

# **HYDROGEOLOGY AND EXTENT OF SALTWATER INTRUSION OF THE LLOYD AQUIFER IN NORTHERN NASSAU COUNTY, NEW YORK**

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## **Abstract**

Fifty-six boreholes were drilled along the northern part of Nassau County from 1991-98 to delineate the hydrogeologic framework and extent of saltwater intrusion. The Lloyd aquifer's thickness, extent, hydrology, and extent of saltwater intrusion were delineated within the study area. Analyses of core-samples, borehole geophysical logs, offshore seismic-reflection surveys, water samples, and water levels indicate four important features about the Lloyd aquifer, 1) it has been extensively or completely eroded in places, 2) it is hydraulically connected to a confined Pleistocene-aged aquifer (North Shore aquifer), 3) public-supply pumping created water levels as much as 40 feet below sea level, and 4) overpumping has induced eight wedges of saltwater intrusion into the aquifer. At least six public-supply wells screened in the Lloyd and North Shore aquifers within the study area have been shutdown due to saltwater intrusion, and several others are currently being affected.

## **Introduction**

In 1991-98, the U.S. Geological Survey (USGS), in cooperation with the Nassau County Department of Public Works (NCDPW), began a study to delineate the hydrogeologic framework and the extent of saltwater intrusion in northern Nassau County for the protection and conservation of the local ground-water supply. Three reports were published delineating the hydrogeologic framework, water-table, potentiometric-surface, and extent of saltwater intrusion (Stumm, 2001; Stumm and others, 2002; 2004). This paper summarizes the hydrogeology and extent of saltwater intrusion in the Lloyd aquifer from these reports.

The study area (fig. 1) encompasses about 30 mi<sup>2</sup> in the northern part of Nassau County and includes three sub-areas Great Neck, Manhasset Neck, and the Oyster Bay area. The study area is bounded on the west by Little Neck Bay in Queens County, on the north by Long Island Sound, and on the east by Cold Spring Harbor in Suffolk County, and on the south by approximately the Long Island Expressway (not labeled on fig. 1)(fig. 1).

## **Acknowledgments**

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## **HYDROGEOLOGY**

Northern Nassau County is underlain by unconsolidated glacial deposits of Pleistocene age and coastal-plain deposits of Late Cretaceous age (Veatch and others, 1906; Fuller, 1914; Suter and others, 1949). These deposits consist of gravel, sand, silt, and clay and rest upon

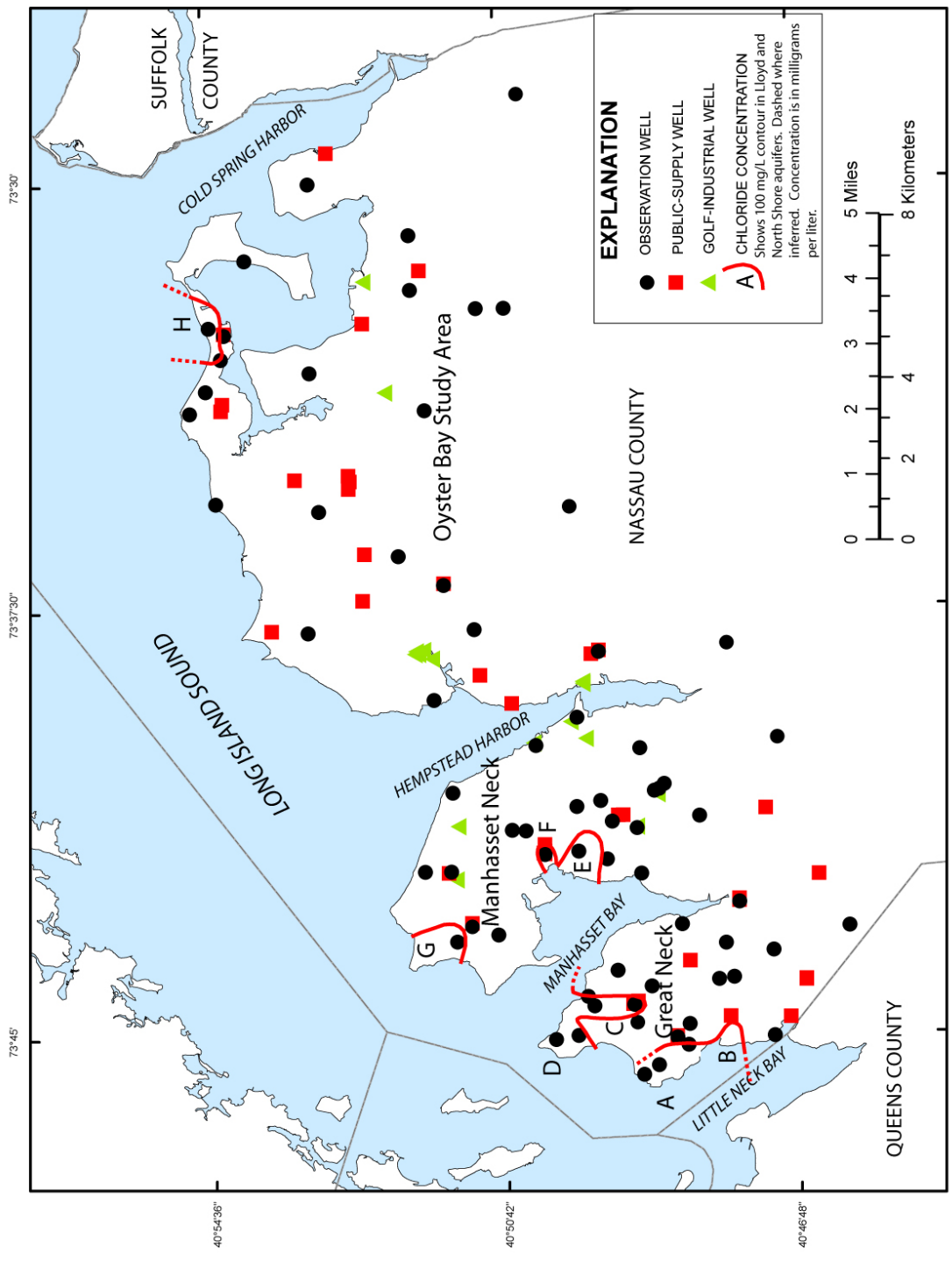


Figure 1. Location of study area and saltwater wedges A-H (Lloyd and North Shore aquifers) in northern Nassau County, N.Y. (Modified from Stumm, 2001; Stumm, 2002, 2004)

crystalline-metamorphic bedrock of early Paleozoic age. The top of the bedrock, which is relatively impermeable, generally forms the base of the ground-water reservoir.

### **Bedrock**

The bedrock underlying the Manhasset Neck area has been mapped as the Hartland Formation of Middle Ordovician to Lower Cambrian Age (Mose and Merguerian, 1985; Baskerville, 1992). The upper surface of the bedrock slopes southeastward from 150 to 600 ft below sea level. Drill-core data indicate the bedrock to be a biotite-garnet schist.

### **Lloyd Aquifer**

The Lloyd Sand Member of the Raritan Formation of Late Cretaceous age (Suter and others, 1949; Cohen and others, 1968) consists of an upward fining sequence of white and pale-yellow (Munsell descriptive color value 2.5Y 7/3) silt, sand, and gravel with white clay lenses (Kollmorgan Instruments Corporation, 1994).

The Lloyd Sand overlies bedrock and generally is overlain by Raritan clay. The Lloyd Sand dips to the southeast, except where it has been removed by glacial erosion within the study area (fig. 2) (Swarzenski, 1963; Isbister, 1966; Kilburn, 1979; Kilburn and Krulikas, 1987; Stumm and others, 2002, 2004). The upper surface ranges from 121 ft to greater than 400 ft below sea level (fig. 2). Where the Lloyd Sand is present, its thickness ranges from 50 to 300 ft. The Lloyd Sand was not present in the northernmost part of the study area because it was removed by glacial erosion (Stumm and others, 2002, 2004). In northern Nassau County, the Lloyd aquifer has an average horizontal hydraulic conductivity of about 60 ft/d (McClymonds and Franke, 1972) and a horizontal to vertical anisotropy of 10:1 (Smolensky and others, 1989).

### **Raritan Clay**

The unnamed clay member of the Raritan Formation, referred to as the Raritan clay in this paper, overlies and confines ground water in the Lloyd aquifer (Suter and others, 1949; Stumm, 2001). The Raritan clay is a solid, compact clay that is multicolored and includes gray (2.5Y 4/1), white (2.5Y 9/1), red (10R 4/8), or tan (2.5Y 4/8), and variegated colors (Stumm and others, 2002, 2004).

### **Magothy Aquifer**

The Magothy aquifer consists of fine micaceous sand, silt, and interbedded clay sediments of Cretaceous age (Suter and others, 1949; Swarzenski, 1963; Isbister, 1966; Kilburn, 1979; Kilburn and Krulikas, 1987). The Magothy aquifer has been removed by glacial erosion in most of the study area (Stumm and others, 2002, 2004).

### **North Shore Aquifer**

The North Shore aquifer is a sequence of Pleistocene-age sediments encountered in buried valleys in the northernmost part of the study area (fig. 3) and is described in detail by Stumm (2001) and Stumm and others (2002, 2004). The North Shore aquifer is a distinct

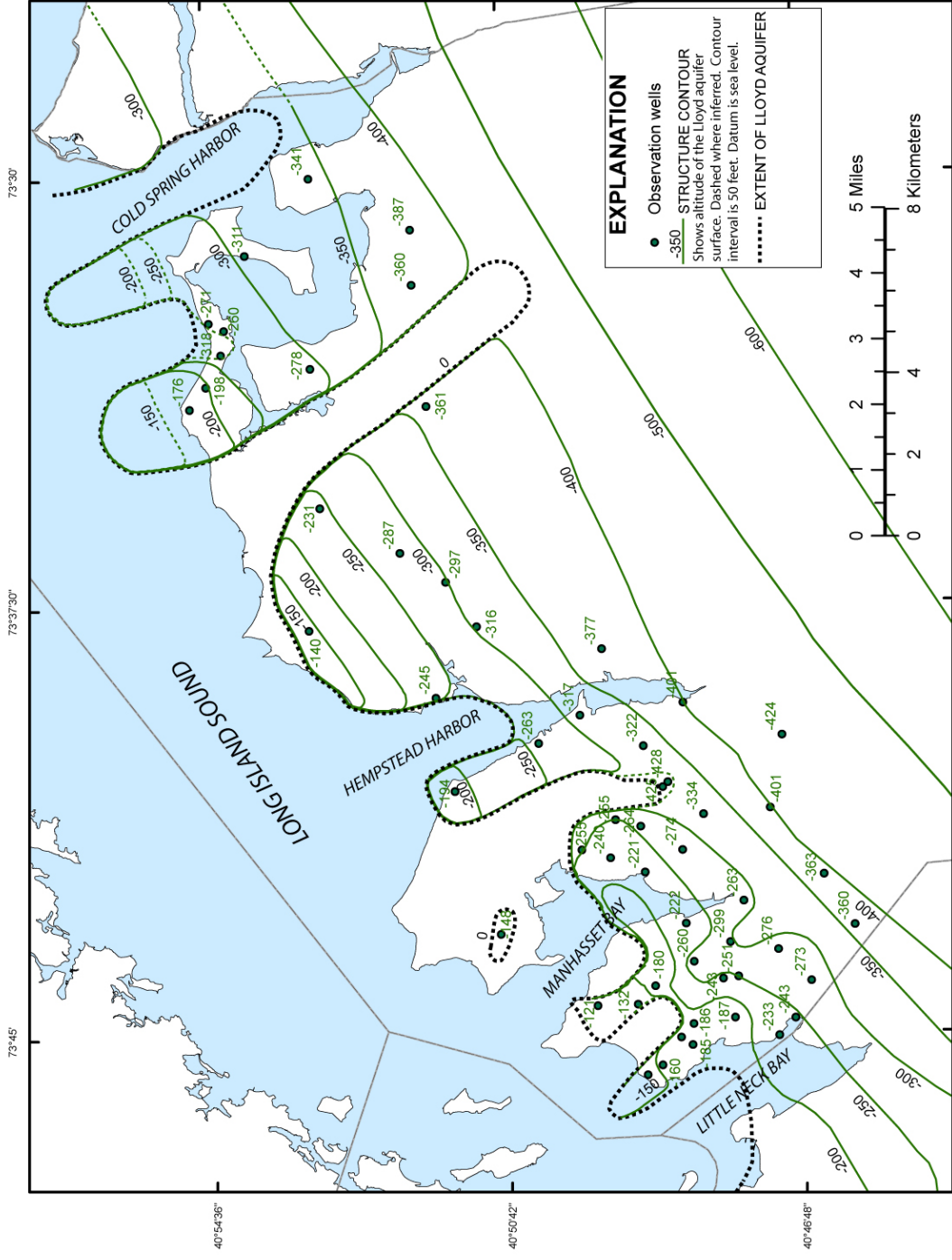


Figure 2. Extent and upper surface altitude of the Lloyd aquifer in northern Nassau County, N.Y. (Modified from Stumm, 2001; Stumm and others, 2002, 2004)

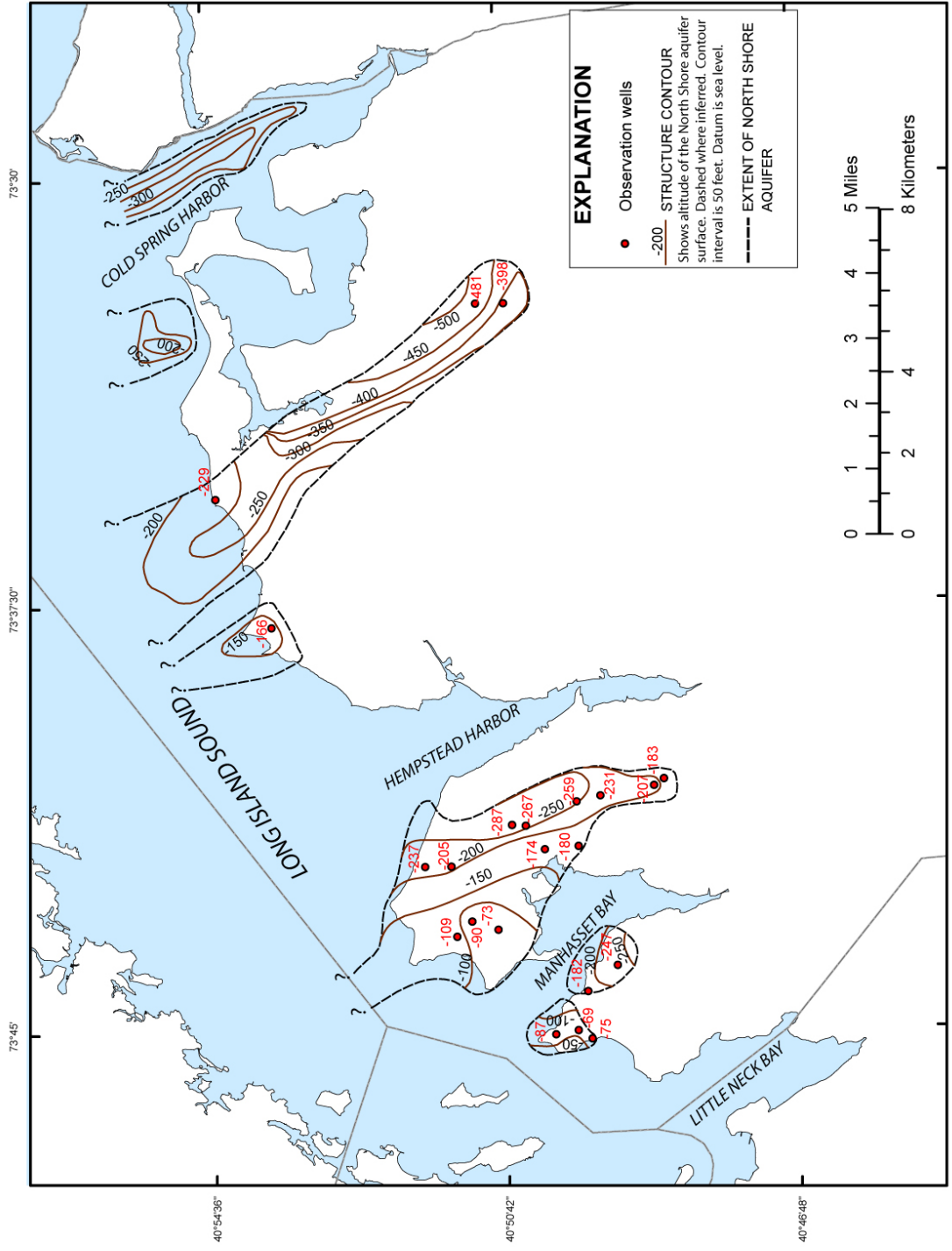


Figure 3. Extent and upper surface altitude of the North Shore aquifer in northern Nassau County, N.Y. (Modified from Stumm, 2001; Stumm and others, 2002, 2004)

hydrogeologic unit that rests upon bedrock and is overlain by a thick sequence of clays and silt (the North Shore confining unit)(fig. 4). The North Shore aquifer is described as a sequence of poorly to moderately sorted dark olive brown (2.5Y 3/3) and olive gray (5Y 6/2) gravel, sand, and silt. The rapid response of water levels to tides and pumping indicates that this unit is moderately to highly permeable and hydraulically interconnected with the Lloyd aquifer.

### **North Shore Confining Unit**

The name North Shore confining unit is given to a sequence of Pleistocene-age clay and silt deposits that are locally present along the northern shore of Long Island. Offshore seismic-reflection surveys, geophysical logs, and drill-core samples were correlated with buried valleys that extend across the study area (Stumm, 2001; Stumm and others, 2002, 2004)(fig. 4). The North Shore confining unit underlies the northern parts of the study area and confines water in the North Shore aquifer. The unit consists of olive-brown (2.5Y 4/2) varved clay and minor amounts of silt and dark-olive gray clay (5Y 4/2) with shells (Stumm and others, 2002, 2004).

### **Upper Glacial Aquifer**

The upper glacial aquifer includes the saturated parts of the upper Pleistocene deposits. It consists of Pleistocene-age beds of fine- to coarse-grained and stratified sand and gravel, unstratified boulders, clay, till, and some small, shallow, pond deposits (Suter and others, 1949).

### **Seismic-Reflection Surveys**

Three separate offshore seismic-reflection surveys within the study area were correlated with the geologic logs of nearshore observation wells. Applications of this technique for hydrogeologic and water-resource studies have been described by Haeni (1986, 1988) and by Reynolds and Williams (1988). Seismic-reflection surveys covered extensive parts of the embayments and Long Island Sound near the coastline of the study area. An example of one of these seismic profiles is B-B´ it is about 8,220 ft (1.6 mi) long and lies about 4,000 ft off the northeastern coast of the Manhasset Neck peninsula (fig. 5). The seismic-reflection profile shows subhorizontal parallel reflections, which are interpreted to be silt and clay deposits that fill a large buried valley that extends to about 400 ft below sea level to bedrock and truncates the surrounding coarse grained deposits (chaotic reflectors) to the east (Stumm and others, 2002) (fig. 5).

### **Borehole Geophysical Logs**

At several sites, natural-gamma radiation (gamma), spontaneous potential (SP), single-point-resistance (SPR), and short- and long-normal resistivity (R) logs were collected in mud-filled open boreholes prior to casing. Focused electromagnetic-induction (EM) logs were obtained in polyvinyl chloride (PVC) cased wells (Stumm, 1993). EM logs indicated a sharp increase in conductivity at the freshwater-saltwater interface of most saltwater wedges within the study area due to active intrusion (Stumm, 1993; Stumm, 2001; Stumm and others, 2002, 2004).

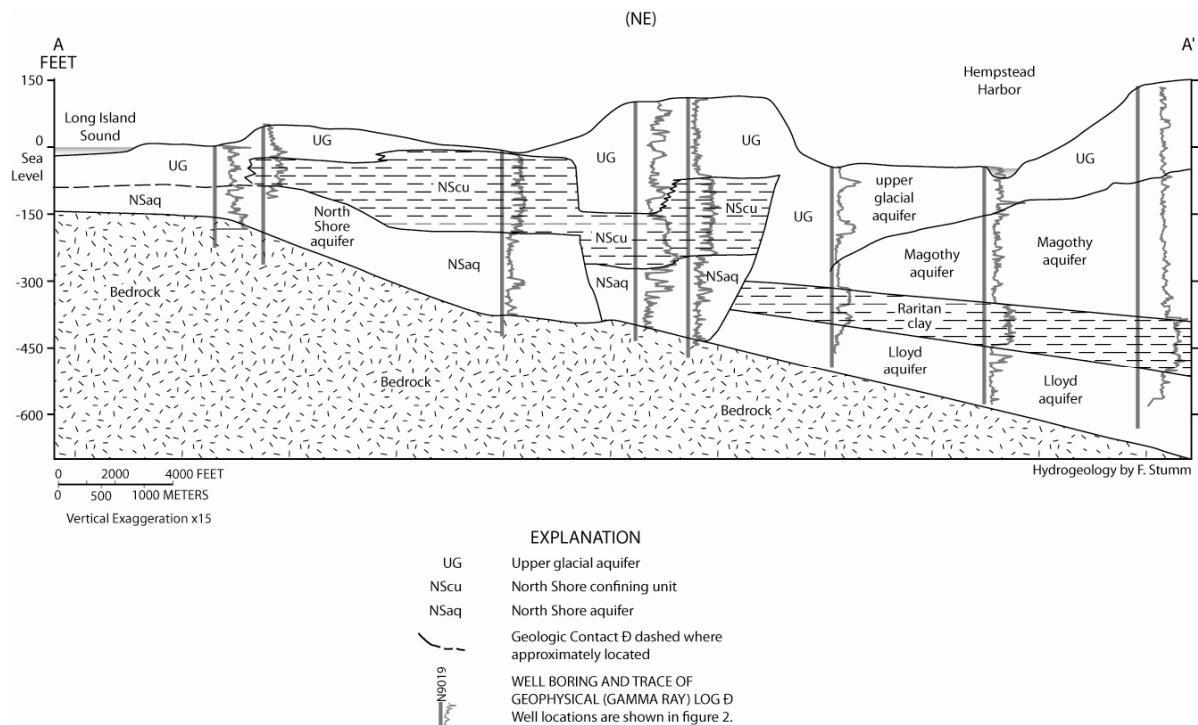


Figure 4. Hydrogeologic section A-A' on Manhasset Neck, Nassau County, N.Y. (Trace of section shown in fig. 1)(Modified from Stumm and others, 2002)

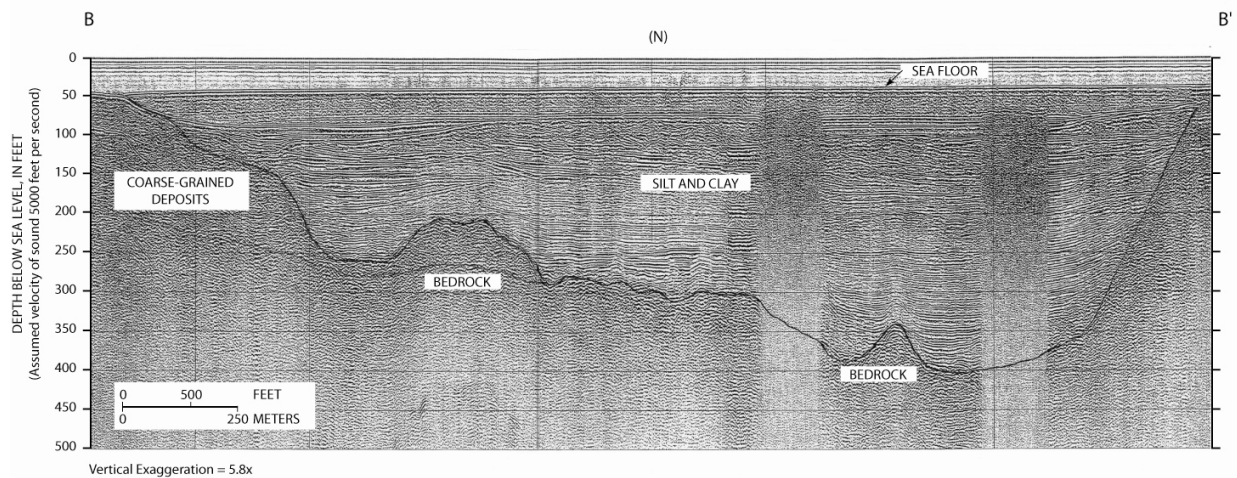


Figure 5. Interpreted stratigraphy along seismic-reflection profile B-B' in Long Island Sound off Manhasset Neck, Nassau County, N.Y. (Trace of section shown in fig. 1) (Modified from Stumm and others, 2002)

## **Pumpage**

Public-supply wells within the study area are owned and operated by thirteen separate water districts. The average annual combined ground-water pumpage of public-supply, golf-course, and industrial wells during 1991-97 from the upper glacial, Magothy, North Shore and Lloyd aquifers was 16,973 Mgal (46.5 Mgal/d). Average annual combined pumpage from the Lloyd and North Shore aquifers was 2,701 Mgal (7.4 Mgal/d) (Stumm, 2001; Stumm and others, 2002, 2004). The percentage of combined pumpage from the Lloyd and North Shore aquifers from total pumpage in the Great Neck, Manhasset Neck, and Oyster Bay study areas was 39, 22, and 7 percent, respectively. Golf-course and industrial well pumpage from the Lloyd and North Shore aquifers averaged 67.6 Mgal (0.2 Mgal/d) or 2.5 percent of the total combined average annual pumpage.

## **Water Levels**

The water table is within the upper glacial aquifer in most of the study area. Water levels of wells screened in the water table (upper glacial and Magothy aquifers) ranged from 3 ft to 120 ft above sea level. Water-level data indicate that the Lloyd and North Shore aquifers are affected by tidal fluctuations as much as 4 ft along the coast and are hydraulically connected (Stumm, 2001). Both aquifers respond to local public-supply and golf-course pumping and show large cones of depression (fig. 6). A compilation of water levels in the Lloyd and North Shore aquifers measured during the summer in 1995-97 are depicted in figure 6 (confined aquifers).

The potentiometric surface of the Lloyd and North Shore aquifers measured in 1995-97 indicates that water levels ranged from 4 ft above to more than 40 ft below mean sea level (Great Neck), 13 ft above to more than 20 ft below sea level (Manhasset Neck), and 58 ft above to more than 2 ft below sea level (Oyster Bay area)(fig. 6). Three large cones of depression in Great Neck, two in Manhasset Neck, and one in the Oyster Bay area developed in response to public-supply and golf-course pumping in the Lloyd and North Shore aquifers.

## **EXTENT OF SALTWATER INTRUSION**

Chloride concentrations in water from public-supply wells screened in the Lloyd aquifer ranged from 5 to 10 mg/L (milligrams per liter), and those in water from the North Shore aquifer were similar. Three public-supply wells (screened in the Lloyd aquifer) in Great Neck, two (Lloyd and North Shore aquifers) in Manhasset Neck, and a one (Lloyd aquifer) in Bayville have been shutdown due to elevated chloride concentrations.

Four saltwater wedges (A-D) in the Lloyd and North Shore aquifers were identified on Great Neck, three on Manhasset Neck (E-G), and one in the Oyster Bay area (Bayville)(H) (fig. 1). Peak chloride concentrations of saltwater wedges within the study area in the Lloyd and North Shore aquifers ranged from 180 to 13,750 mg/L. Analyses of 50 years of chloride concentration and public-supply pumpage data within the study area indicates a typical pattern of saltwater intrusion—first a gradual but steady increase in chloride concentration, and then rapid increases to concentrations above the State maximum contaminant level.



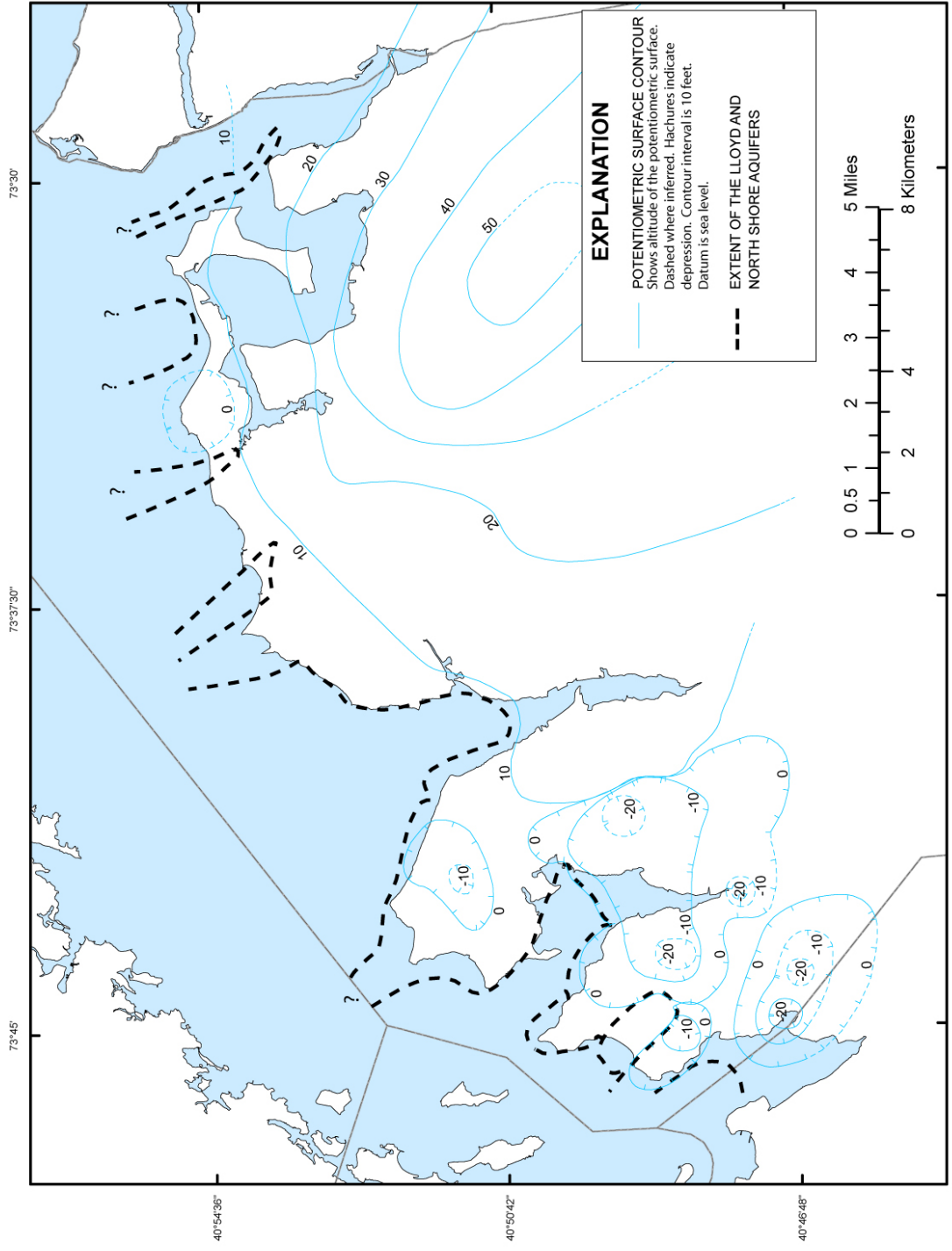


Figure 6. A compilation of the potentiometric-surface altitude in the Lloyd and North Shore aquifer in northern Nassau County 1995-97. (Modified from Stumm, 2001; Stumm, 2002, 2004)

## SUMMARY AND CONCLUSIONS

In 1991-98, the U.S. Geological Survey (USGS), in cooperation with the Nassau County Department of Public Works (NCDPW), began a study to delineate the hydrogeologic framework and the extent of saltwater intrusion in northern Nassau County. Northern Nassau County is underlain by unconsolidated glacial deposits of Pleistocene age and coastal-plain deposits of Late Cretaceous age. These deposits consist of gravel, sand, silt, and clay and rest upon crystalline-metamorphic bedrock of early Paleozoic age.

The Lloyd Sand Member of the Raritan Formation of Late Cretaceous age consists of an upward fining sequence of white and pale-yellow silt, sand, and gravel with white clay lenses. The Lloyd Sand overlies bedrock and generally is overlain by Raritan clay. The Lloyd Sand dips to the southeast, except where it has been removed by glacial erosion in the northernmost part.

The North Shore aquifer is a distinct hydrogeologic unit that rests upon bedrock and is overlain by a thick sequence of clays and silt (the North Shore confining unit). The North Shore confining unit a sequence of Pleistocene-age clay and silt deposits underlies the northern parts of the study area and confines water in the North Shore aquifer.

The percentage of combined pumpage from the Lloyd and North Shore aquifers from total pumpage in the Great Neck, Manhasset Neck, and Oyster Bay study areas was 39, 22, and 7 percent, respectively. Golf-course and industrial well pumpage from the Lloyd and North Shore aquifers averaged 67.6 Mgal (0.2 Mgal/d) or 2.5% of the total combined average annual pumpage.

Both aquifers respond to local public-supply and golf-course pumping and show large cones of depression. The potentiometric surface of the Lloyd and North Shore aquifers measured during the summer in 1995-97 indicates that water levels ranged from 58ft above to more than 40ft below mean sea level.

Three public-supply wells (screened in the Lloyd aquifer) in Great Neck, two (Lloyd and North Shore aquifers) in Manhasset Neck, and a one (Lloyd aquifer) in Bayville have been shutdown due to elevated chloride concentrations. Four saltwater wedges in the Lloyd and North Shore aquifers were identified on Great Neck, three on Manhasset Neck, and one in the Oyster Bay area (Bayville).

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