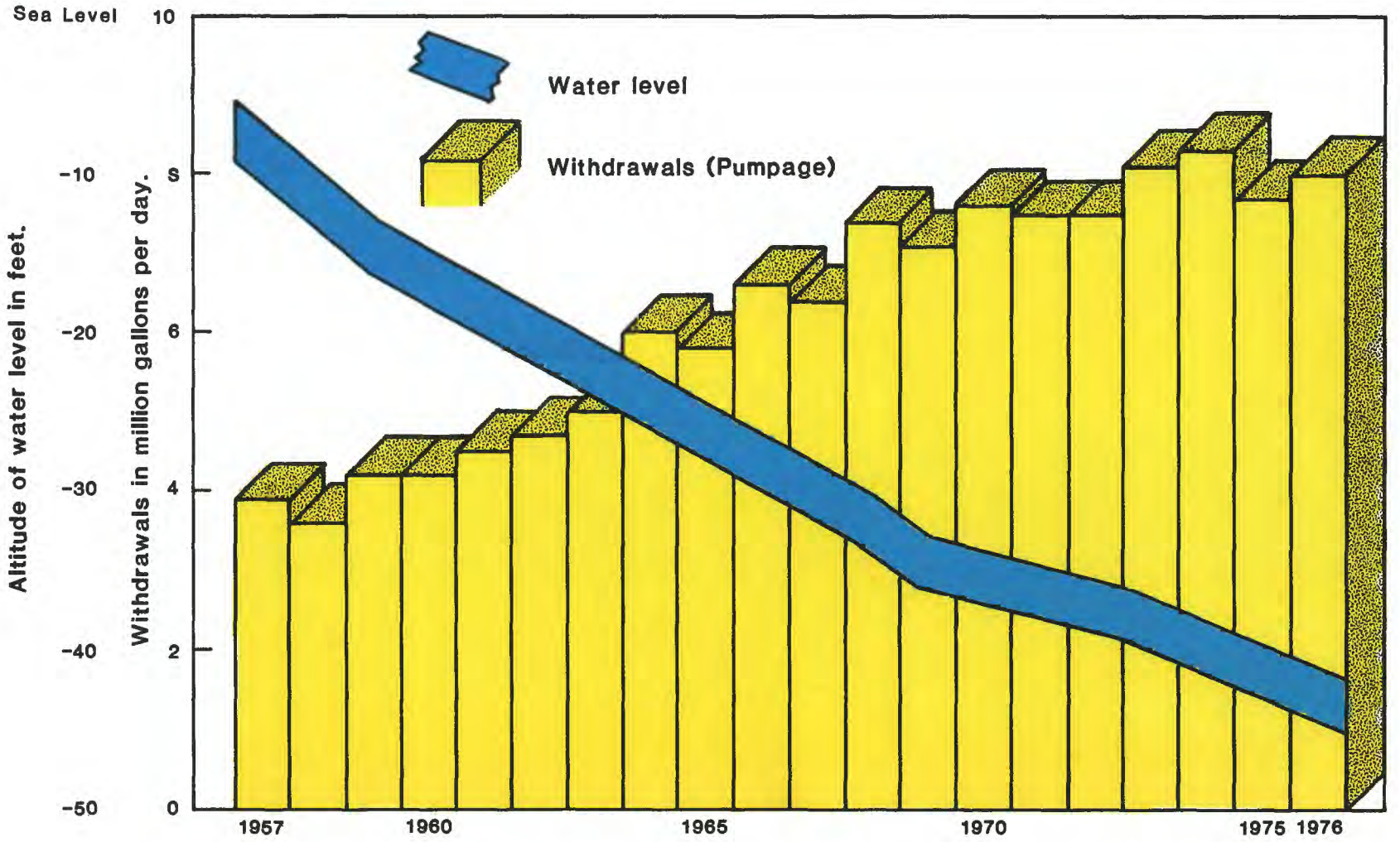

Figure 4.--Ground-water withdrawals from the Old Bridge aquifer and water levels in Hazlet Township.

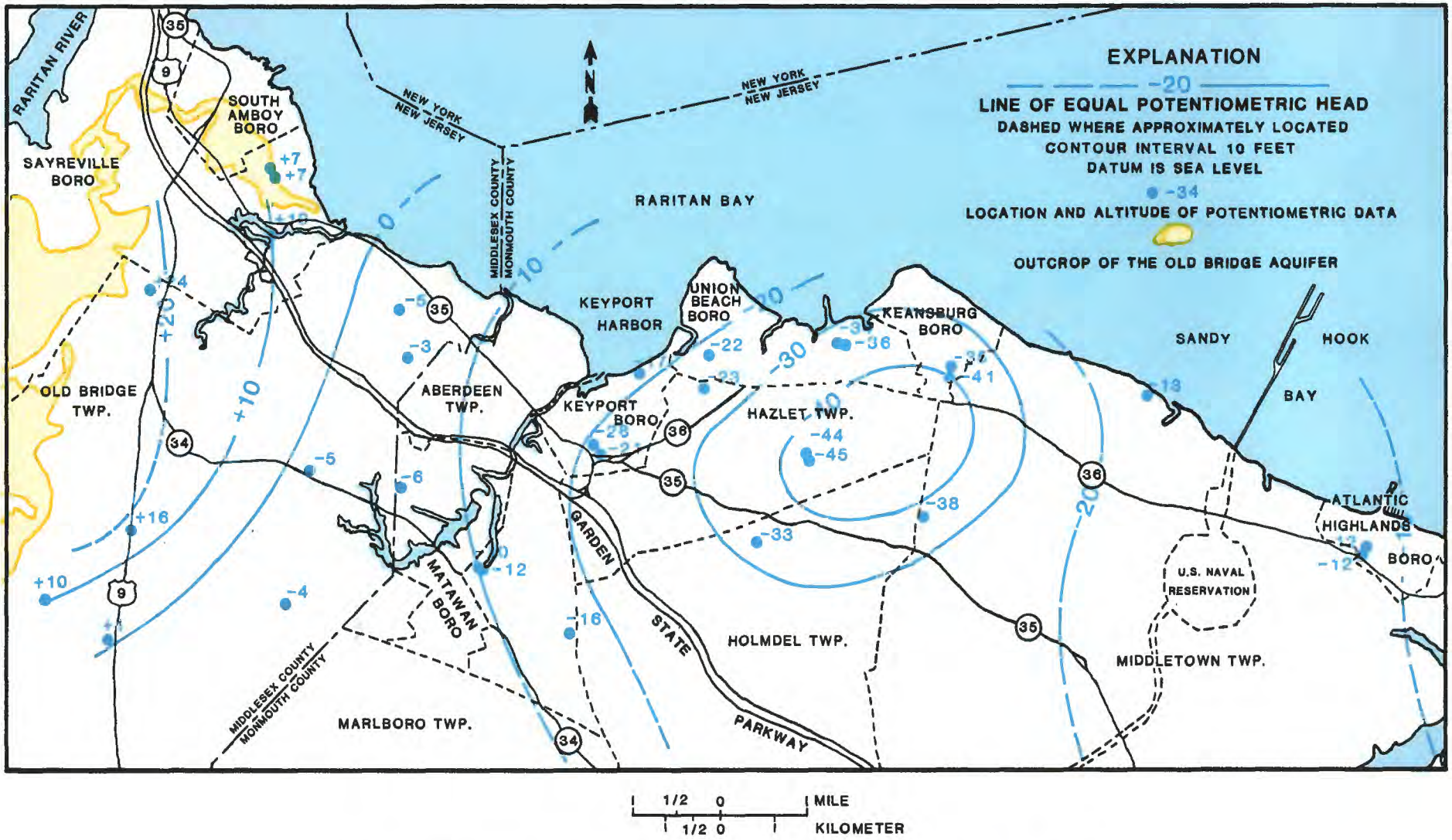

Figure 5.--Potentiometric surface of the Old Bridge aquifer (January 1977).

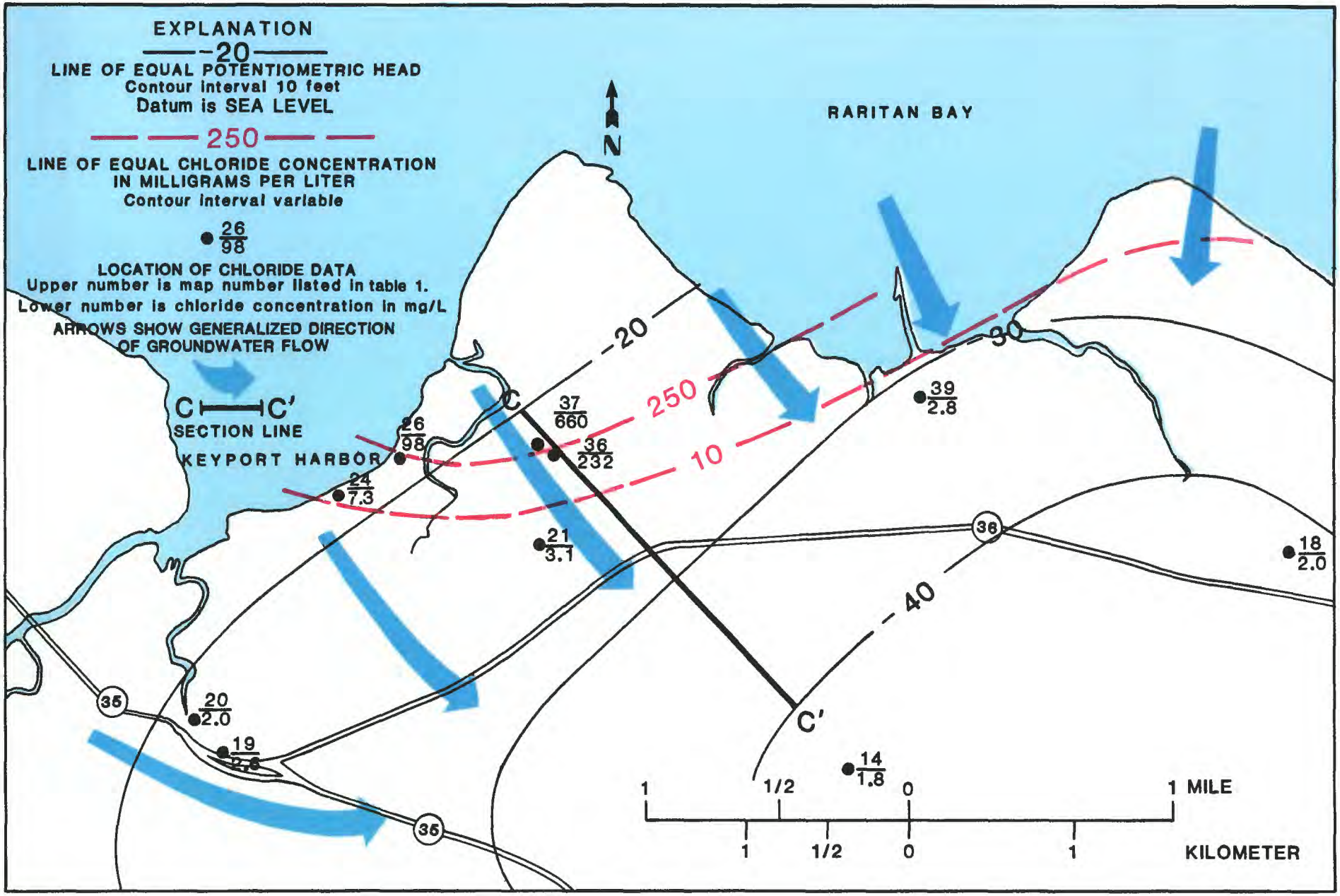

Figure 6.--Potentiometric surface and chloride contours of the Old Bridge aquifer in the Keyport-Union Beach area (1977).

CHLORIDE CONCENTRATIONS OF WATER IN THE OLD BRIDGE AQUIFER

Wells in the coastal area along Raritan Bay in northern Monmouth and northeastern Middlesex Counties generally have been sampled on a semi-annual basis since 1950. Most of the sampling was during the summer, the period of heaviest pumpage. Less comprehensive sampling was done in the spring during most years to continue the surveillance and to determine significant seasonal variations. Water samples were collected from pumping wells, many of which were high-yielding production wells. The samples are analyzed in the laboratory for chloride concentration which is used as an indicator of saltwater intrusion.

Chloride analyses from 27 wells sampled in 1977 show high chloride concentrations in the coastal area along Raritan Bay from the abandoned Keyport Water Department well fieid eastward into Union Beach Borough. The approximate area of the Old Bridge aquifer affected by saltwater is shown by the positions of the 10 mg/L and 250 mg/L chloride contours in figure 6. The 250 mg/L chloride concentration is the maximum recommended for potable water.

Data collected in the area since 1950 are presented graphically in figure 7. These long-term records show no significant increasing trends of chloride concentrations outside of the Keyport-Union Beach area. Chlorides outside of Keyport-Union Beach area are within background levels; about 5 mg/L in that part of the aquifer under artesian conditions, and 10 to 20 mg/L in the outcrop area.

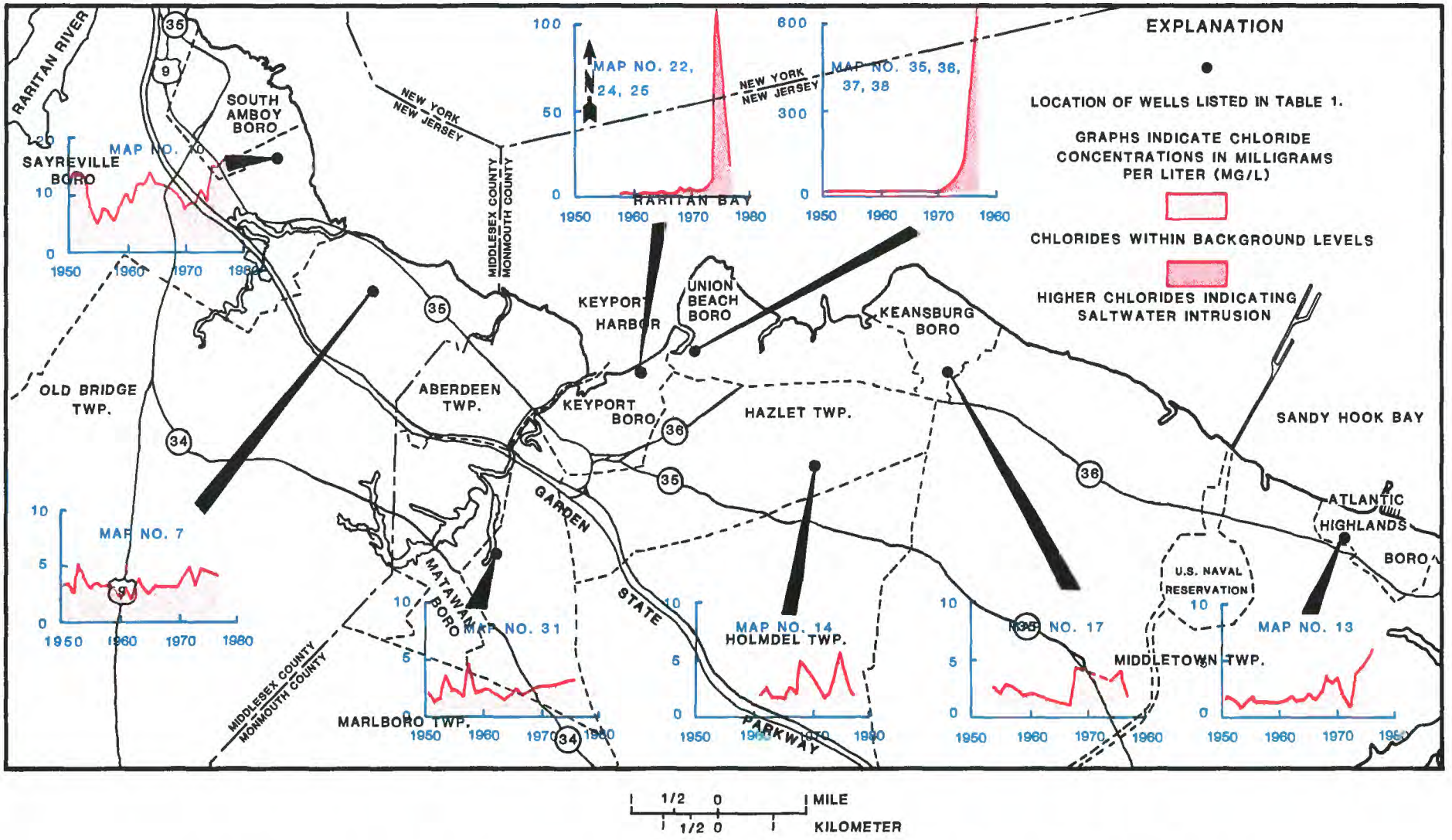

Figure 7.--Trends of chloride concentrations in water samples from wells tapping the Old Bridge aquifer.

Union Beach Borough

Changes in chloride concentration at the Union Beach well field from 1950 to 1977 are shown in figure 8 (reference map nos. 35, 36, 37, and 38). A significant increase of chloride concentration from background levels began about 1970. Since then the chloride concentration has increased steadily and reached 660 mg/L by 1977.

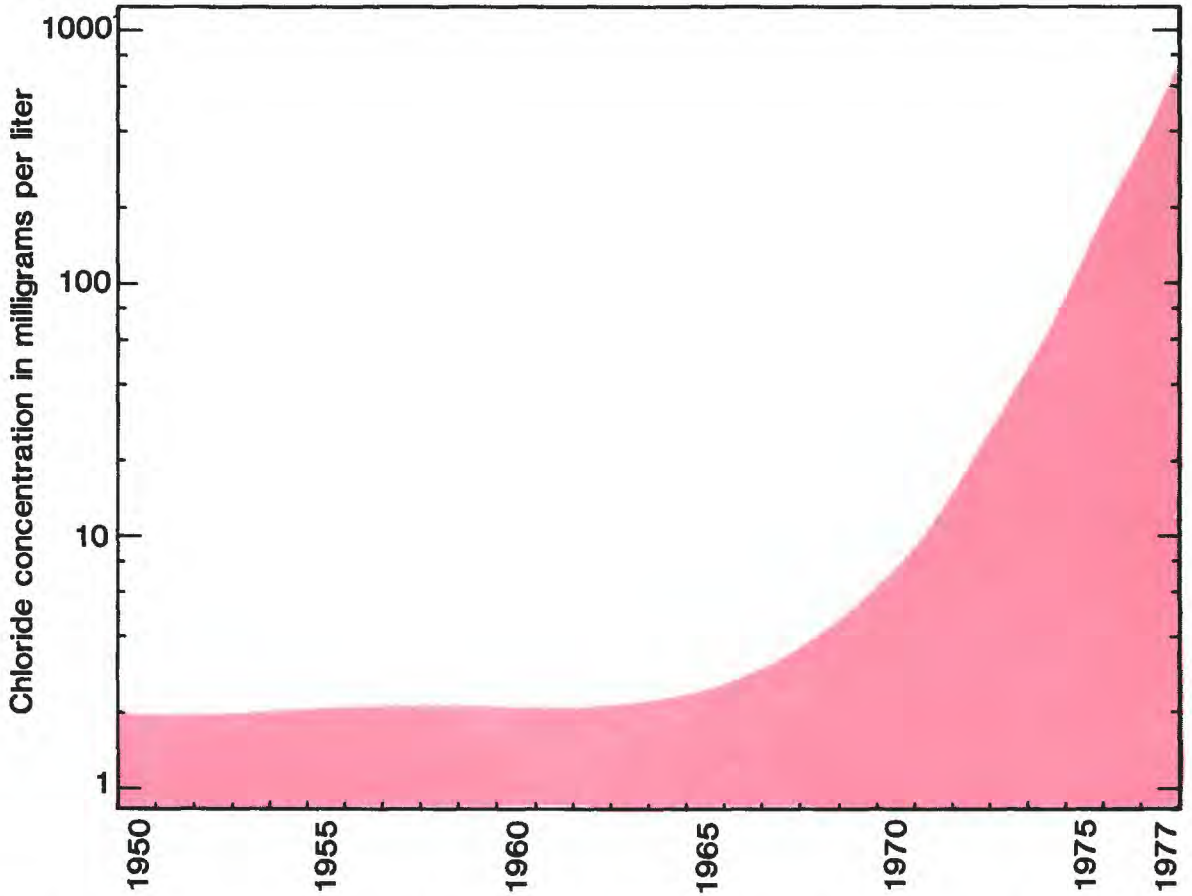

Figure 8.--Chloride concentrations in water samples from the Union Beach Borough well field (1950-77).

Keyport Borough

Changes in chloride concentration at the Keyport Water Department well field from 1950 to 1977 are shown in figure 9 (*reference map nos.* 22, 24, and 25). The pattern of increasing chloride concentration is similar to that at Union Beach Borough. At Keyport, chlorides ranged from about 40 to 110 mg/L prior to the abandonment of the Myrtle Avenue plant in May 1976. Because the pumping was stopped at this plant, chlorides decreased to about 7 mg/L by 1977.

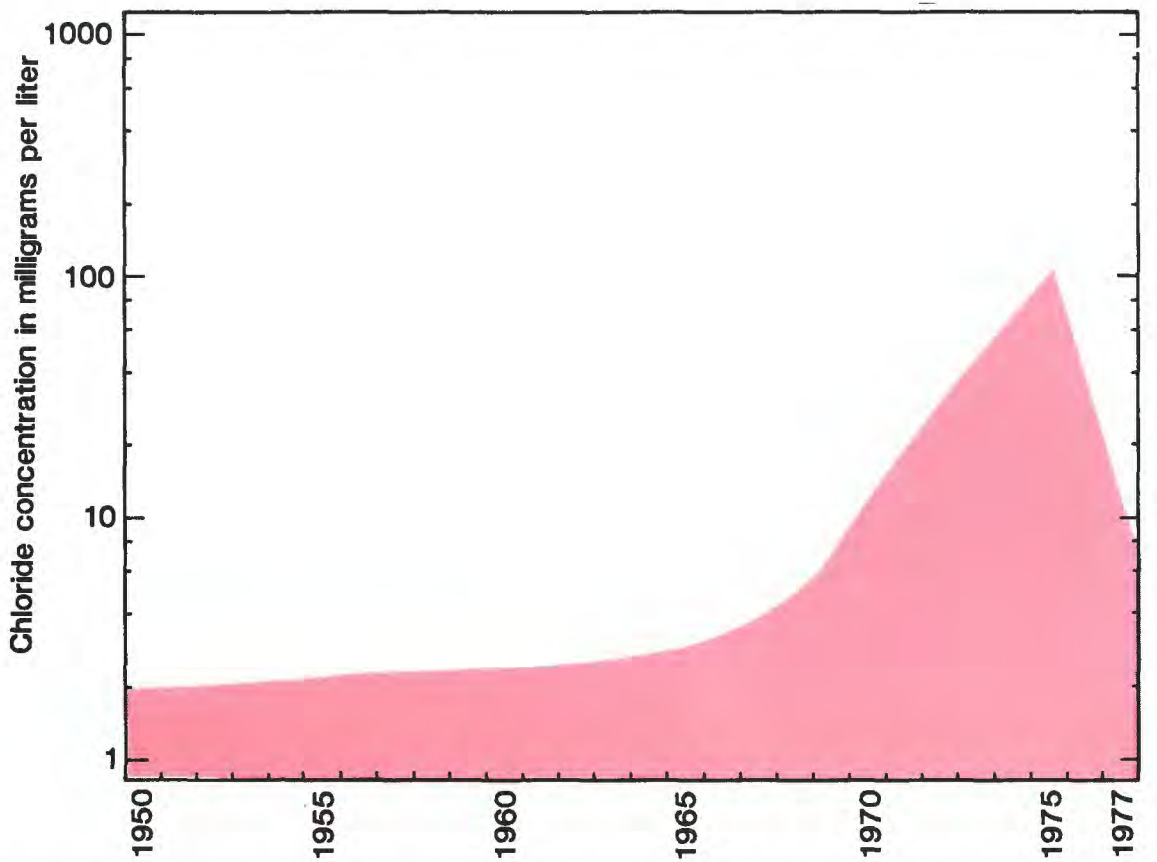

Figure 9.--Chloride concentrations in water samples from the Keyport Borough well field (1950-77).

POSSIBLE SOURCES OF CHLORIDE CONTAMINATION

Three possible sources of chloride contamination were considered:

Saltwater Intrusion into the Old Bridge Aquifer from Raritan Bay

Saltwater intrusion from Raritan Bay is the most probable source of chloride contamination. Ground-water withdrawals have caused a decline in the water level (potentiometric surface) of the Old Bridge aquifer in the Keyport-Union Beach area. As a result, the natural (predevelopment) hydraulic gradient has been reversed, with the potential existing for inland movement of saltwater from the submerged outcrop beneath Raritan Bay (fig. 10). The occurrence of higher chloride concentrations in wells near Raritan Bay than in wells further inland and the increase in chloride concentrations in Keyport-Union Beach wells substantiate the above conclusion.

Contamination Resulting from Large Scale Sewerline Construction

Construction of 12- to 42-inch trunk and main sewerlines in the area could cause chloride contamination if a breach occurred in the confining layer overlying the Old Bridge aquifer. However, the confining layer has an average thickness of 150 feet in the Keyport-Union Beach area with the top of the confining layer (clay) 30 to 40 feet below sea level. Therefore, it is unlikely that excavation for the sewerlines could have cut through this confining layer. In addition, data presented in figures 8 and 9 indicated chloride concentrations began increasing above background level about 1970, while excavations in Union Beach and Keyport occurred later, in 1972 and 1975, respectively.

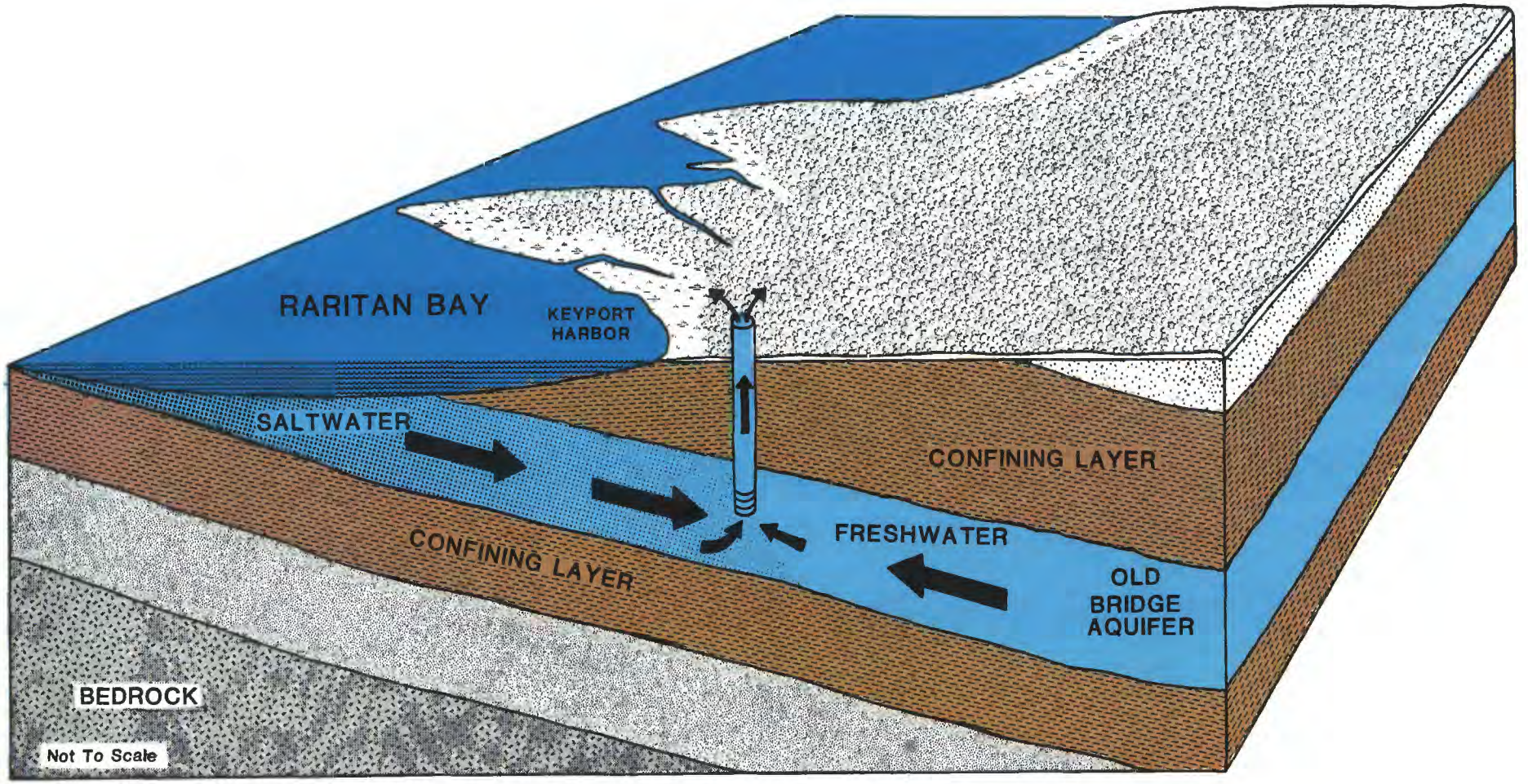

Figure 10.--Ground-water flow showing saltwater intrusion in the Old Bridge aquifer.

Contamination Through Abandoned, Unsealed Wells

Several abandoned wells in the Keyport-Union Beach well fields have been considered as possible sites of contamination. Saltwater in overlying sands and tidal marshes could enter the Old Bridge aquifer through improperly sealed wells or through corroded casings in the abandoned, unsealed wells.

There were two abandoned wells in the Union Beach well field. Well drilling contractors indicated that both wells had been sealed in accordance with state regulations, and an inspection of the sites confirmed that both wells had been covered with concrete pads. Therefore, no significant chloride contamination could have occurred through these wells.

There were eight abandoned and unsealed wells in the Keyport well field. One of the eight wells was found to be filled in while two others could not be located and were presumed to be destroyed. In 1977, static water levels were measured in four of the five remaining wells, and all levels were about 17 feet below sea level. Since the water table in the area was at or near sea level, higher water levels in any one of the wells would have suggested downward leakage. Because the measured water levels were uniform and much lower than the water table, it was deduced that there was no significant leakage. *Specific conductance* and temperature measurements were also taken in one of these wells (reference map no. 24). There were no significant changes in the measurements with depth, also suggesting no casing breaks in the well and, therefore, no leakage.

SUMMARY AND CONCLUSIONS

The increased chloride concentration of well water in Keyport and Union Beach Boroughs is a result of lateral saltwater intrusion into the Old Bridge aquifer from the submerged outcrop beneath Raritan Bay. Increased pumpage has caused the formation of a large cone of depression southeast of Keyport and Union Beach in Hazlet Township. In January 1977, water levels near the center of this cone were as low as 45 feet below sea level. This reduction in freshwater head has caused a reversal of the bayward hydraulic gradient that existed prior to well development. The change in hydraulic gradient now allows saltwater to flow laterally in the Old Bridge aquifer from the Bay toward the center of the cone in Hazlet Township.

The saltwater reached Keyport and Union Beach about 1970 and continues to move in a southeasterly direction. By March 1977, chloride concentrations at the Union Beach well field were as high as 660 mg/L. At Keyport, prior to the abandonment of its Myrtle Avenue plant in May 1976, chlorides ranged from about 40 to 110 mg/L. The rate of ground-water movement was determined to be about 400 ft/yr (1977). Any increases in withdrawal rates in this area may increase the existing gradients and, thereby, accelerate the saltwater intrusion.

The possibility of saltwater contamination from two other sources was evaluated in this study: vertical leakage through abandoned, unsealed wells and contamination resulting from excavations for sewerlines. However, it was shown that neither source has contributed to the contamination of the Old Bridge aquifer.

Continued monitoring of the saltwater intrusion is essential in order to document and possibly predict future contamination of freshwater. Initially, the monitoring program should include quarterly or semiannual chloride analyses and water-level measurements. The monitoring network should extend along the coast from Sayreville eastward to Sandy Hook.

In the Keyport-Union Beach area, the following should be accomplished:

- Maintain Keyport Borough Water Department well 4 for water-level measurements.
- Use Keyport Borough wells 1, 5, and 6 for sampling.
- Maintain Infern-o-therm well in Keyport Borough as a monitoring well.
- Properly seal the remaining Keyport Borough wells in accordance with New Jersey Department of Environmental

Protection regulations.

- If the present Union Beach Borough wells are closed, well 1-1962 should be maintained as a monitoring well.

Test wells should be drilled into the Old Bridge aquifer at strategic locations inland of the present freshwater-saltwater *diffusion zone,* preferably in areas northeast and east of the Union Beach well field where no data are currently available. These wells would provide additional data that would better define the aquifer characteristics and, if continually monitored, would provide additional water-level and water-quality data.

To assist with planning and management, hydrologic computer models should be developed to simulate ground-water flow and the movement of saltwater in the Old Bridge aquifer.

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