

Prepared in cooperation with the New York State Department of Environmental Conservation

Aquifer Transmissivity in Nassau, Queens, and Kings Counties, New York, Estimated From Specific-Capacity Tests at Production Wells

Open-File Report 2020–1108

U.S. Department of the Interior
U.S. Geological Survey

Cover. Artistic image derived from [figure 1](#) of this report.

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By John H. Williams, Madison Woodley, and Jason S. Finkelstein

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DAVID BERNHARDT, Secretary

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Conversion Factors

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
foot squared per day (ft ² /d)	0.09290	meter squared per day (m ² /d)

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Abbreviations

NWIS National Water Information System

NYSDEC New York State Department of Environmental Conservation

USGS U.S. Geological Survey

Aquifer Transmissivity in Nassau, Queens, and Kings Counties, New York, Estimated From Specific-Capacity Tests at Production Wells

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Abstract

As part of a cooperative effort between the U.S. Geological Survey and the New York State Department of Environmental Conservation to evaluate the sustainability of Long Island's sole-source aquifer system, the transmissivities of four aquifers were estimated from specific-capacity tests at 447 production wells in Nassau, Queens, and Kings Counties on Long Island, New York. The specific-capacity test data, which included pumping rate, pumping duration, and drawdown, were obtained from published and unpublished records of driller-reported acceptance tests collected at production wells screened in the upper glacial, Jameco, Magothy, or Lloyd aquifers. Pumping rates from the production wells during the tests generally were greater than 400 gallons per minute and ranged up to 1,800 gallons per minute. Pumping duration generally was 8 hours or more. Transmissivities were estimated from the specific-capacity data by the Cooper-Jacob approximation of the Theis equation. The transmissivity estimates are considered rough approximations because the aquifers do not meet the ideal assumptions of the method, well losses and partial penetration were not accounted for, and aquifer storage coefficients were not known but were only estimated from available data.

The transmissivities estimated from production wells screened in the upper glacial aquifer in the outwash plain south of the moraine generally were greater than those of the aquifer north of the moraine. The transmissivities estimated from the wells screened in the upper glacial aquifer south of the moraine typically ranged (as defined by the 10th and

90th percentiles) from 3,800 to 15,000 feet squared per day (ft^2/d), with a median value of 7,300 ft^2/d . The transmissivities estimated from the wells screened in the upper glacial aquifer north of the moraine typically ranged from 2,100 to 7,400 ft^2/d , with a median value of 4,400 ft^2/d . The Jameco aquifer generally had the highest estimated transmissivities of all the aquifers analyzed. The estimated transmissivities for the Jameco aquifer typically ranged from 5,500 to 43,000 ft^2/d , with a median value of 16,000 ft^2/d . The Magothy and Lloyd aquifers had similar estimated transmissivities. The transmissivities estimated for the Magothy aquifer typically ranged from 2,700 to 13,000 ft^2/d , with a median of 7,100 ft^2/d . The estimated transmissivities of the Lloyd typically ranged from 3,000 to 14,000 ft^2/d , with a median of 7,200 ft^2/d .

Introduction

In 2016, the U.S. Geological Survey (USGS) began a cooperative study with the New York State Department of Environmental Conservation (NYSDEC) to evaluate the sustainability of Long Island's sole-source aquifer system through hydrogeologic mapping, monitoring of groundwater quality and levels, and construction of a groundwater-flow model. As part of the groundwater sustainability study, specific-capacity test data from published and unpublished records were analyzed to estimate transmissivity of selected production wells in Nassau, Queens, and Kings Counties on Long Island, New York ([fig. 1](#)).

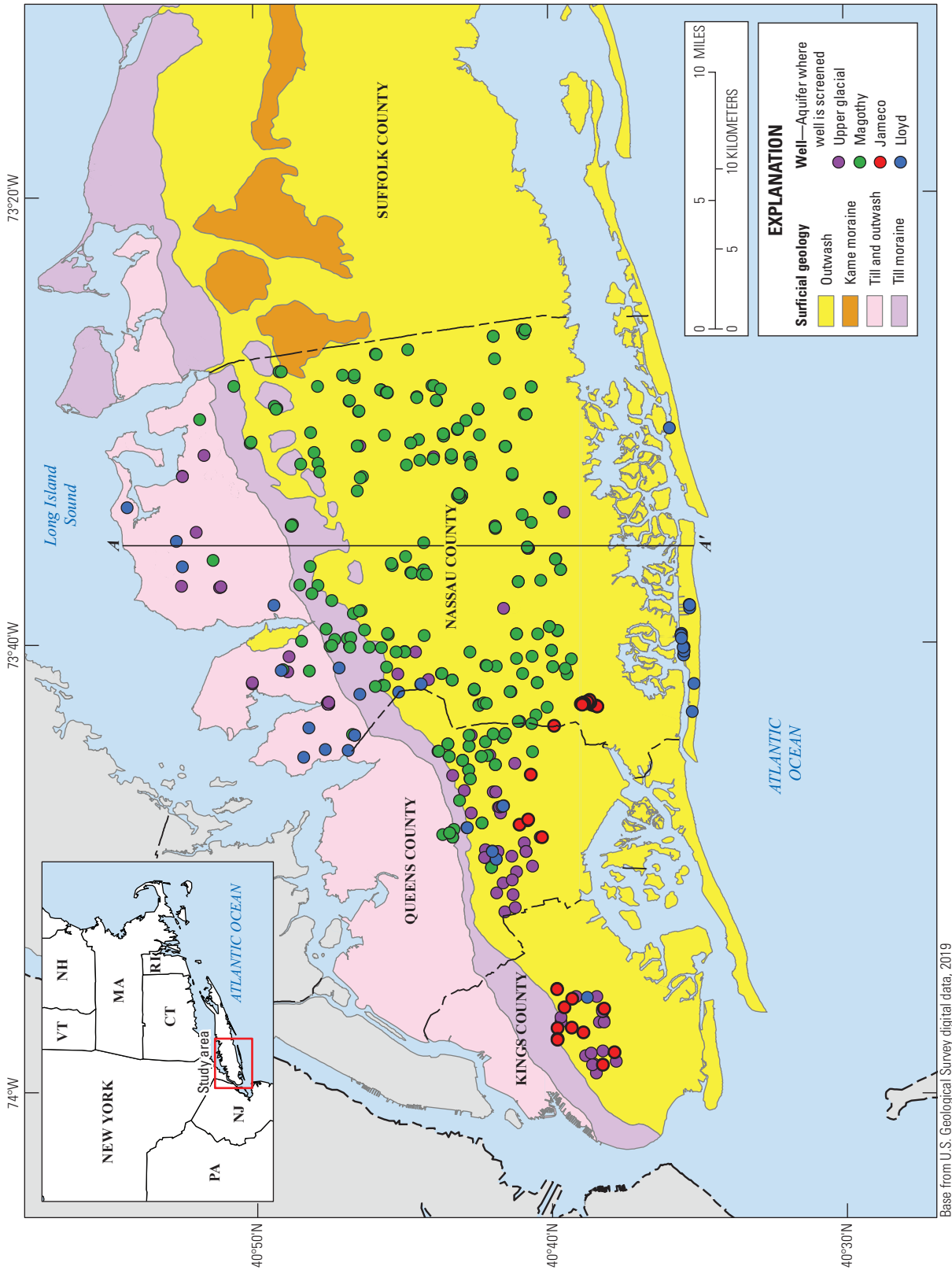


Figure 1. Generalized surficial geology and location of selected production wells with specific-capacity data in Nassau, Queens, and Kings Counties, New York. Surficial geology modified from Cadwell (1989).

Hydrogeologic Setting

The hydrogeologic setting of Long Island is presented in Smolensky and others (1989). The principal aquifers are the upper glacial, Jameco, Magothy, and Lloyd. The hydrogeologic characteristics of the four aquifers are summarized below.

Upper Glacial Aquifer

Till, kame, outwash, lacustrine, and marine sediments deposited during the Pleistocene epoch form the upper glacial aquifer of Long Island. Till is a poorly permeable unsorted mixture of clay, silt, sand, and stones deposited beneath and adjacent to glacial ice. Kame sediments are variably sorted ice-contact deposits of sand, gravel, and silt that range in permeability. Outwash sediments consist of well-sorted sand and gravel deposited in front of glacial ice that are moderately to highly permeable. Moraines, formed by a heterogeneous mix of till and kame sediments, mark the southernmost extent of glacial ice on Long Island (fig. 1). The most extensive deposits of outwash underlie the southern part of Long Island in front of the moraines. Outwash deposits are present with the till north of the moraines but are less extensive. Lacustrine deposits, present mostly in central and eastern Long Island, and marine deposits, locally present along the south shore, are dominantly fine-grained deposits with poor permeability but contain thin local lenses of sand and gravel that are moderately

permeable. The upper glacial aquifer is in hydraulic contact with the Magothy aquifer except along the southern shore where the Gardiners clay restricts vertical flow between the aquifers (fig. 2).

Jameco Aquifer

The Jameco aquifer, formed during the Pleistocene epoch, lies unconformably beneath and is confined by the Gardiners clay on the southern shore of Nassau, Queens, and Kings Counties (fig. 2). The Jameco aquifer is a fluvial deposit of fine to coarse sand and gravel deposited in channels eroded into the underlying Magothy deposits. The Jameco deposits are up to 200 feet (ft) thick and are moderately to highly permeable.

Magothy Aquifer

The Magothy aquifer, formed during the Cretaceous period, extends throughout most of Long Island. In Nassau, Queens, and Kings Counties, it lies unconformably beneath the upper glacial aquifer in the northern and central areas and the Jameco aquifer and Gardiners clay on the southern shore (fig. 2). The Magothy deposits are up to 600 ft thick and consist of alternating beds of sand, silt, and clay with gravel common in the basal zone.

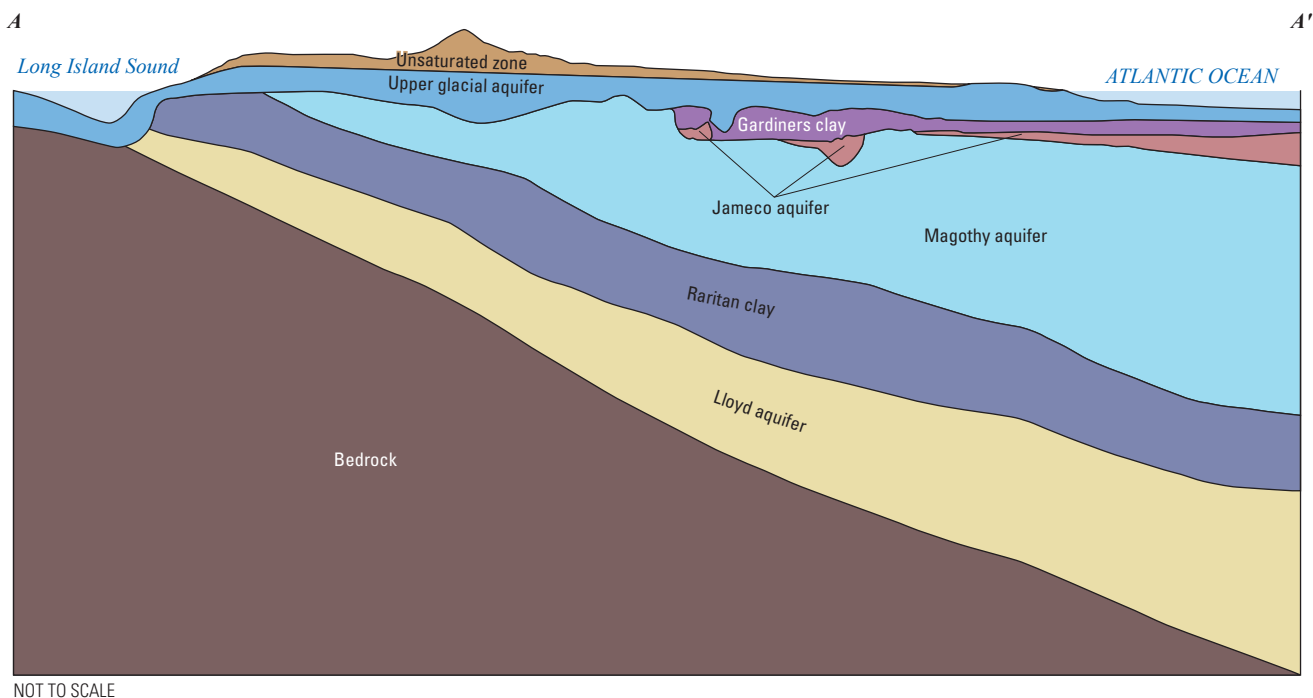


Figure 2. Generalized hydrogeologic section of principal aquifers on Long Island, New York; modified from Smolensky and others (1989). Location of cross section shown on figure 1.

Lloyd Aquifer

The Lloyd aquifer of Cretaceous age lies conformably beneath and is confined by the Raritan clay (fig. 2). The Lloyd aquifer rests unconformably on bedrock throughout most of Long Island and is up to 400 ft thick. The Lloyd aquifer consists of fine to coarse sand and gravel with lenses of silty clay.

Previous Estimates of Hydraulic Properties

Transmissivity and hydraulic conductivity estimates for aquifers on Long Island from selected areal groundwater appraisals and aquifer-test site studies were previously summarized by McClymonds and Franke (1972). These estimates of aquifer hydraulic properties were derived from specific-capacity tests (pumping rate and drawdown data) and aquifer tests (single- and multiple-well time-drawdown data) through analytical methods. McClymonds and Franke (1972) also published statistical summaries and contoured maps of transmissivity and hydraulic conductivity of the aquifers based on an analysis of specific capacities, screen lengths, and lithologic logs from production-well completion reports. Lindner and Reilly (1982), Aronson and others (1983), Prince and Schneider (1989), and Cartwright (1997) used numerical radial-flow models, and Misut and Busciolano (2009) used analytical models to estimate hydraulic properties at selected aquifer-test sites on Long Island. Estimates of aquifer hydraulic properties from these previous studies associated with specific well sites are available from the USGS National Water Information System database (NWIS; U.S. Geological Survey, 2020a) and can be viewed through the Aquifer Test Locator graphical user interface (U.S. Geological Survey, 2020b).

Description of Specific-Capacity Tests and Wells

Specific-capacity test and well-construction data were compiled for 447 tested well sites from a previously published compilation by Chu (1996) for Kings and Queens Counties and from unpublished paper records for Nassau and western Suffolk Counties. Approximately half of the tested well sites were screened in the Magothy aquifer, and one-quarter were screened in the upper glacial aquifer in the outwash plain south of the moraine deposits. The specific-capacity test and well-construction data, which included test date, pumping rate and duration, water levels before and during pumping, screen length and diameter, and depth of top and bottom of the screened interval, were sourced from completion reports of production well-acceptance tests conducted from 1919 to 1982 (NYSDEC, written commun., 1982). The specific-capacity test

and well-construction data compiled for this study were added to the well location, altitude, and aquifer data previously entered in NWIS; the NWIS data can be mapped through the Aquifer Test Locator graphical user interface (U.S. Geological Survey, 2020b).

The production wells typically were screened in the more transmissive part of the aquifer that was penetrated during drilling. Well-screen depths were as shallow as 20 ft below land surface in the upper glacial aquifer to as deep as 1,280 ft below land surface in the Lloyd aquifer on the barrier-beach islands. Median well-screen lengths were 20 ft in the upper glacial aquifer north of the moraine, 29 ft in the upper glacial aquifer south of the moraine, 20 ft in the Jameco aquifer, 52 ft in the Magothy aquifer, and 60 ft in the Lloyd aquifer. Pumping rates from the production wells during the tests generally were greater than 400 gallons per minute (gal/min) and ranged up to 1,800 gal/min. Pumping durations generally were 8 hours or more.

Estimation Method and Limitations

The transmissivities of the aquifers at the selected production wells were estimated from the specific-capacity test and well-construction data following the method of Bradbury and Rothschild (1985). The method applies the Cooper-Jacob approximation of the Theis (1935) equation:

$$T = \frac{Q}{4\pi(s_m - s_w)} \left[\ln \left(\frac{2.25Tt}{r_w^2 S} \right) + 2s_p \right], \quad (1)$$

where

T	is transmissivity, in feet squared per day;
Q	is pumping rate, in cubic feet per day;
s_m	is measured drawdown, in feet;
s_w	is well loss, in feet;
t	is time since pumping began, in days;
r_w	is effective wellbore radius, in feet;
S	is aquifer storage coefficient (dimensionless); and
s_p	is the partial-penetration correction factor (dimensionless).

The iterative solution of equation 1 is based on an initial guess of T , and Q , s_m , and t from the specific-capacity test. The method assumes that the tested aquifer is confined, nonleaky, homogeneous, and isotropic; flow is radial to the pumping well; well loss is known; aquifer thickness is known; and the storage coefficient of the aquifer is known. The transmissivities estimated in this study are considered to be rough approximations because the aquifers do not meet these ideal assumptions, well losses were not considered ($s_w=0$), the partial-penetration correction was not applied ($s_p=0$), and storage coefficients (S) were approximated. Step-drawdown tests that are used to determine well-loss coefficients were not available for the production wells. Because of high

pumping rates, well losses may be substantial in some wells tested, causing reduced specific capacities and estimates of transmissivity.

The degree of partial penetration is dependent on the length of the well screen in relation to the thickness of the aquifer tested. Although well-screen lengths were available, drawdown data in surrounding observation wells and detailed lithologic logs that are needed to determine the effective aquifer thickness were lacking at the production-well test sites. Not applying the partial-penetration correction used in the Bradbury and Rothschild (1985) method to the partially penetrating production wells in this study should have resulted in lower transmissivity estimates than if the partial-penetration correction had been applied. Also, the partial-penetration correction factor used in the method assumes that the horizontal hydraulic conductivity is equal to the vertical hydraulic conductivity, which is not the case for the aquifers of Long Island. Because of the sedimentary depositional environments of the aquifers on Long Island, horizontal hydraulic conductivity is at least an order of magnitude greater than vertical hydraulic conductivity in the aquifers, with the Magothy aquifer displaying the greatest vertical anisotropy (Smolensky and others, 1989). Applying the partial-penetration correction to a vertically anisotropic aquifer should result in overestimation of transmissivity values.

Storage coefficients for the aquifers at the production-well test sites were not known but were approximated based on published values from Lindner and Reilly (1982), Prince

and Schneider (1989), Cartwright (1997), and Misut and Busciolano (2009). Storage values used in the present analysis were as follows: 0.15 for wells screened within 200 ft of the water table in the unconfined upper glacial and Magothy aquifers; 0.003 for wells screened 200 ft below the water table in the semiconfined upper glacial and Magothy aquifers; and 2×10^{-5} for the confined Jameco, Magothy, and Lloyd aquifers. Storage is one of the less sensitive parameters; for example, using an unconfined storage value for a semiconfined aquifer would decrease the transmissivity estimate by less than 20 percent, whereas, conversely, using a confined storage value would increase the transmissivity estimate by not more than the same percentage.

Estimated Transmissivities of Selected Production Wells

The estimated transmissivities of the selected production wells and the specific-capacity and well-construction data are available from the NWIS database and are viewable through the Aquifer Test Locator graphical user interface (U.S. Geological Survey, 2020b). The estimated transmissivities at the production wells of the upper glacial aquifer in the outwash plain south of the moraine were generally greater than those north of the moraine (fig. 3; table 1). The estimated transmissivities at the wells in the upper glacial aquifer

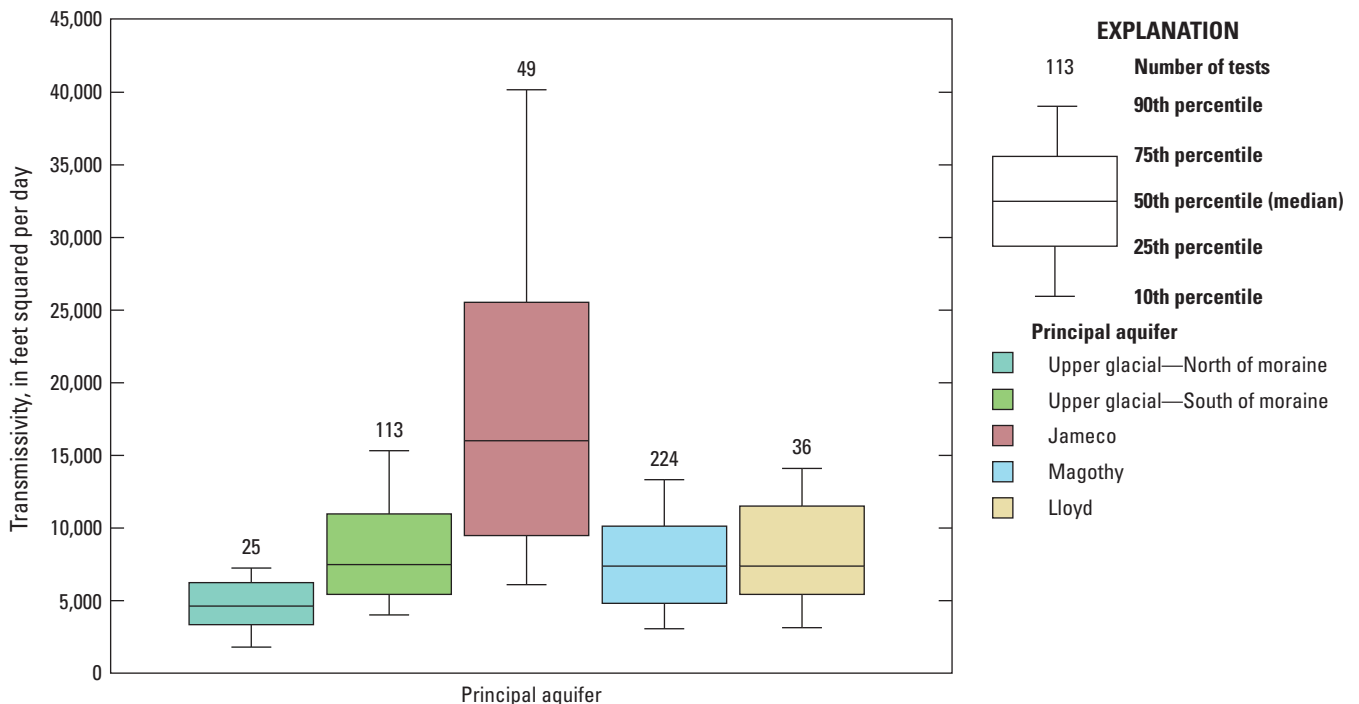


Figure 3. Statistical box plot of transmissivity estimated from specific-capacity tests of selected production wells by principal aquifer, Nassau, Queens, and Kings Counties, Long Island, New York.

Table 1. Summary statistics of transmissivity estimated from specific-capacity tests of selected production wells by principal aquifer in Nassau, Queens, and Kings Counties, Long Island, New York.

Aquifer	Number of wells	Median screen length, in feet	Transmissivity, by percentile, in feet squared per day				
			10th	25th	Median	75th	90th
Upper glacial, north of moraine	25	20	2,100	3,600	4,400	5,700	7,400
Upper glacial, south of moraine	113	29	3,800	5,300	7,300	11,000	15,000
Jameco	49	20	5,500	9,700	16,000	25,000	43,000
Magothy	224	52	2,700	4,800	7,100	9,900	13,000
Lloyd	36	60	3,000	4,900	7,200	11,000	14,000

on the outwash plain south of the moraine typically ranged (as defined by the 10th and 90th percentiles) from 3,800 to 15,000 feet squared per day (ft²/d) and had a median value of 7,300 ft²/d. The estimated transmissivities at the wells in the upper glacial aquifer north of the moraine deposits typically ranged from 2,100 to 7,400 ft²/d and had a median value of 4,400 ft²/d. Production wells in the Jameco aquifer generally had the greatest estimated transmissivities of all the aquifers. The estimated transmissivities at the production wells in the Jameco aquifer typically ranged from 5,500 to 43,000 ft²/d and had a median value of 16,000 ft²/d. The estimated transmissivities of the production wells in the Magothy and Lloyd aquifers generally were similar. The estimated transmissivities at the wells in the Magothy aquifer typically ranged from 2,700 to 13,000 ft²/d and had a median of 7,100 ft²/d. The estimated transmissivities at the wells in the Lloyd aquifer typically ranged from 3,000 to 14,000 ft²/d and had a median of 7,200 ft²/d.

Summary

As part of a cooperative effort between the U.S. Geological Survey and the New York State Department of Environmental Conservation to evaluate the sustainability of Long Island’s sole-source aquifer system, the transmissivities of 447 production wells in Nassau, Queens, and Kings Counties on Long Island, New York, were estimated from specific-capacity tests. The specific-capacity test data, which included pumping rate, pumping duration, and drawdown, were obtained from published and unpublished records of driller-reported acceptance tests collected at production wells screened in the upper glacial, Jameco, Magothy, or Lloyd aquifers. Median well-screen lengths ranged from less than 30 ft in the upper glacial and Jameco aquifers to more than 50 ft in the Magothy and Lloyd aquifers. Pumping rates from the production wells during the tests generally were greater than 400 gallons per minute and ranged up to 1,800 gallons per minute. Pumping duration generally was 8 hours or more. Transmissivity was estimated from the specific-capacity data by the Cooper-Jacob approximation of the Theis equation. The transmissivity values are considered rough

approximations because the aquifers do not meet the ideal assumptions of the method, well losses and partial penetration were not accounted for, and storage was not known but estimated from available data.

The estimated transmissivities at the production wells in the upper glacial aquifer south of the moraine generally were greater than those of the aquifer north of the moraine. Wells in the Jameco aquifer generally had greater estimated transmissivities than those in the other aquifers. Wells in the Magothy and Lloyd aquifers had similar estimated transmissivities. The median aquifer transmissivities were 4,400 ft²/d for the upper glacial aquifer north of the moraine, 7,300 ft²/d for the upper glacial aquifer south of the moraine, 16,000 ft²/d for the Jameco aquifer, 7,100 ft²/d for the Magothy aquifer, and 7,200 ft²/d for the Lloyd aquifer.

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