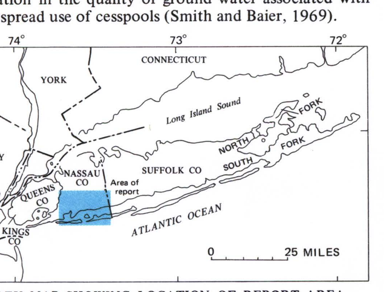
Prepared in cooperation with the
NASSAU COUNTY DEPARTMENT OF PUBLIC WORKS

INTRODUCTION

In Nassau County (index map) all fresh-water supplies are derived from ground-water sources, of which the Magothy is the principal aquifer. Continued population growth and industrial growth will result in increasing ground-water withdrawals. In addition, the increasing use of sewers, instead of cesspools, to dispose of waste water is steadily reducing the amount of artificial recharge to the ground-water reservoir (Franke, 1968). Large-scale sanitary sewerage systems are being constructed largely in an attempt to alleviate or prevent deterioration in the quality of ground water associated with the widespread use of cesspools (Smith and Baier, 1969).



INDEX MAP SHOWING LOCATION OF REPORT AREA.

With continuously increased withdrawals and decreased artificial recharge, the landward movement in southern Nassau County of the interface between fresh and salty ground water (salt-water front) threatens the public-water supplies of the county (Lusczynski and Swarzenski, 1966). However, the threat is long-term because the rate of landward movement of the salt-water fronts is presently minimal, except locally in an area of intensive ground-water development near the zone of diffusion (Cohen and Kimmel, 1970) The positions of the salt-water fronts are shown on the map showing extent of Pleistocene marine clay.

This report evaluates the suitability of the hydrogeologic environment of the Magothy aquifer for development of a hydraulic barrier to retard or halt salt-water intrusion into the aquifer. The barrier, as proposed by Greeley and Hansen, Engineers (1963), would consist of a line of wells through which reclaimed water (highly treated sewage-plant effluent) would be injected into the Magothy aquifer. The line of wells would be about 1 mile south of Sunrise Highway and would extend across the width of Nassau County.

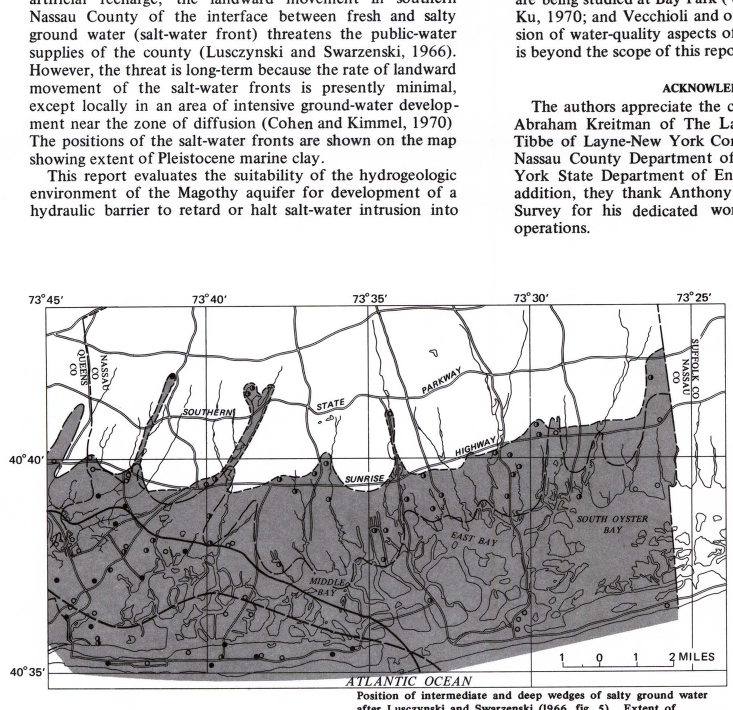
The report area includes that part of Nassau County south of a line from Mineola to Bethpage and encompasses about 150 square miles. Drillers', geological, and geophysical logs for more than 150 wells were studied, and 15 gamma-ray logs were made to supplement the existing data.

The U.S. Geological Survey and the Nassau County Department of Public Works are cooperating on several other closely related studies to determine the feasibility of injecting reclaimed water into the Magothy aquifer. Recharge experiments at Bay Park are part of these studies (Cohen and Durfor, 1967; Peters and Rose, 1968; Perlmutter and others, 1968).

The occurrence and the movement of certain sewage constituents, notably inorganic compounds of nitrogen, in the ground-water system of Nassau County (Perlmutter and Koch, 1971 and 1972) are of considerable concern to water managers. Conceivably, some of the reclaimed water injected into the Magothy aquifer through the proposed barrier-recharge wells would flow inland and reach nearby public-supply wells. Thus, these public-supply wells ultimately might yield water that is partly or largely reclaimed water and, as such, would contain residual sewage constituents, including compounds of nitrogen. Accordingly, water-quality problems associated with the injection of the reclaimed water are being studied at Bay Park (Vecchioli, 1970; Vecchioli and Ku, 1970; and Vecchioli and others, 1972). However, discussion of water-quality aspects of injecting the reclaimed water is beyond the scope of this report.

ACKNOWLEDGMENTS

The authors appreciate the cooperation received from Mr. Abraham Kreitman of The Lauman Co., Inc., Mr. George Tibbe of Layne-New York Company, Inc., personnel of the Nassau County Department of Public Works, and the New York State Department of Environmental Conservation. In addition, they thank Anthony A. Giaimo of the Geological Survey for his dedicated work in the geophysical-logging operations.



EXPLANATION

- EXTENT OF PLEISTOCENE MARINE CLAY
- WELL PENETRATING GARDINERS CLAY
- WELL PENETRATING "20-FOOT" CLAY
- WELL PENETRATING "20-FOOT" CLAY AND GARDINERS CLAY
- APPROXIMATE EXTENT OF "20-FOOT" CLAY
- APPROXIMATE EXTENT OF GARDINERS CLAY
- APPROXIMATE LANDWARD EXTENT OF INTERMEDIATE WEDGE OF SALTY GROUND WATER
- APPROXIMATE LANDWARD EXTENT OF DEEP WEDGE OF SALTY GROUND WATER

Position of intermediate and deep wedges of salty ground water after Lusczynski and Swarzenski (1966, fig. 5). Extent of Pleistocene marine clay after Perlmutter and Geraghty (1963, fig. 7).

MAP SHOWING EXTENT OF PLEISTOCENE MARINE CLAY AND POSITION OF INTERMEDIATE AND DEEP WEDGES OF SALTY GROUND WATER IN SOUTHERN NASSAU COUNTY.

HYDROGEOLOGY OF THE MAGOTHY AQUIFER

A summary of the hydrogeology of the Magothy aquifer and overlying and underlying units in southern Nassau County is given in the table and pertinent data are shown on the hydrogeologic map.

Water in the Magothy aquifer is confined below by the Raritan Clay. The contact between the Magothy aquifer and the underlying Raritan Clay is a fairly regular surface, sloping about 60 feet per mile toward the south-southeast. Under the barrier beaches in the western part of Nassau County, the Raritan Clay separates the fresh-water in the deeper Lloyd aquifer from saline water in the overlying Magothy aquifer (Lusczynski and Swarzenski, 1966, p. 57).

The upper surface of the Magothy aquifer, highly irregular in places, slopes to the south. Deep valleys cut into the Magothy aquifer were subsequently filled with coarse-grained sedimentary deposits during the Pleistocene Epoch. The deeper valleys trend southwestward in the southwest corner of the study area, where they were cut more than 200 feet below the general surface of the Magothy. Three of the valleys cross the proposed line of recharge wells. These valleys are of hydraulic significance because the valley-fill material is moderately to highly permeable and provides a high degree of hydraulic interconnection between the Magothy aquifer and the overlying upper glacial aquifer. Other buried valleys probably exist beneath the southshore bays, but data to define them are not available in those areas. Pleistocene marine clay (combined Gardiners Clay and "20-foot" clay) is found in much of the southern part of the study area, but it pinches out to the north, as shown on the smaller map of southern Nassau County and on section *E-E'*. The Pleistocene marine clay is a confining layer for the underlying Magothy aquifer. In places, the Pleistocene marine clay lies directly above the Magothy aquifer. In other places, especially where buried channels are found, the clay is separated from the Magothy aquifer by the Jameco aquifer.

As shown on the regional hydrogeologic sections, a gravelly zone near the base of the Magothy aquifer is the only laterally extensive unit underlying the area of study. To provide a more detailed analysis of the geology along the proposed recharge-well line, larger scale sections were compiled for four areas of abundant data. These areas are at Bay Park, Rockville Centre, Freeport, and Seaford. The wells used in compiling each of these sections are not more than 2 miles apart. As shown in the section at Bay Park, individual beds in the Magothy aquifer can be correlated between wells that are 300 feet apart. However, the other three sections show few or no correlative units in the Magothy aquifer. The difficulty of correlating between the closely spaced wells suggests that most clayey and silty units in the Magothy aquifer have small areal extent and that the largest lateral dimension of the units generally ranges from 300 to 5,000 feet. The most discernible areally extensive clay bed is in the Freeport area (Section *E-E'*). The areal extent of this northwest-trending unit is about 1 by 3 miles.

Owing to interfingering of the individual sand beds in the Magothy aquifer, the hydraulic effects of injecting water into the Magothy would not be confined to the zone of injection. Rather, the injection head would tend to be dissipated through the full thickness of the aquifer. Along the proposed line of recharge wells the Magothy is as thick as 800 feet (hydrogeologic map). Therefore, the vertical dissipation of the injection head could be considerable.

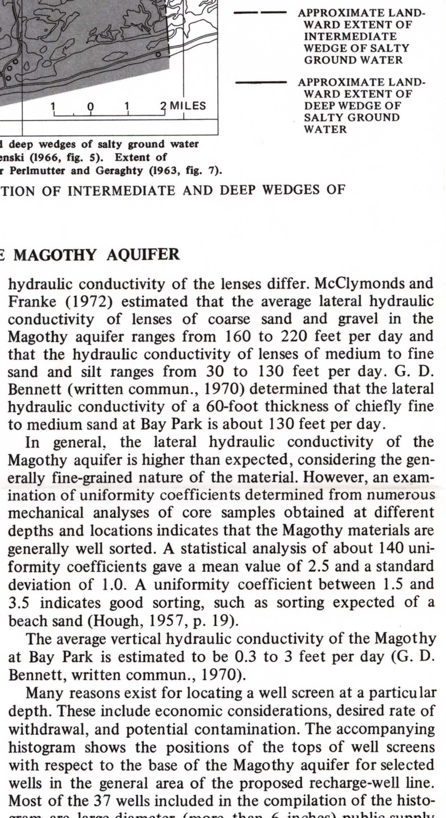
The apparent lack of correlative units between wells may partly be due to a lack of uniform lithologic samples from the Magothy. The drillers' and geologists' logs used in this study were compiled over many years by many individuals. A better definition and correlation of units can commonly be made where lithologic logs are supplemented with geophysical logs, such as gamma-ray logs. The gamma-ray logging technique is particularly useful because logs can be obtained through the casing in the wells and also because on Long Island, gamma logs generally provide an excellent definition between clay and sand. For example, a comparison of the gamma-ray and lithologic logs for wells N4149 and N4150, shown in the Freeport section, *J-J'*, indicates that an increase in natural radiation reflects an increase in clay content.

The Magothy aquifer is made up of many lenses, which differ in mean grain size and clay content. Consequently, the hydraulic conductivity of the lenses differ. McClymonds and Franke (1972) estimated that the average lateral hydraulic conductivity of lenses of coarse sand and gravel in the Magothy aquifer ranges from 160 to 220 feet per day and that the hydraulic conductivity of lenses of medium to fine sand and silt ranges from 30 to 130 feet per day. G. D. Bennett (written commun., 1970) determined that the lateral hydraulic conductivity of a 60-foot thickness of chiefly fine to medium sand at Bay Park is about 130 feet per day.

In general, the lateral hydraulic conductivity of the Magothy aquifer is higher than expected, considering the generally fine-grained nature of the material. However, an examination of uniformity coefficients determined from numerous mechanical analyses of core samples obtained at different depths and locations indicates that the Magothy materials are generally well sorted. A statistical analysis of about 140 uniformity coefficients gave a mean value of 2.5 and a standard deviation of 1.0. A uniformity coefficient between 1.5 and 3.5 indicates good sorting, such as sorting expected of a beach sand (Hough, 1957, p. 19).

The average vertical hydraulic conductivity of the Magothy at Bay Park is estimated to be 0.3 to 3 feet per day (G. D. Bennett, written commun., 1970).

Many reasons exist for locating a well screen at a particular depth. These include economic considerations, desired rate of withdrawal, and potential contamination. The accompanying histogram shows the positions of the tops of well screens with respect to the base of the Magothy aquifer for selected wells in the general area of the proposed recharge-well line. Most of the 37 wells included in the compilation of the histogram are large-diameter (more than 6 inches) public-supply and industrial wells. Thus, the screened intervals of these wells were probably selected, at least in part, on the basis of maximum yield. About two-thirds of the wells are screened in the lower half of the Magothy aquifer. This suggests that the lower part of the Magothy aquifer has a higher hydraulic conductivity than the upper part.

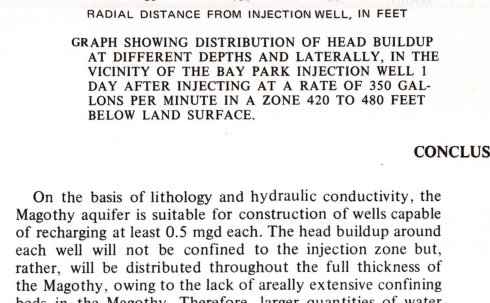


HISTOGRAM SHOWING RELATION OF THE TOP OF WELL SCREENS OF SELECTED WELLS TO THEIR POSITION ABOVE THE BASE OF THE MAGOTHY AQUIFER ALONG THE PROPOSED LINE OF BARRIER-RECHARGE WELLS.

The most favorable zone within the Magothy aquifer for recharge is the gravelly zone near its base. This gravelly zone apparently is the most areally continuous unit in the Magothy aquifer in southern Nassau County. Moreover, it generally has the highest hydraulic conductivity. Most public-supply wells are screened in the lower half of the Magothy aquifer; hence, recharge to the basal zone would probably have the most beneficial hydraulic effect in terms of retarding movement of salty ground water in that heavily pumped zone. In addition, the leading edge of the major salt-water body (deep wedge) is at or near the base of the Magothy aquifer. Therefore, any further landward penetration of the salty water would probably be most advanced at the base of the aquifer.

RESULTS OF EXPERIMENTAL INJECTION

Data from the experimental injection studies at Bay Park (G. D. Bennett, written commun., 1970; Vecchioli and Ku, 1970) can be used in evaluating the potential rise in head in the Magothy aquifer that may be expected from similar artificial-recharge schemes. At Bay Park, reclaimed water was injected at a rate of 350 gpm (gallons per minute), or 0.5 mgd (million gallons per day). This rate of injection has resulted in the equilibrium head-buildup distribution shown on the graph relating head buildup to distance from the point of injection. The graph shows that after about 1 day of injecting, when heads in the observation wells became nearly stable, the head buildup within the injection zone diminished rapidly away from the injection well; it was 10.7 feet immediately adjacent to the well but was only 2.8 feet 200 feet from the well. The Bay Park experimental facility permits observations only to a maximum distance of 200 feet. However, G. D. Bennett (written commun., 1970) concluded from aquifer-test data and from analog-model studies of the Bay Park area that the radius of measurable influence for pumping or injection rates ranging from 100 to 400 gpm is probably between 2,000 and 11,000 feet.



GRAPH SHOWING DISTRIBUTION OF HEAD BUILDUP AT DIFFERENT DEPTHS AND LATERALLY, IN THE VICINITY OF THE BAY PARK INJECTION WELL 1 DAY AFTER INJECTING AT A RATE OF 350 GALLONS PER MINUTE IN A ZONE 420 TO 480 FEET BELOW LAND SURFACE.

The hydraulic effects of injecting water into a zone 420 to 480 feet below land surface were not confined to that zone; rather, the increased heads were dissipated vertically as well as laterally. For example, in a zone about 60 feet below the bottom of the injection screen, the head buildup was 1.2 feet at a radial distance of 20 to 100 feet from the injection well. In a zone 110 feet above the top of the screen, it was 0.7 feet at the same radial distances from the well.

The following conclusions on injection applicable to this study were derived from the injection testing at Bay Park.

(1) The hydraulic character of the Magothy aquifer at Bay Park is probably similar to that at any point along the proposed line of barrier wells. Therefore, the Bay Park results can be extrapolated to other areas of the Magothy with a moderate degree of assurance of similar behavior.

(2) The head buildup around an injection well recharging the Magothy aquifer at a rate of 0.5 mgd decreases from 10.7 feet at the well to a fraction of a foot within a radial distance of 1,000 feet from the well. Some head buildup will occur in strata above and below the injection stratum, but this too is on the order of 1 foot or less for vertical distances of at least 100 feet and radial distances of at least 200 feet.

(3) The Bay Park well has been as optimumly designed as feasible, yet substantial clogging has occurred during injection of the reclaimed water (Vecchioli and Ku, 1972). The clogging has resulted in a maximum excessive head buildup in the recharge well of several tens of feet above normal hydraulic head buildup within 1 month from the start of injection. The average barrier-recharge well most likely would not greatly exceed the operating characteristics of the Bay Park well.

(4) Injection at rates several times greater than 0.5 mgd per well would result in proportionately greater head-buildup than that shown in the head-buildup graph.

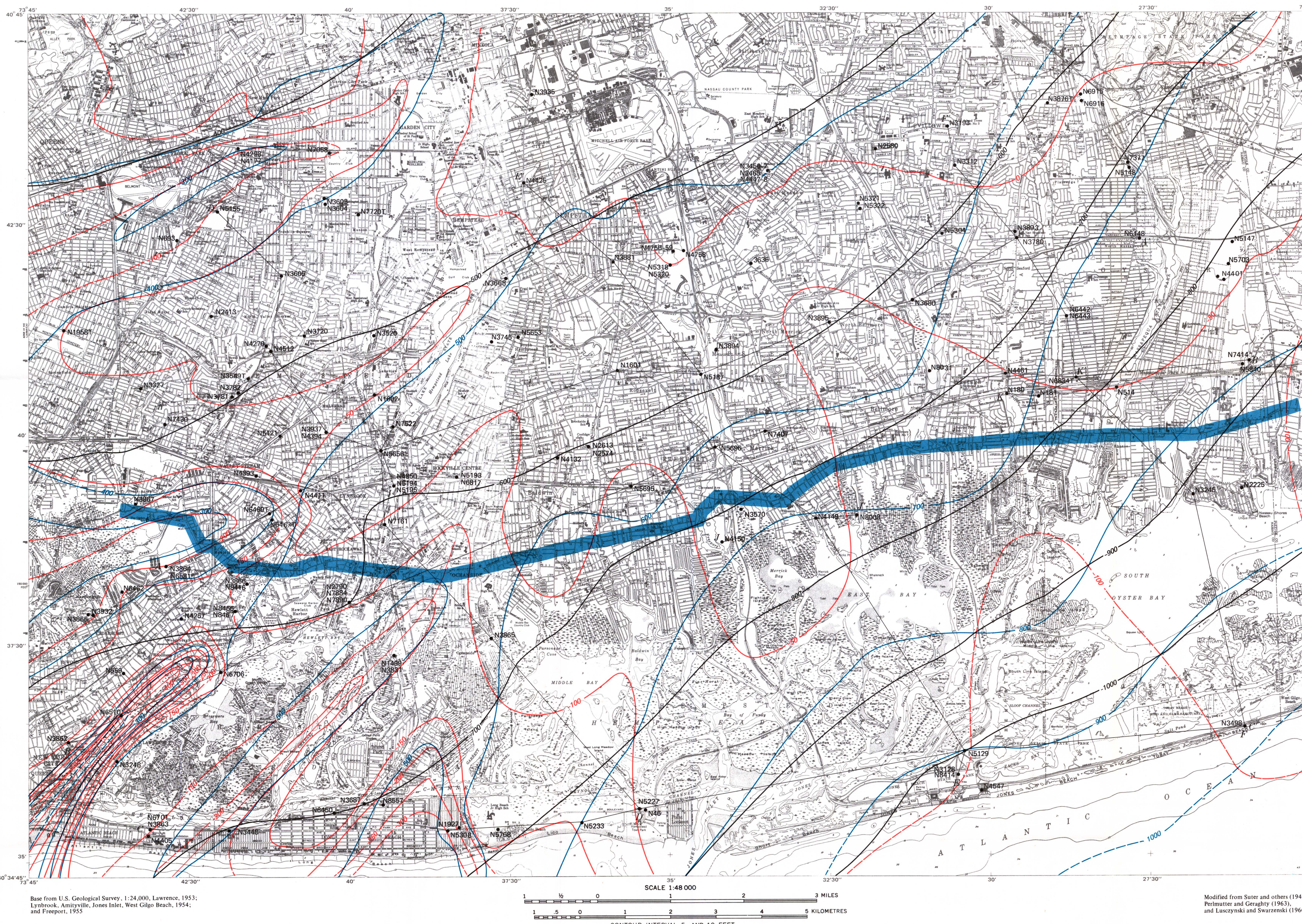
CONCLUSIONS

On the basis of lithology and hydraulic conductivity, the Magothy aquifer is suitable for construction of wells capable of recharging at least 0.5 mgd each. The head buildup around each well will not be confined to the injection zone but, rather, will be distributed throughout the full thickness of the Magothy, owing to the lack of areally extensive confining beds in the Magothy. Therefore, larger quantities of water would have to be injected in a given stratum to achieve a certain head buildup within that stratum than would be required if the stratum were confined. On the other hand, injection into any zone would afford some degree of protection against salt-water encroachment to all beds of the Magothy. Adding to the complexities of predicting the head buildup resulting from a given injection scheme, is the seeming lack of areally extensive, laterally continuous sand units, as well as clay units.

The most favorable zone within the Magothy aquifer for recharge is the gravelly zone near its base, because that zone: (1) is the most areally continuous unit, (2) has the highest hydraulic conductivity, (3) is the most heavily pumped zone, and (4) is probably penetrated the deepest by the major salt-water body.

The proposed location of the recharge barrier, about 1 mile south of Sunrise Highway, seems reasonable in that it: (1) is south of any public-supply wells that tap the Magothy aquifer and (2) is within that part of the Magothy aquifer confined by overlying Pleistocene clay units. The confinement provided by the overlying Pleistocene clay units would greatly inhibit vertical dissipation of the recharge head beyond the top of the Magothy and would lead to maximum effectiveness of the hydraulic barrier. However, the west end of the recharge line is in an area where highly permeable Pleistocene deposits in deep buried channels are in contact with the Magothy aquifer. Flow through these deposits would probably readily dissipate the increased head and thus make it more difficult to maintain an effective hydraulic barrier in that area.

Finally, several potential water-quality problems associated with the proposed injection of reclaimed water into barrier-recharge wells are recognized. Additional studies evaluating these problems are in progress.



Base from U.S. Geological Survey, 1:24,000, Lawrence, 1953; Lynbrook, Amityville, Jones Inlet, West Gilgo Beach, 1954, and Freeport, 1955

Modified from Suter and others (1949), Perlmutter and Geraghty (1963), and Lusczynski and Swarzenski (1966)

HYDROGEOLOGIC MAP

EXPLANATION

- -700 — STRUCTURE CONTOUR SHOWS ALTITUDE OF TOP OF RARITAN CLAY – Dashed where approximately located. Contour interval 100 feet. Datum is mean sea level
- -50 — STRUCTURE CONTOUR SHOWS ALTITUDE OF TOP OF MAGOTHY AQUIFER – Dashed where approximately located. Contour interval 50 feet. Datum is mean sea level
- TRACE OF VALLEY AXIS ON TOP OF MAGOTHY AQUIFER
- 700 — LINE OF EQUAL THICKNESS OF THE MAGOTHY AQUIFER – Dashed where approximately located. Interval 100 feet
- N5187 — WELL LOCATION AND NUMBER – Two or more numbers at a well symbol indicate two or more wells at or near the same site. N, Nassau County; T, test hole
- A — A' — LINE OF GEOLOGIC SECTION
- PROPOSED BARRIER-RECHARGE-WELL ALINEMENT – After Greeley and Hansen, Engineers, 1963

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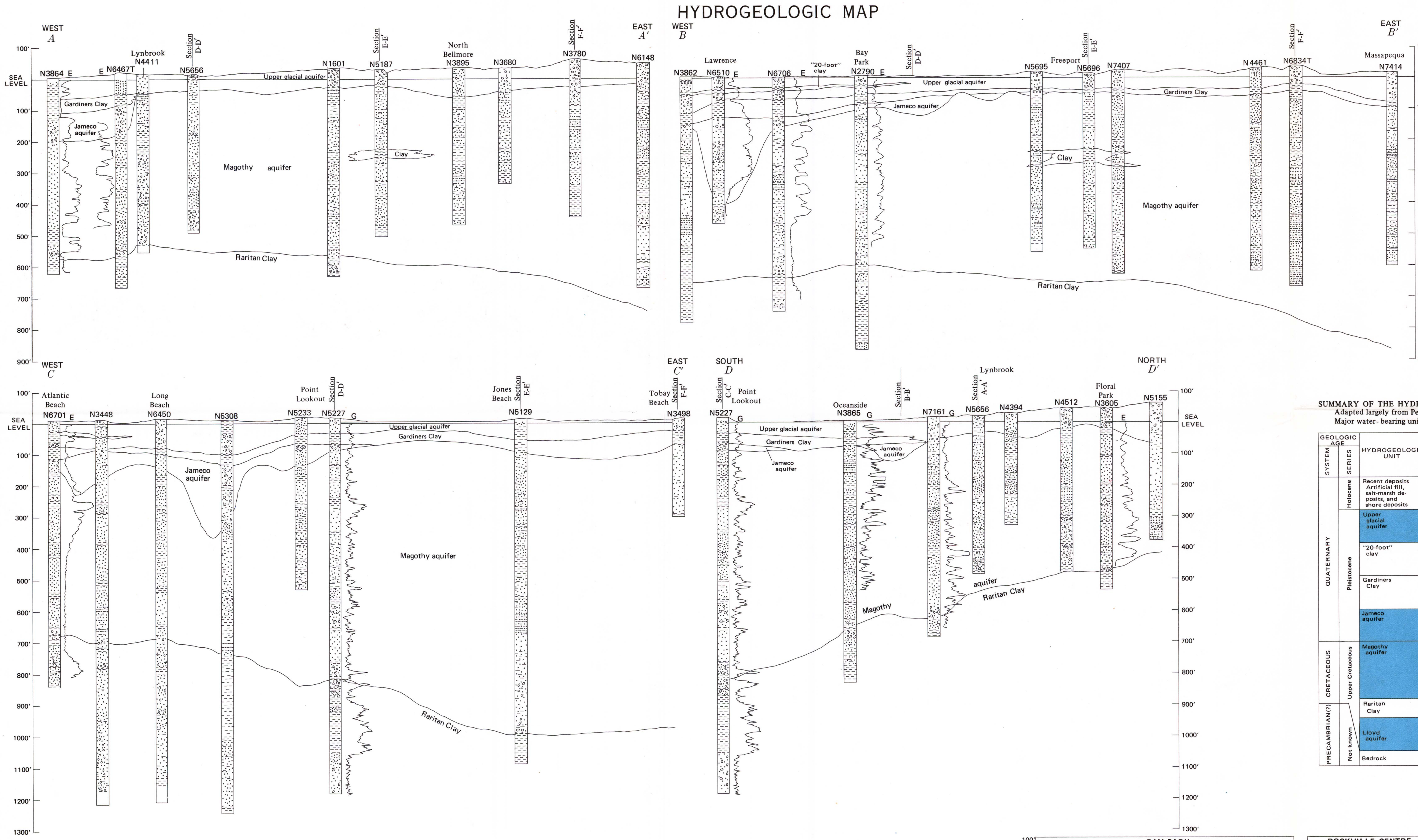
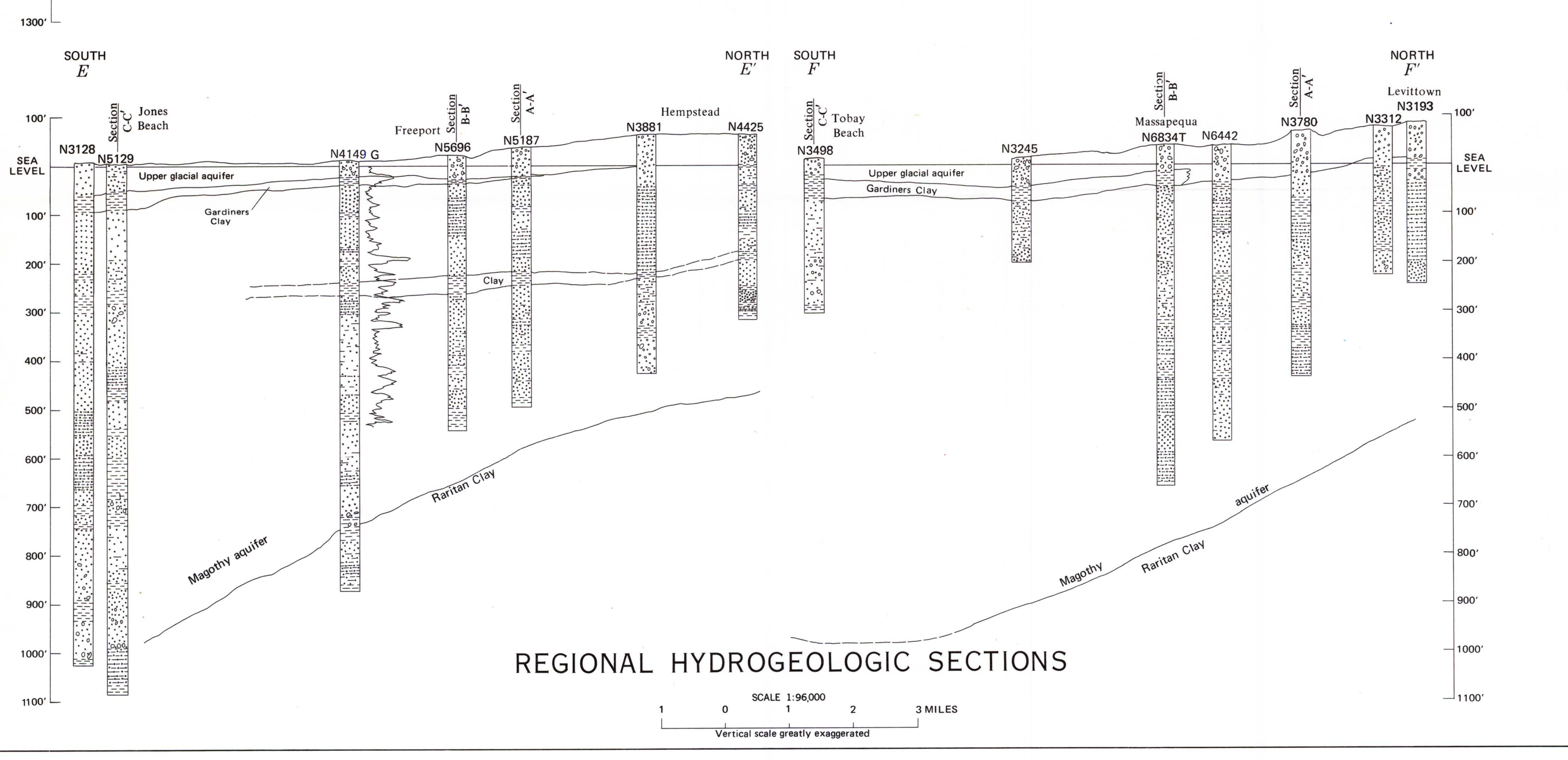




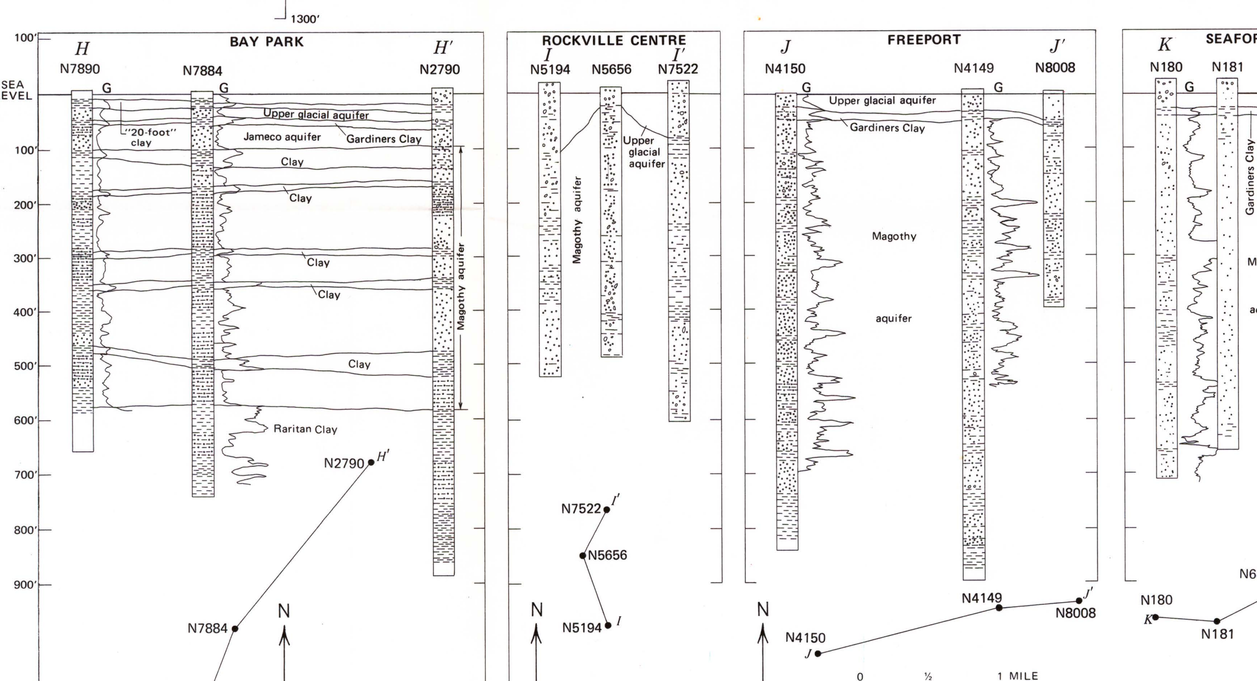
REGIONAL HYDROGEOLOGIC SECTIONS

EXPLANATION

- SAND AND GRAVEL
- SAND
- SAND, SILT, AND CLAY
- CLAY
- CONTACT – Dashed where approximately located
- G- GAMMA RAY LOG
- E- ELECTRIC LOG

SUMMARY OF THE HYDROGEOLOGIC PROPERTIES OF STRATA UNDERLYING SOUTHERN NASSAU COUNTY, LONG ISLAND, N.Y.
Adapted largely from Perlmutter and Geraghty, 1963, p. 14–15; hydrogeologic nomenclature largely after Cohen, Franke, and Foxworthy, 1968.
Major water-bearing units are indicated by blue shading

GEOLOGIC AGE: SYSTEM	GEOLOGIC AGE: SERIES	HYDROGEOLOGIC UNIT	APPROXIMATE RANGE IN THICKNESS (FEET)	CHARACTER	WATER-BEARING PROPERTIES
QUATERNARY	Holocene	Recent deposits Artificial fill, salt-marsh deposits, and shore deposits	0–40	Sand, gravel, clay, silt, organic mud, peat, loam, and shells; gray and brown.	Sandy beds of moderate to high permeability beneath barrier beaches, locally yield fresh or salty water from shallow depths. Clayey and silty beds beneath bays retard salt-water encroachment and confine underlying aquifers.
QUATERNARY	Pleistocene	Upper glacial aquifer	30–300	Outwash consisting mainly of brown fine to coarse sand and gravel, stratified. Interbedded with "20-foot" clay.	Sand and gravel part of outwash highly permeable; yields of individual wells are as much as 1,700 gpm. Specific capacities of wells as much as 109 gpm per foot of drawdown. Water fresh except near shorelines.
QUATERNARY	Pleistocene	"20-foot" clay	0–40	Clay and silt, gray and grayish green; some lenses of sand and gravel. Contains shells, foraminifer, and peat. Altitude of top of unit about 20 ft below mean sea level. Interbedded with outwash in southern part of area.	Relatively impermeable confining unit. Retards salt-water encroachment in shallow depths.
QUATERNARY	Pleistocene	Gardiners Clay	0–40	Clay and silt, grayish-green; some lenses of sand and gravel. Contains lignitic material, shells, glauconite, foraminifers, and diatoms. Interglacial deposit. Altitude of surface about 50 ft or more below mean sea level.	Relatively impermeable confining layer above Jameco aquifer. Locally contains moderately to highly permeable sand and gravel lenses.
QUATERNARY	Pleistocene	Jameco aquifer	0–300	Sand, fine to coarse, dark-gray and brown; gravel. Contains some thin beds of silt and clay. Probably older glacial outwash.	Highly permeable. Yields as much as 1,300 gpm to individual wells. Specific capacities as high as 135 gpm per foot of drawdown. Contains water under artesian pressure. Water commonly has high iron content and is salty near shoreline.
CRETACEOUS	Upper Cretaceous	Magothy aquifer	200–900	Sand, fine to medium gray; interfingered with lenses of coarse sand, sandy clay, silt, and solid clay. Generally contains gravel in bottom 50 to 100 ft. Lignite and pyrite abundant.	Slightly to highly permeable. Principal source of public-supply water in Nassau County. Individual wells yield as much as 2,200 gpm. Specific capacities as high as 80 gpm per foot of drawdown. Water mainly under artesian pressure; some wells in southern part of area flow. Water generally is of excellent quality except where contaminated by salty water in southwestern part of area or by dissolved constituents associated with activities of man.
CRETACEOUS	Upper Cretaceous	Raritan Clay	100–300	Clay, gray, white, and some red and purple; mainly in solid silty and rarely sandy lenses. Some lenses of sand and gravel. Lignite and pyrite abundant.	Relatively impermeable confining unit. Local lenses and layers of sand and gravel, moderate to high permeability.
CRETACEOUS	Upper Cretaceous	Lloyd aquifer	150–300	Sand, fine to coarse, gray and white, and gravel; some lenses of solid and sandy clay, and clayey sand. Thin beds of lignite locally.	Moderately permeable. Yields as much as 2,000 gpm to individual wells. Specific capacities as high as 44 gpm per foot of drawdown. Water under artesian pressure; some wells flow. Water of good quality except for high iron content.
PRECAMBRIAN(?)	Not known	Bedrock	———	Crystalline metamorphic and igneous rocks. Soft, clayey weathered zone at top, as thick as 50 ft.	Virtually impermeable. Locally contains water along joints and fault zones.



HYDROGEOLOGIC SECTIONS AT BAY PARK, ROCKVILLE CENTRE, FREEPORT, AND SEAFORD

HYDROGEOLOGY ALONG THE PROPOSED BARRIER-RECHARGE-WELL ALINEMENT IN SOUTHERN NASSAU COUNTY, LONG ISLAND, NEW YORK

By
H. F. H. Ku, John Vecchioli, and L. A. Cerrillo
1975

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1975
For sale by U.S. Geological Survey, Reston, Virginia 22092, price $1.00