Relation Between Land Use and Quality of Shallow, Intermediate, and Deep Ground Water in Nassau and Suffolk Counties, Long Island, New York

By Paul E. Stackelberg

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TABLES

CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	2.590	square kilometer
	Flow	
foot per day (ft/d)	0.3048	meter per day
	Temperature	
degree Fahrenheit	5/9 x (°F-32)	degree Celsius

Specific Conductance

Microsiemens per centimete at 25 degrees Celsius (µS/cm)

Equivalent concentration terms

milligrams per liter (mg/L) equals parts per million (ppm)

micrograms per liter (µg/L) equals parts per billion (ppb)

Other abbreviations used in this report

horsepower (hp)

foot per mile (ft/mi)

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Abstract

Water-quality data from a network of 207 wells in five areas of differing land use in Nassau and Suffolk Counties on Long Island were statistically evaluated to determine whether (1) the spatial distribution of contaminants within the ground water system can be related to land use and (or) depth below the water table, (2) shallow ground water that has been altered by human activities has reached the intermediate and deep zones of the aquifer system, and (3) construction of sewers has resulted in an improvement in ground-water quality within suburban areas. The five study areas lie along the regional ground-water divide, where the predominant direction of ground-water flow is downward. The areas were defined, on the basis of the predominant land use and age of sewers in 1986, as follows: (1) suburban area with long-term sewering (longer than 22 years); (2) suburban area, recently sewered (less than 8 years); (3) suburban area, unsewered; (4) agricultural area; and (5) undeveloped area. The sampling depths were delineated on the basis of estimated traveltime of ground water along vertical flow paths from the water table to the midpoint of each well screen. Wells were classified as shallow (estimated traveltimes of 10 years or less), intermediate (estimated traveltimes between 10 and 100 years), and deep (estimated traveltimes of 100 years or more).

Analyses of water samples from the shallow and intermediate zones indicate that concentrations of inorganic constituents were lowest and least variable in the undeveloped area and generally highest and most variable in the agricultural area. Concentrations in the two sewered suburban areas generally were medium to high. Volatile organic compounds were detected only within the suburban areas. These results are similar to those from previous studies that statistically related land use to shallow ground-water quality. Concentrations of most inorganic constituents and values of most physical properties decreased with depth in the aquifer. This decrease is attributed to (1) physical and chemical reactions that remove constituents from solution, and (2) dilution by hydrodynamic dispersion and ionic diffusion as constituents move along flow paths.

Traveltimes of ground water along vertical flow paths from the water table to the midpoint of each well screen indicate that water in the deep zone is old enough to represent pristine (predevelopment) water quality. Concentrations of inorganic constituents in samples from the deep and overlying intermediate zone were more variable, and the median concentrations higher, than those from a data set representing predevelopment ground-water quality. This difference indicates downward migration of these constituents and is attributed to local pumping, which accelerates the downward flow of shallow ground water into intermediate and deep zones of the aquifer system by increasing the vertical hydraulic gradient.

Median concentrations of inorganic constituents in shallow and deep zones of the three suburban areas, and detection frequencies of volatile organic compounds from all depths within each suburban area, indicate an improvement of ground-water quality in the long-term sewered area. Median concentrations of several inorganic constituents in the shallow zone, which represents relatively young water, were highest in the unsewered and recently sewered areas as a result of the continued loading from cesspools, septic tanks, and nonpoint sources, and the persistence of inorganic compounds introduced before sewers were constructed; the highest median concentrations in the deep zone, which represents relatively old water, were in the long-term-

sewered area, which has been developed the longest. Additionally, detection frequencies of volatile organic compounds (VOC's) in the long-term-sewered area were higher in the intermediate zone than in the shallow zone, whereas their detection frequencies in the unsewered and recently sewered areas were highest in the shallow zone because of continued loading from industrial and residential sources and the persistence of VOC's introduced before sewers were constructed.

INTRODUCTION

In 1984, the U.S. Geological Survey (USGS) began the Toxic Substances Hydrology Program to assess the quality of the Nation's ground-water resources and the nature and extent of ground-water contamination (Helsel and Ragone, 1984). As part of that program, 14 study areas that represent a variety of climatic and hydrogeologic conditions and land uses were selected to provide information on regional ground-water quality and its relation to local hydrologic and human influences. The Long Island aquifer system in Nassau and Suffolk Counties was selected as part of this program because (1) a vast amount of hydrogeologic and chemical data is available; (2) all development is directly above the water-table aquifer, and the high permeability of the soils makes the system susceptible to contamination introduced at or just beneath land surface; (3) the area encompasses a variety of land-use settings that range from highly urbanized in the west (near New York City) to nearly pristine in parts of eastern Suffolk County (fig. 1); (4) the Long Island aquifer system has been classified as a sole-source aquifer by the U.S. Environmental Protection Agency (the aquifer supplies potable water to more than 3.2 million people, including the entire population of Nassau and Suffolk Counties and about 500,000 New York City residents in Queens County); (5) the aquifer system is regional in extent (1,170 mi^2) and is hydrologically similar to others along the Atlantic Coastal Plain.

The first phase of the Long Island study, begun in 1984, was a reconnaissance in which the chemical quality of water in the water-table aquifer in Nassau and Suffolk Counties was statistically examined in relation to 10 types of land use to evaluate the effect of human activities on ground water (Eckhardt, Flipse, and Oaksford, 1989). Results indicated a correlation

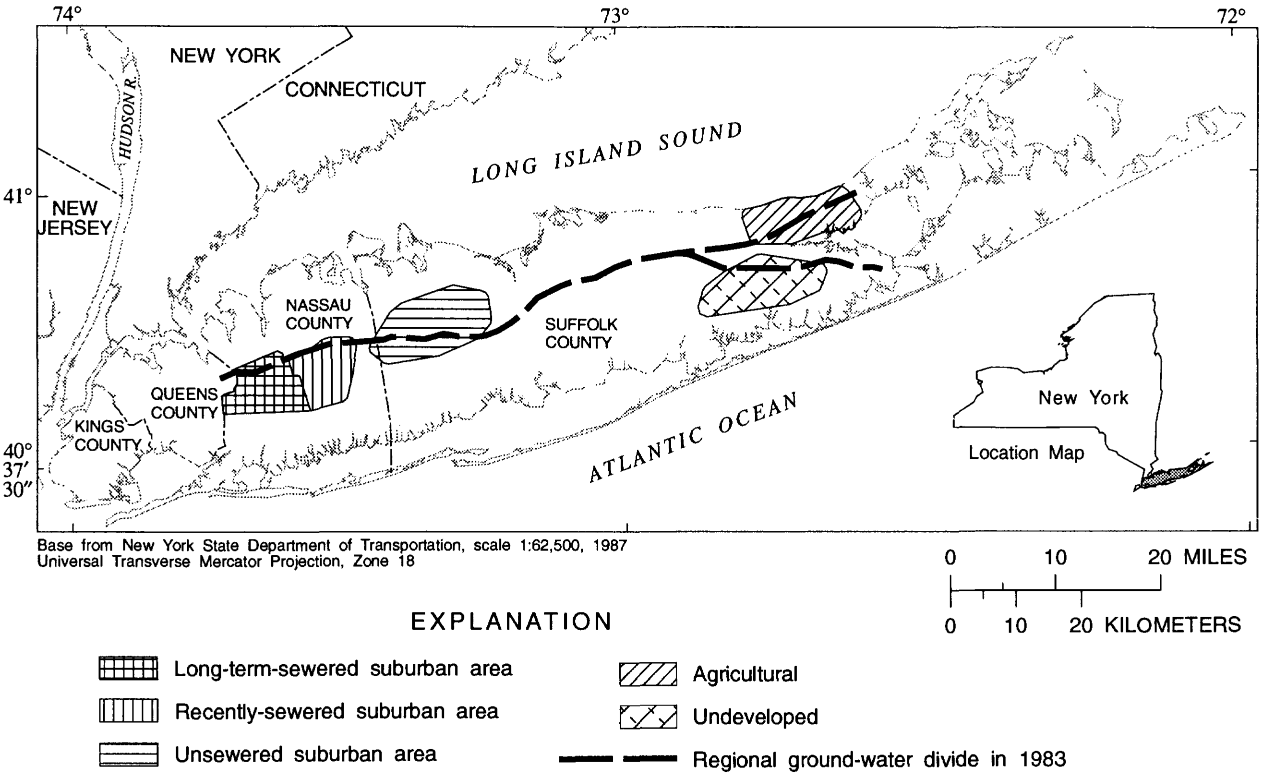


Figure 1. Location of the five study areas and the regional ground-water divide on Long Island, N.Y.

between land use and quality of shallow ground water and confirmed that contamination from human activities has affected the quality of water in the water-table aquifer. That phase was preliminary, however, and did not address the effects of the local direction and rate of ground-water flow, the length of time that suburban areas have been sewered, or historical land-use practices. A refined approach was used in the second phase (1986), which was designed to statistically evaluate the quality of shallow ground water beneath five areas of differing land use along the regional ground-water divide (fig. 1) (Eckhardt and Stackelberg, in press; LeaMond and others, 1992). This approach incorporated the effects of the factors not addressed in the first phase of investigation. The third phase of investigation, described herein, was designed to extend the statistical analysis of ground-water quality within the five study areas into deeper zones of the aquifer system.

Purpose and Scope

This report presents the results of the third phase of investigation of the effects of land use on ground-water quality in Nassau and Suffolk Counties. Also included are: (1) descriptions of the five study areas in terms of land use, population density, and hydrogeology; (2) estimates of ground-water traveltime from the water table to the midpoint of each well screen for 207 randomly selected wells; (3) comparisons of the chemical quality of water from the shallow zone of each study area with that in the underlying intermediate zone; and (4) comparisons of the chemical quality of water from the shallow zones of the three suburban areas with that in the underlying intermediate and deep zones. Also discussed in the report is whether effects of development on shallow ground water observed in previous studies are evident in intermediate and deep zones of the aquifer and whether sewers affect water quality in the three suburban areas. Water-quality data collected by USGS investigators from 207 randomly selected wells screened in shallow, intermediate, and deep zones beneath the five study areas are evaluated in this report.

Each well was sampled once during the study (1987-88). Sampling depths were delineated on the basis of estimated traveltime of ground water along vertical flow paths from the water table to the midpoint of each well screen. Wells were classified as shallow (estimated traveltimes of 10 years or less), intermediate (estimated traveltimes of between 10 and 100 years), and deep (estimated traveltimes of 100 years or more). The resulting data were statistically evaluated for evidence of water-quality differences among the five areas and three depth intervals. This statistical evaluation, coupled with an estimation of the traveltime of ground water from the water table to the midpoint of each screen, was used to determine whether (1) the spatial distribution of contaminants within the aquifer system can be related to local land use, depth below the water table or both, (2) contamination resulting from human activities has reached the intermediate and deep zones of the aquifer system, and (3) construction of sewer systems in the suburban areas resulted in an improvement in ground-water quality.

Previous Investigations

Concern about increasing contamination of surface-water and ground-water resources in Nassau and Suffolk Counties since their rapid development after World War II has prompted many investigations into the extent and sources of contamination. Perlmutter and others (1964) and Perlmutter and Koch (1971) investigated the extent of detergent contamination emanating from hundreds of thousands of cesspools and septic tanks in Nassau County and found that the contamination was widespread in the water-table aquifer, although generally in low concentrations. Detergents were seldom detected in samples from underlying aquifers, except in areas where pumped wells were screened a short distance below detergent-rich water of the overlying water-table aquifer. Perlmutter and Koch (1972) found that nitrate concentrations in large areas of the water-table aquifer in southern Nassau County approached or exceeded the U.S. Public Health Service's recommended limit of 10 mg/L (as N) for drinking water and observed that nitrate-enriched water from the water-table aquifer had penetrated the full thickness of the underlying Magothy aquifer. They attributed the increasing nitrate concentrations to infiltration of sewage, leachate from fertilizers, and wastes from decayed crops. Ku and Sulam (1976) studied the concentrations of nitrate, chloride, and dissolved solids in ground water in southern Nassau County from the 1950's to 1973 and found that (1) concentrations had increased steadily, and (2) the elevated concentrations had moved vertically downward from tens of feet to a few hundred feet. The Nassau-Suffolk Regional Planning Board, in an extensive investigation of surface- and ground-water quality in the two-county area during the mid-1970's, found nitrate concentrations to be increasing significantly in the two-county area, most notably in areas of recharge to deep aquifer systems (Koppelman, 1978). Katz and others (1978) and Porter (1980) attributed the increasing nitrate concentrations in the two-county area to wastewater from cesspools and septic tanks and to fertilizers used on lawns and agricultural areas.

Sewer systems were installed in parts of Nassau County during the 1950's and 1960's in response to the deterioration in ground-water quality. Shortly thereafter, several studies were done to evaluate differences between ground-water quality in sewered areas and in unsewered areas (Perlmutter and Koch, 1972; Koppelman, 1978; Ku and Sulam, 1979; Katz and others, 1980; Porter, 1980; Ragone and others, 1981). These investigators concluded that, although ground-water quality in sewered areas had improved or was improving, the improvement was being masked by the slow rate at which the water-table aquifer could discharge nitrate that had been introduced before sewer construction and by the continuing introduction of nitrogen from nonpoint sources.

The first detection of volatile organic compound (VOC) contamination of ground water in the two-county area was documented in 1975. Subsequent sampling of public-supply wells in Nassau County revealed VOC contamination throughout the ground-water system; the highest concentrations were near industrial areas, and concentrations were higher in water from shallow wells than in water from intermediate or deep wells (Myott, 1980). During the mid-1970's, the Nassau-Suffolk Regional Planning Board, as part of an investigation of surface- and ground-water quality, detected VOC's in shallow and deep aquifers in parts of both counties (Koppelman, 1978). In an investigation of chlorinated organic compounds at a contaminated commercial site in Nassau County, Eckhardt and Pearsall (1989) detected VOC's at concentrations as high as 38,000 µg/L and at depths as great as 500 ft below land surface.

Although routine analyses of public-supply and monitoring wells in Nassau County have not detected metals at concentrations exceeding current drinking-water standards (Myott, 1988), investigations as far back as the early 1960's delineated plumes of ground water with high concentrations of certain dissolved metal species in Nassau County (Perlmutter and others, 1963).

In the late 1960's, several studies addressed statistical relations between human activities and the chemical quality of surface- and ground-water bodies. Because virtually all of the water in Long Island streams is derived from ground water, the quality of streamflow is indicative of the quality of ground water in that part of the aquifer that discharges to the streams. Koch (1970) compared the quality of water from streams in sparsely populated parts of Suffolk County with that in streams in moderately to densely populated parts of Nassau County and found that the concentration of certain constituents derived from human activity were significantly higher in Nassau County than in Suffolk County. K.A. Pearsall (U.S. Geological Survey, written commun., 1988) compared estimated pristine-water concentrations of selected inorganic constituents with 1987-88 concentrations in residential and agricultural areas and found that (1) the elevated concentrations of several of these constituents in shallow ground water were the result of human activity, and (2) the constituents studied constituted from about 60 percent to virtually 100 percent of the total inorganic constituent load to the aquifer system in residential and agricultural areas. The effects of natural geochemical processes on constituent concentrations in these areas was found to be small. In 1984-85, as part of the Toxic Substances Hydrology Program, Eckhardt, Flipse, and Oaksford (1989) examined water-quality data from more than 900 wells in Nassau and Suffolk Counties that represented 10 different types of land use to evaluate the effect of human activities on ground-water quality and found contamination in the water-table aquifer throughout the two-county area (Eckhardt, Flipse, and Oaksford, 1989; Eckhardt and Oaksford, 1986). The highest median concentrations of inorganic constituents were generally in high-density residential and agricultural areas, and the highest concentrations and most frequent detections of VOC's were in commercial and industrial areas. VOC detection in high-density residential areas also was high, and the percentage of samples having detectable concentrations was directly correlated with population density. A subsequent study under the Toxic Substances Hydrology Program in the late 1980's statistically evaluated the quality of shallow ground water from five areas of differing land use along the regional ground-water divide in Nassau and Suffolk Counties; results indicated that water from undeveloped areas had the lowest and least variable concentrations of most human-derived constituents (Eckhardt and Stackelberg, in press; LeaMond and others, 1992; Eckhardt, Siwiec, and Cauller, 1989; Eckhardt and Helsel, 1988; Eckhardt and others, 1988). Concentrations of inorganic constituents in samples from the agricultural area generally were highest and most variable, and, in general, concentrations in samples from residential areas also were medium to high. VOC's were detected most frequently and at highest concentrations in samples from residential areas. During that investigation, the potential for ground-water contamination was evaluated through maximum-likelihood logistic-regression models that relate the presence or absence of specific contaminants to selected explanatory variables that describe the degree of human activities at land surface (Eckhardt and Stackelberg, in press; Stackelberg and Eckhardt, in press; Eckhardt, Siwiec, and Cauller, 1989; Eckhardt and Helsel, 1988; Eckhardt and others, 1988). Explanatory variables that were found to be significantly correlated with the presence of VOC's, nitrate, and boron within the shallow ground-water system included population density and the percentage of residential, agricultural, industrial, and commercial land use within a 1/2-mi radius of sampled wells.

DESCRIPTION OF STUDY AREAS

The five study areas, which were defined according to the predominant land use and age of sewers in 1986, are categorized as (1) suburban, with long-term sewering (longer than 22 years), (2) suburban, recently sewered (less than 8 years), (3) suburban, unsewered, (4) agricultural, and (5) undeveloped (fig. 1). Predominant land use reflects the types of human activities within each study area and provides a basis for evaluating relations between human activity and ground-water quality. The delineation of suburban areas on the basis of the presence and age of sewers in 1986 allows comparison of water quality in an unsewered area with that in areas sewered for longer than 22 years or less than 8 years. All five areas lie along the regional ground-water divide, where the predominant direction of ground-water flow is vertically downward, and contamination introduced at or near land surface is transported deeper into the aquifer system than elsewhere.

Land Use

Land use within the five study areas can be assessed and described in terms of (1) land-use categories and (2) population density. Land use within each study area in 1981, as compiled at a scale of 1:24,000 (Long Island Regional Planning Board, 1982), is depicted in figures 2A through 2E and is summarized in table 1.

Suburban area, long-term sewered.—This study area encompasses 33.5 mi^2 in central Nassau County that has been sewered since 1964. The predominant land-use category is residential, which constitutes

Table 1. Land use in the five study areas in Nassau and Suffolk Counties, N.Y.

[Locations are shown in fig. 1; values are in percent; land-use columns may not add to 100 percent because of independent rounding]

Land-use category	Suburban: Long-term sewered	Suburban: Recently sewered	Suburban: Unsewered	Agricultural	Undeveloped
Residential:					
Number of dwelling units per acre:					
0.99 or fewer	2.63	2.96	18.59	2.84	2.91
1 to 4.99	5.75	.57	33.21	5.53	1.95
5 to 9.99	48.90	57.37	.06	1.27	.36
10 or more	1.69	.68	.05	.62	.39
Commercial	12.82	6.56	3.35	1.69	.28
Commercial recreational	.0	.0	.02	.08	.13
Industrial	3.63	6.82	3.34	1.28	.40
Institutional	9.21	5.71	9.45	1.45	1.72
Open space and recreational	9.51	11.43	10.26	2.91	11.84
Agricultural	.02	.01	3.78	58.61	7.82
Transportation and utilities	3.27	5.63	7.51	2.86	10.07
Vacant	2.55	2.16	10.38	20.64	61.94
Water bodies	.02	.10	.01	.21	.18

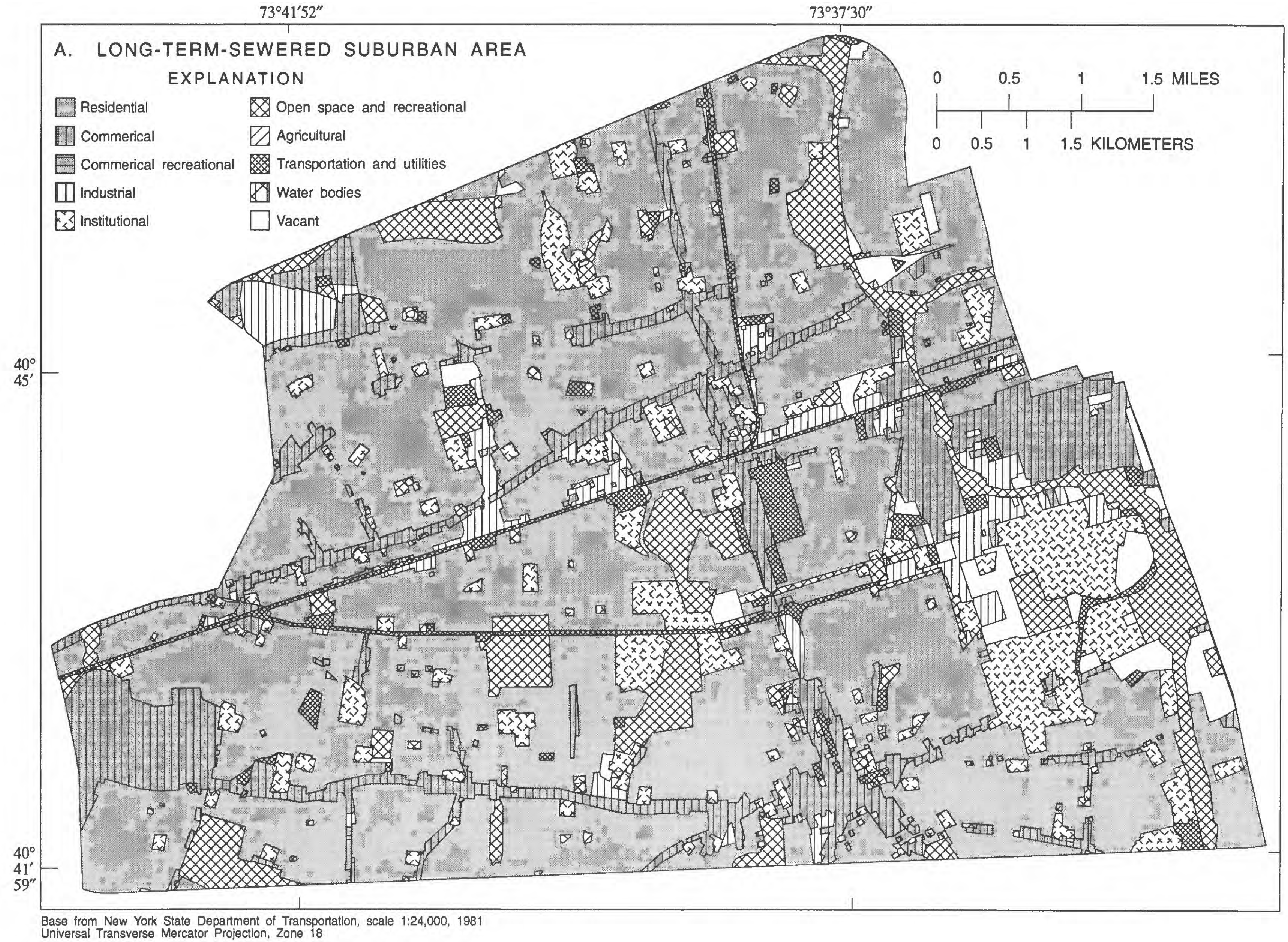
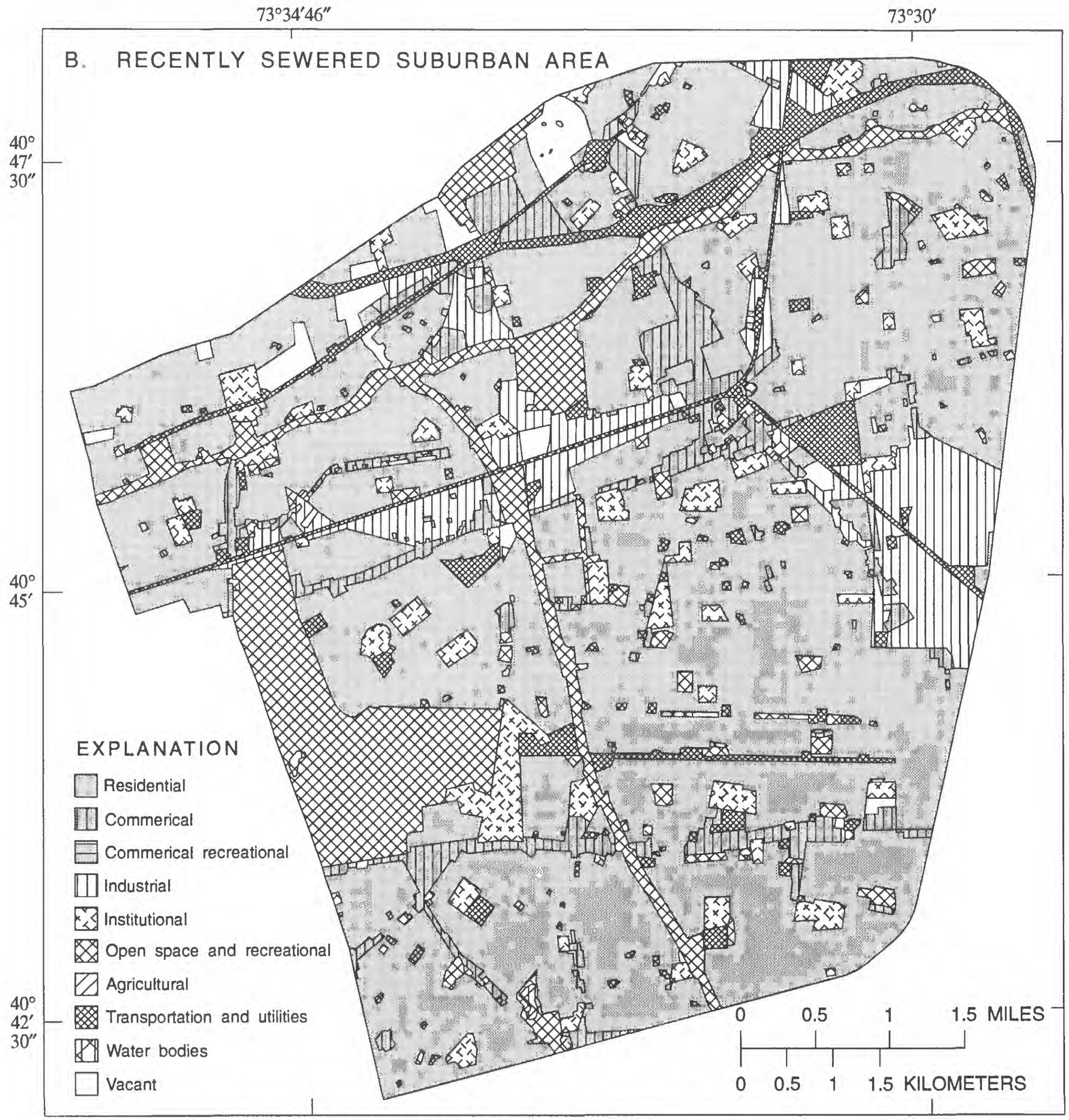


Figure 2A. Land use in the long-term sewered suburban area, Long Island, N.Y. (Location is shown in fig. 1. Data from Long Island Regional Planning Board, 1982.)



Base from New York State Department of Transportation, scale 1:24,000, 1981
Universal Transverse Mercator Projection, Zone 18

Figure 2B. Land use in the recently sewered suburban area, Long Island, N.Y. (Location is shown in fig. 1. Data from Long Island Regional Planning Board, 1982.)

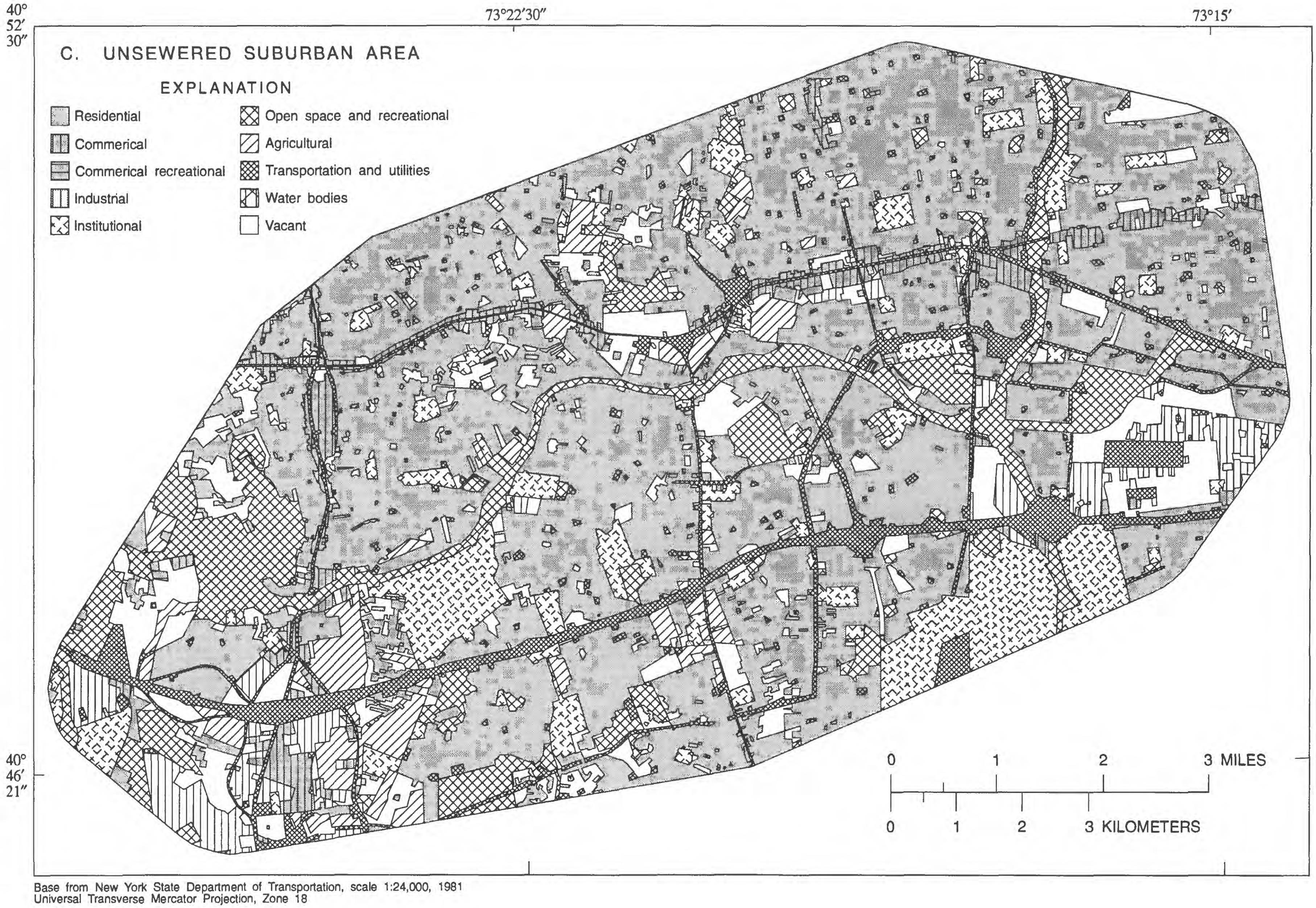


Figure 2C. Land use in the unsewered suburban area, Long Island, N.Y. (Location is shown in fig. 1. Data from Long Island Regional Planning board, 1982.)

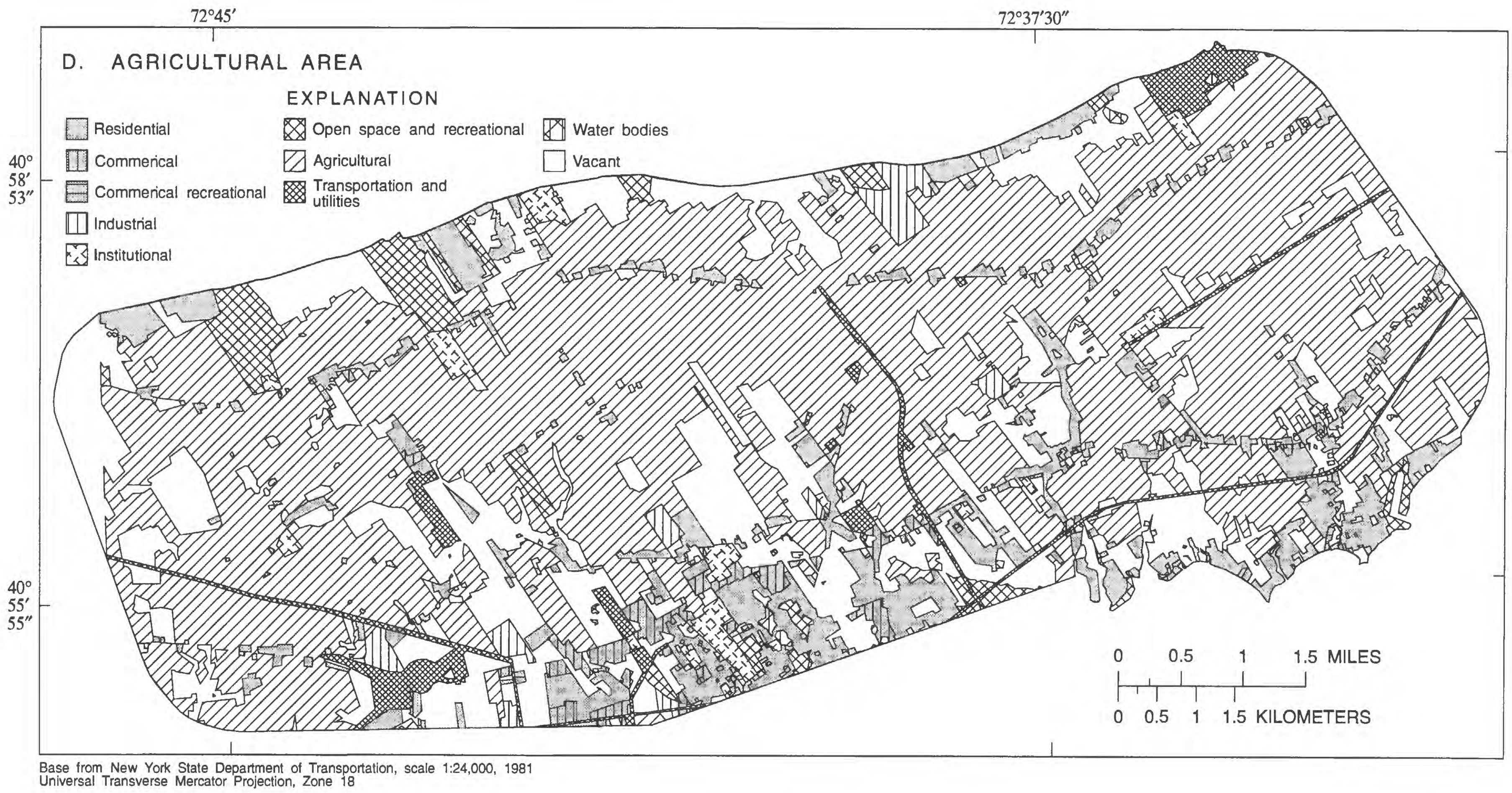


Figure 2D. Land use in the agricultural area, Long Island, N.Y. (Location is shown in fig. 1. Data from Long Island Regional Planning Board, 1982.)

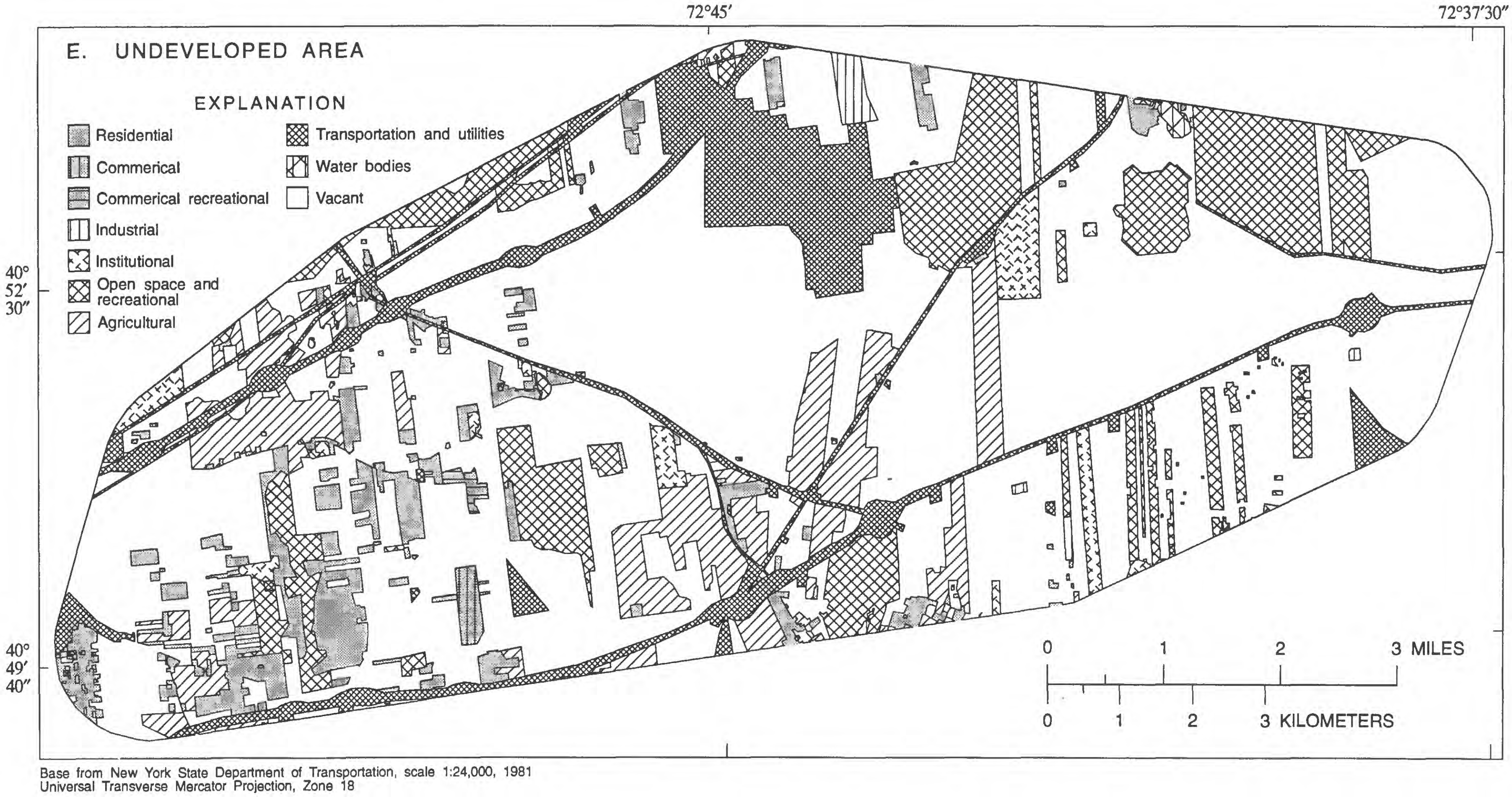


Figure 2E. Land use in the undeveloped area, Long Island, N.Y. (Location is shown in fig. 1. Data from Long Island Regional Planning Board, 1982.)

58.97 percent of the area (fig. 2A and table 1). The commercial and industrial categories together constitute 16.45 percent of the area and are concentrated along major transportation corridors. The open space and recreational category constitutes 9.51 percent of the area and includes motor parkways that cross the area. The institutional category constitutes 9.21 percent of the study area and is represented primarily by two universities in the southeastern part. The transportation and utilities category constitutes 3.27 percent of the area; vacant land constitutes only 2.55 percent, and water bodies and agricultural land together constitute less than 0.1 percent.

Suburban area, recently sewered.—This study area (fig. 2B) is adjacent to the east side of the long-term sewered area and encompasses 30.2 mi^2 in central Nassau County (fig. 1). Although the two areas differ in age of sewers, their land-use patterns are similar. In 1987, sewers had been installed for less than 8 years in those parts of the study area that are serviced by sewers. The predominant land-use category is residential, which constitutes 61.58 percent of the area (fig. 2B and table 1). Commercial and industrial land-use categories together constitute 13.38 percent of the area and are concentrated along major transportation corridors. The open-space and recreational land-use category constitutes 11.43 percent of the area and is represented primarily by motor parkways and a large public park in the west-central part of the study area. The institutional category and the transportation and utilities category constitute 5.71 and 5.63 percent of the study area, respectively, and vacant land accounts for 2.16 percent. Water bodies and agricultural land together constitute about 0.1 percent.

Suburban area, unsewered.—This study area (fig. 2C) encompasses 58.8 mi^2 in the westernmost part of Suffolk County (fig. 1). It differs from the two other suburban areas primarily in its lack of sewers and in the greater percentage of vacant land and smaller percentage of commercial and industrial land. The predominant land-use category is residential, which constitutes 51.91 percent of the area (fig. 2C and table 1). The vacant-land category and the open-space and recreational category constitute 10.38 and 10.26 percent of the area, respectively, and the institutional and agricultural categories constitute 9.45 and 3.78 percent, respectively. Transportation and utilities constitute 7.51 percent. Commercial and industrial land together constitute only 6.69 percent, substantially less than in the two sewered areas. Water bodies and commercial-recreational land together constitute less than 0.1 percent of the study area.

Agricultural area.—This study area (fig. 2D) encompasses 41.2 mi^2 in eastern Suffolk County (fig. 1). The predominant land-use category is agricultural, which constitutes 58.61 percent of the area (fig. 2D and table 1). Vacant land constitutes 20.64 percent of the area, and residential land use constitutes 10.26 percent. Transportation and utilities constitute 2.86 percent, open space and recreational land constitutes 2.91 percent, institutional land constitutes 1.45 percent, and commercial and industrial land together constitute 2.97 percent of the study area. Water bodies and commercial-recreational land together constitute less than 1 percent.

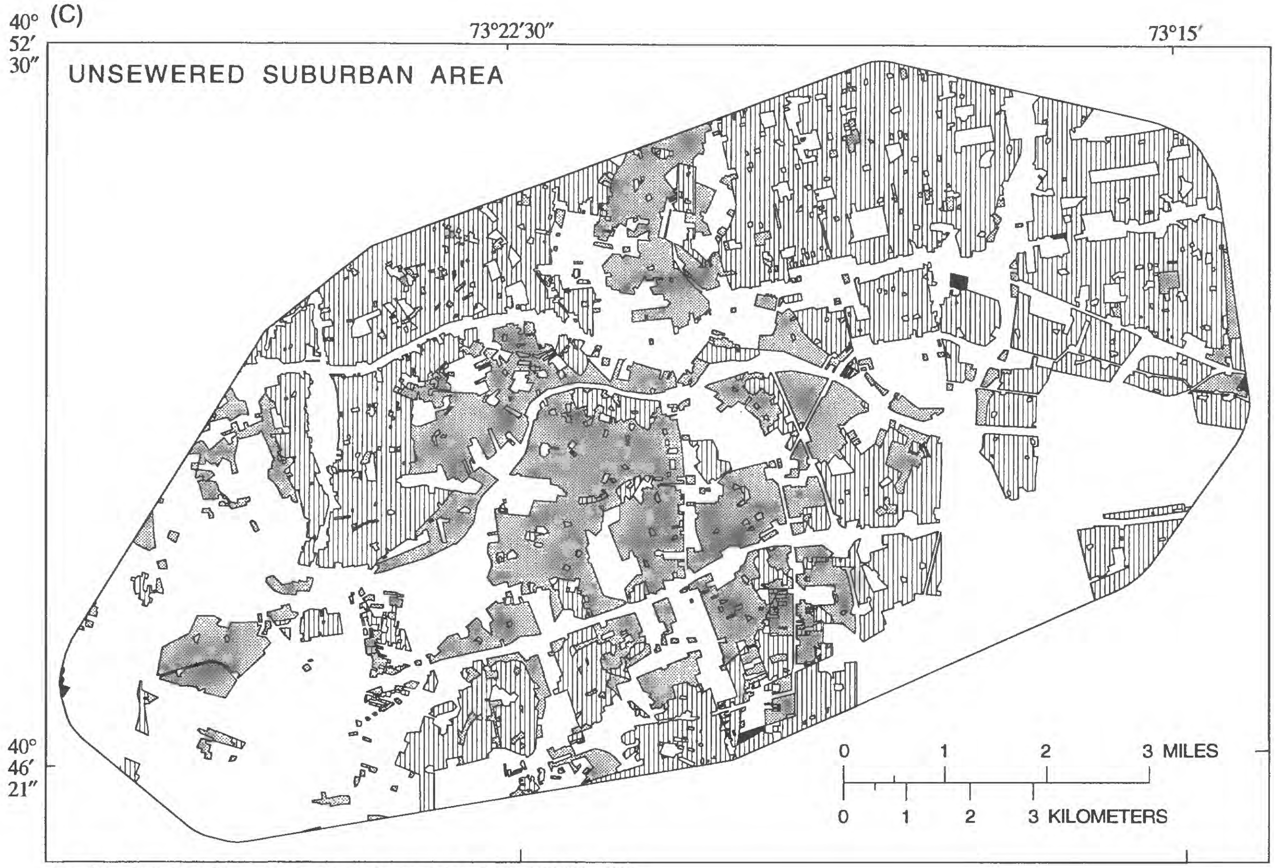
Undeveloped area.—This study area (fig. 2E), also in eastern Suffolk County (fig. 1), encompasses 48.9 mi^2. Vacant land constitutes 61.94 percent of the area (fig. 2E and table 1), and open space and recreational land constitutes 11.84 percent. The transportation and utilities category constitutes 10.07 percent of the area and is represented primarily by major transportation corridors and an industrial plant in the north-central part of the study area. Agricultural and residential land constitute 7.82 and 5.61 percent of the area, respectively, and institutional land accounts for only 1.72 percent. Water bodies and commercial, commercial-recreational, and industrial land together constitute slightly less than 1 percent of the study area.

Population Density

The general distribution and density of population within the study areas, as indicated by the distribution and density of dwelling units, is shown in figures 3A through 3D. Population data were obtained in digital format from the U.S. Census Bureau and represent 1985 totals. Population density for each study area was calculated as the population within each study area divided by the number of acres in each study area. The long-term-sewered suburban area (fig. 3A) is the most densely populated, with an average of 13.64 persons per acre, and more than 50 percent of the land contains five or more dwelling units per acre (fig. 3A). The recently sewered suburban area (fig. 3A) also is heavily residential; 58 percent of the area has five or

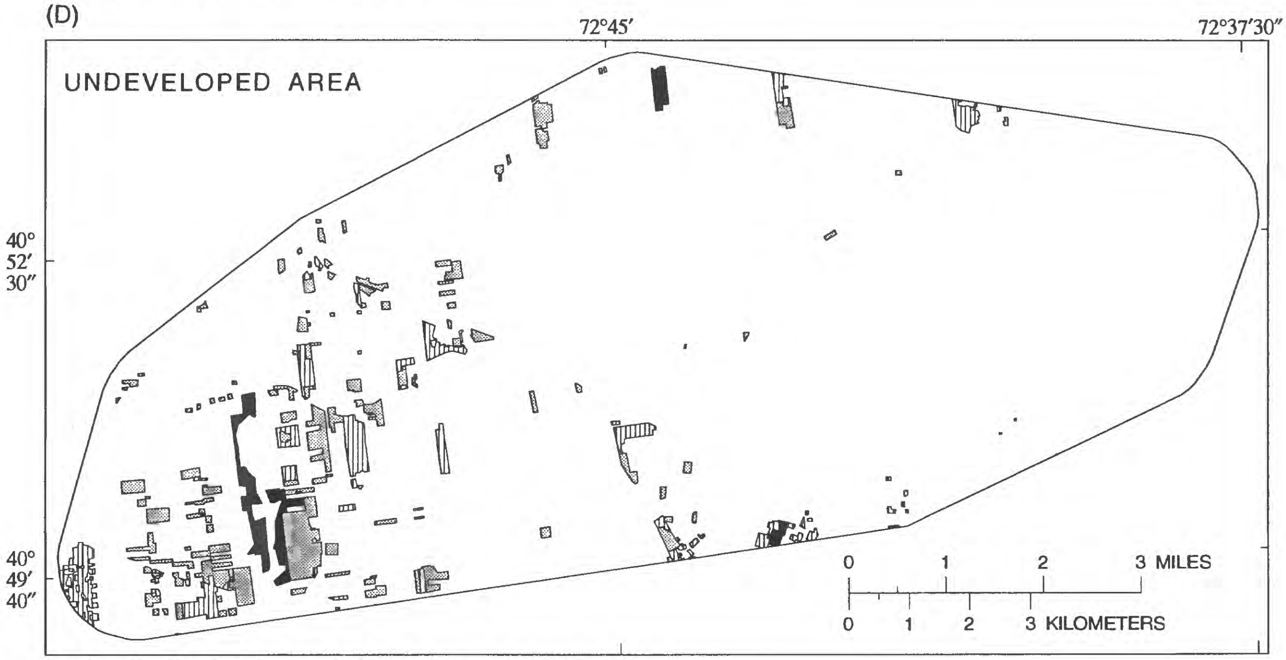
Figure 3. Number of dwelling units per acre in the five study areas, Long Island, N.Y. (Locations are shown in fig. 1. Data from

(C)



Base from New York State Department of Transportation, scale 1:24,000, 1981
Universal Transverse Mercator Projection, Zone 18

(D)



Base from New York State Department of Transportation, scale 1:24,000, 1981
Universal Transverse Mercator Projection, Zone 18

EXPLANATION

Number of dwelling units per acre (white space represents nonresidential land use)

0-0.99 1-4.99 5-10.99 11 or more

Long Island Regional Planning board, 1982.

more dwelling units per acre, but the population density averages only 9.69 persons per acre. The unsewered suburban area (fig. 3C) is less populated than the sewered areas; more than 51 percent of the area contains fewer than 5 dwelling units per acre, and only 0.11 percent of the area contains 5 or more dwelling units per acre (fig. 3C). The average population density in this area is 5.63 persons per acre. The agricultural area (fig. 3B) is about 10 percent residential, but more than 8 percent of this is land with 4.99 or fewer dwelling units per acre. The average population density is 0.72 persons per acre. The undeveloped area (fig. 3D) is about 5.5 percent residential land, 4.86 percent of which has 4.99 or fewer dwelling units per acre (fig. 3D). The average population density is only 0.53 persons per acre.

Hydrogeology

The Long Island aquifer system consists primarily of unconsolidated deposits of sand and gravel interbedded with layers of sandy clay, clayey sand, and silt of glacial, marine, and fluvial or deltaic origin (fig. 4). Cretaceous sediments unconformably overlie nearly impermeable crystalline bedrock and, like the bedrock, dip southeastward at about 65 ft/mi (McClymonds and Franke, 1972). Local erosion of Cretaceous sediments by streams and glaciers left an irregular surface of moderate relief upon which sediments of Pleistocene age were deposited. The following discussion of hydrogeology is limited to the Pleistocene upper glacial (water-table) aquifer and the underlying Cretaceous Magothy aquifer because all wells sampled in this study were screened within these two units.

The upper glacial aquifer consists of material deposited by Pleistocene glaciers as terminal moraines. Some of this material was reworked by glacial meltwater to form large outwash-plain deposits of stratified sand and gravel. Sediments that form the upper glacial aquifer are highly permeable and have an average horizontal hydraulic conductivity of 270 ft/d and an estimated average vertical hydraulic conductivity of 27 ft/d (Franke and Cohen, 1972). Within Nassau and Suffolk Counties, the upper glacial aquifer is 50 to 300 ft thick except where it extends into valleys carved into the underlying Magothy aquifer by rivers; glacial deposits that extend into these valleys reach thicknesses of 600 to 700 ft.

The Magothy aquifer consists of material deposited in marine and fluvial or deltaic environments during the Cretaceous Period. These deposits consist of beds and lenses of sandy clay, clayey sand, silt, and sand and gravel; the coarsest sediments generally are

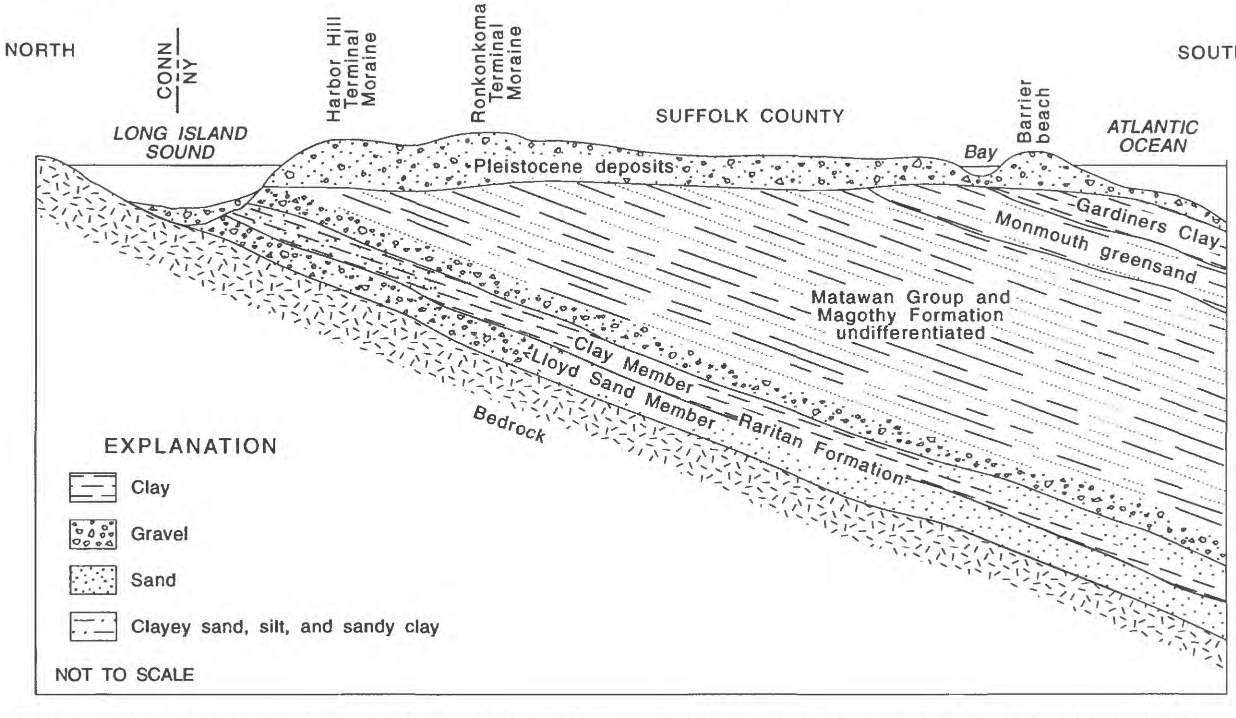


Figure 4. Diagrammatic geologic section of the Long Island aquifer system in Nassau County, N.Y. (Modified from McClymonds and Franke, 1972, fig. 3.)

within the basal 50 to 100 ft of the unit (Franke and Cohen, 1972; Soren and Simmons, 1987). The average horizontal hydraulic conductivity of the Magothy aquifer is estimated to be 50 ft/d (Franke and Cohen, 1972); however, horizontal hydraulic conductivity can differ substantially from place to place according to the composition of the deposits (Soren and Simmons, 1987). In Nassau and Suffolk Counties, the Magothy aquifer is 200 to 1,000 ft thick.

The downward flow of ground water from the upper glacial aquifer to the Magothy aquifer in the five study areas generally is not significantly restricted by confining units; but clay lenses within the upper part of the Magothy can restrict flow locally. Further discussions of the geology and hydrogeology of Long Island are given in Suter and others (1949), Isbister (1966), Perlmutter and Geraghty (1963), Swarzenski (1963), and Buxton and others (1981).

APPROACH AND METHODS

The approach used in this study is based on the premise that contamination of ground water by human activities can be considered a function of land use; that is, land uses determine the amounts and types of chemicals that are applied at land surface and, thus, the amounts and types of contaminants that reach ground water (Helsel and Ragone, 1984). The study entailed three procedures: (1) collection of water-quality data from a network of 207 wells, (2) classification of wells as shallow, intermediate, or deep, on the basis of estimated ground-water traveltimes from the water table to the midpoint of each well screen, and (3) statistical analyses of water-quality data.

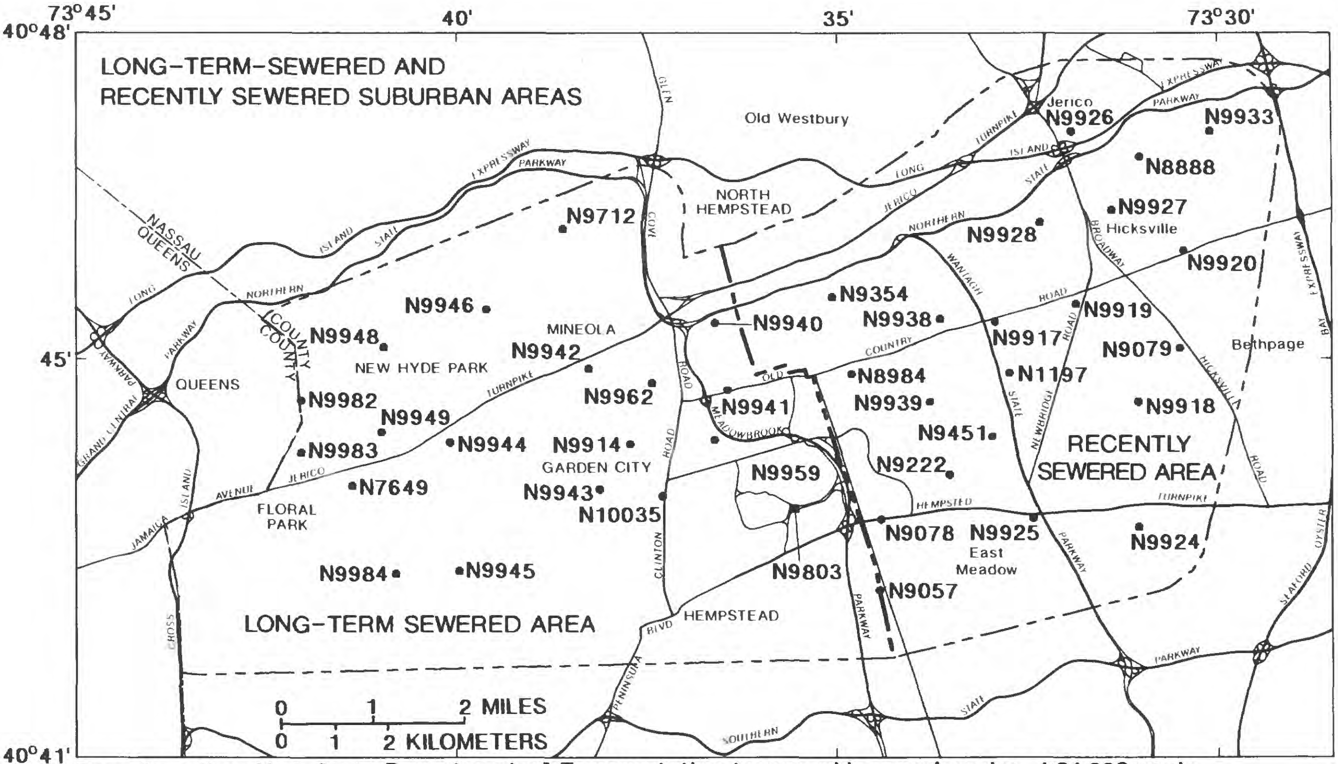
Data Collection

Water samples were collected from June 1987 through September 1988 from a network of wells within the five study areas (figs. 5, 6, and 7). Wells were chosen by a random-selection procedure, wherein a grid was superimposed over a map of each study area, and one well was selected from each grid cell (LeaMond and others, 1992). This procedure ensured uniform distribution of wells and collection of chemical data representative of ground-water quality in each depth zone of each study area. Wells in the intermediate depth zones of the unsewered suburban and undeveloped areas were sparse, and not every grid cell contained a well appropriate for this study; therefore, two wells outside the established study-area boundaries were included in the network (figs. 6C and 6D).

Classification of wells as shallow, intermediate, or deep was based on the traveltime of ground water along vertical flow paths from the water table to the midpoint of each well screen to ensure that all wells within a given depth zone produced samples of similar age. Vertical flow rates were calculated from cell-to-cell flow rates by the regional ground-water-flow model of Long Island (H.T. Buxton and D.A. Smolensky, U.S. Geological Survey, written commun., 1990), which simulates ground-water flow under average steady-state conditions for 1968-75, a period in which precipitation rates were similar to long-term average rates and ground-water pumpage was steady (S.M. Feldman, U.S. Geological Survey, oral commun., 1990). The vertical flow rates were then used to calculate traveltimes along vertical flow paths from the water table to the midpoint of each well screen. Although this method does not address traveltimes through the unsaturated zone, unsaturated zone thickness is statistically similar in four of the five areas, as discussed in appendix 4. Additionally, the steady-state simulation does not account for localized pumping, which would serve to decrease estimated traveltimes. Any wells indicated by modeling results to be in ground-water discharge areas were eliminated from the analysis. Shallow wells were classified as having estimated traveltimes of 10 years or less, intermediate wells as having estimated traveltimes of between 10 and 100 years, and deep wells as having estimated traveltimes of 100 years or more.

In all, 83 shallow wells, 70 intermediate-depth wells, and 54 deep wells were sampled. Locations of shallow wells in each study area are shown in figure 5, those of intermediate-depth wells in figure 6, and those of deep wells in figure 7. The shallow zone was represented by 11 to 20 wells per study area, the intermediate zone by 10 to 17 wells per study area, and the deep zone by 17 to 19 wells per study area. The agricultural and undeveloped areas had no deep wells; the deepest wells in those areas were screened in the intermediate zone. All wells sampled were screened only within the depth zone for which they were classified.

Of the 207 wells sampled, 57 percent were monitoring wells, 22 percent were public-supply wells, and 21 percent were classified as "unspecified withdrawal." Median screen length for monitoring wells was 5 ft; the 25th- and 75th-percentile screen lengths



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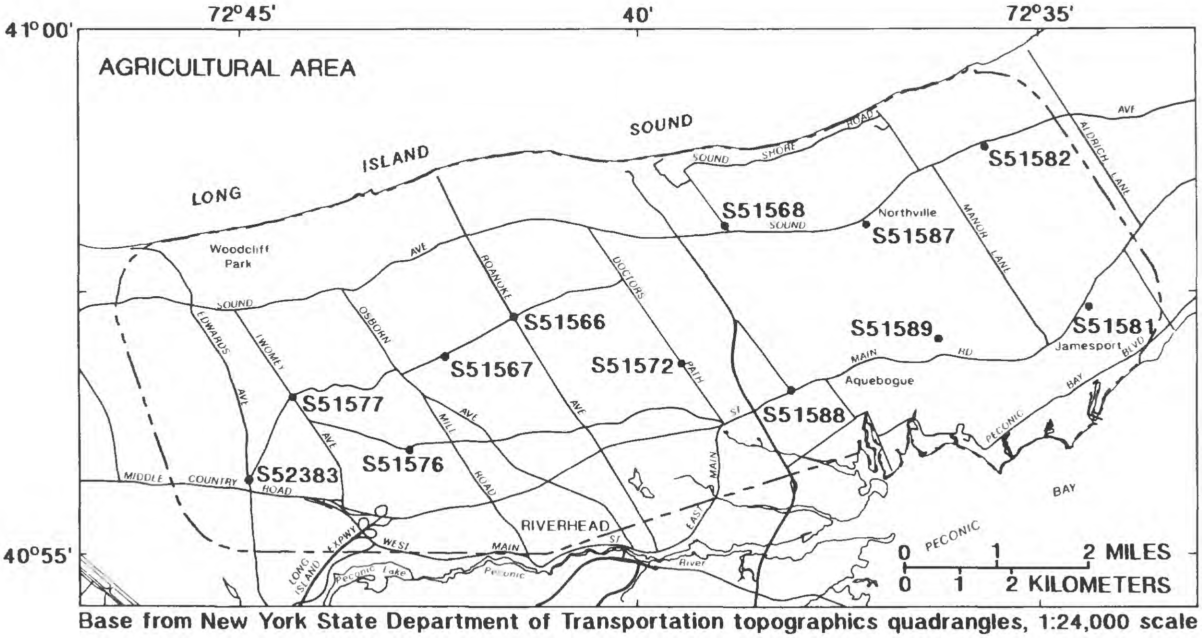

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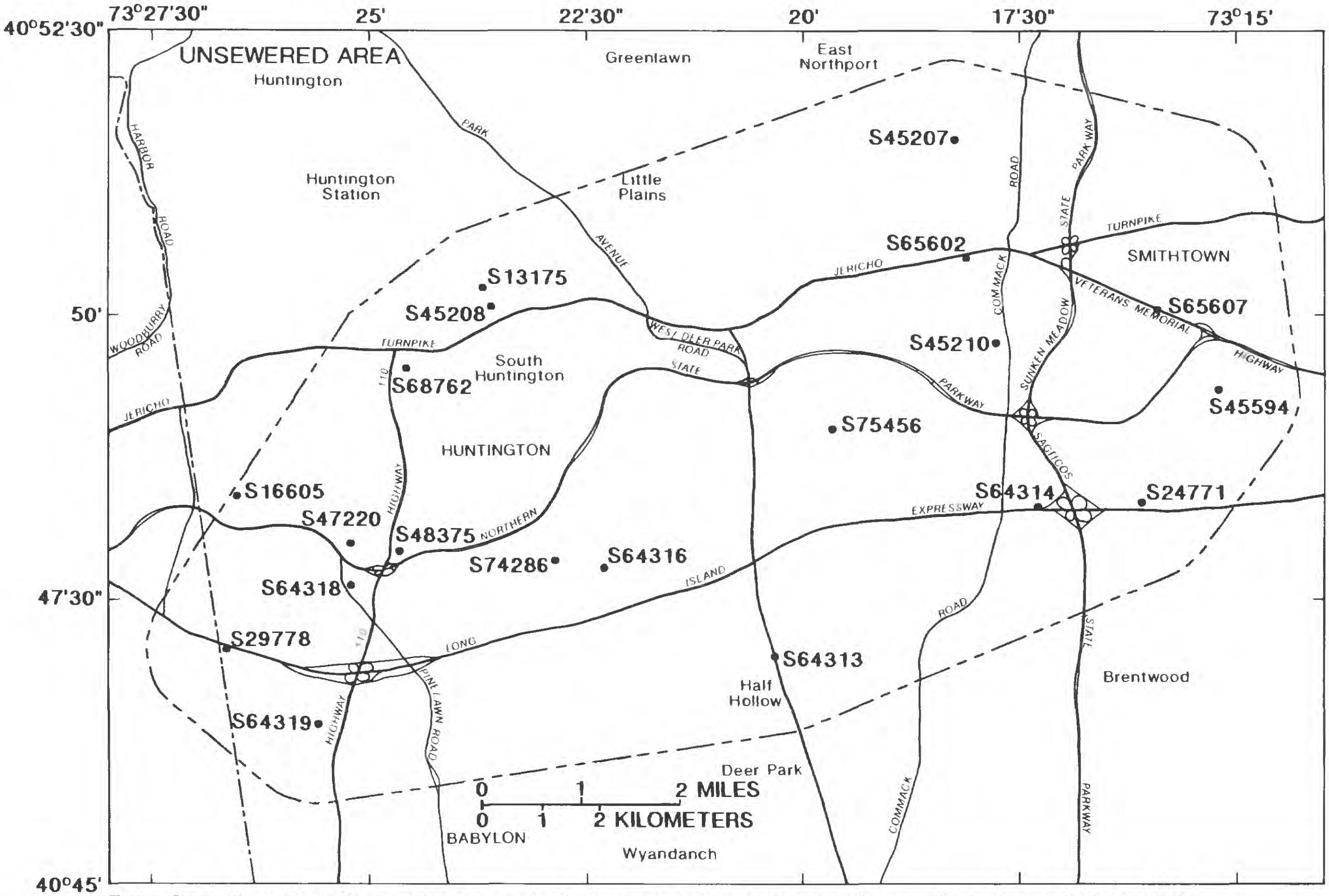
EXPLANATION

—— - - —— STUDY-AREA BOUNDARY

• N9712 WELL LOCATION AND NUMBER PREFIX N OR S REFERS TO NASSAU OR SUFFOLK COUNTY

Figure 5. Locations of sampled wells screened in shallow zone of long-term sewered suburban area, recently sewered



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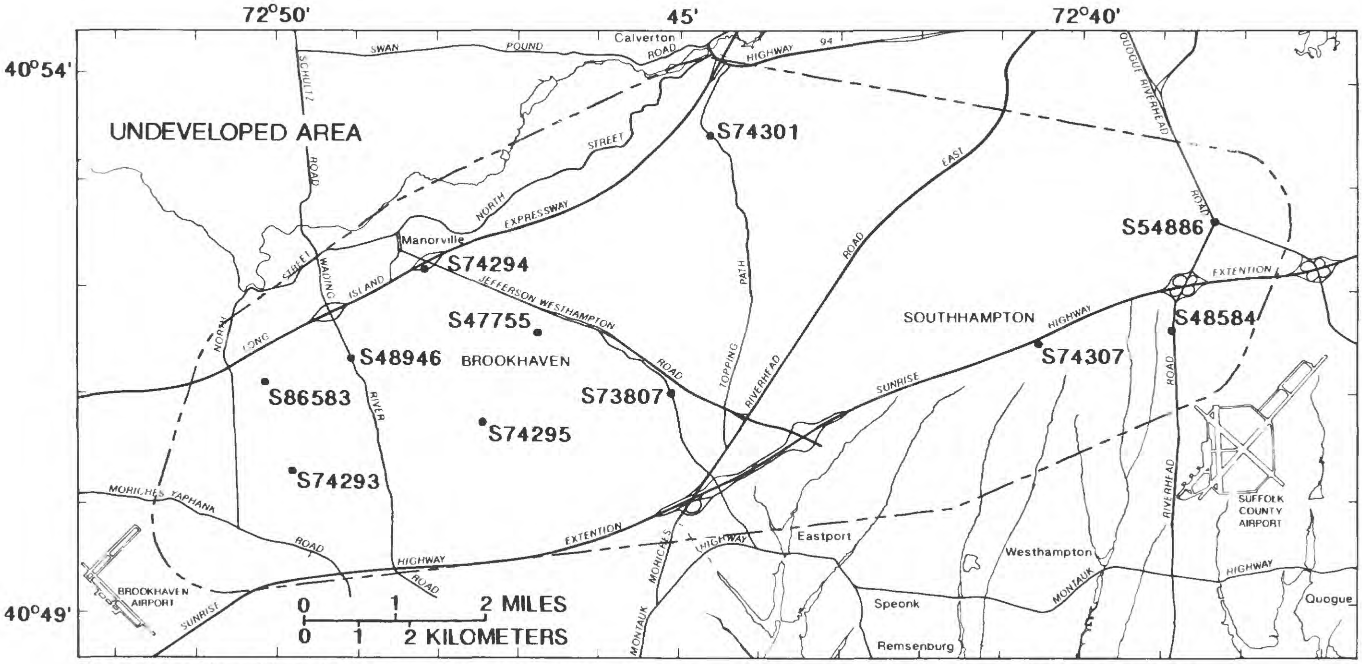

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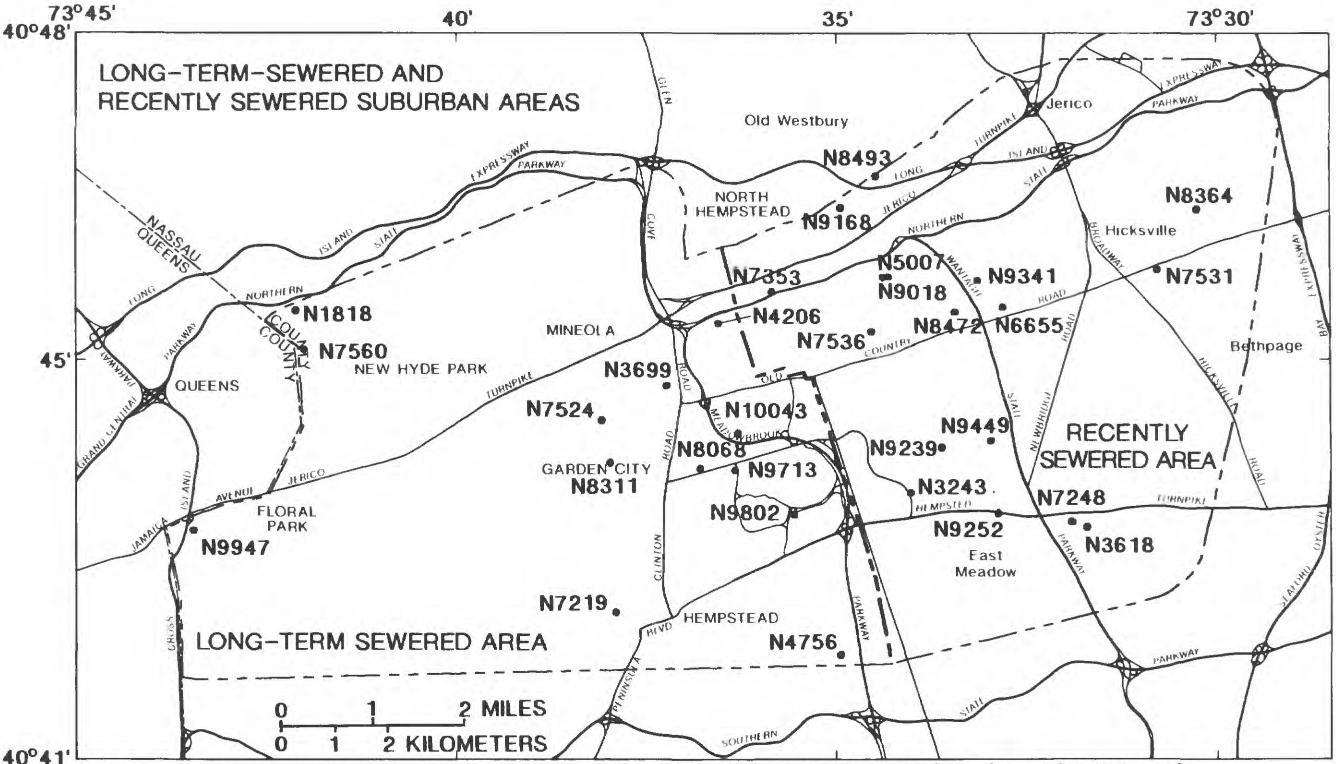
suburban area, agricultural area, unsewered area, and undeveloped area, Long Island, N.Y. (Locations are shown in fig. 1.)



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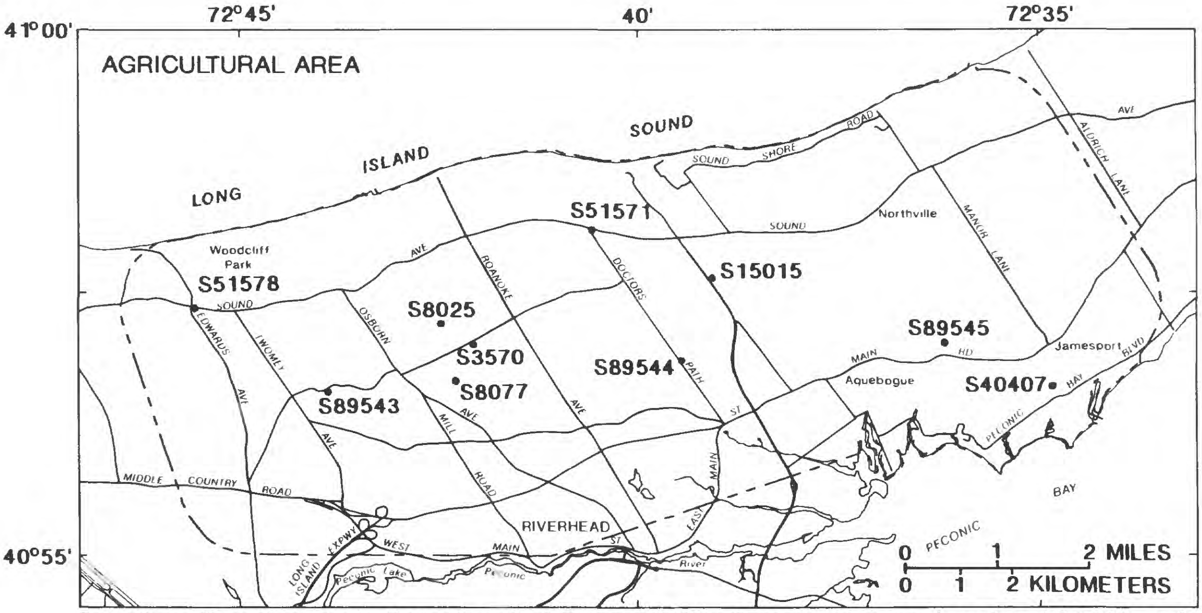

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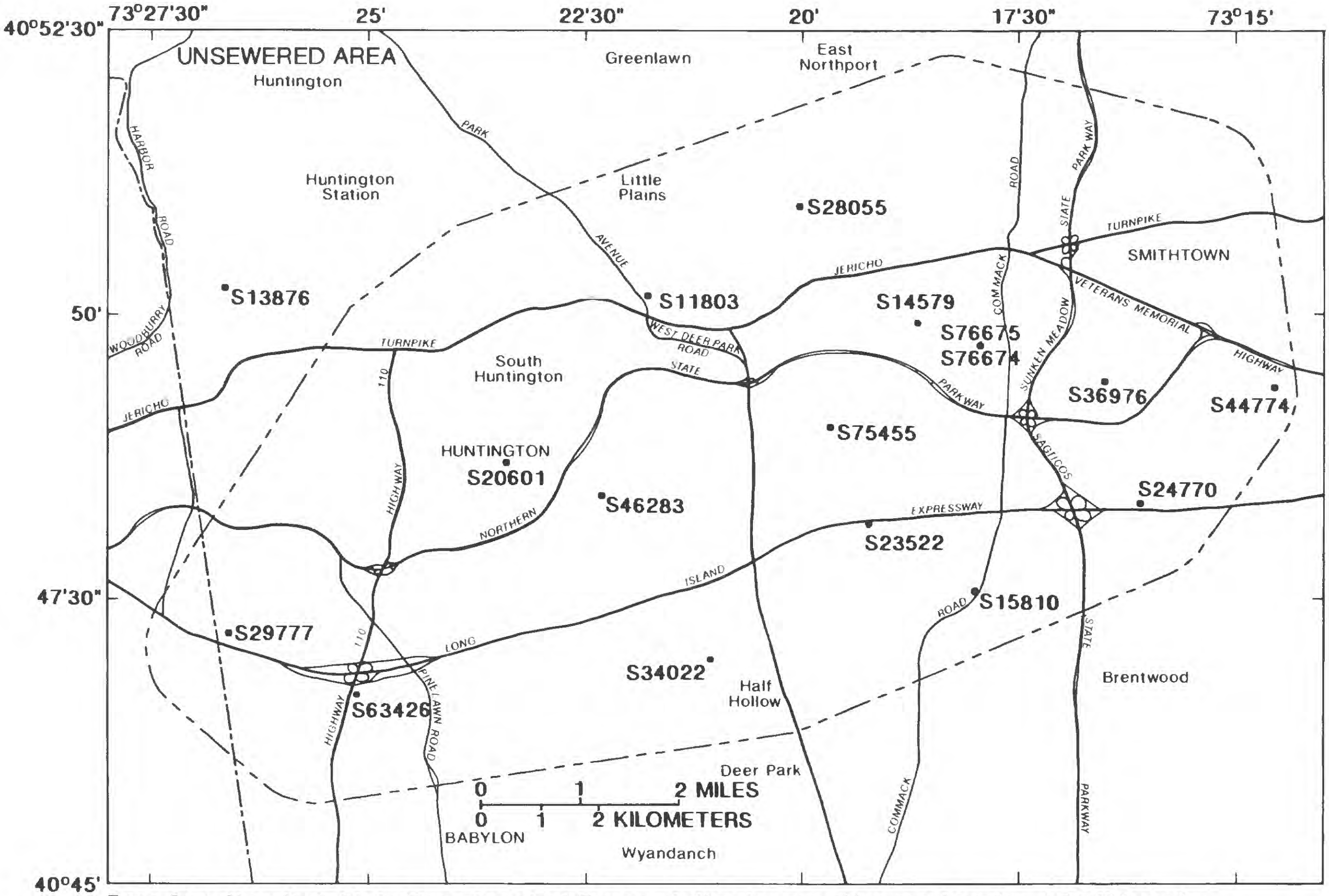
EXPLANATION

—— - - —— STUDY-AREA BOUNDARY

• N1818 WELL LOCATION AND NUMBER PREFIX N OR S REFERS TO NASSAU OR SUFFOLK COUNTY

Figure 6. Locations of sampled wells screened in intermediate zone of long-term sewered suburban area, recently sewered



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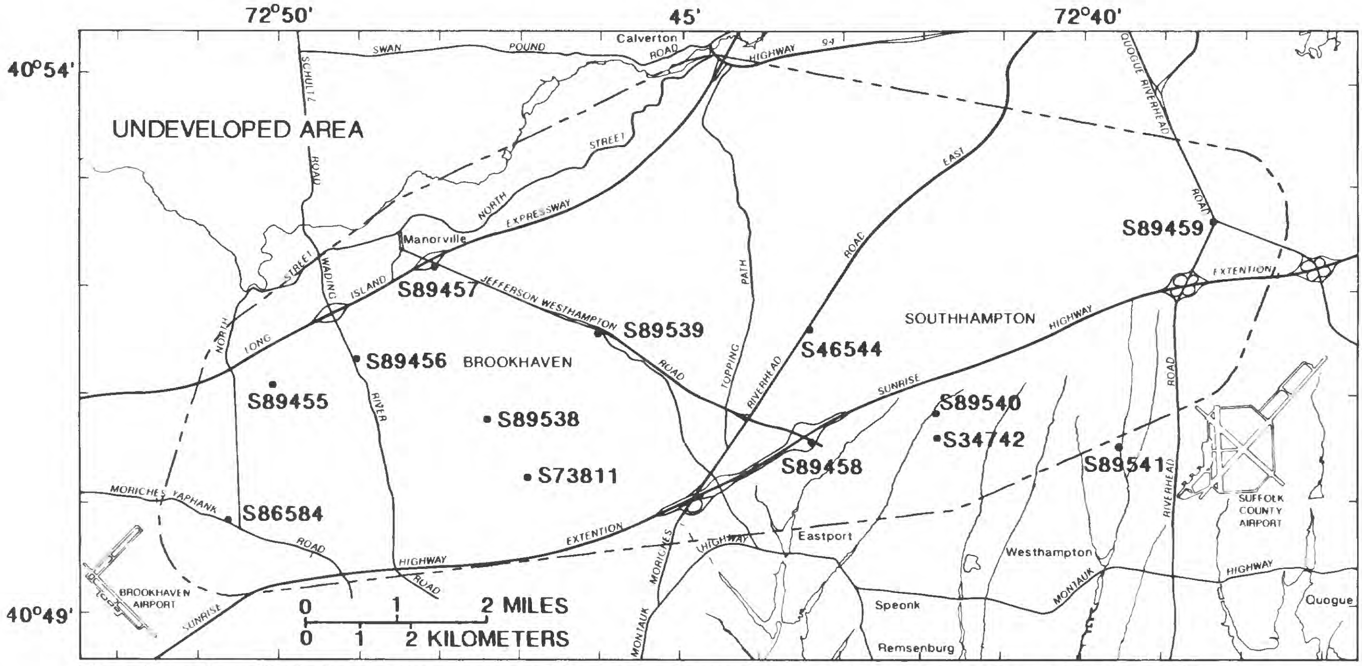

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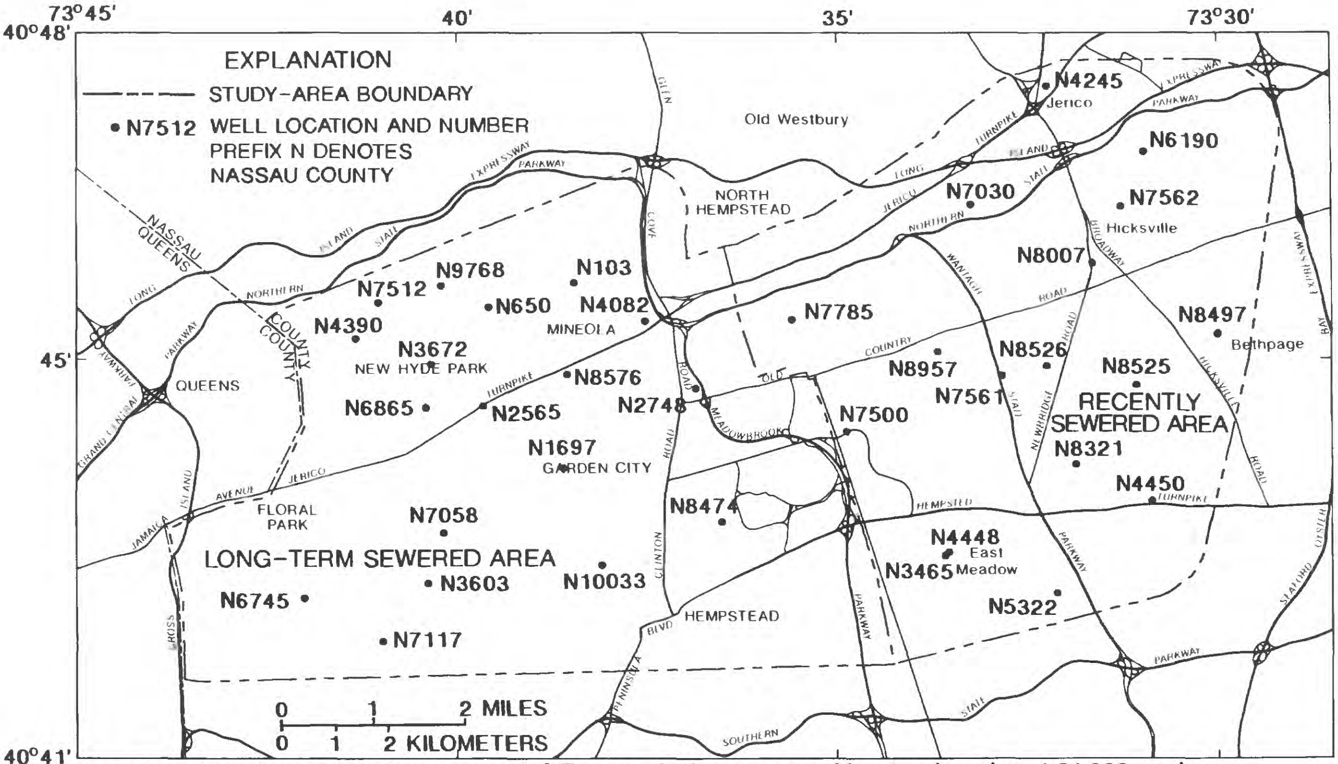
suburban area, agricultural area, unsewered area, and undeveloped area, Long Island, N.Y. (Locations are shown in fig. 1.)



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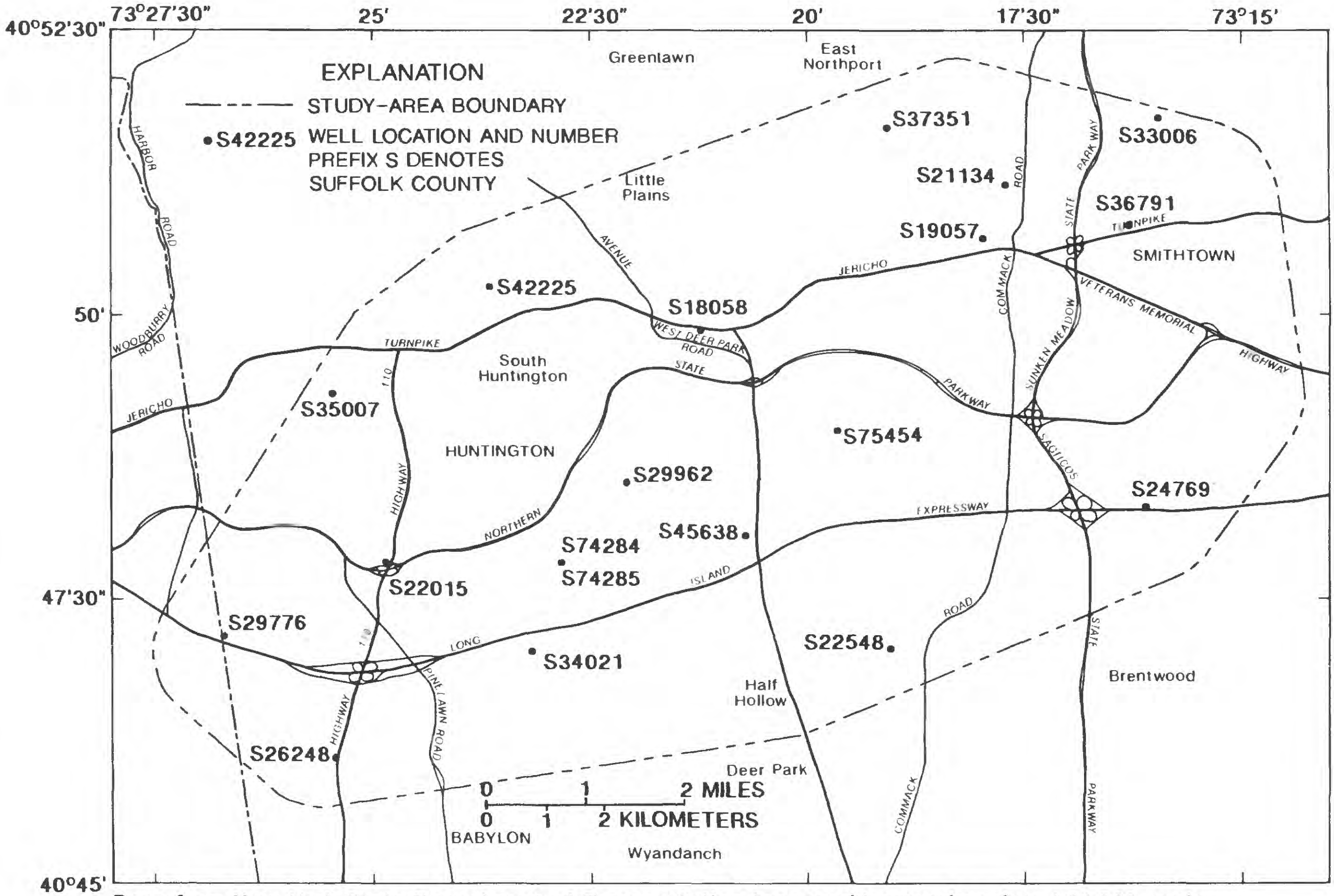

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Figure 7. Locations of sampled wells screened in deep zone of the long-term sewered and recently sewered suburban areas (top) and the unsewered suburban area (bottom), Long Island, N.Y. (Locations are shown in fig. 1.)

were 5 ft and 10 ft, respectively. Median screen length for public-supply wells was 61 ft; the 25th and 75th percentiles were 50 ft and 85 ft, respectively. The median screen length for unspecified withdrawal wells was 37.5 ft; the 25th and 75th percentiles were 20.5 ft and 51 ft, respectively. At each monitoring well, water levels were measured before pumping, and at least three casing volumes were evacuated; drawdown, specific conductance, pH, and temperature were allowed to stabilize before samples were collected. At each public-supply and unspecified-withdrawal well, at least three casing volumes of water were evacuated; measurements of specific conductance, pH, and temperature were made before samples were collected.

Monitoring wells were evacuated and sampled with a 2-in.-diameter, stainless-steel submersible pump with 1/2-in. Teflon[1] discharge tubing. The pump was placed 5 ft above the top of the well screen. At sites where the small-diameter pump was not adequate to evacuate the well, a 1-hp, seven-stage submersible pump with polyvinyl chloride (PVC) flush thread pipe and Teflon sampling tube was used (LeaMond and others, 1992). The Teflon sampling tube was equipped with a smaller diameter Teflon variable-flow tube designed to minimize aeration and exposure of ground water to the atmosphere during sample collection and thereby minimize volatilization of certain organic compounds or escape of dissolved gases that may be present in the sample (LeaMond and others, 1992). At public-supply and unspecified-withdrawal wells, a 1/2-in. Teflon sampling tube equipped with a smaller diameter Teflon variable-flow tube was fitted to the well in front of any pressure or holding tanks.

Dissolved oxygen was measured by the Winkler titration method (Brown and others, 1970) just before the water sample was collected from each well. Samples to be analyzed for dissolved metals and dissolved boron were filtered and acidified in the field with nitric acid (LeaMond and others, 1992). Analyses for inorganic constituents (except boron) and VOC's were done by the Nassau County Department of Health; analysis for boron was done by the USGS National Water-Quality Laboratory.

[1]Use of brand, trade, or firm names is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Statistical Techniques

Nonparametric statistical procedures and contingency-table analyses were used to evaluate the effect of land use and depth on constituent concentrations. Nonparametric procedures, such as analysis of variance (ANOVA) on rank-transformed data, are robust in that they are insensitive to outlying values and assumptions of equal variance or normality (Helsel and Hirsch, 1992; Iman and Conover, 1983). Contingency-table analyses are a means of evaluating highly censored data sets. Censored data sets contain values whose concentrations are reported as "less than the analytical detection limit."

These statistical procedures are used to assess whether water-quality data differ significantly among land-use and depth categories. Two-way factorial ANOVA's on rank-transformed water-quality data were used to examine the effect of land use and depth simultaneously. The null hypothesis for this test states that mean concentration ranks are identical among all land-use and depth groups; thus, neither land use nor depth, nor their interaction, has any effect. Rejection of the null hypothesis indicates that at least one mean concentration rank from the land-use and depth groups differs from the others and that the effect of land use or depth, or their interaction, is significant. If interaction is significant, then the effect of depth on mean-concentration ranks differs among land-use areas; otherwise the effect of depth on mean-concentration ranks is identical in all study areas (Helsel and Hirsch, 1992). All ANOVA models evaluated in this study were unbalanced (unequal numbers of observations for different combinations of land use and depth); therefore, ANOVA models were expressed in the framework of linear models. This method is closely related to linear-regression techniques, in which categorical explanatory variables are represented as combinations of indicator variables that take on values of 0 or 1 (Knopman, 1990; SAS Institute Inc., 1988).

If the null hypothesis was rejected by the ANOVA test, indicating that at least one mean concentration-rank value differed from another, Tukey's honest significant difference test (Tukey's test) was used to determine which means differed.

Contingency-table analyses were used to examine water-quality differences among study areas and depth zones for constituents whose censored values constituted more than 50 percent of the total values. Contingency-table analyses do not evaluate the effects of multiple factors simultaneously; therefore, separate tests were done on land-use and depth data to evaluate their effects on constituent-detection rates. The null hypothesis tested was that the proportion of constituent detections was the same for each study area or depth zone; rejection of the null hypothesis indicates that the proportion of constituent detections differed among study areas or depth zones.

If a contingency-table analysis indicated that the proportion of samples in which a constituent was detected differed among study areas or depth zones, individual-cell chi-square statistics were examined to identify which areas or depth zones had more or less than the expected proportion of constituent detections. The positive or negative sign of the difference between the observed and expected frequencies indicates more or fewer detections than expected within that area or depth zone, and the magnitude of the chi-square statistic indicates which cells contribute most to the rejection of the null hypothesis (Helsel and Hirsch, 1992). For example, table 5 (p. 29) contains results from a contingency-table analysis of sulfate-detection data from the shallow and intermediate zones of the five study areas. The difference between observed and expected detection frequencies indicates more sulfate detection in samples from the long-term-sewered, agricultural, and undeveloped areas than would be expected if all five areas were alike, and fewer detections than expected in samples from the recently sewered and unsewered areas. The magnitude of each cell's chi-square statistic indicates that the unsewered suburban area contributes the most toward rejection of the null hypothesis.

The level of significance (α) for all hypothesis testing reported herein is 0.05. This corresponds to a 95-percent confidence level and describes the probability of rejecting the null hypothesis when it is true. Results of all hypothesis testing are reported as p-values (attained significance level). Null hypotheses were rejected if the p-value was below a significance level of 0.05.

If contingency-table assumptions were violated—that is, if a cell had an expected frequency of less than 1.0, or if fewer than 80 percent of the cells had expected frequencies greater than or equal to 5.0—detection frequencies were used to examine water-quality differences among land-use areas and depth zones.

Selected chemical constituents and physical properties are represented as box plots that indicate the median, the range and skewness, and the absence or presence of unusual "outside" or "far-outside" values (Helsel and Hirsch, 1992). Summary statistics for water-quality data that contained "censored values" were calculated through a log-probability regression technique (Helsel and Hirsch, 1992), a robust procedure that minimizes the root mean square error.

RELATION BETWEEN LAND USE AND QUALITY OF GROUND-WATER

Results of statistical tests to evaluate water-quality differences among land-use areas and depth zones are presented in the following sections; water-quality data are listed in appendixes 1 through 3. Summary statistics for selected inorganic constituents and field-measured properties are represented as box plots in figures 8 through 12. Results of Tukey's test are displayed as capital letters above each plot to indicate which study areas or depth zones differ significantly from one another; plots with one or more letters in common have mean ranks that do not differ significantly from one another.

The effect that land use, depth, or their interaction have on the concentrations of selected constituents was evaluated through factorial ANOVA. When the effect of land use on constituent concentrations was evaluated, data from all depth zones of each land-use area were combined, and when the effect of depth on constituent concentrations was evaluated, data for that depth zone in each study area were combined. Results from the factorial ANOVA's are presented in table 2 as p-values for the shallow and intermediate zones of all five study areas and in table 6 (p. 30) for all depth zones in the three suburban areas. A p-value less than 0.05 indicates a significant effect. Significant interaction between land use and depth indicates that the effect of depth differs among study areas; lack of significant interaction indicates that the effect of depth is similar among areas.

When the majority of data for a constituent were censored, contingency tables with two rows and five columns (2-by-5) were used to evaluate the effect of land use on the proportion of constituent detections in samples from the shallow and intermediate zones of the five study areas, and 2-by-2 contingency tables were used to evaluate the overall effect of depth within the shallow and intermediate zones. The effect of land use and depth on the proportion of constituent detections in the shallow, intermediate, and deep zones of the three suburban areas was evaluated through use of 2-by-3 contingency tables. Results of contingency-table analyses are presented as p-values in table 4 (p. 29) and 8 (p. 34). A p-value less than 0.05 indicates a significant effect on constituent detection rates. Observed and expected detection frequencies and chi-square statistics for each cell of a contingency table are presented in table 5 (p. 29) and 9 (p. 35).

Shallow and Intermediate Zones of All Study Areas

Differences in water quality among the five study areas are discussed only in relation to the shallow and intermediate zones because the agricultural and undeveloped areas contained no deep wells. The data are presented in figure 8, which represents each study area by two box plots—one for shallow wells and one for intermediate-depth wells. Results of two-way ANOVA's on rank-transformed field measurements and constituent concentrations are presented in table 2; median concentration values for samples from each study area and the shallow and intermediate-depth zones are presented in table 3 (p. 26). Results from contingency-table analyses are presented in tables 4 and 5 (p. 28-29).

Field-Measured Properties and Dissolved Oxygen

Specific conductance, dissolved-oxygen concentration, and temperature differed significantly among the study areas, and specific conductance, pH, and temperature differed significantly between the shallow and intermediate depth zones (table 2). Interaction between land use and depth was significant only for temperature.

Table 2. p-values from two-way factorial analysis of variance indicating the effect of land use, depth, and their interaction on rank-transformed values of physical properties and concentrations of inorganic constituents in the shallow and intermediate-depth zones of the five study areas

Property or constituent	Factor		
	Land use	Depth	Interaction
Specific conductance	0.0001	0.0001	0.1090
pH	.5155	.0270	.1121
Dissolved oxygen	.0001	.2541	.1950
Temperature	.0001	.0001	.0031
Dissolved solids	.0001	.0001	.0981
Alkalinity	.0023	.3118	.1070
Hardness	.0001	.0001	.0354
Nitrate	.0001	.0001	.0361
Phosphorus	.3177	.7757	.9204
Silica (SiO_2)	.2885	.2374	.0755
Potassium	.0001	.0001	.0071
Sodium	.0001	.0001	.8183
Chloride	.0002	.0001	.4011
Calcium	.0001	.0001	.0541
Magnesium	.0001	.0121	.0205

Specific conductance.—Specific conductance is a general indicator of the amount of dissolved solids in solution. The presence of dissolved ionic species such as chloride, calcium, potassium, and magnesium makes water conductive; as ionic concentration increases, specific conductance of ground water increases. Specific conductance was significantly affected by land use and depth (table 2). The highest median specific conductance (325 µS/cm) resulted from the combination of shallow and intermediate-depth samples from the agricultural area (table 3), but results of Tukey's test indicate that the mean specific-conductance rank for this area does not differ significantly from those for the two sewered suburban areas (fig. 8A). The lowest median specific conductance (98 µS/cm) was for the combination of shallow and intermediate samples in the undeveloped area (table 3), but the mean specific-conductance rank for this area does not differ significantly from that for the unsewered suburban area (fig. 8A). Elevated specific conductance within the agricultural and sewered suburban areas is due primarily to the introduction of ionic species from (1) fertilization of crops, lawns, and commercial recreational facilities such as golf courses; (2) discharge of effluent from cesspools, septic tanks, and leakage from sewer systems; and (3) application of deicing salts to roads.

Depth significantly affects specific conductance; samples from the shallow zone of all five areas combined had a higher median value than those from the intermediate zone (tables 2 and 3). Some dissolved ionic species that contribute to the specific conductance of ground water can react physically or chemically with the aquifer substrate and subsequently be removed from solution; the resulting decrease in ionic concentrations will decrease the specific conductance of ground water. Additionally, dilution along flow paths by hydrodynamic dispersion and ionic diffusion can reduce specific conductance with depth.

pH.—pH (the logarithm of the inverse of the hydrogen-ion activity) is a measure of the hydrogen-ion concentration in an aqueous solution. Depth was the only factor found to significantly affect pH (table 2); samples from the shallow zone of all five study areas had a lower median pH than those from the intermediate zone (table 3, p. 26). The increase in pH from the shallow to intermediate zone is greatest in the undeveloped area and least apparent in the agricultural and suburban areas (fig. 8B); the smaller increase in pH with

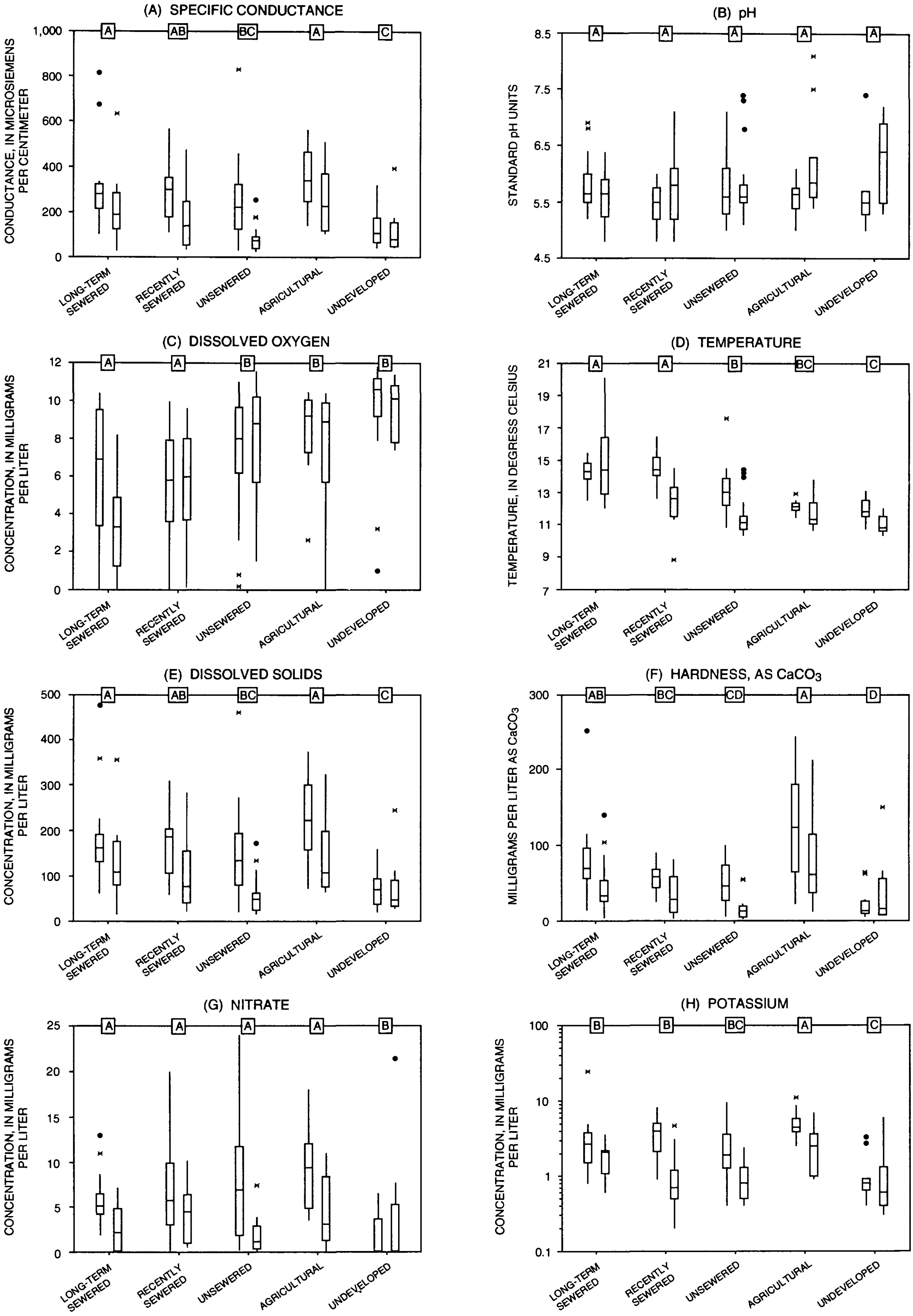
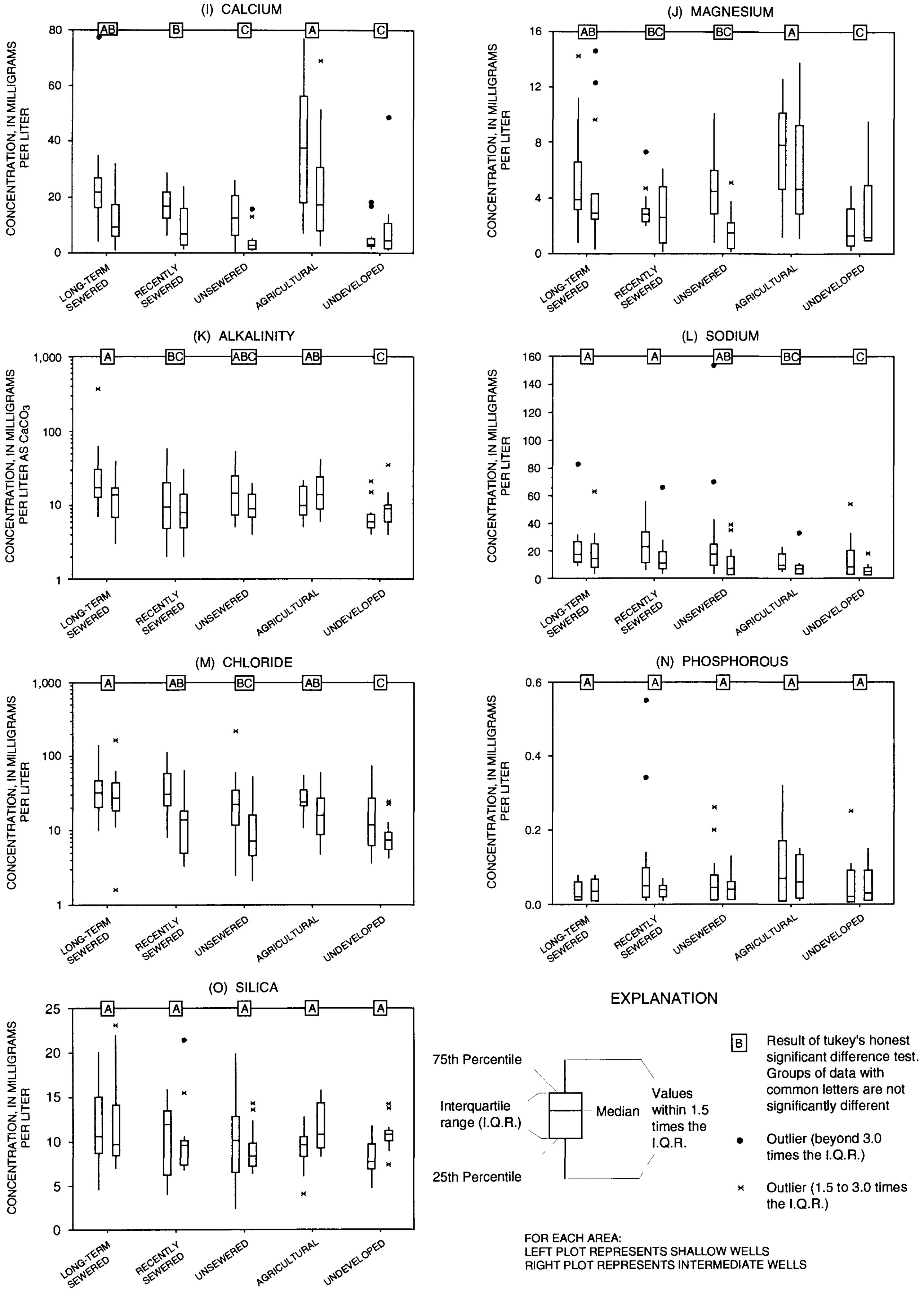


Figure 8. Distribution of physical-property values and inorganic chemical concentrations in water samples from shallow and



intermediate zones of the five study areas, Long Island, N.Y. (Locations are shown on fig. 1.)

Table 3. Median physical-property values and inorganic-constituent concentrations, by study area and depth zone

[Locations are shown in fig. 1; µS/cm, microsiemens per centimeters at 25 degrees Celsius; mg/L, milligrams per liter; °C, degrees Celsius]

Property or constituent	Study area (shallow and intermediate depths): Long-term sewered suburban	Recently sewered suburban	Unsewered suburban	Agricultural	Undeveloped	Depth zone (all five areas): Shallow	Intermediate
Field-measured properties and dissolved oxygen							
Specific conductance (µS/cm)	258	212	124	325	98	261	123
pH	5.7	5.6	5.6	5.7	5.7	5.6	5.7
Dissolved oxygen (mg/L)	5.2	6.0	8.7	9.1	10.5	7.9	7.6
Temperature (°C)	14.4	13.7	12.2	12.1	11.4	13.5	11.8
Alkalinity, hardness, and inorganic constituents (mg/L)							
Dissolved solids	159	133	75	193	64	159	76
Alkalinity (as $CaCO_3$)	16	9	10	12	7.5	12	9
Hardness (as $CaCO_3$)	61	48	22	102	14	61	25
Nitrate (as N)	4.55	4.78	2.57	7.48	.08	5.25	2.04
Phosphorus	.02	.05	.04	.07	.03	.03	.04
Silica (SiO_2)	10.3	9.7	8.4	10.1	9.9	10.1	9.7
Potassium	2.2	2.1	1.4	3.9	.7	3.1	1.0
Sodium	17	16	11	8	5	16	8
Chloride	31.2	22.7	13.6	22.8	8.2	25.4	11.9
Calcium	18.5	14.2	5.3	27.9	3.6	17	6.0
Magnesium	3.7	2.7	2.8	7.1	1.2	3.3	2.4

depth in agricultural and suburban areas likely reflects the introduction of nitrogen in the form of ammonium, ammonia, or organic nitrogen to the ground-water system through disposal of human wastes in cesspools and septic tanks, leaks from sewer systems, and through the application of fertilizers on commercial crops and lawns. The conversion of this nitrogen to nitrate through oxidation (nitrification) produces hydrogen ions, which lower the pH.

Dissolved oxygen.—Oxygen is supplied to ground water through ground-water recharge and the movement of air through the unsaturated zone. Dissolved-oxygen concentrations differed significantly among study areas (table 2). The highest median concentration (10.5 mg/L) resulted from the combination of shallow and intermediate-depth samples from the undeveloped area (table 3), but results of Tukey's test indicate that the mean concentration rank for this area does not differ significantly from those for the unsewered suburban or agricultural areas (fig. 8C). The lowest median concentration (5.2 mg/L) resulted from the combination of shallow and intermediate-depth samples from the long-term sewered suburban area (table 3), but the mean concentration rank from this area was not significantly different from that for the recently sewered suburban area (fig. 8C). Processes that can accelerate the depletion of dissolved oxygen within the sewered suburban areas include nitrification and increased bacterial activity. Nitrification of ammonium introduced by cesspools, septic tanks, and sewer systems consumes dissolved oxygen. Additionally, dissolved organic carbon introduced from the same sources in suburban areas can fuel bacterial activity, which consumes dissolved oxygen.

Dissolved-oxygen concentrations were not found to differ significantly with depth (table 2); thus, the concentrations in the intermediate zone of all five study areas combined were similar to those in the shallow zone. The extent to which dissolved-oxygen concentrations can be maintained with depth depends in part on (1) the hydraulic properties of soils and aquifer materials through which ground water flows, and (2) the rate at which oxygen-depleting processes are occurring within the unsaturated and saturated zones of the aquifer. Elevated dissolved oxygen concentrations in the intermediate zone indicate that (1) soils and aquifer materials in the five study areas are highly permeable, well drained, and subsequently well aerated, and (2) processes that deplete dissolved oxygen (such as nitrification, bacterial activity, and oxidation of organic matter) are insufficient to exhaust dissolved-oxygen supplies within the depths examined.

Water temperature.—Land use, depth, and their interaction were found to significantly affect water temperature (table 2). The highest median temperature (14.4°C) resulted from the combination of shallow- and intermediate-depth samples from the long-term-sewered suburban area (table 3); but results of Tukey's test indicate that the mean rank for this area does not differ significantly from that of the recently sewered suburban area (fig. 8D). The lowest median temperature (11.4°C) resulted from the combination of shallow- and intermediate-depth samples from the undeveloped area (table 3); but the mean rank for this area did not differ significantly from that for the agricultural area (fig. 8D).

Temperature in developed areas can be elevated through the absorption of heat from artificial surfaces (such as asphalt and concrete) by precipitation before infiltration and through the reinjection of warmed cooling water at industrial and commercial facilities.

Depth significantly affected water temperature; samples from the shallow zone of all study areas had a higher median temperature than those from the intermediate zone (tables 2 and 3). Additionally, the effect of depth on temperature differed significantly among the study areas (as illustrated in fig. 8D); median temperature decreased from the shallow to the intermediate zone of each area except the long-term-sewered suburban area. This anomaly in the latter area is attributed to (1) the effects of greater local pumping in the long-term-sewered area than elsewhere, which causes water from the shallow zone to enter the cooler intermediate zone at a greater rate than in the other areas, and (or) (2) industrial discharge of warmed cooling water into the intermediate-depth zone of the long-term-sewered suburban area.

Alkalinity, Hardness, and Inorganic Constituents

Concentrations of dissolved solids, alkalinity, hardness, nitrate, potassium, sodium, chloride, calcium, and magnesium differed significantly among study areas and, except for alkalinity, differed significantly between depth zones (table 2). Interaction between the effects of land use and depth were found to be significant for hardness, nitrate, potassium, and magnesium (table 2).

Dissolved-solids concentration is a measure of all the dissolved materials in a sample and is strongly correlated with a sample's specific conductance. As ionic concentrations increase, dissolved-solids concentration and specific conductance increase. Hardness is a property of water imparted by several cations, predominantly calcium and magnesium (Hem, 1989). Hardness is expressed herein in terms of an equivalent concentration of calcium carbonate. Nitrate is a common component of fertilizers and also is a component of human wastes discharged to cesspools, septic tanks, and sewer systems. Potassium, calcium, and magnesium are components of fertilizer products and of many common household cleaning products.

Dissolved solids, hardness, nitrate, potassium, calcium, and magnesium.—The highest median concentrations of dissolved solids (193 mg/L), hardness (102 mg/L), nitrate (7.48 mg/L), potassium (3.9 mg/L), calcium (27.9 mg/L), and magnesium (7.1 mg/L) resulted from the combination of shallow- and intermediate-depth samples from the agricultural area, and the lowest resulted from the combination of shallow- and intermediate-depth samples from the undeveloped area (table 3). Results of Tukey's test indicate that the mean ranks for these constituents in the agricultural area do not differ significantly from those in one or more of the suburban areas, except for potassium, whose mean rank for the agricultural area is significantly higher than those for all other study areas (fig. 8E, 8F, 8G, 8H, 8I, and 8J). Elevated concentrations of these constituents in the agricultural and suburban areas is due primarily to their introduction through (1) fertilization of crops, lawns, and commercial recreational facilities such as golf courses, and (2) discharge of effluent from cesspools and septic tanks, and leakage from sewer systems.

Depth significantly affected concentrations of dissolved solids, hardness, nitrate, potassium, calcium, and magnesium; samples from the shallow zones of all five study areas combined had higher median concentrations than those from the intermediate-depth zone (tables 2 and 3). Additionally, the effect of depth differed significantly among the study areas for each of these constituents except dissolved solids and calcium (figs. 8F, 8G, 8H, 8J); median concentrations in the intermediate zone were lower than in the shallow zone in all but the undeveloped area. This pattern is attributed to the introduction of these constituents in the suburban and agricultural areas as fertilizer and as effluent from cesspools and septic tanks. The absence of significant interaction for dissolved solids is illustrated in figure 8E, where median concentrations are shown to decrease from the shallow to intermediate-depth zone of each study area. Because the p-value of 0.054 for the effect of interaction on calcium concentration (fig. 8I) was greater than 0.05, this effect is reported as not significant.

Alkalinity, sodium, and chloride.—Alkalinity is a measure of the acid-neutralizing capacity of a water sample and is measured through titration of a sample with acid. In the absence of other acid-neutralizing constituents, alkalinity is the sum of the equivalents of carbonate and bicarbonate. Water from wells on Long Island generally contains only negligible amounts of weak acids other than carbonate species; thus, the alkalinity arises almost entirely from carbonate and bicarbonate (inorganic carbon) (Pearsall and Aufderheide, 1994).

The highest median concentration for alkalinity (16 mg/L as $CaCO_3$), sodium (17 mg/L), and chloride (31.2 mg/L) resulted from the combination of shallow- and intermediate-depth samples in the long-term-sewered suburban area (table 3). Results of Tukey's test indicate that (1) alkalinity concentrations in the long-term-sewered suburban area did not differ significantly from those in the unsewered suburban area or the agricultural area (fig. 8K), (2) sodium concentrations were similar among all three suburban areas (fig. 8L), and (3) chloride concentrations in the long-term-sewered suburban area did not differ significantly from those in the recently sewered suburban or agricultural areas (fig. 8M). The lowest median concentrations for these constituents resulted from the combination of shallow- and intermediate-depth samples from the undeveloped area (table 3); but results of Tukey's test indicate that (1) the mean rank of alkalinity for the undeveloped area does not differ significantly from those for the recently sewered or unsewered suburban areas (fig. 8K), (2) the mean rank of sodium for the undeveloped area does not differ significantly from that for the agricultural area (fig. 8L), and (3) the mean rank of chloride for the undeveloped area does not differ significantly from that for the unsewered area (fig. 8M). Elevated alkalinity concentrations in suburban areas can result from the generation of CO_2 during the bacterial consumption of organic wastes from cesspools, septic tanks, and leaking sewer lines.

Sodium and chloride concentrations were elevated in the suburban areas and, to a lesser degree, in the agricultural and undeveloped areas. This is attributed mainly to the use of road-deicing salts. These compounds are also found in common household cleaning products and can be a component of cesspool and septic-tank effluents. Recycling of irrigation water in the agricultural area also can elevate sodium and chloride concentrations.

Depth significantly affected concentrations of sodium and chloride; samples from the shallow zones of all five study areas combined had a higher median concentration than those from the intermediate-depth zone (tables 2 and 3). Interaction was not found to be significant for sodium and chloride; this indicates that the effect of depth on sodium and chloride concentrations was similar in each study area (table 2).

Phosphorus, silica, fluoride, and orthophosphorus.—Concentrations of phosphorus and silica were not significantly affected by land use, depth, or their interaction (table 2 and fig. 8E). Detections of fluoride and orthophosphorus were infrequent, and their concentrations were low in samples from both depth zones of all five study areas (appendixes 1A and 1B).

Sulfate.—Contingency-table analyses to test for a difference in the proportion of sulfate detections among samples from the five study areas and two depth zones indicate significant differences among study areas and the two depth zones (table 4). The direction of the difference between the observed and expected detection frequencies and the magnitude of each contingency-table cell's chi-square statistic indicate that detections of sulfate in samples from both depth zones of the long-term-sewered suburban and agricultural areas were more numerous than would be expected if all study areas were alike, and detections in samples from both zones of the unsewered area were less numerous; therefore, sulfate seems to be more prevalent in the long-term-sewered suburban and agricultural areas than in the unsewered suburban area (table 5). The frequency

Table 4. p-values from contingency-table analyses indicating the effect of land use and depth on the proportion of constituent detections in samples from shallow and intermediate depth zones of the five study areas

[<, less than; --, analysis not done]

Constituent	Factor: Land use	Factor: Depth
Sulfate	<0.001	<0.001
Dissolved iron	.018	.285
Dissolved manganese	<.001	.005
Dissolved boron	--	<.001

of sulfate detections in samples from both depth zones of each study area ranged from 91 percent in the agricultural area to 46 percent in the unsewered suburban area (appendixes 1A and 1B). Elevated sulfate concentrations in the agricultural area result from the application of fertilizers. The highest sulfate concentration of all five study areas was in the intermediate zone of the agricultural area (920 mg/L) (appendix 1B). Elevated sulfate concentrations in suburban areas are attributed to the application of lawn and garden fertilizers and effluent from cesspools, septic tanks, and leaking sewer systems. Although sulfate was detected frequently in both zones of the undeveloped area (79 percent), concentrations in this area were lower than elsewhere (appendixes 1A and 1B). Sulfate detections in samples from the shallow zone of all five study areas combined were more numerous than would be expected if the shallow and intermediate-depth zones were alike; therefore, sulfate seems to be more prevalent in the shallow zone (table 5).

Trace Elements

Iron and manganese.—Results of contingency-table analyses for dissolved iron and manganese indicate that (1) the proportions of detections of each constituent in samples from both depth zones differ significantly among study areas, and (2) the proportion of detections of dissolved manganese in samples from the shallow zone of all five areas differs significantly from that of samples from the intermediate zone (table 4). The direction of the difference between the observed and expected detection frequencies and the magnitude of each contingency-table cell's chi-square statistic for dissolved iron indicates that detections of iron in samples combined from the shallow and intermediate-depth zone of the agricultural area were much more numerous than would be expected if all study areas were alike, and detections in samples from the undeveloped area were much less numerous; therefore, iron seems to be more prevalent in the agricultural area than in the undeveloped area (table 5). The direction of the difference between observed and expected frequencies and the magnitude of each contingency-table cell's chi-square statistic for dissolved manganese indicates that detections of manganese in samples combined from both depth zones of the agricultural and recently sewered suburban areas were much more numerous than would be expected if all study areas were alike and that detections in the long-term-sewered suburban and

Table 5. Contingency-table analyses showing individual-cell observed detection frequencies, expected detection frequencies, and chi-square statistics for selected constituents, by study area and depth zone
[<, less than]

Observed and expected detection frequency and chi-square statistic	Constituent detection					
	Sulfate		Dissolved iron		Manganese	
	Yes	No	Yes	No	Yes	No
STUDY AREA						
Long-term sewered suburban						
Observed	29	4	11	22	4	28
Expected	24.16	8.84	11.86	21.14	10.74	21.26
Chi-square statistic	.97	2.65	.06	.03	4.23	2.13
Recently sewered						
Observed	27	10	17	20	20	17
Expected	27.08	9.91	13.30	23.70	12.41	24.59
Chi-square statistic	<.00	<.00	1.03	.58	4.63	2.34
Unsewered suburban						
Observed	17	20	10	27	12	25
Expected	27.08	9.91	13.30	23.70	12.41	24.59
Chi-square statistic	3.75	10.26	.82	.46	.01	.01
Agricultural						
Observed	20	2	13	9	13	9
Expected	16.10	5.89	7.91	14.09	7.38	14.62
Chi-square statistic	.94	2.57	3.28	1.84	4.28	2.16
Undeveloped						
Observed	19	5	4	20	2	22
Expected	17.57	6.43	8.63	15.37	8.05	15.95
Chi-square statistic	.12	.32	2.48	1.39	4.55	2.30
DEPTH ZONE						
Shallow						
Observed	73	10	74	8	36	47
Expected	60.76	22.24	63.55	18.46	27.85	55.15
Chi-square statistic	2.47	6.74	1.72	5.93	2.38	1.20
Deep						
Observed	39	31	43	26	15	54
Expected	51.24	18.76	53.46	15.54	23.15	45.85
Chi-square statistic	2.92	7.99	2.05	7.05	2.87	1.45

undeveloped areas were much less numerous; therefore, manganese seems to be more prevalent in the agricultural and recently sewered suburban areas than in the undeveloped area (table 5). Elevated concentrations of dissolved iron and manganese in the agricultural area are probably not derived from human-related sources. Examination of appendix 2A indicates that detection frequencies and concentrations of dissolved iron and manganese are much greater in samples from the agricultural area than those from the other areas. Soren and Stelz (1984) indicate that interstadial clay beds seem to be continuous within the agricultural area and that depth to the top of the clay beds is 40 to 50 ft. These clay beds could be the cause of localized anoxic environments in the shallow zone of the agricultural area that result in elevated concentrations of dissolved iron and manganese. Additionally, detections of manganese in samples from the shallow zone of all five areas are more numerous than would be expected if the shallow and intermediate zones were alike; therefore, manganese is probably more prevalent in the shallow zone (table 5).

Boron.—The percentages of boron detections in samples from both depth zones of each study area ranged from 100 percent in the agricultural area to about 59 percent in the unsewered suburban area (appendixes 2A and 2B). Sources of boron in the suburban and agricultural areas include fertilizers and laundry detergents that are introduced to the ground-water system through septic-tank and cesspool effluent. Although boron was detected frequently in samples from both depth zones of the undeveloped area (82 percent), concentrations in this area were lower than elsewhere (appendixes 2A and 2B).

A contingency-table analysis to evaluate the effect of depth on boron detection revealed a significant difference between shallow and intermediate zones of all five study areas (table 4). The direction of the difference between observed and expected detection frequencies and the magnitude of each contingency-table cell's chi-square statistic (table 5) indicates that detections of boron in the shallow zone were more numerous than would be expected if both depth zones were alike; therefore, boron seems to be more prevalent in the shallow zone. Boron is a conservative constituent (that is, it does not react readily with the aquifer substrate); therefore, the apparent decrease in detection frequency with depth is attributed to dilution through hydrodynamic dispersion and ionic diffusion along flow paths.

Other trace elements.—Detections of barium, cadmium, chromium, copper, methylene blue active substances (MBAS), and lead were infrequent, and concentrations in samples from both depth zones of all study areas were low. Arsenic, mercury, selenium, and silver were not detected in any samples (appendixes 2A and 2B).

All Depth Zones of the Three Suburban Areas

Water-quality differences among the shallow, intermediate, and deep zones of the aquifer system are discussed only in relation to the three suburban areas in this section because the agricultural and undeveloped areas have no deep wells. Water-quality data are presented in figures 9 through 12, which contain three box plots for each area—one for shallow wells, one for intermediate-depth wells, and one for deep wells. Results of two-way factorial ANOVA's on rank-transformed field-measured properties and constituent concentrations are presented in table 6; median concentration values for samples from the three suburban areas and the three depth zones are presented in table 7; and results from contingency-table analyses are presented in tables 8 and 9 (p. 34-35). VOC detection frequencies are presented as bar charts in figure 13 (p. 40). Data given in this section allow interpretation of the effect of sewering on ground-water quality in suburban areas of Nassau and Suffolk Counties.

Table 6. p-values from two-way factorial analysis of variance indicating the effect of land use, depth, and their interaction on rank-transformed values of physical properties and concentrations of inorganic constituents in all three depth zones of the three suburban study areas

Property or constituent	Factor		
	Land use	Depth	Interaction
Specific conductance	0.0001	0.0001	0.1891
pH	.2089	.5139	.2872
Dissolved oxygen	.0001	.3012	.0089
Temperature	.0001	.0001	.0035
Dissolved solids	.0001	.0001	.2869
Alkalinity	.0002	.0048	.6818
Hardness	.0001	.0001	.4490
Nitrate	.0140	.0001	.0903
Phosphorus	.4701	.8555	.1065
Silica (SiO_2)	.0001	.4368	.2487
Potassium	.0001	.0001	.0062
Sodium	.0004	.0001	.3682
Chloride	.0001	.0001	.3668
Calcium	.0001	.0001	.8068
Magnesium	.0001	.0121	.0199

Table 7. Median physical-property values and inorganic-constituent concentrations in all three depth zones of the three suburban areas

[Locations are shown in fig. 1; µS/cm, microsiemens per centimeters at 25 degrees Celsius; mg/L, milligrams per liter; °C, degrees Celsius]

Property or constituent	Study area (shallow, intermediate, and deep wells): Long-term sewered suburban	Study area: Recently sewered suburban	Study area: Unsewered suburban	Depth zone: Shallow	Depth zone: Intermediate	Depth zone: Deep
Field-measured properties and dissolved oxygen						
Specific conductance (µS/cm)	198	143	89	268	123	67
pH	5.7	5.6	5.6	5.6	5.6	5.7
Dissolved oxygen (mg/L)	5.6	6.8	8.3	6.9	6	7.1
Temperature (°C)	13.4	12.6	11.6	14.2	12.4	12.1
Alkalinity, hardness, and inorganic constituents (mg/L)						
Dissolved solids	123	89	57	161	72	41
Alkalinity (as $CaCO_3$)	16	8	10	14	9	8
Hardness (as $CaCO_3$)	52	35	18	61	25	14
Nitrate (as N)	4.42	4.17	1.62	5.64	2.33	2.28
Phosphorus	.03	.03	.04	.03	.04	.04
Silica (SiO_2)	10.6	9.1	7.7	10.6	9.4	8.8
Potassium	1.5	1.0	.8	3	.8	.7
Sodium	14	10.5	7.5	19.5	10	5
Chloride	19.7	14.7	10.2	29.1	15.1	6.9
Calcium	12.6	9.2	4.1	17.1	5.9	3.3
Magnesium	3.7	2.6	1.9	3.3	2.2	1.5

Field-Measured Properties and Dissolved Oxygen

Specific conductance, dissolved-oxygen concentration, and temperature differed significantly among the three suburban areas, and specific conductance and temperature differed significantly among depth zones (table 6). Interaction between land use and depth was found to be significant for dissolved oxygen and temperature (table 6).

Specific conductance.—The highest median specific conductance value (198 µS/cm) resulted from the combination of samples from all three depth zones of the long-term sewered suburban area, and the lowest resulted from this combination in the unsewered suburban area (table 7 and fig. 9). Elevated specific conductance in samples from the long-term-sewered suburban area reflects the longer period of development and greater loading rates of many contaminants there than in the other suburban areas. Depth was found to affect specific conductance significantly; samples from the shallow zone of all three suburban areas combined had the highest median value, and samples from the deep zone had the lowest (table 7 and fig. 10).

Water temperature.—Temperature was significantly affected by land use, depth, and their interaction (table 6). The highest median temperature (13.4°C) resulted from the combination of samples from all three depth zones of the long-term-sewered area, and the lowest resulted from this combination in the unsewered area (table 7 and fig. 9). Samples from the shallow zone of all three suburban areas had the highest median, and samples from the deep zone had the lowest (table 7 and fig. 10). Additionally, significant interaction between land use and depth indicates that the effect of depth on temperature differs among the three suburban areas. This is illustrated in figure 9, which shows median temperatures to decrease from the shallow to intermediate-depth zones in the recently sewered and unsewered areas but not in the long-term-sewered area. As mentioned previously, this difference is attributed to (1) the effects of local pumping, which accelerates the vertical flow of ground water in the long-term-sewered area more than in the other suburban areas, and (or) (2) industrial discharge of warmed cooling water to the intermediate zone.

pH.—pH was not significantly affected by land use, depth, or their interaction (table 6 and fig. 9).

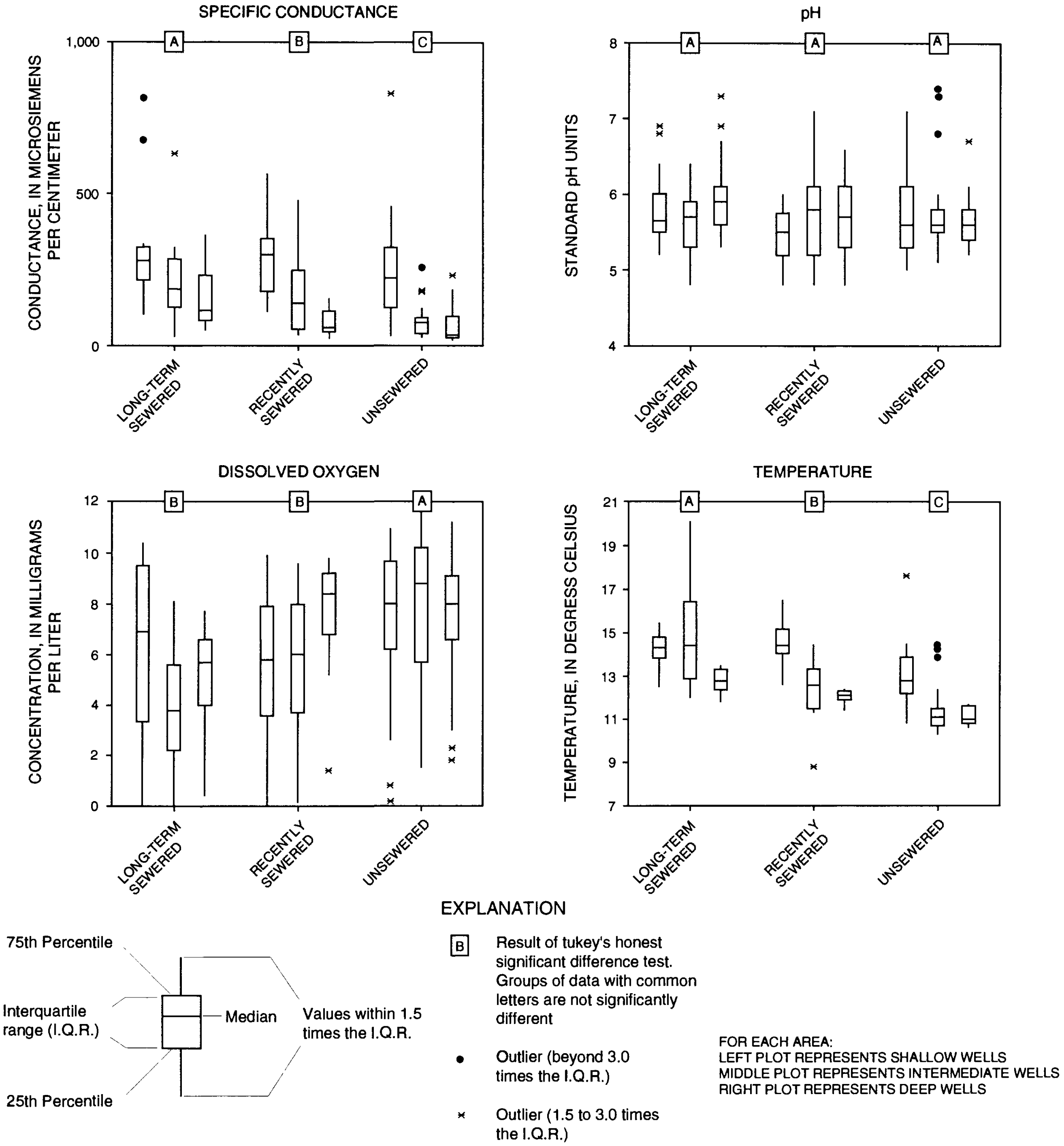


Figure 9. Distribution of physical-property values in water samples from all three depth zones in each suburban area, Long Island, N.Y.

Dissolved oxygen.—Dissolved-oxygen concentrations differed significantly among suburban areas, and interaction between land use and depth was found to be significant (table 6). The highest median concentration of dissolved oxygen (8.3 mg/L) resulted from the combination of samples from all depth zones of the unsewered suburban area, and the lowest was from this combination in the long-term-sewered suburban area (table 7). Results of Tukey's test indicate that the mean concentration rank for dissolved oxygen in the long-term-sewered suburban area does not differ significantly from that of the recently sewered area (fig. 9). Nitrogen and dissolved organic carbon introduced historically by dense networks of cesspools and septic tanks in the sewered suburban areas, in addition to the continued loading of effluent from leaking sewer lines, results in depleted dissolved-oxygen concentrations in these areas by fueling such processes as nitrification and bacterial activity.

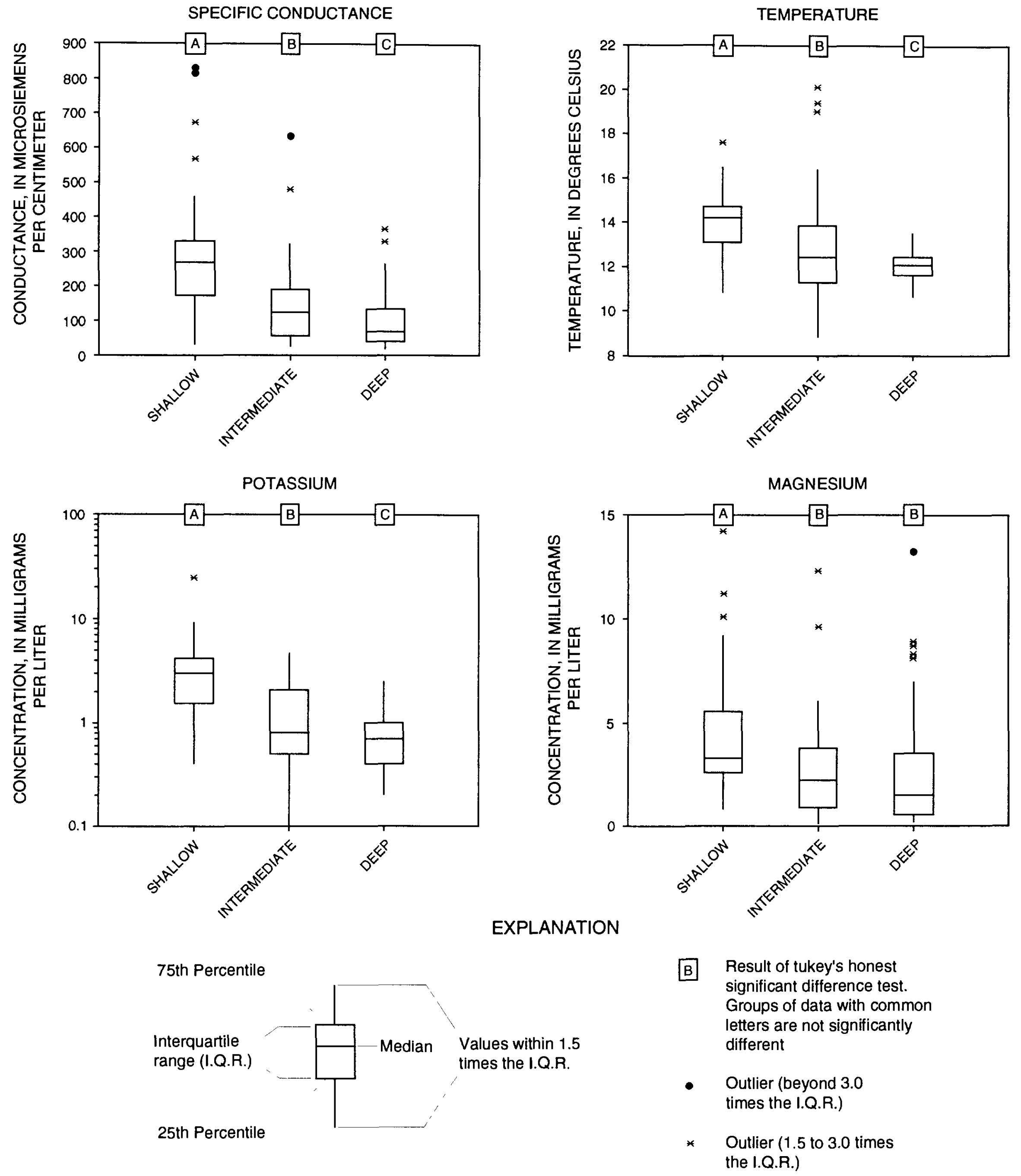


Figure 10. Distribution of physical-property values and inorganic-chemical concentrations in all three depth zones in the three suburban areas combined, Long Island, N.Y.

Dissolved-oxygen concentrations were not found to differ significantly with depth; this finding indicates that samples from the shallow zone of each study area, combined, do not differ significantly from those of the intermediate or deep zones. As mentioned previously, elevated dissolved-oxygen concentrations in the intermediate and deep zones indicate that (1) soils and aquifer materials in the suburban study areas are highly permeable and well drained and thus are well aerated, and (2) processes that deplete dissolved oxygen, are insufficient to exhaust dissolved-oxygen supplies within depths examined. Significant interaction between land use and depth indicates that the effect of depth on dissolved-oxygen concentration differs among the suburban study areas (table 6). This pattern is illustrated in figure 9, which shows median dissolved-oxygen concentrations to decrease from the shallow to the intermediate zone of the long-term-sewered area but to increase or remain constant with depth in the recently sewered and unsewered areas.

Alkalinity, Hardness, and Inorganic Constituents

Concentrations of alkalinity, hardness, and all inorganic constituents listed in table 6 (except phosphorus) differed significantly among study areas, and concentrations of all except phosphorus and silica differed significantly among depth zones. Interaction between land use and depth was significant for potassium and magnesium (table 6).

The highest median concentration for each of these constituents (except phosphorous) resulted from the combination of samples from all three depth zones of the long-term-sewered suburban area, and the lowest (except for phosphorous and alkalinity) resulted from the combination of samples from all three depth zones of the unsewered suburban area (table 7). Results of Tukey's test indicate that mean concentration ranks for alkalinity, hardness, silica, potassium, calcium, and magnesium in the long-term-sewered area are significantly higher than those in the other suburban areas (fig. 11), whereas mean concentration ranks for dissolved solids, sodium, and chloride are not significantly different from those in the recently sewered area (fig. 11). The statistical similarity of concentrations of dissolved solids, sodium, and chloride in the two sewered suburban areas probably reflects similar application rates of road-deicing salts in the two areas.

Depth significantly affected concentrations of dissolved solids, alkalinity, hardness, and all inorganic constituents except phosphorous and silica (table 6). The highest median concentration of all constituents (except phosphorus) resulted from the combination of samples from the shallow zone of all three areas, and the lowest (except phosphorus) resulted from the combination of samples from the deep zone of all three areas combined (table 7). Tukey's test results indicate that the mean concentration ranks for the combination of samples from the shallow zone of all three areas were significantly higher than those of samples from the intermediate or deep zones for dissolved solids, alkalinity, hardness, nitrate, sodium, chloride, and calcium (fig. 12). Elevated concentrations of these constituents in the shallow zone indicate the continued loading of contaminants from nonpoint sources in sewered and unsewered areas.

The effect of depth on potassium and magnesium concentrations differed significantly among the study areas (fig. 11); the decrease in median concentrations with depth was greater in the recently sewered and unsewered areas than in the long-term-sewered area. This pattern is attributed to the longer period of development within the long-term-sewered area and to the effects of local pumping, both of which have resulted in a greater vertical migration of ground water within the long-term-sewered area than in the other suburban areas.

Neither land use nor depth, nor their interaction were found to significantly affect phosphorus concentrations (table 6 and fig. 11), and detections of fluoride and orthophosphorus were infrequent, and the concentrations were low, in samples from all three depth zones of all three suburban areas (appendixes 1A-1C).

Contingency-table analyses were done to test for a difference in the proportion of sulfate detections among samples from the three study areas and three depth zones. Results indicate that the proportion of sulfate detection in samples from all three depth zones differed significantly among study areas (table 8). The direction of the difference between observed and expected frequencies and the magnitude of each contingency-table cell's chi-square statistics for sulfate indicate that detections of sulfate in samples from all three depth zones of the long-term-sewered area were more numerous than would be expected if all three suburban areas were alike, and that detections in all three zones of the unsewered area were less numerous than would be expected; therefore, sulfate seems to be most prevalent in the long-term-sewered area, and least prevalent in the unsewered area (table 9). The frequency of sulfate detection in samples from all three depth zones of each

Table 8. p-values from contingency-table analyses indicating the effect of land use and depth on the proportion of constituent detections in samples from all three depth zones of the three suburban areas

[<, less than; --, analysis not done]

Constituent	Factor: Land use	Factor: Depth
Sulfate	<0.001	<0.001
Dissolved iron	.263	.096
Dissolved manganese	.002	<.001
Dissolved boron	.049	<.001
Dissolved copper	.235	--
1,1,1-Trichloroethane	.078	<.001
Tetrachloroethylene	.001	.950
Trichloroethylene	.097	.524

suburban study area ranged from 82 percent in the long-term-sewered area to 38 percent in the unsewered area. The greater frequency of sulfate detection for the long-term-sewered area, which is the most densely populated, reflects the greater (1) applications of lawn and garden fertilizers, and (2) loading of effluent from cesspools, septic tanks, and leaking sewer lines, than elsewhere. Detections of sulfate in the shallow zone of all three suburban areas were more numerous than would be expected if all three depth zones were alike, and detections in the deep zone were less numerous than would be expected; therefore, sulfate seems to be most prevalent in the shallow zone and least prevalent in the deep zone (table 9).

Trace Elements

Results of contingency-table analyses for dissolved boron and manganese indicate that the proportion of detections differed significantly among study areas and among depth zones (table 8).

Manganese.—The direction of the difference between observed and expected detection frequencies and the magnitude of each contingency-table cell's chi-square statistic for dissolved manganese indicate that detections of manganese in samples from all depth zones of the recently sewered area were more numerous than would be expected if all three suburban areas were alike, and that detections for all depth zones of

Table 9. Contingency-table analyses showing individual-cell observed detection frequencies, expected detection frequencies, and chi-square statistics for selected constituents, by study area and depth zone
[Dashes indicate no analysis performed]

Observed and expected detection frequency and chi-square statistic	Constituent detection									
	Sulfate		Dissolved manganese		Dissolved boron		Tetra-chloroethene		1,1,1-Trichloroethane	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
STUDY AREA										
Long-term sewered suburban										
Observed	42	9	5	45	35	16	17	34	--	--
Expected	29.64	21.36	11.95	38.05	29.51	21.49	10.58	40.41	--	--
Chi-square statistic	5.15	7.15	4.04	1.27	1.02	1.40	3.89	1.02	--	--
Recently sewered										
Observed	30	24	21	33	32	21	13	39	--	--
Expected	31.39	22.61	12.91	41.09	30.67	22.33	10.79	41.21	--	--
Chi-square statistic	.06	.08	5.08	1.59	.06	.08	.45	.12	--	--
Unsewered suburban										
Observed	21	34	12	43	25	30	3	53	--	--
Expected	31.97	23.03	13.14	41.85	31.82	23.18	11.62	44.23	--	--
Chi-square statistic	3.76	5.22	.10	.03	1.46	2.01	6.40	1.67	--	--
DEPTH ZONE										
Shallow										
Observed	53	7	27	33	52	7	--	--	25	34
Expected	34.87	25.12	14.34	45.66	34.14	24.86	--	--	15.96	43.04
Chi-square statistic	9.42	13.07	11.18	3.51	9.34	12.83	--	--	5.13	1.90
Intermediate										
Observed	20	27	9	37	24	23	--	--	13	33
Expected	27.32	19.68	10.99	35.01	27.19	19.80	--	--	12.44	33.56
Chi-square statistic	1.96	2.72	.36	.11	.37	.51	--	--	.02	.01
Deep										
Observed	20	33	2	51	16	37	--	--	5	49
Expected	30.81	22.19	12.67	40.33	30.67	22.33	--	--	14.60	39.40
Chi-square statistic	3.79	5.26	8.98	2.82	7.01	9.63	--	--	6.31	2.34

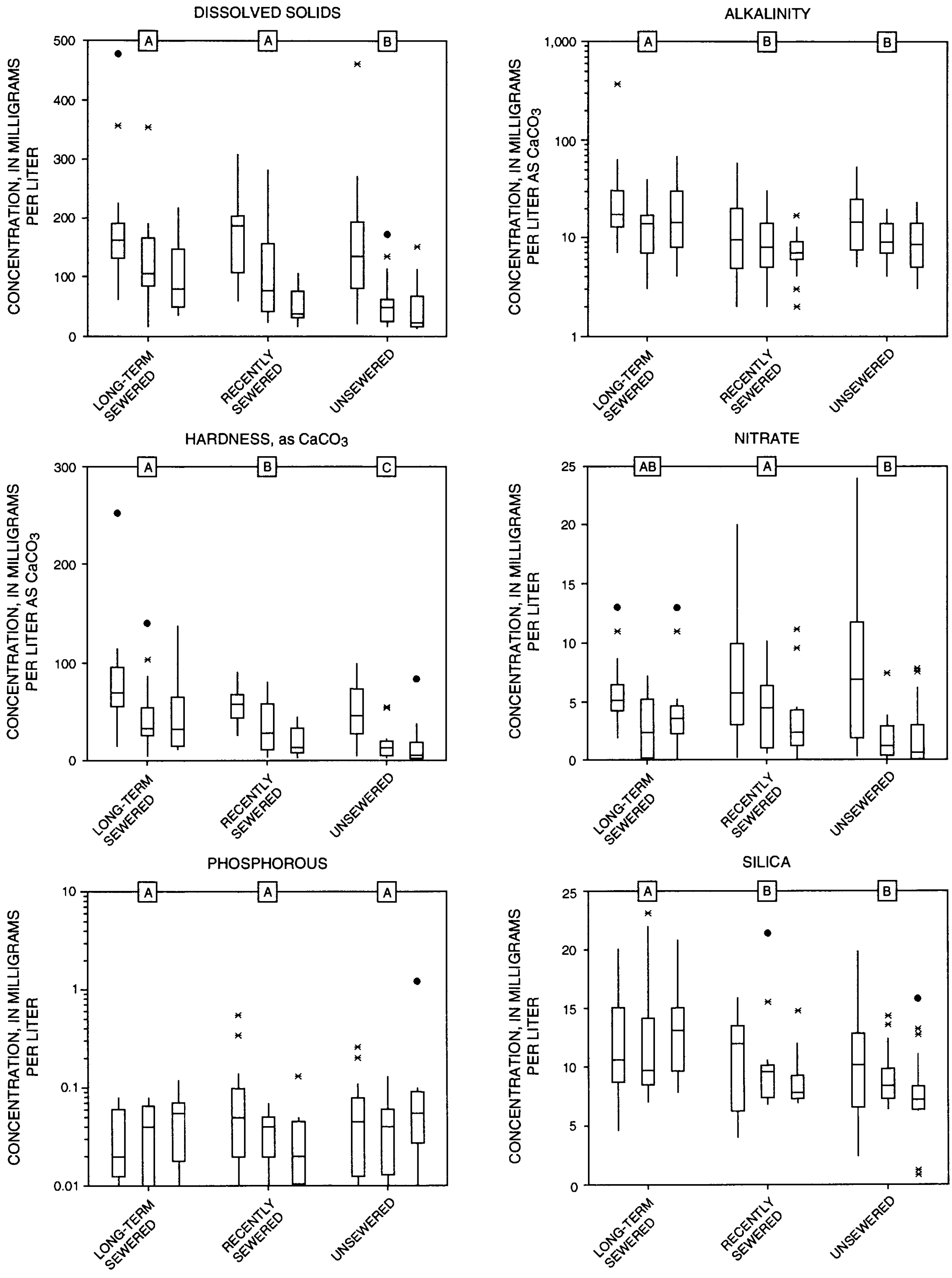


Figure 11. Distribution of inorganic-chemical concentrations in water samples from all three depth zones in each suburban area, Long Island, N.Y.

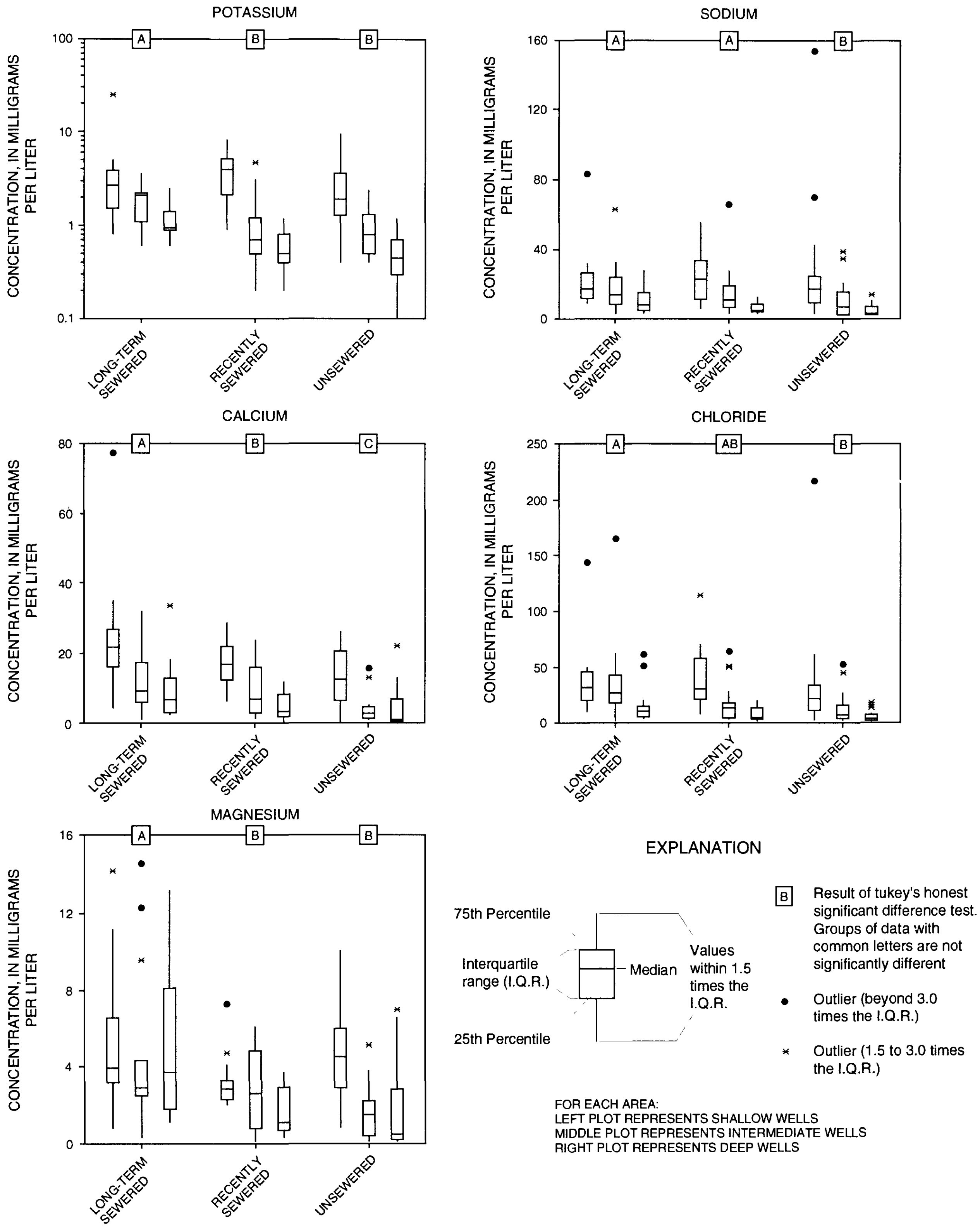


Figure 11. Distribution of inorganic-chemical concentrations in water samples from all three depth zones in each suburban area, Long Island, N.Y. (cont.)

the long-term-sewered area were less numerous than would be expected; therefore, manganese seems to be most prevalent in the recently sewered area and least prevalent in the long-term sewered area (table 9). Additionally, detections of manganese in samples from the shallow zone of all three suburban areas were more numerous than would be expected if all depth zones were alike, and detections in samples from the deep zones were less numerous than would be expected; therefore, manganese seems to be most prevalent in the shallow zone and least prevalent in the deep zone (table 9).

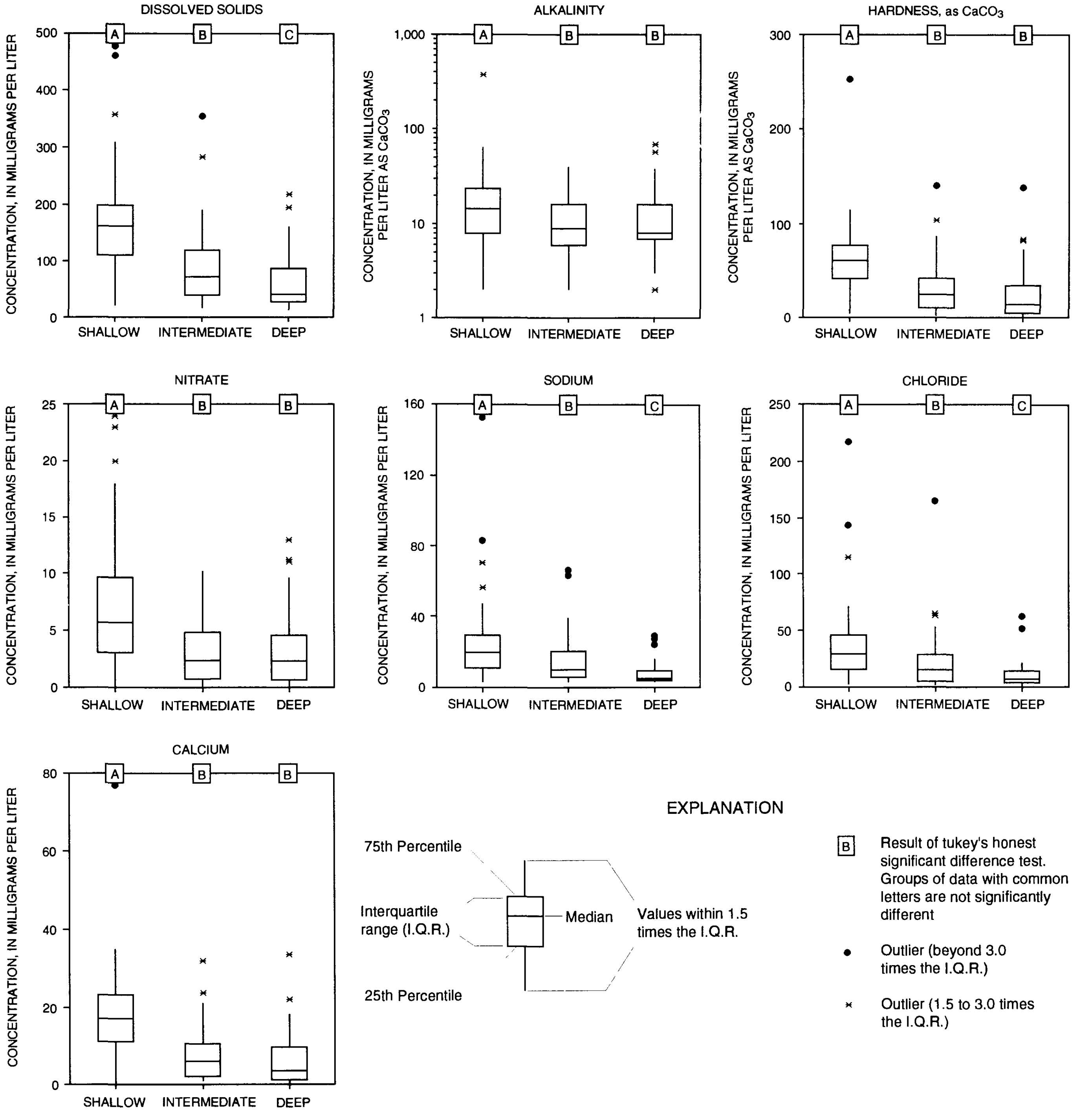


Figure 12. Distribution of inorganic-chemical concentrations in water samples from all three depth zones of the three suburban areas combined, Long Island, N.Y.

Boron.—The direction of the difference between observed and expected detection frequencies and the magnitude of each contingency-table cell's chi-square statistic for dissolved boron indicates that detections of boron in samples from all three zones of the long-term-sewered area were more numerous than would be expected if all three suburban areas were alike, and that detections for all three zones of the unsewered area were less numerous than would be expected; therefore, boron seems to be most prevalent in the long-term-sewered area and least prevalent in the unsewered area (table 9). Additionally, detections of boron in samples from the shallow zone of all three suburban areas were more numerous than would be expected if all three depth zones were alike, and the detections for the deep zone of all three areas were less numerous than would be expected; therefore, boron seems to be most prevalent in the shallow zone and least prevalent in the deep zone (table 9).

Dissolved iron and dissolved copper.—Contingency-table analyses for dissolved iron and dissolved copper indicate that the proportions of detection of these constituents in samples from all three depth zones do not differ significantly among the three areas and that the proportions of dissolved iron detection does not differ significantly with depth (table 8).

Other trace elements.—Detection of barium, cadmium, chromium, MBAS, and lead was infrequent, and concentrations were low, in samples from all three depth zones of all suburban areas (appendixes 2A-2C). Arsenic, mercury, selenium, and silver were not detected in any of these samples (appendixes 2A-2C).

Volatile Organic Compounds

Volatile organic compounds (VOC's) were detected only in the suburban areas, except chloroform, which was detected in three samples (23 percent) from the intermediate zone of the undeveloped area. The following discussion, therefore, addresses the detection and spatial distribution of VOC's only within the suburban areas.

VOC's were detected in 40 percent of the samples from the suburban areas. Of the samples from the long-term-sewered area, about 55 percent contained VOC's, as did 43 percent of those from the recently sewered area and 23 percent of those from the unsewered area. The most commonly detected VOC's and their maximum concentrations were 1,1,1-trichloroethane (TCA) 12,000 µg/L; trichloroethene (TCE) 660 µg/L; tetrachloroethene (PCE) 280 µg/L; 1,1-dichloroethane 34 mg/L; and 1,2-*trans*-dichloroethene 940 µg/L (appendix 3). Sources of VOC contamination within suburban areas include (1) commercial facilities commonly associated with residential areas, such as dry cleaners and gas stations, (2) industrial facilities where VOC's are used as solvents and degreasers, (3) use of VOC degreasers in cesspools and septic tanks, (4) accidental spills from storage tanks and sewer lines, and (5) residues from the extensive road networks.

1,1,1-Trichloroethane.—The frequency of TCA detections in samples from all depth zones of each suburban area ranged from 38 percent in the recently sewered area to 21 percent in the unsewered area, but contingency-table analyses indicated that the differences were not significant (table 8). TCA is used in industrial and commercial operations as a solvent and degreaser and, in residential areas as a cesspool and septic-tank cleaner and as a component of certain pesticides; thus, its similar detection frequency in all three suburban areas was expected. The proportion of detections changed significantly with depth, however. The direction of the difference between observed and expected detection frequencies and the magnitude of each contingency-table cell's chi-square statistic for TCA indicates that detections of TCA in samples from the shallow zones of all three suburban areas (42 percent) were more numerous than would be expected if all three depth zones were alike, and that detections in samples from the deep zones of all three areas (9 percent) were less numerous than would be expected; therefore, TCA seems to be most prevalent in the shallow zones.

Trichloroethene.—The frequency of TCE detections in samples from all depth zones ranged from 29 percent in the long-term-sewered area to 12 percent in the unsewered area, but this difference was found not to be significant (table 8). TCE also is used in industrial and commercial operations as a solvent and degreaser and in residential areas as a component of certain pesticides; thus, its similar detection frequency in all three suburban areas was expected. The frequency of TCE detections in samples from all three suburban areas was 25 percent for the shallow zone, 22 percent for the intermediate zone, and 17 percent for the deep zone, but this difference was found to be not significant (table 8).

Tetrachloroethene.—The proportion of PCE detections in samples from all depth zones was found to differ significantly among the three suburban areas; detections of PCE were more numerous in samples from the long-term-sewered area (33 percent) than would be expected if all three areas were alike, and detections were less numerous in samples from the unsewered area (5 percent); therefore, PCE seems to be most prevalent in the long-term-sewered area (tables 8 and 9). Sources of PCE are mostly industrial and commercial operations, where it is used as a solvent, degreaser, and drying agent; thus, the significantly lower detection frequency in the unsewered area, which contains little industry and commerce, was expected. The frequency of PCE detections in samples from all three areas was 22 percent for the shallow zone, 19 percent for the intermediate zone, and 20 percent for the deep zone, but these differences were not significant (table 8).

Detection frequencies.—Detection rates of TCA, TCE, PCE, 1,1-dichloroethane, and 1,2-*trans*-dichloroethene in samples from all three depth zones of the three suburban areas (fig. 13) show a general decrease from shallow to deep zones in the recently sewered and unsewered areas, but an increase from the shallow to intermediate zones in the long-term-sewered area. Additionally, VOC concentrations exceeding 50 µg/L in the long-term-sewered area were found most frequently in samples from the intermediate zone, whereas those in the recently sewered and unsewered areas were found most frequently in samples from the shallow zone. This pattern is attributable to three factors: (1) the long-term-sewered area has been highly urbanized and industrialized longer than the recently sewered and unsewered areas and, thus, has likely received a greater loading of VOC's with time; (2) ground-water pumping, which accelerates the vertical movement of contaminants, is greater in the long-

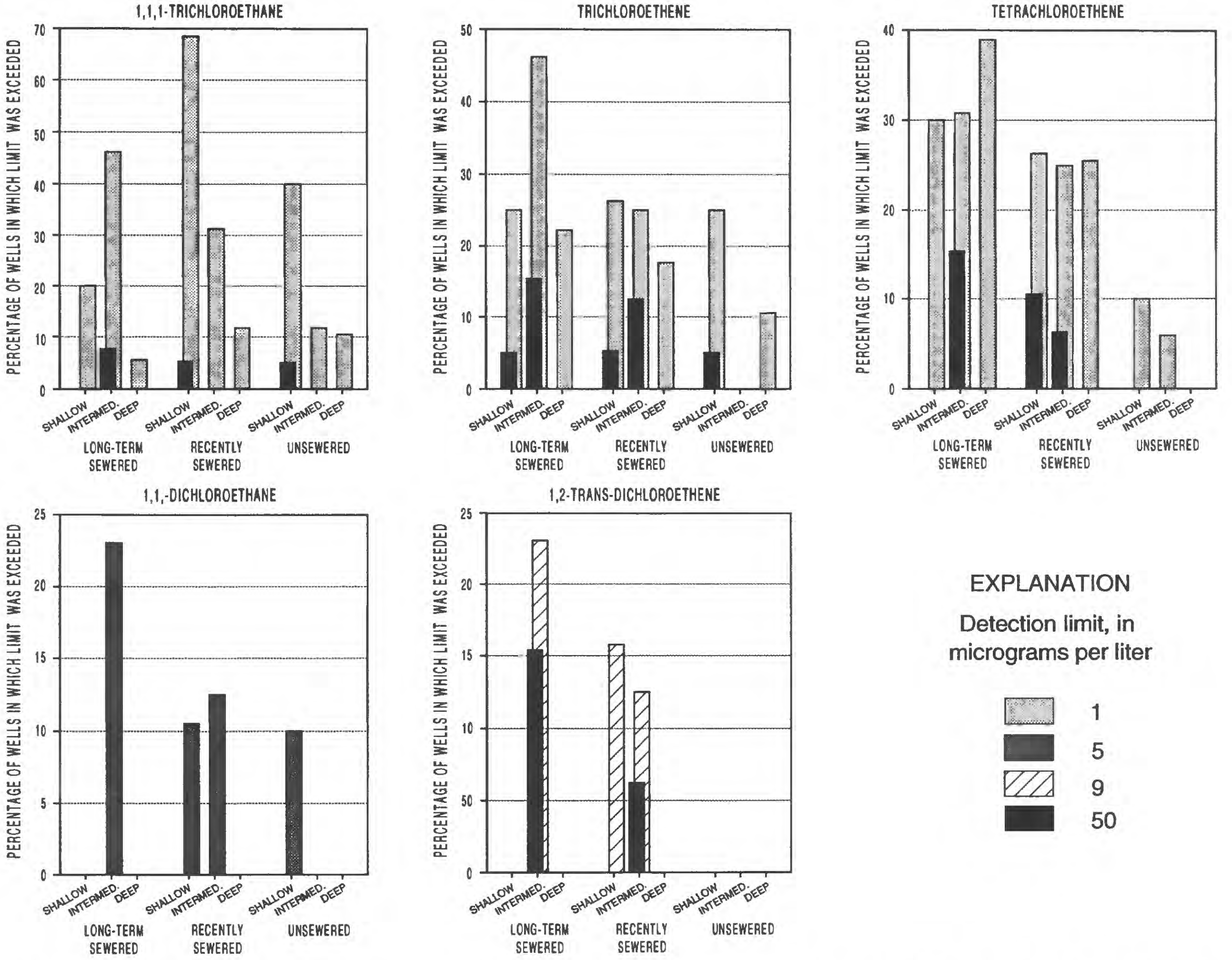


Figure 13. Detection frequencies for volatile organic compounds from each depth zone of the three suburban areas, Long Island, N.Y.

term-sewered area than in the recently sewered or unsewered areas; and (3) the persistence of contaminants introduced into the water-table aquifer before the construction of sewers.

VOC's that were detected infrequently and at low concentrations include trichlorofluoromethane, carbon tetrachloride, 1,1,2-trichloroethane, benzene, chlorobenzene, ethylbenzene, and xylene. No dichlorobromomethane, bromoform, or toluene was detected in any water samples (appendix 3).

Effects of Development and Construction of Sewers

Information from the previous sections can be used to determine whether (1) ground water that has been affected by contamination derived from human activities has reached the intermediate and deep zones of the Long Island aquifer system, and (2) water quality differs significantly among the long-term-sewered, recently sewered, and unsewered suburban areas.

Water-quality data obtained in this study were compared with data on the quality of native (predevelopment) ground water (K.A. Pearsall, U.S. Geological Survey, written commun., 1988) to determine whether water that has been affected by human activities has reached the intermediate and deep zones of the aquifer system in Nassau and Suffolk Counties. Pearsall screened a data base of 8,500 wells on Long Island to identify those at which water might reflect native (predevelopment) conditions. Screening criteria used were a chloride concentration of 10 mg/L or less and a nitrate concentration of less than 1.0 mg/L. These criteria were selected because previous investigators concluded that concentrations above those levels indicated contamination from human activities (Perlmutter and Geraghty, 1963; Perlmutter and Koch, 1972). About 220 wells were subsequently sampled and those at which chloride or nitrate concentrations exceeded the screening criteria were discarded. Inorganic constituents for which concentration data were available for comparison included sodium, potassium, calcium, magnesium, chloride, nitrate, alkalinity, and dissolved solids. Median concentrations of these constituents in samples from 30 wells screened in the lower half of the Magothy aquifer were used to represent pristine ground-water quality because these samples were more likely to reflect predevelopment ground-water quality for two reasons: (1) the age of ground water generally increases with depth in the flow system, therefore, water in the deepest part of the Magothy aquifer should be the least affected by human activities; and (2) a few shallow wells, although the best obtainable, were nevertheless somewhat affected by human activities (K.A. Pearsall, U.S. Geological Survey, written commun., 1988). Median concentrations in samples from the intermediate and deep zones of the five study areas, and those from the pristine-water (lower Magothy) data base, are listed in table 10.

Intermediate depth zone.—The median concentration of each constituent in samples from the intermediate-depth zone of each area is higher than the pristine-water median, and concentrations of each constituent in the intermediate-depth zone of each area were more variable than in pristine water. Thus, water affected by human activities probably has reached the intermediate depth in Nassau and Suffolk Counties. Its effect is most severe in the sewered suburban and agricultural areas and is least severe in the undeveloped area.

Deep zone.—Estimated median traveltimes of ground water (fig. A-1, p. 82) indicate that water within the deep zone of the suburban areas should represent predevelopment quality, but median concentrations of inorganic constituents in samples from the deep zone of the two sewered areas were higher than those in the pristine-water data base (table 10), as were the medians for some of these constituents in the deep zone of the unsewered area. Also, concentrations of each constituent in the suburban areas were more variable than those of pristine water. Thus, water affected by human activities appears to have reached the deep zone, and its effect is most severe in the long-term-sewered area and is least severe in the unsewered area. This difference is consistent with historical patterns of contaminant loading and the greater local pumping in the long-term-sewered area than elsewhere, which has accelerated the vertical migration of contaminated water into deep parts of the aquifer system.

Several investigators have examined water-quality differences between sewered and unsewered suburban areas on Long Island (Katz and others 1980; Ragone and others, 1981; Porter, 1980). Katz and others (1980) and Ragone and others (1981) found no significant difference between median nitrate concentrations in sewered areas and those in unsewered areas of the water-table aquifer in 25 years of record, but this has been attributed to possible biases in the data base, the amount of time required for the water-table aquifer to discharge contaminants introduced before construction of sewers, and the continued loading of nitrate from nonpoint sources, all of which obscure the effects of sewers (Porter, 1980). Analyses of 1972-76 data by Katz and others (1980) and Ragone and others (1981) indicate a relative improvement in water quality in the sewered area, as evidenced by significantly lower (1) nitrate concentrations in base flow of streams, (2) median ammonium concentrations in shallow ground water in the sewered areas, and (3) median nitrate concentrations near the water table beneath the sewered areas. They also noted decreasing long-term nitrate trends at most wells within the sewered areas.

Comparison of water-quality data among the three suburban areas reveals significant differences in median concentrations and detection rates for nearly all inorganic and trace-element constituents studied. In all three depth zones of the three suburban areas, median concentrations and detection rates were generally highest in samples from the long-term-sewered area and lowest in samples from the unsewered area, and the median concentrations and detection rates in all three areas were higher in samples from the shallow zone than from the intermediate or deep zone. These results reflect the greater loading in the long-term-sewered area than elsewhere and the continued introduction of contaminants into the shallow ground-water system from surface sources, but they also indicate a possible improvement in ground-water quality beneath the sewered areas. The shallow zone of the long-term-sewered area generally had the lowest median concentrations of nitrate, phosphorus, potassium, magnesium,

Table 10. Median values and concentrations of selected properties and inorganic constituents in water from the intermediate and deep zones of the five study areas and in pristine (predevelopment) water

[Values are in milligrams per liter; --, no data]

Constituent and depth zone	Study area					Pristine water[1]
	Long-term sewered	Recently sewered	Unsewered	Agricultural	Undeveloped	
Sodium						
Intermediate	14.5	11.0	7.0	7.0	5.0	3.3
Deep	8.0	5.0	3.0	--	--	
Potassium						
Intermediate	2.1	0.7	0.8	2.5	0.6	0.44
Deep	.9	.5	.4	--	--	
Calcium						
Intermediate	9.3	6.9	2.8	17.3	4.6	1.2
Deep	6.8	3.4	1.0	--	--	
Magnesium						
Intermediate	2.9	2.6	1.5	4.6	1.2	0.56
Deep	3.7	1.1	.5	--	--	
Chloride						
Intermediate	28.2	13.7	7.2	16.3	7.4	4.0
Deep	10.7	5.1	3.9	--	--	
Nitrate						
Intermediate	2.18	4.47	1.17	3.08	0.07	0.20
Deep	3.55	2.36	.60	--	--	
Alkalinity						
Intermediate	14	8	9	14	9	7
Deep	14.5	7	8.5	--	--	
Dissolved solids						
Intermediate	108	77	49	107	48	25
Deep	80	38	23	--	--	

[1] Depth classifications do not apply to pristine water. Pristine-water data from K.A. Pearsall, U.S. Geological Survey, written commun., 1988.

dissolved solids, and sodium, and the shallow zone of the unsewered and recently sewered areas had the highest. The pattern for the deep zone was the reverse: the long-term sewered area generally had the highest median concentrations, and the unsewered area the lowest. This could be the result of the historical pattern of sewer construction. The highest median concentrations in the shallow zone, which contains relatively young ground water (fig. A-1, p. 82), were in the recently sewered or unsewered areas as a result of contaminants that were introduced before sewer construction and the continued loading from cesspools, septic tanks, and lawn fertilizers. The highest median concentrations in the deep zone, which contains much older water (fig. A-1), are in the long-term-sewered area as a result of the long period of loading from cesspool systems, septic tanks, sewer-line leakage, and lawn fertilizers.

VOC-detection frequencies in samples from all three depth zones of the three suburban areas (fig. 13) confirm a relative improvement in ground-water quality beneath the long-term-sewered area. Because this area is more densely populated and industrialized than the unsewered area (figs. 2 and 3 and table 1) and has been developed longer than the recently sewered area, it probably has received the greatest loading of VOC's from industrial sources and from individual households. The percentage of wells at which concentrations of four of the five most commonly detected VOC's exceed detection limits of 1 or 50 µg/L in the shallow zone of the long-term-sewered area is equal to or lower than the percentage for the recently sewered or unsewered areas (fig. 13). Conversely, the percentage of wells in the long-term-sewered area at which concentrations of the same VOC's exceed detection limits of 1 or 50 µg/L in the intermediate and deep zones, which contain water that was contaminated before sewer construction (fig. A-1), is equal to or greater than that in the recently sewered or unsewered areas (fig. 13). This contrast not only indicates that ground-water quality beneath areas that have been sewered for several decades is improving; it supports conclusions of other studies, that the large amount of time required for the water-table aquifer to flush contaminants introduced before sewer construction, and the continued loading of some constituents from nonpoint sources, tend to mask the water-quality benefits of sewers.

SUMMARY

The Long Island aquifer system in Nassau and Suffolk Counties was included in the USGS Toxic Substances Hydrology Program to provide information on regional ground-water quality and its relation to local hydrologic and human influences. In the third phase of investigation, described herein, the effects of land use on ground-water quality in shallow, intermediate, and deep zones of the aquifer system were statistically evaluated. Water samples were collected from 207 randomly selected wells in five study areas that were defined on the basis of predominant land use and age of sewers. The study areas were categorized in 1986 as (1) suburban area, long-term-sewered (longer than 22 years); (2) suburban area, recently sewered (fewer than 8 years); (3) suburban area, unsewered; (4) agricultural area; and (5) undeveloped area. Each area lies along the regional ground-water divide, where ground water moves predominantly downward and transports contamination introduced at or near land surface deeper into the aquifer system than elsewhere on the island.

Water-quality data from the 207 wells screened in the shallow, intermediate, and deep zones of the aquifer system beneath the five study areas were statistically evaluated to determine whether water-quality differences exist among the five areas and three depth zones and among the three suburban areas, which have differing histories of sewer construction. This statistical evaluation was coupled with an estimation of ground-water traveltimes to the midpoint of each well screen to determine whether (1) the spatial distribution of contaminants within the aquifer system can be related to land use or depth below the water table; (2) contaminants derived from human activities have reached the intermediate and deep zones of the aquifer system; and (3) the sewer systems in two of the three suburban areas have resulted in an improvement in ground-water quality.

Statistical evaluation of water-quality data from the shallow and intermediate zones of the aquifer indicates that concentrations of inorganic constituents were lowest and least variable within the undeveloped area and generally highest and most variable in the agricultural area and generally were intermediate to high in the two sewered suburban areas. Trace-element concentrations also were highest in the agricultural and sewered suburban areas and lowest in the undeveloped area. VOC's were detected only in the suburban

areas. These results are similar to those obtained in previous studies that defined relations between land use and quality of shallow ground water on Long Island. Concentrations of most inorganic constituents and values of most physical properties decreased from the shallow to intermediate and deep zones of the aquifer system; this decrease is attributed to (1) physical and chemical reactions that remove constituents from solution and (2) dilution due to hydrodynamic dispersion and ionic diffusion as constituents move along flow paths.

Alkalinity and concentrations of inorganic constituents (sodium, potassium, calcium, magnesium, chloride, nitrate, and dissolved solids) in samples from intermediate and deep wells were compared with concentrations from a data base representing pristine (predevelopment) ground-water quality to determine whether water affected by human activities has reached the intermediate and deep zones of the aquifer system. Although traveltime analysis indicated that ground water in the deep zone should reflect predevelopment conditions, concentrations of each constituent in samples from the intermediate and deep wells were more variable, and most medians higher, than those in the pristine-water data base. This finding is attributed to the effects of local pumping, which accelerates the downward movement of water and thereby has induced water from the shallow zone, which has been affected by human activities, to migrate to intermediate and deep zones of the aquifer system.

The concentrations of several inorganic constituents in samples from the shallow and deep zones of the three suburban areas, as well as the frequency of VOC detections of samples from each suburban area, indicate that ground-water quality is improving in areas that have been sewered for more than two decades. The highest median concentrations of nitrate, phosphorus, potassium, magnesium, dissolved solids, and sodium in the shallow zone, which contains relatively young ground water, were in samples from the recently sewered area, where the benefits of sewers are not yet apparent, and in the unsewered suburban area; the highest median concentrations of these constituents in the deep zone, which contains relatively old ground water, were in samples from the long-term-sewered suburban area, where development has been the most extensive. Additionally, VOC detection frequency for the long-term-sewered area was higher among intermediate-zone samples than the shallow zone samples, whereas detection frequency for the recently sewered and unsewered suburban areas was highest in samples from the shallow zone, where loading of VOC's from industrial and residential sources continues and contaminants introduced before sewers were constructed have not had sufficient time to be flushed from the system.

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APPENDIX 1

Concentrations of major inorganic constituents and field-measured properties values in ground water in Nassau and Suffolk Counties, Long Island, N.Y.

Appendix 1A. Major inorganic constituents in, and selected physical properties of, water samples from network wells screened in the shallow zone, Nassau and Suffolk Counties, Long Island, N.Y.

[mg/L, milligrams per liter; μS/cm, microsiemens per centimeter at 25 degrees Celsius; deg. C, degrees Celsius; <, less than; --, no data]

Well number	Silica, total (mg/L as SiO_2)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity, lab (mg/L as $CaCO_3$)	Sulfate (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Nitrogen, nitrate, total (mg/L as N)
LONG-TERM-SEWERED SUBURBAN AREA										
N9946	15.6	12.1	3.2	10	3.3	14	37	15.6	<0.2	1.86
N9940	10.5	14.4	2.7	9.0	3.9	9	23	12.4	<.2	5.81
N9948	18.0	77.4	14.2	32	24.7	370	<5.0	45.6	.2	<.01
N9942	11.7	19.0	3.2	30	3.1	18	36	45.4	<.2	5.48
N9962	6.2	28.9	3.2	11	2.9	50	29	16.2	<.2	4.69
N9941	9.1	18.5	5.7	22	5.0	7	31	31.6	<.2	11.0
N9982	20.1	25.7	7.2	17	1.7	18	43	34.5	<.2	5.05
N9949	10.3	35.0	6.7	16	.8	64	45	24.6	<.2	3.85
N9959	4.6	4.2	.8	12	1.0	33	8.0	9.9	<.2	<.01
N9914	7.6	28.2	6.4	24	2.4	34	47	39.2	<.2	5.20
N9944	13.2	21.6	4.1	31	4.8	11	47	50.1	<.2	6.38
N9983	19.1	24.8	4.9	13	1.4	16	38	24.2	<.2	6.36
N9943	10.2	27.6	8.8	83	3.8	28	44	143.0	<.2	4.41
N10035	5.2	9.3	2.4	24	1.3	24	11	29.0	<.2	4.19
N9803	8.8	19.0	3.3	29	3.8	14	25	48.8	<.2	6.50
N9945	8.7	18.1	3.7	17	1.9	17	38	30.9	<.2	4.42
N9984	13.5	22.8	2.6	21	2.5	12	27	33.4	<.2	6.45
N9057	10.7	21.9	3.5	11	3.6	8	35	32.4	<.2	8.70
N9712	15.1	25.4	11.2	18	2.0	26	34	46.3	<.2	13.00
N7649	14.9	11.6	5.6	12	.9	17	16	17.1	<.2	4.74
RECENTLY SEWERED SUBURBAN AREA										
N9933	12.8	15.5	2.6	10	0.9	19	26	8.0	<0.2	2.65
N9926	4.2	6.3	2.3	11	1.6	7	7.0	26.6	<.2	1.50
N8888	13.1	16.3	2.8	28	4.4	11	29	37.9	<.2	8.91
N9927	15.5	21.6	2.6	21	6.9	2	24	25.0	<.2	18.00
N9928	15.9	17.3	3.1	23	8.2	3	24	24.5	.49	20.00
N9920	4.6	15.1	2.6	43	4.0	21	34	45.1	<.2	7.70
N9354	15.6	19.6	3.3	28	4.8	15	36	29.2	<.2	9.82
N9919	12.9	19.9	4.1	31	5.3	6	26	50.9	<.2	14.00
N9938	8.6	13.1	7.3	36	1.9	8	26	70.8	<.2	3.96
N9917	6.0	24.8	3.3	29	2.1	42	22	64.7	<.2	.16
N9079	5.1	28.7	4.7	56	3.9	59	26	114.0	<.2	2.27
N1197	12.6	21.9	3.2	23	5.6	11	33	36.2	<.2	10.00
N8984	4.0	8.6	2.3	12	1.4	21	16	22.7	<.2	2.71
N9918	6.6	7.8	2.0	6.0	2.2	4	<5.0	12.1	<.2	4.51
N9939	11.4	12.0	3.2	14	4.0	2	26	20.5	<.2	8.95
N9451	14.9	28.2	2.2	16	3.7	10	41	32.4	<.2	4.89
N9222	12.5	14.2	2.2	10	3.9	4	25	14.5	<.2	6.24
N9925	13.8	23.3	2.9	43	6.5	8	31	64.9	<.2	11.00
N9078	8.2	11.8	3.0	8.0	3.3	9	28	9.0	<.2	3.39
N9924	9.2	20.2	2.3	47	4.3	23	27	69.8	<.2	5.25

Appendix 1A. Major inorganic constituents in, and selected physical properties of, water samples from network wells screened in the shallow zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	Nitrogen, nitrite, total (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, total (mg/L as P)	Solids, sum of constituents, dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)	Specific conductance, field (μS/cm)	pH, lab (standard units)	Temperature, water (deg. C)	Oxygen, dissolved (mg/L)
LONG-TERM-SEWERED SUBURBAN AREA										
N9946	0.002	<0.01	0.02	<0.01	113	43	168	5.50	13.4	4.4
N9940	<.001	<.01	<.01	<.01	107	47	169	5.60	14.0	9.8
N9948	.004	20.00	.03	<.01	478	251	815	6.80	14.8	0
N9942	.001	<.01	.02	.01	161	60	303	5.50	15.2	7.2
N9962	.009	<.01	.02	<.01	149	85	264	6.10	13.1	7.9
N9941	.002	.13	.02	<.01	176	69	286	5.30	15.0	2.3
N9982	.002	<.01	.07	.02	183	94	292	5.90	14.7	9.6
N9949	.003	<.01	.03	<.01	159	115	323	6.20	14.8	6.0
N9959	<.001	<.01	.08	<.01	62	13	102	6.90	14.4	.2
N9914	.003	<.01	.02	<.01	198	96	321	6.40	14.2	9.6
N9944	<.001	<.01	.07	<.01	207	70	335	5.60	14.7	10.3
N9983	<.001	<.01	.07	<.01	163	82	252	5.60	14.2	8.5
N9943	.004	<.01	<.01	<.01	357	105	673	5.90	15.2	9.1
N10035	<.001	<.01	.03	<.01	115	33	193	5.70	15.5	1.6
N9803	<.001	<.01	.03	<.01	175	61	288	5.40	13.7	6.0
N9945	.002	<.01	<.01	<.01	148	60	240	5.70	14.2	10.4
N9984	.001	<.01	.08	.01	159	67	251	5.50	14.7	9.4
N9057	.003	.08	<.01	<.01	162	69	274	5.20	14.2	2.2
N9712	.011	<.01	.02	<.01	226	109	329	5.70	12.7	6.6
N7649	<.001	<.01	.01	<.01	109	52	173	5.60	12.5	4.8
RECENTLY SEWERED SUBURBAN AREA										
N9933	<0.001	<0.01	0.55	<0.01	101	49	157	5.80	14.6	7.2
N9926	<.001	<.01	.05	<.01	70	25	123	5.70	13.5	10.0
N8888	.003	<.01	.08	<.01	178	52	272	5.50	14.6	7.8
N9927	<.001	<.01	<.01	<.01	198	64	295	4.80	14.7	8.0
N9928	<.001	.02	.02	<.01	208	55	318	4.80	14.4	9.8
N9920	.002	.04	.03	<.01	196	48	335	5.60	15.3	3.4
N9354	.004	.16	.05	<.01	191	62	303	5.50	13.9	3.8
N9919	<.001	<.01	.06	<.01	216	66	355	5.10	15.9	6.0
N9938	<.001	<.01	.02	<.01	186	62	349	5.30	16.5	3.8
N9917	.003	.05	.09	<.01	189	75	383	6.00	15.0	0
N9079	.297	.19	.10	<.01	309	91	568	5.90	15.5	0
N1197	<.001	.02	.03	<.01	187	67	311	5.60	14.2	4.3
N8984	.022	.20	.14	.07	77	30	184	5.90	14.3	3.3
N9918	<.001	<.01	.07	<.01	59	27	111	5.30	13.7	4.8
N9939	<.001	<.01	.01	<.01	133	43	212	4.90	14.4	5.6
N9451	.019	<.01	.34	<.01	167	79	261	5.50	14.3	8.0
N9222	<.001	<.01	.02	<.01	113	44	174	5.00	12.6	8.8
N9925	.006	<.01	<.01	<.01	239	70	391	5.70	14.3	6.0
N9078	.002	<.01	.13	<.01	93	41	149	5.80	12.9	6.8
N9924	<.001	<.01	<.01	<.01	218	59	375	5.50	15.3	.5

Appendix 1A. Major inorganic constituents in, and selected physical properties of, water samples from network wells screened in the shallow zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	Silica, total (mg/L as SiO_2)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity, lab (mg/L as $CaCO_3$)	Sulfate (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Nitrogen, nitrate, total (mg/L as N)
UNSEWERED SUBURBAN AREA										
S45207	12.5	14.1	3.7	14	3.2	14	19	12.6	<0.2	7.63
S65602	17.3	26.2	5.1	19	5.7	6	32	26.2	<.2	23.00
S65607	15.6	16.0	7.2	23	4.0	7	26	32.2	<.2	16.00
S45208	19.9	24.1	9.2	32	3.2	19	29	34.9	<.2	24.00
S45210	18.0	23.5	10.1	9.0	1.5	31	37	10.2	<.2	12.00
S68762	12.0	15.4	3.5	22	1.9	9	20	22.7	<.2	9.97
S45594	11.5	8.1	3.0	11	1.9	12	14	11.2	<.2	4.31
S75456	10.1	4.3	2.8	5.0	.8	10	6.0	11.8	<.2	1.74
S24771	10.2	8.6	5.1	20	2.2	34	13	18.5	<.2	6.46
S64314	5.0	22.1	6.1	154	1.2	54	16	217.0	<.2	1.51
S47220	5.5	<.1	.8	5.0	.4	5	<5.0	2.5	<.2	.85
S48375	6.9	6.5	1.6	70	9.5	39	22	62.1	<.2	13.00
S74286	6.6	1.1	1.3	3.0	.6	6	<5.0	5.0	<.2	1.08
S64316	6.6	17.0	5.8	10	2.8	6	23	33.0	<.2	7.75
S64318	6.1	2.2	3.1	16	1.1	8	<5.0	25.4	<.2	2.00
S64313	2.4	11.0	1.0	43	1.8	19	<5.0	60.3	<.2	.24
S29778	7.5	6.6	4.7	6.0	1.5	23	8.0	13.2	<.2	2.94
S64319	10.8	21.7	5.5	26	5.0	15	21	57.2	<.2	6.79
S13175	13.1	14.1	6.5	20	1.4	21	9.0	21.4	<.2	11.50
S16605	7.2	9.1	4.3	14	5.0	27	<5.0	11.9	<.2	7.03
AGRICULTURAL AREA										
S51582	10.5	41.9	7.7	5.0	3.8	16	80	20.1	<0.2	8.31
S51587	11.7	33.1	6.5	14	11.0	20	59	23.4	.46	13.10
S51568	8.9	60.3	9.2	23	5.2	22	79	54.8	<.2	17.00
S51581	8.8	31.1	7.9	8.0	3.9	8	114	20.3	<.2	3.51
S51566	10.5	77.0	12.6	10	4.4	9	140	33.7	<.2	18.00
S51589	6.1	7.0	1.2	21	3.9	8	8.0	37.8	.34	3.55
S51567	10.6	76.0	12.2	9.0	2.5	11	150	27.2	<.2	11.00
S51572	12.8	18.5	4.1	22	6.4	20	31	34.8	<.2	9.91
S51588	8.7	49.7	10.1	10	4.5	15	97	24.1	<.2	11.00
S51577	10.4	51.9	10.1	7.0	8.7	7	113	22.2	<.2	8.91
S51576	8.0	17.8	5.2	6.0	4.3	7	45	10.6	<.2	4.73
S52383	4.1	7.1	1.4	7.0	4.5	5	<5.0	23.4	.62	4.96
UNDEVELOPED AREA										
S74301	9.9	3.2	0.8	<3.0	0.6	6	6.0	3.6	<0.2	<0.01
S54886	4.7	2.9	.4	54	.4	5	18	74.0	<.2	.32
S74294	5.4	1.9	.3	33	.8	15	10	44.7	<.2	.09
S48584	7.1	2.4	1.0	<3.0	.6	7	<5.0	4.7	<.2	<.01
S74307	6.8	4.2	1.6	20	.9	4	9.0	36.7	<.2	.24
S47755	7.7	3.1	1.3	3.0	.8	5	7.0	11.4	<.2	<.01
S48946	9.5	16.9	4.9	9.0	3.3	21	22	16.2	<.2	6.50
S73807	10.0	18.3	4.5	5.0	2.7	5	8.0	19.1	<.2	.02
S86583	9.3	4.0	4.4	5.0	.9	4	<5.0	11.7	<.2	5.86
S74295	7.3	1.4	.2	8.0	.7	7	12	4.4	<.2	<.01
S74293	11.8	6.0	2.1	8.0	.9	8	12	8.3	<.2	3.64

Appendix 1A. Major inorganic constituents in, and selected physical properties of, water samples from network wells screened in the shallow zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	Nitrogen, nitrite, total (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Phos-phorus, total (mg/L as P)	Phos-phorus, ortho, total (mg/L as P)	Solids, sum of constituents, dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)	Specific conduct-ance, field (µS/cm)	pH, lab (standard units)	Temper-ature, water (deg. C)	Oxygen, dissolved (mg/L)
UNSEWERED SUBURBAN AREA										
S45207	0.003	<0.01	0.06	<0.01	122	50	175	5.90	13.1	8.8
S65602	.002	<.01	.20	<.01	238	86	354	5.10	13.9	7.4
S65607	.002	<.01	.04	<.01	200	69	313	5.10	12.2	7.4
S45208	.001	<.01	.02	.01	272	98	413	5.50	13.5	6.4
S45210	.004	<.01	.01	<.01	181	100	275	6.90	13.0	10.4
S68762	.002	<.01	.10	.05	147	52	219	5.30	13.8	6.8
S45594	<.001	<.01	.02	<.01	87	32	122	6.10	12.6	8.7
S75456	<.001	<.01	.07	<.01	55	22	89	5.50	10.9	11.0
S24771	.006	1.20	<.01	<.01	128	42	216	5.60	14.5	.8
S64314	<.001	<.01	.02	.02	461	80	830	6.10	13.5	6.0
S47220	<.001	<.01	<.01	<.01	21	4	31	5.60	10.8	10.2
S48375	.042	.75	.26	.20	262	22	459	5.50	17.6	.2
S74286	<.001	<.01	.07	<.01	26	8	49	5.30	13.9	10.6
S64316	.003	<.01	.08	<.01	136	66	236	5.00	12.6	9.1
S64318	<.001	<.01	<.01	<.01	68	18	124	7.00	12.4	10.6
S64313	.005	.17	.05	.01	133	31	226	5.60	14.1	4.6
S29778	<.001	.10	.05	<.01	75	35	127	7.10	11.5	8.6
S64319	<.001	<.01	.03	<.01	186	76	330	5.30	12.2	7.1
S13175	<.001	<.01	.11	<.01	149	61	235	5.80	12.2	9.0
S16605	.015	.68	.01	<.01	100	40	153	6.20	--	2.6
AGRICULTURAL AREA										
S51582	0.004	<0.01	0.25	<0.01	216	136	346	5.80	12.1	10.4
S51587	.024	.03	.07	<.01	229	109	335	5.70	12.5	9.0
S51568	.059	.25	.08	<.01	330	188	510	5.70	12.3	8.9
S51581	<.001	<.01	<.01	<.01	216	110	323	5.60	12.9	10.0
S51566	.002	<.01	<.01	<.01	373	244	563	5.50	12.1	9.4
S51589	.004	<.01	--	--	108	22	189	5.00	11.4	2.6
S51567	.003	<.01	<.01	<.01	342	240	521	5.50	11.9	10.5
S51572	.032	.74	.32	<.01	193	63	296	5.80	12.2	0
S51588	.020	.38	.17	.03	265	165	421	5.70	12.3	6.6
S51577	.001	<.01	.01	<.01	267	171	412	5.30	12.0	10.1
S51576	<.001	<.01	.08	<.01	122	65	202	6.10	11.9	10.0
S52383	.006	.07	.05	.01	73	23	140	5.00	11.9	8.0
UNDEVELOPED AREA										
S74301	0.001	<0.01	0.04	<0.01	28	11	43	5.70	10.7	11.4
S54886	<.001	<.01	<.01	<.01	159	8	320	5.00	12.7	11.2
S74294	.002	<.01	<.01	<.01	105	5	188	7.40	12.5	1.0
S48584	.002	<.01	<.01	<.01	20	10	41	5.70	11.2	10.6
S74307	<.001	<.01	<.01	<.01	82	17	159	5.30	11.8	11.2
S47755	<.001	<.01	.11	.05	38	13	69	5.30	12.5	7.9
S48946	.032	.27	.09	.03	129	62	217	5.70	13.1	3.1
S73807	<.001	<.01	.02	<.01	71	64	99	5.40	11.7	11.1
S86583	<.001	<.01	.25	<.01	64	28	114	5.20	11.4	10.5
S74295	<.001	<.01	<.01	<.01	38	4	67	5.60	11.6	11.8
S74293	.001	<.01	.09	.02	70	23	107	5.50	12.2	10.5

Appendix 1B. Major inorganic constituents in, and selected physical properties of, water samples from network wells screened in the intermediate zone, Nassau and Suffolk Counties, Long Island, N.Y.

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg. C, degrees Celsius; <, less than; --, no data]

Well number	Silica, total (mg/L as SiO_2)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity, lab (mg/L as $CaCO_3$)	Sulfate (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Nitrogen, nitrate, total (mg/L as N)
LONG-TERM-SEWERED SUBURBAN AREA										
N1818	21.5	32.0	14.6	63	2.7	34	24	165.0	<0.2	2.33
N7560	23.1	18.9	9.6	26	2.2	28	22	63.0	<.2	2.04
N3699	8.5	17.2	2.8	33	3.6	16	24	42.9	<.2	5.82
N7524	10.1	9.6	4.3	15	2.2	9	42	29.5	<.2	.09
N10043	9.7	7.2	3.7	14	3.6	6	6.0	19.7	<.2	7.25
N8068	8.1	5.9	2.5	20	1.4	3	<5.0	48.7	<.2	3.64
N9713	8.0	3.1	1.2	7.0	.6	7	<5.0	11.1	<.2	1.90
N9802	9.1	11.0	1.2	9.0	.7	17	6.0	18.5	<.2	4.42
N4756	7.0	1.0	.3	<3.0	.1	8	<5.0	1.6	<.2	.17
N9947	22.0	21.2	12.3	11	2.1	40	43	27.0	<.2	4.93
N7219	9.5	6.1	2.9	8.0	1.1	3	26	18.4	<.2	<.01
N8311	10.6	6.1	2.6	22	1.6	14	23	36.1	<.2	.18
N4206	14.1	9.3	4.2	10	2.2	14	9.0	17.3	<.2	5.45
RECENTLY SEWERED SUBURBAN AREA										
N8493	10.6	2.2	0.4	3.0	0.3	11	<5.0	3.3	<0.2	0.53
N8364	15.5	18.5	6.1	14	3.1	10	37	13.7	<.2	9.42
N9168	21.4	6.9	2.7	7.0	.8	31	<5.0	5.0	<.2	1.04
N7531	9.6	15.9	4.4	23	2.7	16	20	28.6	<.2	10.00
N5007	10.0	3.0	.9	11	.4	14	<5.0	4.0	<.2	.95
N9341	10.2	19.8	5.5	66	1.9	20	61	64.5	<.2	8.61
N6655	9.0	23.8	5.3	28	4.7	27	32	51.1	--	4.47
N8472	9.9	16.5	5.2	26	1.0	11	21	50.9	<.2	4.04
N9449	6.8	1.3	<.1	6.0	.4	2	<5.0	9.7	<.2	1.03
N9239	7.4	4.1	1.5	7.0	.6	8	<5.0	6.0	<.2	4.78
N3243	7.4	9.1	2.6	11	.7	7	<5.0	17.0	<.2	5.72
N9252	9.7	9.9	3.5	16	1.2	5	31	16.1	<.2	3.16
N9018	7.4	1.5	.7	4.0	.5	4	<5.0	4.3	--	.56
N7353	10.1	6.9	2.0	8.0	.6	7	<5.0	10.1	<.2	4.53
N7536	7.9	6.5	2.2	19	.7	5	9.0	15.1	<.2	10.20
N3618	6.9	1.4	.5	4.0	.2	3	<5.0	3.3	<.2	1.80
N7248	9.3	9.4	3.0	15	1.0	3	6.0	17.9	<.2	6.34
UNSEWERED SUBURBAN AREA										
S28055	7.2	4.5	1.8	8.0	1.0	10	<5.0	14.7	<0.2	3.18
S11803	11.8	13.1	5.1	39	2.2	16	13	45.5	<.2	7.41
S14579	7.5	1.2	.3	3.0	.5	7	<5.0	7.2	<.2	.24
S76675	6.4	2.0	3.3	17	1.3	5	<5.0	27.6	<.2	2.47
S36976	9.7	2.8	1.2	6.0	.5	7	<5.0	4.6	<.2	2.13

Appendix 1B. Major inorganic constituents in, and selected physical properties of, water samples from network wells screened in the intermediate zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	Nitrogen, nitrite, total (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, total (mg/L as P)	Solids, sum of constituents, dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)	Specific conductance, field (µS/cm)	pH, lab (standard units)	Temperature, water (deg. C)	Oxygen, dissolved (mg/L)
LONG-TERM-SEWERED SUBURBAN AREA										
N1818	0.001	<0.01	0.01	<0.01	354	140	632	5.90	19.4	5.6
N7560	<.010	<.01	.06	<.01	191	86	323	5.90	20.1	6.8
N3699	<.001	<.01	.03	<.01	165	54	283	5.50	--	--
N7524	.004	1.22	.04	<.01	123	41	215	5.20	13.4	0
N10043	<.001	<.01	<.01	<.01	100	33	154	5.80	14.4	4.0
N8068	<.001	<.01	.02	<.01	105	25	186	4.90	15.0	2.2
N9713	.005	.03	.04	.01	45	12	70	5.30	12.4	2.3
N9802	<.001	<.01	.07	<.01	85	32	127	5.80	12.7	4.1
N4756	<.001	<.01	<.01	<.01	16	3	29	6.40	12.9	3.8
N9947	<.001	<.01	.08	<.01	185	103	283	5.90	14.5	2.8
N7219	<.001	.05	.01	<.01	77	27	123	4.80	14.3	0
N8311	.003	.07	.07	<.01	112	25	192	5.40	--	--
N4206	.001	<.01	.05	<.01	101	40	157	5.70	12.0	7.3
RECENTLY SEWERED SUBURBAN AREA										
N8493	0.001	0.02	0.05	<0.01	29	7	42	6.10	8.8	8.0
N8364	<.001	<.01	.07	<.01	156	71	246	5.30	13.7	7.2
N9168	.003	<.01	.02	<.01	67	28	86	7.10	11.4	8.4
N7531	<.001	<.01	.02	<.01	158	57	254	5.80	14.5	5.2
N5007	<.001	<.01	.07	<.01	42	11	55	5.70	11.3	9.6
N9341	.038	2.51	.04	<.01	283	72	479	5.80	13.8	2.2
N6655	.010	<.01	.05	.03	190	81	316	6.10	13.2	6.0
N8472	<.001	<.01	.01	<.01	155	62	278	5.80	13.4	8.4
N9449	.005	<.01	.07	<.01	30	3	55	4.80	12.4	.1
N9239	<.001	<.01	.05	<.01	53	16	84	7.00	12.6	3.7
N3243	<.001	<.01	<.01	<.01	77	33	139	6.20	11.5	5.8
N9252	.005	<.01	.04	<.01	105	39	177	5.00	12.6	.2
N9018	<.001	<.01	.04	<.01	23	6	34	5.30	12.0	7.8
N7353	<.001	<.01	.03	<.01	62	25	95	5.80	11.5	8.9
N7536	.004	<.01	.05	<.01	109	25	147	5.00	13.3	6.8
N3618	<.001	<.01	<.01	<.01	26	5	45	5.20	11.8	4.2
N7248	<.001	<.01	.05	<.01	91	35	172	4.80	13.1	2.2
UNSEWERED SUBURBAN AREA										
S28055	<0.001	<0.01	0.05	0.04	57	18	90	6.80	10.8	10.2
S11803	<.001	<.01	.06	<.01	172	53	256	5.60	12.4	7.4
S14579	<.001	<.01	.05	.04	24	4	29	5.60	10.9	10.8
S76675	<.001	<.01	<.01	<.01	72	18	124	5.10	10.9	8.8
S36976	<.001	<.01	.04	<.01	39	11	57	5.60	11.2	8.3

Appendix 1B. Major inorganic constituents in, and selected physical properties of, water samples from network wells screened in the intermediate zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	Silica, total (mg/L as SiO_2)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity, lab (mg/L as $CaCO_3$)	Sulfate (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Nitrogen, nitrate, total (mg/L as N)
UNSEWERED SUBURBAN AREA (continued)										
S44774	14.3	5.3	2.1	7.0	0.4	19	<5.0	4.7	<.2	0.74
S75455	7.3	1.5	<.1	<3.0	.4	5	<5.0	2.4	<.2	.28
S24770	7.2	1.5	.4	<3.0	.5	9	<5.0	2.9	<.2	<.01
S23522	9.4	3.5	2.0	9.0	.8	16	<5.0	15.8	<.2	1.17
S15810	8.4	15.8	3.8	21	2.4	20	39	13.6	<.2	3.86
S29777	6.8	1.0	<.1	<3.0	.4	10	<5.0	2.1	<.2	.99
S34022	9.8	.9	.4	7.0	.8	7	<5.0	4.0	<.2	.79
S63426	8.4	4.8	2.3	35	1.5	4	<5.0	52.9	<.2	1.50
S13876	13.6	4.0	2.0	10	.8	13	<5.0	10.0	<.2	3.16
S76674	7.7	1.7	1.5	14	2.0	6	<5.0	19.8	<.2	.50
S20601	12.4	3.0	1.4	<3.0	.5	14	<5.0	5.3	<.2	2.57
S46283	8.1	1.0	.5	3.0	.5	7	<5.0	6.3	<.2	.29
AGRICULTURAL AREA										
S15015	8.3	22.0	4.6	33	3.1	9	46	59.9	<0.2	3.41
S8025	14.3	30.5	9.2	4.0	2.5	15	<5.0	21.5	<.2	7.16
S89545	8.3	4.6	1.1	5.0	3.6	34	11	5.0	--	<.01
S3570	11.8	51.3	13.8	8.0	2.5	24	920	20.7	<.2	7.81
S89544	15.8	12.7	2.9	7.0	1.0	42	7.0	4.7	--	<.01
S40407	15.8	2.6	1.4	9.0	.9	22	14	11.9	<.2	1.81
S8077	12.6	8.2	3.9	<3.0	1.0	13	16	8.8	<.2	1.47
S89543	9.8	69.0	9.8	7.0	7.0	6	145	26.7	--	10.00
S51571	9.7	25.3	7.9	11	4.3	9	6.3	28.4	<.2	11.00
S51578	9.3	11.5	4.7	<3.0	1.8	6	37	10.0	<.2	2.76
UNDEVELOPED AREA										
S89459	13.7	4.6	1.2	5.0	0.3	15	<5.0	5.6	--	<0.01
S89457	11.1	4.8	1.7	18	6.0	8	14	22.4	--	1.54
S89539	14.2	2.8	1.1	7.0	.6	35	6.0	7.0	--	<.01
S89456	11.2	48.5	6.9	8.0	4.2	9	40	24.2	--	21.40
S89455	10.3	1.1	1.0	10	.4	5	8.0	9.3	<0.2	.07
S89540	10.1	1.7	.9	5.0	.4	11	5.0	4.3	--	<.01
S89538	11.0	1.9	1.1	7.0	.4	9	<5.0	5.6	--	<.01
S89458	10.4	10.7	9.5	5.0	.7	6	32	12.8	--	6.18
S89541	11.6	1.5	.9	4.0	.3	10	<5.0	5.3	--	<.01
S46544	9.7	13.2	5.7	<3.0	.7	4	31	7.4	<.2	4.31
S34742	7.4	6.0	2.8	3.0	1.8	9	9.0	7.4	<.2	1.08
S73811	8.9	1.7	.9	<3.0	.6	8	7.0	4.2	<.2	.02
S86584	10.8	14.0	4.9	<3.0	1.3	4	18	8.1	<.2	7.70

Appendix 1B. Major inorganic constituents in, and selected physical properties of, water samples from network wells screened in the intermediate zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	Nitrogen, nitrite, total (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Phos-phorus, total (mg/L as P)	Phos-phorus, ortho, total (mg/L as P)	Solids, sum of constituents, dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)	Specific conduct-ance, field (µS/cm)	pH, lab (standard units)	Temper-ature, water (deg. C)	Oxygen, dissolved (mg/L)
UNSEWERED SUBURBAN AREA (continued)										
S44774	0.003	<0.01	0.04	<0.01	49	21	75	5.80	11.2	4.2
S75455	<.001	<.01	<.01	<.01	16	4	26	5.40	10.5	5.7
S24770	<.001	<.01	<.01	<.01	19	5	31	6.00	--	--
S23522	<.010	<.01	.13	<.01	55	16	89	7.40	11.5	9.0
S15810	.011	<.01	.08	.02	134	55	177	5.60	14.4	3.8
S29777	.005	<.01	.02	<.01	21	2	41	5.60	10.6	5.0
S34022	<.001	<.01	.03	<.01	31	3	38	5.30	10.3	11.6
S63426	<.001	<.01	<.01	<.01	114	21	181	5.20	14.2	9.4
S13876	.002	<.01	.01	<.01	62	18	85	5.80	11.4	11.0
S76674	.001	<.01	.06	.03	53	10	80	5.50	10.7	10.8
S20601	.001	<.01	.04	<.01	43	13	65	7.30	10.5	10.0
S46283	<.001	.01	.07	<.01	26	4	40	5.50	13.9	8.8
AGRICULTURAL AREA										
S15015	0.003	<0.01	0.13	0.02	198	73	328	5.60	--	--
S8025	.003	<.01	.05	<.01	123	114	299	5.70	11.2	9.2
S89545	.010	.29	.04	<.01	74	16	120	6.20	10.6	0
S3570	.004	<.01	.08	.01	167	184	386	6.30	--	--
S89544	<.001	.02	.15	.06	77	43	117	8.10	11.2	.3
S40407	.008	<.01	.01	<.01	77	12	137	6.00	13.8	5.7
S8077	<.001	<.01	.02	<.01	65	36	105	7.50	12.5	9.9
S89543	<.001	.01	.14	<.01	323	212	512	5.60	10.9	9.8
S51571	<.001	.03	<.01	<.01	205	95	370	5.70	12.2	10.2
S51578	.004	<.01	.07	<.01	91	48	156	5.40	11.4	10.4
UNDEVELOPED AREA										
S89459	0.008	<0.01	0.11	0.09	40	16	61	6.40	10.5	10.6
S89457	<.001	<.01	.04	<.01	90	18	148	5.60	12.0	7.4
S89539	.008	.08	.11	.04	75	11	98	6.90	11.7	0
S89456	.001	.03	.15	.04	244	149	394	6.50	11.5	7.8
S89455	.003	<.01	<.01	<.01	43	6	67	5.50	10.6	7.6
S89540	<.001	<.01	.02	<.01	34	7	44	7.20	10.8	10.6
S89538	<.001	<.01	.01	<.01	32	9	50	6.50	10.6	11.4
S89458	<.001	<.01	.03	<.01	112	65	179	5.90	10.6	10.0
S89541	.002	<.01	.03	<.01	30	7	43	6.90	10.3	10.0
S46544	<.001	<.01	<.01	<.01	89	56	153	5.30	11.8	10.8
S34742	<.001	<.01	.01	<.01	48	26	80	5.50	10.8	10.1
S73811	<.001	<.01	.07	<.01	28	7	45	7.00	10.4	11.4
S86584	<.001	<.01	.03	<.01	94	55	159	5.30	11.0	11.4

Appendix 1C. Major inorganic constituents in, and selected physical properties of, water samples from network wells screened in the deep zone, Nassau and Suffolk Counties, Long Island, N.Y.

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg. C, degrees Celsius; <, less than; --, no data]

Well number	Silica, total (mg/L as SiO_2)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity, lab (mg/L as $CaCO_3$)	Sulfate (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Nitrogen, nitrate, total (mg/L as N)
LONG-TERM-SEWERED SUBURBAN AREA										
N103	13.1	6.8	3.6	7.0	0.9	18	9.0	9.1	<0.2	4.60
N9768	15.3	9.8	5.8	8.0	1.1	30	12	13.0	<.2	4.60
N7512	19.3	12.8	8.3	10	1.5	38	19	14.3	<.2	3.82
N650	14.0	13.5	6.8	16	1.3	32	13	13.7	<.2	11.00
N4082	9.6	2.4	1.1	5.0	.6	8	<5.0	3.7	<.2	1.72
N3672	18.5	12.6	8.1	24	1.4	69	22	14.7	<.2	3.58
N8576	9.7	5.6	2.6	7.0	1.1	9	<5.0	5.9	<.2	4.46
N2748	10.1	4.7	2.4	5.0	.9	8	<5.0	5.9	<.2	3.53
N2565	15.0	14.7	8.9	15	1.5	22	18	17.0	<.2	13.00
N1697	7.9	3.1	1.8	8.0	.9	7	5.0	12.3	<.2	1.58
N8474	7.8	3.3	1.2	14	.6	21	<5.0	7.9	--	2.69
N7058	13.2	6.8	3.8	8.0	1.0	10	9.0	8.9	<.2	5.09
N10033	7.9	2.5	1.2	5.0	.9	4	8.0	7.9	<.2	.03
N3603	10.7	2.9	1.8	3.0	.8	8	<5.0	4.8	<.2	2.39
N6745	14.3	10.8	4.8	12	.9	13	24	21.2	<.2	2.28
N7117	10.3	3.1	1.6	4.0	.7	7	10	3.9	<.2	.61
N6865	13.1	18.3	8.7	28	1.8	16	30	61.7	<.2	5.25
N4390	21.0	33.5	13.2	27	2.5	57	21	51.3	<.2	3.07
RECENTLY SEWERED SUBURBAN AREA										
N4245	14.8	9.4	3.4	7.0	1.2	17	6.0	17.8	<0.2	3.94
N6190	7.8	8.2	3.0	9.0	.8	8	<5.0	15.0	<.2	9.60
N7562	6.9	1.3	.5	4.0	.4	8	<5.0	3.1	<.2	1.38
N7030	11.3	12.0	3.7	7.0	.9	9	17	7.2	<.2	4.32
N8007	9.2	2.3	1.2	5.0	.5	13	<5.0	4.0	<.2	.99
N7785	12.0	10.6	3.3	9.0	1.1	9	<5.0	13.7	<.2	4.54
N8497	8.9	3.8	1.1	5.0	.3	6	<5.0	4.7	<.2	2.36
N8957	9.4	2.0	.7	5.0	.4	7	<5.0	4.2	--	1.23
N8526	7.3	3.1	1.1	5.0	.6	8	<5.0	4.9	<.2	3.00
N7561	8.8	5.2	1.5	9.0	.6	7	<5.0	11.5	<.2	4.09
N8525	7.5	8.7	2.9	13	1.0	4	<5.0	20.5	<.2	11.20
N7500	9.0	2.4	.8	4.0	.2	6	<5.0	4.0	<.2	1.68
N8321	7.0	1.1	.7	5.0	.5	7	<5.0	3.7	<.2	1.15
N4450	7.3	5.2	1.5	8.0	.7	3	<5.0	13.4	<.2	4.25
N4448	7.2	.2	.3	<3.0	.2	9	<5.0	1.4	<.2	.24
N5322	7.7	1.6	.6	4.0	.5	2	9.0	9.3	<.2	.07
N3465	7.5	3.4	1.1	5.0	.3	5	<5.0	5.1	<.2	2.28

Appendix 1C. Major inorganic constituents in, and selected physical properties of, water samples from network wells screened in the deep zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	Nitrogen, nitrite, total (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Phos-phorus, total (mg/L as P)	Phos-phorus, ortho, total (mg/L as P)	Solids, sum of constituents, dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)	Specific conduct-ance, field (µS/cm)	pH, lab (standard units)	Temper-ature, water (deg. C)	Oxygen, dissolved (mg/L)
LONG-TERM-SEWERED SUBURBAN AREA										
N103	<0.001	<0.01	0.04	<0.01	81	31	109	6.70	13.3	7.6
N9768	<.001	<.01	<.01	<.01	103	48	158	6.00	12.3	6.6
N7512	<.001	<.01	<.01	<.01	125	66	198	6.00	12.8	6.2
N650	<.001	<.01	.06	<.01	146	61	230	7.30	12.1	5.4
N4082	.002	<.01	.06	<.01	35	10	50	5.90	12.4	6.6
N3672	<.001	<.01	.06	<.01	159	64	250	6.00	11.8	6.0
N8576	.002	<.01	.01	<.01	57	24	100	5.60	13.0	6.4
N2748	.002	<.01	.07	<.01	50	21	86	5.60	12.8	7.4
N2565	<.001	<.01	.07	<.01	161	73	264	6.10	13.1	4.9
N1697	<.001	<.01	.02	<.01	50	15	83	5.90	13.3	3.6
N8474	.004	<.01	<.01	<.01	60	13	93	6.10	12.7	6.2
N7058	.003	<.01	.04	<.01	79	32	123	5.60	12.2	5.2
N10033	.002	<.01	.07	<.01	37	11	66	5.30	12.7	.4
N3603	.002	<.01	.06	<.01	40	14	66	5.70	13.0	4.5
N6745	<.001	<.01	<.01	<.01	106	46	162	5.50	13.3	3.6
N7117	.002	<.01	.12	<.01	41	14	67	5.60	13.4	2.2
N6865	.021	.08	.07	<.01	195	81	328	5.70	12.7	4.0
N4390	<.001	.36	.05	<.01	218	138	364	6.90	13.5	7.8
RECENTLY SEWERED SUBURBAN AREA										
N4245	<0.001	<0.01	<0.01	<0.01	87	37	113	6.10	11.9	9.0
N6190	<.001	<.01	.03	<.01	91	32	134	6.60	12.1	9.8
N7562	<.001	<.01	<.01	<.01	27	5	33	6.60	11.4	9.8
N7030	.003	<.01	.04	<.01	84	45	136	6.00	11.9	9.4
N8007	<.001	<.01	.02	<.01	34	10	49	6.60	12.4	8.4
N7785	<.001	<.01	.05	.01	75	40	118	5.70	12.4	7.4
N8497	<.001	<.01	.03	<.01	38	14	54	5.70	12.0	9.2
N8957	.003	<.01	<.01	<.01	32	7	38	6.10	12.2	9.4
N8526	<.001	<.01	.03	<.01	40	12	57	5.50	12.3	7.8
N7561	<.001	<.01	.13	<.01	59	19	93	5.30	11.8	5.3
N8525	<.001	<.01	<.01	<.01	106	33	158	5.00	11.9	6.8
N7500	<.001	<.01	.05	<.01	32	9	46	5.80	12.1	9.2
N8321	<.001	<.01	.02	<.01	27	5	45	5.50	12.4	7.2
N4450	<.001	<.01	<.01	<.01	57	19	98	5.00	11.9	5.2
N4448	<.001	<.01	<.01	<.01	16	1	23	5.50	12.2	8.4
N5322	<.001	<.01	<.01	<.01	35	6	60	4.80	12.2	1.4
N3465	<.001	<.01	.05	<.01	36	13	61	5.30	12.4	6.4

Appendix 1C. Major inorganic constituents in, and selected physical properties of, water samples from network wells screened in the deep zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	Silica, total (mg/L as SiO_2)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity, lab (mg/L as $CaCO_3$)	Sulfate (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Nitrogen, nitrate, total (mg/L as N)
				UNSEWERED SUBURBAN AREA						
S37351	7.7	9.5	3.4	9.0	1.1	6	5.0	88	<0.2	7.53
S36791	11.1	4.3	1.7	5.0	.5	17	<5.0	2.5	<.2	.90
S42225	12.7	6.9	3.3	14	.7	16	<5.0	14.0	<.2	6.24
S18058	--	--	--	--	--	--	--	--	--	--
S75454	6.3	1.0	.5	3.0	.7	7	<5.0	3.4	<.2	.74
S24769	7.2	1.0	.5	3.0	.5	12	<5.0	4.4	<.2	<.01
S45638	7.3	1.1	.5	3.0	.4	24	<5.0	4.2	<.2	.05
S74284	7.4	.9	.3	<3.0	.2	9	<5.0	2.2	<.2	.19
S22015	6.8	<.1	<.1	5.0	.5	3	<5.0	2.0	<.2	.07
S29776	6.4	.6	.2	<3.0	.3	10	<5.0	1.2	<.2	<.01
S34021	7.2	.4	.2	<3.0	.2	5	<5.0	1.6	<.2	<.01
S33006	8.3	2.1	.7	5.0	.4	8	<5.0	2.6	<.2	.93
S21134	15.8	6.9	2.8	6.0	.8	22	6.0	7.1	<.2	1.94
S19057	13.2	22.1	6.6	11	1.2	14	35	18.4	<.2	7.85
S35007	6.6	.8	.2	3.0	.4	4	<5.0	3.7	<.2	.46
S29962	8.8	13.2	7.0	9.0	1.0	11	25	16.2	<.2	6.01
S74285	1.2	.5	<.1	<3.0	.1	8	<5.0	6.9	<.2	<.01
S22548	6.2	.6	.3	3.0	.4	4	<5.0	4.7	<.2	.88
S26248	6.4	.3	.1	3.0	.3	3	<5.0	3.6	<.2	.21

Appendix 1C. Major inorganic constituents in, and selected physical properties of, water samples from network wells screened in the deep zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	Nitrogen, nitrite, total (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, total (mg/L as P)	Solids, sum of constituents, dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)	Specific conductance, field (µS/cm)	pH, lab (standard units)	Temperature, water (deg. C)	Oxygen, dissolved (mg/L)
UNSEWERED SUBURBAN AREA										
S37351	<0.001	<0.01	0.09	<0.01	82	37	133	5.40	11.4	10.2
S36791	<.001	<.01	.02	<.01	39	17	57	5.70	11.5	7.0
S42225	.001	<.01	.03	<.01	89	30	119	6.10	10.7	7.8
S18058	--	--	--	--	--	--	--	--	10.7	8.4
S75454	.004	<.01	<.01	<.01	23	4	32	5.60	10.9	6.4
S24769	<.001	<.01	<.01	<.01	24	4	42	5.80	--	--
S45638	<.001	<.01	.09	<.01	30	4	37	5.40	11.7	3.0
S74284	.002	<.01	1.21	<.01	21	3	26	5.80	11.6	9.6
S22015	<.001	<.01	.04	<.01	17	1	23	5.30	11.6	8.4
S29776	<.001	<.01	.10	<.01	15	2	30	5.50	11.7	2.3
S34021	<.001	<.01	.03	.02	13	1	19	5.50	10.6	10.6
S33006	<.001	<.01	.06	<.01	28	8	40	5.60	11.7	8.2
S21134	.003	<.01	.05	<.01	67	28	94	5.90	10.9	6.8
S19057	.002	<.01	.09	<.01	151	82	231	5.80	10.9	8.8
S35007	.002	<.01	.08	<.01	19	2	29	5.20	10.9	9.4
S29962	<.001	<.01	.06	<.01	113	61	187	5.60	11.0	11.2
S74285	<.001	<.01	.04	<.01	14	1	17	6.70	10.6	8.0
S22548	<.001	<.01	.02	<.01	22	2	32	5.20	10.6	5.8
S26248	<.001	<.01	.07	<.01	17	1	24	5.20	11.6	7.4

APPENDIX 2

Concentrations of inorganic trace-elements in ground water in Nassau and Suffolk Counties, Long Island, N.Y.

Appendix 2A. Inorganic trace-element concentrations in water samples from network wells screened in the shallow aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.[1]

[mg/L, milligrams per liter, µg/L, micrograms per liter; <, less than; --, no data]

Well number	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Barium, dissolved (µg/L as Ba)	Boron, dissolved (µg/L as B)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Copper, dissolved (µg/L as Cu)	Lead, dissolved (µg/L as Pb)	Methylene blue active substances (mg/L)
LONG-TERM-SEWERED SUBURBAN AREA									
N9946	<50	<50	<200	20	<1	<10	<50	<10	<0.02
N9940	<50	<50	<200	20	<1	<10	<50	<10	<.02
N9948	14,800	2,750	<200	340	<1	<10	<50	<10	<.02
N9942	<50	<50	<200	60	<1	<10	<50	<10	<.02
N9962	530	<50	<200	50	<1	<10	<50	<10	<.02
N9941	<50	190	<200	130	<1	<10	<50	<10	<.02
N9982	50	<50	400	70	<1	<10	<50	<10	<.02
N9949	<50	<50	<200	150	<1	<10	<50	<10	<.02
N9959	1,580	70	<200	40	<1	<10	<50	<10	<.02
N9914	<50	<50	<200	40	<1	<10	<50	<10	<.02
N9944	<50	<50	<200	60	<1	<10	<50	<10	<.02
N9983	<50	<50	<200	80	<1	<10	<50	<10	<.02
N9943	<50	<50	<200	60	<1	<10	<50	<10	<.02
N10035	<50	<50	<200	50	<1	<10	<50	<10	<.02
N9803	<50	<50	<200	50	<1	<10	<50	<10	<.02
N9945	<50	<50	<200	50	<1	<10	<50	<10	<.02
N9984	<50	<50	<200	60	<1	<10	<50	<10	<.02
N9057	<50	180	<200	110	<1	<10	<50	<10	<.02
N9712	460	<50	<200	30	<1	<10	<50	<10	<.02
N7649	<50	<50	<200	<10	<1	<10	<50	<10	<.02
RECENTLY SEWERED SUBURBAN AREA									
N9933	<50	<50	<200	70	<1	<10	60	<10	<0.02
N9926	60	<50	<200	20	<1	<10	<50	<10	<.02
N8888	230	120	<200	130	<1	<10	60	<10	<.02
N9927	<50	660	<200	80	<1	<10	<50	<10	<.02
N9928	<50	1,250	<200	--	<1	<10	<50	<10	<.02
N9920	850	200	<200	60	<1	<10	<50	<10	<.02
N9354	910	900	<200	230	<1	<10	<50	<10	<.02
N9919	190	240	<200	110	<1	<10	<50	<10	<.02
N9938	<50	110	<200	360	<1	<10	<50	<10	<.02
N9917	7,400	3,500	<200	110	<1	<10	<50	<10	<.02
N9079	5,550	19,000	<200	90	<1	<10	<50	<10	<.02
N1197	150	160	<200	170	<1	<10	<50	<10	<.02
N8984	120	<50	<200	60	<1	<10	<50	<10	.13
N9918	<50	<50	<200	20	<1	<10	<50	<10	<.02
N9939	<50	950	<200	<10	<1	<10	<50	<10	<.02
N9451	<50	300	<200	80	<1	<10	<50	<10	<.02
N9222	<50	180	<200	70	<1	<10	<50	<10	<.02
N9925	<50	480	<200	100	<1	<10	<50	<10	<.02
N9078	150	<50	<200	30	<1	40	<50	60	<.02
N9924	<50	810	<200	80	<1	<10	<50	<10	<.02

[1] The following constituents were not detected above detection limit in network wells from the shallow zone (detection limit in parentheses): arsenic (5 µg/L), selenium (5 µg/L), and silver (50 µg/L).

Appendix 2A. Inorganic trace-element concentrations in water samples from network wells screened in the shallow aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	Iron, dissolved (μg/L as Fe)	Manganese, dissolved (μg/L as Mn)	Barium, dissolved (μg/L as Ba)	Boron, dissolved (μg/L as B)	Cadmium, dissolved (μg/L as Cd)	Chromium, dissolved (μg/L as Cr)	Copper, dissolved (μg/L as Cu)	Lead, dissolved (μg/L as Pb)	Methylene blue active substances (mg/L)
UNSEWERED SUBURBAN AREA									
S45207	110	<50	<200	40	<1	<10	<50	<10	<0.02
S65602	<50	900	<200	80	3	<10	<50	<10	<.02
S65607	<50	330	300	70	<1	<10	<50	<10	<.02
S45208	2,000	210	<200	150	<1	<10	<50	<10	<.02
S45210	<50	<50	<200	20	<1	<10	<50	<10	<.02
S68762	<50	<50	<200	60	<1	<10	<50	<10	<.02
S45594	110	<50	<200	20	<1	<10	<50	<10	<.02
S75456	<50	<50	<200	<10	<1	<10	<50	10	<.02
S24771	<50	<50	<200	40	<1	<10	<50	<10	<.02
S64314	<50	<50	<200	30	<1	<10	<50	<10	<.02
S47220	110	90	<200	<10	<1	<10	<50	<10	<.02
S48375	150	700	<200	350	<1	<10	<50	<10	.02
S74286	<50	<50	<200	10	<1	<10	<50	<10	<.02
S64316	<50	60	<200	20	<1	<10	<50	<10	<.02
S64318	<50	<50	<200	<10	<1	<10	<50	<10	<.02
S64313	<50	1,090	<200	<10	<1	<10	<50	<10	<.02
S29778	60	<50	<200	20	1	<10	<50	<10	<.02
S64319	<50	<50	<200	20	<1	<10	<50	<10	<.02
S13175	<50	<50	<200	60	<1	<10	80	<10	<.02
S16605	<50	90	<200	<10	<1	<10	<50	<10	<.02
AGRICULTURAL AREA									
S51582	<50	<50	<200	80	<1	<10	<50	<10	<0.02
S51587	200	310	<200	60	2	<10	<50	<10	<.02
S51568	380	90	<200	100	<1	<10	<50	<10	<.02
S51581	1,120	60	<200	80	<1	<10	<50	<10	<.02
S51566	70	<50	<200	90	2	<10	<50	<10	<.02
S51589	1,990	130	<200	60	2	<10	<50	<10	<.02
S51567	90	<50	<200	140	<1	<10	<50	<10	<.02
S51572	4,300	1,500	<200	50	<1	<10	<50	<10	<.02
S51588	2,750	170	<200	260	<1	<10	<50	10	<.02
S51577	<50	270	<200	90	<1	<10	<50	<10	<.02
S51576	90	90	<200	320	<1	<10	<50	20	<.02
S52383	200	120	<200	50	<1	<10	<50	<10	<.02
UNDEVELOPED AREA									
S74301	<50	<50	<200	10	<1	<10	<50	<10	<0.02
S54886	<50	<50	<200	10	<1	<10	<50	<10	<.02
S74294	<50	<50	<200	<10	<1	<10	<50	<10	<.02
S48584	<50	<50	<200	10	<1	<10	<50	<10	<.02
S74307	<50	<50	<200	10	<1	<10	<50	<10	<.02
S47755	70	<50	<200	10	<1	<10	<50	<10	<.02
S48946	4,800	<50	<200	30	<1	<10	<50	<10	<.02
S73807	<50	<50	<200	10	<1	<10	<50	<10	<.02
S86583	<50	<50	<200	10	<1	<10	<50	<10	<.02
S74295	<50	<50	<200	10	<1	<10	<50	<10	<.02
S74293	<50	<50	<200	40	<1	<10	<50	<10	<.02

Appendix 2B. Inorganic trace-element concentrations in water samples from network wells screened in the intermediate aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.[1]

[mg/L, milligrams per liter, µg/L, micrograms per liter; <, less than; --, no data]

Well number	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Barium, dissolved (µg/L as Ba)	Boron, dissolved (µg/L as B)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Copper, dissolved (µg/L as Cu)	Lead, dissolved (µg/L as Pb)	Methylene blue active substances (mg/L)
LONG-TERM-SEWERED SUBURBAN AREA									
N1818	<50	<50	<200	30	<1	<10	<50	<10	<0.02
N7560	<50	<50	<200	30	<1	<10	<50	<10	<.02
N3699	<50	<50	<200	80	<1	<10	120	<10	<.02
N7524	2,770	<50	<200	40	<1	<10	<10	<10	<.02
N10043	<50	<50	<200	30	<1	<10	<50	<10	<.02
N8068	<50	<50	<200	20	<1	<10	100	<10	<.02
N9713	740	<50	<200	<10	<1	<10	<50	<10	<.02
N9802	50	<50	<200	<10	<1	<10	<50	<10	<.02
N4756	<50	<50	<200	<10	<1	<10	<50	<10	<.02
N9947	390	<50	<200	60	<1	<10	<50	<10	<.02
N7219	3,060	<50	<200	10	<1	<10	<50	<10	<.02
N8311	760	<50	<200	40	<1	<10	<50	<10	<.02
N4206	<50	<50	<200	10	<1	<10	<50	<10	<.02
RECENTLY SEWERED SUBURBAN AREA									
N8493	350	50	<200	<10	<1	<10	380	<10	<0.02
N8364	310	50	<200	190	<1	<10	<50	20	<.02
N9168	0.18	<50	<200	<10	<1	<10	<50	<10	<.02
N7531	<50	130	<200	90	<1	<10	<50	30	<.02
N5007	<50	<50	<200	<10	<1	<10	<50	<10	<.02
N9341	120	160	<200	180	<1	<10	<50	<10	.11
N6655	<50	<50	<200	100	<1	20	60	<10	<.02
N8472	60	<50	<200	40	<1	<10	<50	<10	<.02
N9449	240	<50	<200	<10	<1	<10	<50	<10	<.02
N9239	<50	<50	<200	<10	<1	<10	<50	<10	<.02
N3243	<50	<50	<200	<10	<1	<10	60	<10	<.02
N9252	550	70	<200	10	<1	<10	<50	<10	<.02
N9018	<50	<50	<200	<10	<1	<10	<50	<10	<.02
N7353	<50	<50	<200	<10	<1	<10	<50	<10	<.02
N7536	<50	<50	<200	20	<1	<10	<50	<10	<.02
N3618	<50	<50	<200	<10	<1	<10	<50	<10	<.02
N7248	<50	<50	<200	<10	<1	<10	<50	30	<.02
UNSEWERED SUBURBAN AREA									
S28055	<50	<50	<200	<10	<1	<10	<50	<10	<0.02
S11803	<50	80	<200	40	<1	<10	<50	<10	<.02
S14579	<50	<50	<200	<10	<1	<10	<50	<10	<.02
S76675	50	<50	<200	<10	<1	<10	<50	20	<.02
S36976	<50	<50	<200	<10	<1	<10	<50	<10	<.02
S44774	<50	<50	<200	20	<1	<10	<50	<10	<.02
S75455	<50	<50	<200	<10	<1	<10	<50	<10	<.02
S24770	570	60	<200	<10	<1	<10	<50	<10	<.02
S23522	<50	<50	<200	<10	<1	<10	<50	<10	<.02
S15810	140	230	<200	60	<1	<10	1,150	<10	<.02

[1] The following constituents were not detected above detection limit in network wells from the intermediate zone (detection limit in parentheses): arsenic (5 µg/L), selenium (5 µg/L), and silver (50 µg/L).

Appendix 2B. Inorganic trace-element concentrations in water samples from network wells screened in the intermediate aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	Iron, dissolved (μg/L as Fe)	Manganese, dissolved (μg/L as Mn)	Barium, dissolved (μg/L as Ba)	Boron, dissolved (μg/L as B)	Cadmium, dissolved (μg/L as Cd)	Chromium, dissolved (μg/L as Cr)	Copper, dissolved (μg/L as Cu)	Lead, dissolved (μg/L as Pb)	Methylene blue active substances (mg/L)
UNSEWERED SUBURBAN AREA (continued)									
S29777	<50	<50	<200	<10	3	<10	<50	<10	<0.02
S34022	<50	<50	<200	10	<1	<10	<50	<10	<.02
S63426	<50	<50	<200	20	<1	<10	260	30	<.02
S13876	<50	<50	<200	10	<1	<10	<50	<10	<.02
S76674	<50	<50	<200	<10	<1	<10	<50	<10	<.02
S20601	<50	<50	<200	<10	<1	<10	<50	<10	<.02
S46283	370	70	<200	10	<1	<10	<50	<10	<.02
AGRICULTURAL AREA									
S15015	<50	<50	<200	20	<1	<10	<50	<10	<0.02
S8025	<50	<50	<200	30	<1	<10	<50	<10	<.02
S89545	3.8	1,010	<200	40	<1	<10	<50	<10	<.02
S3570	<50	<50	<200	40	<1	<10	<50	<10	<.02
S89544	<50	<50	<200	10	<1	<10	<50	<10	<.02
S40407	<50	<50	<200	20	<1	<10	<50	<10	<.02
S8077	<50	<50	<200	10	<1	<10	<50	<10	<.02
S89543	<50	100	<200	110	<1	<10	<50	<10	<.02
S51571	1,850	70	<200	20	<1	<10	<50	<10	<.02
S51578	820	50	<200	30	<1	<10	<50	<10	<.02
UNDEVELOPED AREA									
S89459	<50	<50	<200	10	<1	<10	<50	<10	<0.02
S89457	<50	<50	<200	20	<1	<10	<50	<10	<.02
S89539	14,200	720	<200	70	<1	<10	<50	<10	<.02
S89456	<50	<50	200	--	<1	<10	<50	<10	<.02
S89455	<50	<50	<200	20	<1	<10	<50	<10	<.02
S89540	<50	<50	<200	10	<1	<10	<50	<10	<.02
S89538	310	130	<200	<10	<1	<10	<50	<10	<.02
S89458	<50	<50	<200	30	<1	<10	<50	<10	<.02
S89541	<50	<50	<200	<10	<1	<10	<50	<10	<.02
S46544	<50	<50	<200	20	<1	<10	<50	<10	<.02
S34742	<50	<50	<200	10	<1	<10	<50	<10	<.02
S73811	<50	<50	<200	<10	<1	<10	<50	<10	<.02
S86584	<50	<50	<200	30	<1	<10	<50	<10	<.02

Appendix 2C. Inorganic trace-element concentrations in water samples from network wells screened in the deep aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.[1]

[mg/L, milligrams per liter, µg/L, micrograms per liter; <, less than; --, no data]

Well number	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Boron, dissolved (µg/L as B)	Cadmium, dissolved (µg/L as Cd)	Copper, dissolved (µg/L as Cu)	Lead, dissolved (µg/L as Pb)
LONG-TERM-SEWERED SUBURBAN AREA						
N103	<50	<50	<10	<1	<50	<10
N9768	<50	<50	170	<1	<50	<10
N7512	<50	<50	<10	<1	<50	<10
N650	<50	<50	10	<1	<50	<10
N4082	<50	<50	<10	<1	<50	<10
N3672	<50	<50	<10	<1	<50	<10
N8576	<50	<50	<10	<1	<50	<10
N2748	<50	<50	<10	<1	<50	<10
N2565	<50	<50	20	<1	170	<10
N1697	<50	<50	<10	<1	<50	<10
N8474	150	60	<10	7	<50	50
N7058	<50	<50	<10	<1	<50	<10
N10033	480	<50	<10	<1	<50	<10
N3603	<50	<50	<10	<1	<50	<10
N6745	<50	<50	10	<1	<50	<10
N7117	<50	<50	<10	<1	<50	<10
N6865	<50	<50	30	<1	<50	<10
N4390	<50	<50	40	<1	<50	<10
RECENTLY SEWERED SUBURBAN AREA						
N4245	<50	<50	<10	<1	<50	<10
N6190	<50	<50	<10	<1	220	<10
N7562	<50	<50	20	<1	80	<10
N7030	70	<50	10	<1	<50	<10
N8007	<50	<50	<10	<1	<50	<10
N7785	<50	<50	10	<1	<50	<10
N8497	<50	<50	10	<1	<50	<10
N8957	100	60	10	3	<50	10
N8526	<50	<50	20	<1	<50	<10
N7561	<50	<50	<10	<1	<50	<10
N8525	<50	<50	20	<1	<50	<10
N7500	<50	<50	<10	<1	<50	40
N8321	<50	<50	<10	<1	<50	<10
N4450	<50	<50	<10	<1	<50	<10
N4448	<50	<50	<10	<1	60	<10
N5322	340	<50	<10	<1	<50	<10
N3465	<50	<50	<10	<1	<50	<10

[1] The following constituents were not detected above detection limit in network wells from the deep zone (detection limit in parentheses): arsenic (5 µg/L), barium (200 µg/L), chromium (10 µg/L), methylene blue active substances (0.02 mg/L), mercury (0.5 µg/L), selenium (5 µg/L), and silver (50 µg/L).

Appendix 2C. Inorganic trace-element concentrations in water samples from network wells screened in the deep aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Boron, dissolved (µg/L as B)	Cadmium, dissolved (µg/L as Cd)	Copper, dissolved (µg/L as Cu)	Lead, dissolved (µg/L as Pb)
			UNSEWERED SUBURBAN AREA (continued)			
S37351	<50	<50	<10	<1	<50	<10
S36791	<50	<50	<10	<1	<50	<10
S42225	<50	<50	--	<1	<50	<10
S18058	--	--	20	--	--	--
S75454	1,020	<50	<10	<1	<50	<10
S24769	50	<50	10	<1	<50	<10
S45638	<50	<50	<10	<1	<50	<10
S74284	<50	<50	<10	<1	<50	<10
S22015	<50	<50	<10	<1	70	<10
S29776	180	<50	<10	<1	<50	<10
S34021	<50	<50	<10	<1	<50	<10
S33006	<50	<50	<10	<1	<50	<10
S21134	110	<50	<10	<1	<50	<10
S19057	<50	<50	<10	<1	<50	<10
S35007	<50	<50	<10	<1	<50	<10
S29962	<50	<50	20	<1	<50	<10
S74285	<50	<50	<10	<1	<50	<10
S22548	60	<50	<10	<1	<50	50
S26248	<50	<50	<10	<1	<50	<10

APPENDIX 3

Concentrations of volatile organic compounds in ground water in Nassau and Suffolk Counties, Long Island, N.Y.

Appendix 3A. Concentrations of volatile organic compounds in water samples from network wells screened in the shallow aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.

[µg/L, micrograms per liter; <, less than; --, no data]

Well number	Trichloro-fluoro-methane, total (µg/L)	1,2-Trans-dichloro-ethene, total (µg/L)	1,1-Dichloro-ethane, total (µg/L)	Chloroform, total (µg/L)	1,1,1-Trichloro-ethane, total (µg/L)	Carbon tetra-chloride, total (µg/L)	Trichloro-ethylene, total (µg/L)	Dichloro-bromo-methane, total (µg/L)
LONG-TERM-SEWERED SUBURBAN AREA								
N9946	<1	<7	<5	<1	<1	<1	<1	<2
N9940	<1	<7	<5	<1	<1	<1	<1	<2
N9948	<1	<7	<5	<1	<1	<1	<1	<2
N9942	<1	<7	<5	<1	<1	<1	<1	<2
N9962	<1	<9	<5	<1	<1	<1	<1	<1
N9941	<1	<7	<5	<1	1	<1	<1	<2
N9982	<1	<7	<5	<1	<1	<1	<1	<2
N9949	<1	<7	<5	<1	5	<1	4	<2
N9959	<1	<9	<5	<1	<1	<1	<1	<1
N9914	<1	<7	<5	<1	<1	<1	<1	<2
N9944	<1	<7	<5	<1	<1	<1	2	<2
N9983	<1	<7	<5	<1	<1	<1	<1	<2
N9943	<1	<7	<5	<1	<1	1	4	<2
N10035	<1	<9	<5	<1	<1	<1	24	<1
N9803	<1	<9	<5	<1	<1	<1	<1	<1
N9945	<1	<7	<5	<1	<1	<1	<1	<2
N9984	<1	<7	<5	<1	2	<1	<1	<2
N9057	<1	<9	<5	<1	<1	<1	<1	<1
N9712	<1	<9	<5	<1	<1	<1	<1	<1
N7649	1	<11	<2	<1	3	<1	160	<2
RECENTLY SEWERED SUBURBAN AREA								
N9933	<1	<9	<5	<1	5	<1	<1	<1
N9926	<1	<7	<5	<1	<1	<1	<1	<2
N8888	<1	<9	<5	<1	5	<1	1	<1
N9927	<1	<7	<5	<1	2	<1	<1	<2
N9928	<1	<7	<5	<1	1	<1	<1	<2
N9920	<1	<7	<5	<1	2	<1	<1	<2
N9354	--	--	--	--	--	--	--	--
N9919	<1	<7	<5	<1	3	<1	<1	<2
N9938	<1	9	34	6	12,000	<10	390	<2
N9917	<1	<7	<5	<1	<1	<1	<1	<2
N9079	<1	45	<5	<1	<1	<1	12	<1
N1197	<1	<9	5	<1	19	<1	5	<1
N8984	<1	<9	<5	<1	<1	<1	<1	<1
N9918	<1	<7	<5	<1	2	<1	<1	<2
N9939	<1	12	<5	<1	3	<1	3	<2
N9451	<1	<9	<5	<1	<1	<1	<1	<1
N9222	<1	<9	<5	<1	3	<1	<1	<1
N9925	<1	<7	<5	<1	2	<1	<1	<2
N9078	<1	<9	<5	<1	<1	<1	<1	<1
N9924	<1	<9	<5	<1	1	<1	<1	<1

Appendix 3A. Concentrations of volatile organic compounds in water samples from network wells screened in the shallow aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	1,1,2-Trichloro-ethane, total (μg/L)	Tetrachloro-ethylene, total (μg/L)	Bromoform, total (μg/L)	Benzene, total (μg/L)	Toluene, total (μg/L)	Chloro-benzene, total (μg/L)	Ethyl-benzene, total (μg/L)	Xylene, total, water whole tot rec (μg/L)
				LONG-TERM-SEWERED SUBURBAN AREA				
N9946	<1	<1	<2	<3	<3	<4	<4	<6
N9940	<1	<1	<2	<3	<3	<4	<4	<6
N9948	<1	<1	<2	<3	<3	6	<4	<6
N9942	<1	<1	<2	<3	<3	<4	<4	<6
N9962	<2	<1	<2	<3	<3	<3	<4	<6
N9941	<1	<1	<2	<3	<3	<4	<4	<6
N9982	<1	<1	<2	<3	<3	<4	<4	<6
N9949	<1	25	<2	<3	<3	<4	<4	<6
N9959	<2	<1	<2	<3	<3	<3	<4	<6
N9914	<1	<1	<2	<3	<3	<4	<4	<6
N9944	<1	3	<2	<3	<3	<4	<4	<6
N9983	<1	2	<2	<3	<3	<4	<4	<6
N9943	<1	<1	<2	<3	<3	<4	<4	<6
N10035	<2	16	<2	<3	<3	<3	<4	<6
N9803	<2	<1	<2	<3	<3	<3	<4	<6
N9945	<1	<1	<2	<3	<3	<4	<4	<6
N9984	<1	<1	<2	<3	<3	<4	<4	<6
N9057	<2	<1	<2	<3	<3	<3	<4	<6
N9712	<2	10	<2	<3	<3	<3	<4	<4
N7649	<1	15	<2	<3	<5	<5	6	17
				RECENTLY SEWERED SUBURBAN AREA				
N9933	<2	<1	<2	<3	<3	<3	<4	<6
N9926	<1	<1	<2	<3	<3	<4	<4	<6
N8888	<2	1	<2	<3	<3	<3	<4	<6
N9927	<1	<1	<2	<3	<3	<4	<4	<6
N9928	<1	8	<2	<3	<3	<4	<4	<6
N9920	<1	<1	<2	<3	<3	<4	<4	<6
N9354	--	--	--	--	--	--	--	--
N9919	<1	89	<2	<3	<3	<4	<4	<6
N9938	3	83	<2	<3	<3	<4	<4	<6
N9917	<1	<1	<2	<3	<3	<4	<4	<6
N9079	<2	<1	<2	210	<3	<3	<4	12
N1197	<2	<1	<2	<3	<3	<3	<4	<6
N8984	<2	<1	<2	<3	<3	<3	<4	<6
N9918	<1	<1	<2	<3	<3	<4	<4	<6
N9939	<1	14	<2	<3	<3	<4	<4	<6
N9451	<2	<1	<2	<3	<3	<3	<4	<6
N9222	<2	<1	<2	<3	<3	<3	<4	<6
N9925	<1	<1	<2	<3	<3	<4	<4	<6
N9078	<2	<1	<2	<3	<3	<3	<4	<6
N9924	<2	<1	<2	<3	<3	<3	<4	<6

Appendix 3A. Concentrations of volatile organic compounds in water samples from network wells screened in the shallow aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	Trichloro-fluoro-methane, total (μg/L)	1,2-Trans-dichloro-ethene, total (μg/L)	1,1-Dichloro-ethane, total (μg/L)	Chloroform, total (μg/L)	1,1,1-Trichloro-ethane, total (μg/L)	Carbon tetra-chloride, total (μg/L)	Trichloro-ethylene, total (μg/L)	Dichloro-bromo-methane, total (μg/L)
UNSEWERED SUBURBAN AREA								
S45207	<1	<3	4	<1	12	<1	7	<1
S65602	<1	<4	<6	<1	4	<1	<1	<1
S65607	<1	<4	<6	<1	<1	<1	<1	<1
S45208	<1	<4	20	<1	28	<1	1	<1
S45210	<1	<4	<6	<1	<1	<1	<1	<1
S68762	<1	<3	<4	<1	4	<1	<1	<1
S45594	<1	<3	<4	<1	<1	<1	<1	<1
S75456	<1	<3	<4	<1	<1	<1	<1	<1
S24771	<1	<3	4	<1	66	<1	290	<1
S64314	<1	<3	<4	<1	<1	<1	<1	<1
S47220	<1	<4	<6	<1	3	<1	<1	<1
S48375	<1	<4	<6	<1	<1	<1	<1	<1
S74286	<1	<4	<6	<1	<1	<1	<1	<1
S64316	<1	<4	<6	<1	<1	<1	<1	<1
S64318	<1	<4	<6	<1	<1	<1	<1	<1
S64313	<1	<3	<4	<1	<1	<1	<1	<1
S29778	3	<3	<4	<1	32	<1	3	<1
S64319	<1	<3	<4	<1	<1	<1	<1	<1
S13175	<1	<7	10	<1	15	<1	6	<2
S16605	<1	<3	<4	<1	<1	<1	<1	<1
AGRICULTURAL AREA								
S51582	<1	<3	<4	<1	<1	<1	<1	<1
S51587	<1	<9	<5	<1	<1	<1	<1	<1
S51568	<1	<9	<5	<1	<1	<1	<1	<1
S51581	<1	<3	<4	<1	<1	<1	<1	<1
S51566	<1	<9	<5	<1	<1	<1	<1	<1
S51589	<1	<9	<5	<1	<1	<1	<1	<1
S51567	<1	<9	<5	<1	<1	<1	<1	<1
S51572	<1	<9	<5	<1	<1	<1	<1	<1
S51588	<1	<9	<5	<1	<1	<1	<1	<1
S51577	<1	<9	<5	<1	<2	<1	<2	<1
S51576	<1	<9	<5	<1	<1	<1	<1	<1
S52383	<1	<9	<5	<1	<1	<1	<1	<1
UNDEVELOPED AREA								
S74301	<1	<9	<5	<1	<1	<1	<1	<1
S54886	<1	<9	<5	<1	<1	<1	<1	<1
S74294	<1	<9	<5	<1	<1	<1	<1	<1
S48584	<1	<9	<5	<1	<1	<1	<1	<1
S74307	<1	<4	<6	<1	<1	<1	<1	<1
S47755	<1	<9	<5	<1	<1	<1	<1	<1
S48946	<1	<9	<5	<1	<1	<1	<1	<1
S73807	<1	<9	<5	<1	<1	<1	<1	<1
S86583	<1	<3	<4	<1	<1	<1	<1	<1
S74295	<1	<9	<5	<1	<1	<1	<1	<1
S74293	<1	<9	<5	<1	<1	<1	<1	<1

Appendix 3A. Concentrations of volatile organic compounds in water samples from network wells screened in the shallow aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	1,1,2-Trichloro-ethane, total (μg/L)	Tetrachloro-ethylene, total (μg/L)	Bromoform, total (μg/L)	Benzene, total (μg/L)	Toluene, total (μg/L)	Chloro-benzene, total (μg/L)	Ethyl-benzene, total (μg/L)	Xylene, total, water whole tot rec (μg/L)
				UNSEWERED SUBURBAN AREA				
S45207	<2	<1	<2	<3	<3	<3	<3	<4
S65602	<1	<1	<1	<3	<4	<4	<5	<7
S65607	<1	<1	<1	<3	<4	<4	<5	<7
S45208	<1	<1	<1	<3	<4	<4	<5	<7
S45210	<1	<1	<1	<3	<4	<4	<5	<7
S68762	<2	<1	<2	<3	<3	<3	<3	<4
S45594	<2	<1	<2	<3	<3	<3	<3	<4
S75456	<2	<1	<2	<3	<3	<3	<3	<4
S24771	<2	1	<2	<3	<3	<3	<3	<4
S64314	<2	<1	<2	<3	<3	<3	<3	<4
S47220	<1	<1	<1	<3	<4	<4	<5	<7
S48375	<1	<1	<1	<3	<4	<4	<5	<7
S74286	<1	<1	<1	<3	<4	<4	<5	<7
S64316	<1	<1	<1	<3	<4	<4	<5	<7
S64318	<1	<1	<1	<3	<4	<4	<5	<7
S64313	<2	<1	<2	<3	<3	<3	<3	<4
S29778	<2	25	<2	<3	<3	<3	<3	<4
S64319	<2	<1	<2	<3	<3	<3	<3	<4
S13175	<1	<1	<2	<3	<3	<4	<4	<6
S16605	<2	<1	<2	<3	<3	<3	<3	<4
				AGRICULTURAL AREA				
S51582	<2	<1	<2	<3	<3	<3	<3	<4
S51587	<1	<1	<2	<3	<7	<3	<7	<10
S51568	<1	<1	<2	<3	<7	<3	<7	<10
S51581	<2	<1	<2	<3	<3	<3	<3	<4
S51566	<1	<1	<2	<3	<7	<3	<7	<10
S51589	<1	<1	<2	<3	<7	<3	<7	<10
S51567	<1	<1	<2	<3	<7	<3	<7	<10
S51572	<1	<2	<2	<3	<7	<3	<7	<10
S51588	<1	<2	<2	<3	<7	<3	<7	<10
S51577	<1	<1	<2	<3	<7	<3	<7	<12
S51576	<1	<2	<2	<3	<7	<3	<7	<10
S52383	<1	<1	<2	<3	<3	<3	<7	<10
				UNDEVELOPED AREA				
S74301	<1	<1	<2	<3	<3	<3	<7	<10
S54886	<1	<1	<2	<3	<3	<3	<7	<10
S74294	<1	<1	<2	<3	<3	<3	<7	<10
S48584	<1	<1	<2	<3	<3	<3	<7	<10
S74307	<1	<1	<1	<3	<4	<4	<5	<7
S47755	<1	<1	<2	<3	<3	<3	<7	<10
S48946	<1	<1	<2	<3	<3	<3	<7	<10
S73807	<1	<1	<2	<3	<3	<3	<7	<10
S86583	<2	<1	<2	<3	<3	<3	<3	<4
S74295	<1	<1	<2	<3	<3	<3	<7	<10
S74293	<1	<1	<2	<3	<3	<3	<7	<10

Appendix 3B. Concentrations of volatile organic compounds in water samples from network wells screened in the intermediate aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.

[μg/L, micrograms per liter; <, less than; --, no data]

Well number	Trichloro-fluoro-methane, total (μg/L)	1,2-Trans-dichloro-ethene, total (μg/L)	1,1-Dichloro-ethane, total (μg/L)	Chloroform, total (μg/L)	1,1,1-Trichloro-ethane, total (μg/L)	Carbon tetra-chloride, total (μg/L)	Trichloro-ethylene, total (μg/L)	Dichloro-bromo-methane, total (μg/L)
LONG-TERM-SEWERED SUBURBAN AREA								
N1818	1	940	<2	2	<1	<1	390	<2
N7560	1	200	<2	<1	<1	<1	130	<2
N3699	<1	<11	3	2	2	<1	<1	<2
N7524	<1	<8	<4	<1	<1	<1	9	<1
N10043	--	<7	<6	3	1	1	4	<1
N8068	<1	10	<4	<1	8	<1	24	<1
N9713	<1	<11	<2	<1	3	<1	<1	<2
N9802	<1	<9	8	<1	180	<1	24	<1
N4756	--	<7	<6	<1	<1	<1	<1	<1
N9947	<1	<9	<5	<1	<1	<1	<1	<1
N7219	<1	<11	<2	<1	<1	<1	<1	<2
N8311	<1	<6	5	<1	38	<1	<1	<1
N4206	--	<7	<6	<1	<1	<1	<1	<1
RECENTLY SEWERED SUBURBAN AREA								
N8493	--	<9	<5	<1	<1	<1	<1	<1
N8364	<1	<8	5	<1	10	<1	1	<1
N9168	<1	<11	<2	<1	<1	<1	<1	<2
N7531	<1	<10	<5	<1	4	<1	1	<1
N5007	--	<7	<6	<1	<1	<1	<1	<1
N9341	--	190	<60	<1	20	<1	660	<1
N6655	<1	9	16	<1	11	<1	130	<1
N8472	--	<9	<5	<1	1	<1	<1	<1
N9449	<1	<5	<4	<1	<1	<1	<1	<1
N9239	<1	<11	<2	<1	<1	<1	<1	<2
N3243	<1	<11	<2	<1	<1	<1	<1	<2
N9252	<1	<11	<2	<1	<1	<1	<1	<2
N9018	<1	<8	<4	<1	<1	<1	<1	<1
N7353	--	<7	<6	<1	<1	<1	<1	<1
N7536	--	--	--	--	--	--	--	--
N3618	--	<7	<6	<1	<1	<1	<1	<1
N7248	<1	11	<2	<1	<1	<1	<1	<2
UNSEWERED SUBURBAN AREA								
S28055	<1	<7	<5	<1	<1	<1	<1	<2
S11803	<1	<3	<4	<1	3	<1	<1	<1
S14579	<1	<6	<2	<1	<1	<1	<1	<1
S76675	<1	<4	<6	<1	<1	<1	<1	<1
S36976	<1	<11	<2	<1	<1	<1	<1	<2

Appendix 3B. Concentrations of volatile organic compounds in water samples from network wells screened in the intermediate aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	1,1,2-Trichloro-ethane, total (µg/L)	Tetrachloro-ethylene, total (µg/L)	Bromoform, total (µg/L)	Benzene, total (µg/L)	Toluene, total (µg/L)	Chloro-benzene, total (µg/L)	Ethyl-benzene, total (µg/L)	Xylene, total, water whole tot rec (µg/L)
LONG-TERM-SEWERED SUBURBAN AREA								
N1818	<1	190	<2	<3	<5	<5	<4	<3
N7560	<1	51	<2	<3	<5	<5	<4	<3
N3699	<1	<1	<2	<3	<5	<5	<4	<3
N7524	<1	<1	<2	<3	<3	<3	<4	<5
N10043	<1	<1	<2	<3	<4	<5	<7	<8
N8068	<1	22	<2	<3	<3	<3	<4	<5
N9713	<1	<1	<2	<3	<7	<6	<5	<10
N9802	<2	<1	<2	<3	<3	<3	<4	<6
N4756	<1	<1	<2	<3	<4	<5	<7	<8
N9947	<2	2	<2	<3	<3	<3	<4	<6
N7219	<1	<1	<2	<3	<5	<5	<4	<3
N8311	<1	<1	<1	<3	<6	<3	<3	<4
N4206	<3	<1	<1	<3	<4	<4	<5	<6
RECENTLY SEWERED SUBURBAN AREA								
N8493	<2	<1	<1	<3	<3	<3	<6	<8
N8364	<1	1	<2	<3	<3	<3	<4	<5
N9168	<1	<1	<2	<3	<7	<6	<5	<10
N7531	<2	1	<2	<3	<4	<4	<4	<5
N5007	<1	<1	<2	<3	<4	<5	<7	<8
N9341	<1	280	<2	<3	<4	5	12	22
N6655	<1	3	<2	<3	<3	<3	<4	<5
N8472	<2	<1	<1	<3	<3	<3	<6	<8
N9449	<2	<1	<1	<3	<3	<3	<4	<6
N9239	<1	<1	<2	<3	<5	<5	<4	<3
N3243	<1	<1	<2	<3	<5	<5	<4	<3
N9252	<1	<1	<2	<3	<5	<5	<4	<3
N9018	<1	<1	<2	<3	<3	<3	<4	<5
N7353	<1	<1	<2	<3	<4	<5	<7	<8
N7536	--	--	--	--	--	--	--	--
N3618	<1	<1	<2	<3	<4	<5	<7	<8
N7248	<1	<1	<2	<3	<5	<5	<4	<3
UNSEWERED SUBURBAN AREA								
S28055	<1	<1	<2	<3	<3	<4	<4	<6
S11803	<2	<1	<2	<3	<3	<3	<3	<4
S14579	<1	<1	<1	<3	<6	<3	<3	<4
S76675	<1	<1	<1	<3	<4	<4	<5	<7
S36976	<1	<1	<2	<3	<5	<5	<4	<3

Appendix 3B. Concentrations of volatile organic compounds in water samples from network wells screened in the intermediate aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	Trichloro-fluoro-methane, total (µg/L)	1,2-Trans-dichloro-ethene, total (µg/L)	1,1-Dichloro-ethane, total (µg/L)	Chloroform, total (µg/L)	1,1,1-Trichloro-ethane, total (µg/L)	Carbon tetra-chloride, total (µg/L)	Trichloro-ethylene, total (µg/L)	Dichloro-bromo-methane, total (µg/L)
UNSEWERED SUBURBAN AREA (continued)								
S44774	<1	<11	<2	<1	3	<1	<1	<2
S75455	<1	<4	<6	<1	<1	<1	<1	<1
S24770	<1	<4	<6	<1	<1	<1	<1	<1
S23522	<1	<6	<2	<1	<1	<1	<1	<1
S15810	<1	<3	<4	<1	<1	<1	<1	<1
S29777	<1	<4	<6	<1	<1	<1	<1	<1
S34022	<1	<3	<4	<1	<1	<1	<1	<1
S63426	<1	<3	<4	4	<1	<1	<1	<1
S13876	<1	<3	<4	<1	<1	<1	<1	<1
S76674	<1	<3	<4	<1	<1	<1	<1	<1
S20601	<1	<3	<4	<1	<1	<1	<1	<1
S46283	<1	<4	<6	<1	<1	<1	<1	<1
AGRICULTURAL AREA								
S15015	<1	<9	<5	<1	<1	<1	<1	<1
S8025	<1	<4	<6	<1	<1	<1	<1	<1
S89545	<1	<8	<4	<1	<1	<1	<1	<1
S3570	<1	<9	<5	<1	<1	<1	<1	<1
S89544	<1	<8	<4	<1	<1	<1	<1	<1
S40407	<1	<9	<5	<1	<1	<1	<1	<1
S8077	<1	<9	<5	<1	<1	<1	<1	<1
S89543	<1	<8	<4	<1	<1	<1	<1	<1
S51571	<1	<3	<4	<1	<1	<1	<1	<1
S51578	<1	<3	<4	<1	<1	<1	<1	<1
UNDEVELOPED AREA								
S89459	<1	<8	<4	<1	<1	<1	<1	<1
S89457	<1	<8	<4	<1	<1	<1	<1	<1
S89539	<1	<8	<4	<1	<1	<1	<1	<1
S89456	<1	<8	<4	<1	<1	<1	<1	<1
S89455	<1	<8	<4	<1	<1	<1	<1	<1
S89540	<1	<8	<4	<1	<1	<1	<1	<1
S89538	<1	<8	<4	2	<1	<1	<1	<1
S89458	<1	<8	<4	<1	<1	<1	<1	<1
S89541	<1	<8	<4	1	<1	<1	<1	<1
S46544	<1	<4	<6	<1	<1	<1	<1	<1
S34742	<1	<9	<5	1	<1	<1	<1	<1
S73811	<1	<9	<5	<1	<1	<1	<1	<1
S86584	<1	<3	<4	<1	<1	<1	<1	<1

Appendix 3B. Concentrations of volatile organic compounds in water samples from network wells screened in the intermediate aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	1,1,2-Trichloro-ethane, total (µg/L)	Tetrachloro-ethylene, total (µg/L)	Bromoform, total (µg/L)	Benzene, total (µg/L)	Toluene, total (µg/L)	Chloro-benzene, total (µg/L)	Ethyl-benzene, total (µg/L)	Xylene, total, water whole tot rec (µg/L)
UNSEWERED SUBURBAN AREA								
S44774	<1	<2	<2	<3	<5	<5	<4	<3
S75455	<1	<1	<1	<3	<4	<4	<5	<7
S24770	<1	<1	<1	<3	<4	<4	<5	<7
S23522	<1	<1	<1	<3	<6	<3	<3	<4
S15810	<2	<1	<2	<3	<3	<3	<3	<4
S29777	<1	<1	<1	<3	<4	<4	<5	<7
S34022	<2	<1	<2	<3	<3	<3	<3	<4
S63426	<2	<1	<2	<3	<3	<3	<3	<4
S13876	<2	<1	<2	<3	<3	<3	<3	<4
S76674	<2	<1	<2	<3	<3	<3	<3	<4
S20601	<2	<1	<2	<3	<3	<3	<3	<4
S46283	<1	<1	<1	<3	<4	<4	<5	<7
AGRICULTURAL AREA								
S15015	<1	<1	<2	<3	<3	<3	<7	<10
S8025	<1	<1	<1	<3	<4	<4	<5	<7
S89545	<1	<1	<1	<3	<3	<4	<8	<9
S3570	<1	<1	<2	<3	<3	<3	<7	<10
S89544	<1	<1	<1	<3	<3	<4	<8	<9
S40407	<1	<1	<2	<3	<3	<3	<7	<10
S8077	<1	<1	<2	<3	<3	<3	<7	<10
S89543	<1	<1	<1	<3	<3	<4	<8	<9
S51571	<2	<1	<2	<3	<3	<3	<3	<4
S51578	<2	<1	<2	<3	<3	<3	<3	<4
UNDEVELOPED AREA								
S89459	<1	<1	<1	<3	<3	<4	<8	<9
S89457	<1	<1	<1	<3	<3	<4	<8	<9
S89539	<1	<1	<1	<3	<3	<4	<8	<9
S89456	<1	<1	<1	<3	<3	<4	<8	<9
S89455	<1	<1	<1	<3	<3	<4	<8	<9
S89540	<1	<1	<1	<3	<3	<4	<8	<9
S89538	<1	<1	<1	<3	<3	<4	<8	<9
S89458	<1	<1	<1	<3	<3	<4	<8	<9
S89541	<1	<1	<1	<3	<3	<4	<8	<9
S46544	<1	<1	<1	<3	<4	<4	<5	<7
S34742	<1	<1	<2	<3	<3	<3	<7	<10
S73811	<1	<1	<2	<3	<3	<3	<7	<10
S86584	<2	<1	<2	<3	<3	<3	<3	<4

Appendix 3C. Concentrations of volatile organic compounds in water samples from network wells screened in the deep aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.

[µg/L, micrograms per liter; <, less than; --, no data]

Well number	Trichloro-fluoro-methane, total (µg/L)	1,2-Trans-dichloro-ethene, total (µg/L)	1,1-Dichloro-ethane, total (µg/L)	Chloroform, total (µg/L)	1,1,-Trichloro-ethane, total (µg/L)	Carbon tetra-chloride, total (µg/L)	Trichloro-ethylene, total (µg/L)	Dichloro-bromo-methane, total (µg/L)
LONG-TERM-SEWERED SUBURBAN AREA								
N103	<1	<10	<5	<1	<1	<1	<1	<1
N9768	--	<7	<6	<1	<1	<1	<1	<1
N7512	--	<7	<6	<1	<1	<1	<1	<1
N650	--	<7	<6	<1	<1	<1	<1	<1
N4082	--	<7	<6	<1	<1	<1	<1	<1
N3672	--	<7	<6	<1	<1	<1	<1	<1
N8576	--	<7	<6	<1	<1	<1	2	<1
N2748	--	<7	<6	<1	<1	<1	<1	<1
N2565	--	<7	<6	<1	<1	<1	<1	<1
N1697	--	<7	<6	<1	<1	<1	<1	<1
N8474	<1	<8	<5	<1	<1	<1	<1	<1
N7058	--	<7	<6	<1	<1	<1	17	<1
N10033	--	<7	<6	<1	<1	<1	<1	<1
N3603	--	<7	<6	<1	<1	<1	<1	<1
N6745	<1	<11	<2	<1	<1	<1	<1	<2
N7117	--	<7	<6	<1	<1	<1	5	<1
N6865	<1	<11	<2	<1	<1	<1	<1	2
N4390	--	<9	<5	<1	2	<1	5	<1
RECENTLY SEWERED SUBURBAN AREA								
N4245	--	<7	<6	<1	<1	<1	<1	<1
N6190	<1	<10	<5	<1	<1	<1	<1	<1
N7562	<1	<10	<5	<1	39	<1	1	<1
N7030	--	<7	<6	<1	<1	<1	<1	<1
N8007	<1	<11	<2	<1	<1	<1	<1	<2
N7785	--	<7	<6	<1	<1	<1	<1	<1
N8497	--	<7	<6	<1	<1	<1	<1	<1
N8957	<1	<8	<5	<1	<1	<1	<1	<1
N8526	<1	<10	<5	<1	12	<1	7	<1
N7561	<1	<6	<2	<1	<1	<1	3	<1
N8525	<1	<10	<5	<1	<1	<1	<1	<1
N7500	<1	<11	<2	<1	<1	<1	<1	<2
N8321	--	<7	<6	<1	<1	<1	<1	<1
N4450	--	<7	<6	<1	<1	<1	<1	<1
N4448	--	<7	<6	<1	<1	<1	<1	<1
N5322	--	<7	<6	<1	<1	<1	<1	<1
N3465	--	<7	<6	<1	<1	<1	<1	<1

Appendix 3C. Concentrations of volatile organic compounds in water samples from network wells screened in the deep aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	1,1,2-Trichloro-ethane, total (µg/L)	Tetrachloro-ethylene, total (µg/L)	Bromoform, total (µg/L)	Benzene, total (µg/L)	Toluene, total (µg/L)	Chloro-benzene, total (µg/L)	Ethyl-benzene, total (µg/L)	Xylene, total, water whole tot rec (µg/L)
LONG-TERM-SEWERED SUBURBAN AREA								
N103	<2	<1	<2	<3	<4	<4	<4	<5
N9768	<1	<1	<2	<3	<4	<5	<7	<8
N7512	<1	<1	<2	<3	<4	<5	<7	<8
N650	<3	9	<1	<3	<4	<4	<5	<6
N4082	<3	<1	<1	<3	<4	<4	<5	<6
N3672	<1	<1	<2	<3	<4	<5	<7	<8
N8576	<3	3	<1	<3	<4	<4	<5	<6
N2748	<3	<1	<1	<3	<4	<4	<5	<6
N2565	<3	19	<1	<3	<4	<4	<5	<6
N1697	<3	<1	<1	<3	<4	<4	<5	<6
N8474	<1	<1	<1	<3	<3	<3	<4	<4
N7058	<3	2	<1	<3	<4	<4	<5	<6
N10033	<3	<1	<1	<3	<4	<4	<5	<6
N3603	<3	<1	<1	<3	<4	<4	<5	<6
N6745	<1	1	<2	<3	<5	<5	<4	<3
N7117	<3	<1	<1	<3	<4	<4	<5	<6
N6865	<1	2	<2	<3	<5	<5	<4	<3
N4390	<2	16	<1	<3	<3	<3	<6	<8
RECENTLY SEWERED SUBURBAN AREA								
N4245	<1	<1	<2	<3	<4	<5	<7	<8
N6190	<2	<1	<2	<3	<4	<4	<4	<5
N7562	<2	2	<2	<3	<4	<4	<4	<5
N7030	<1	<1	<2	<3	<4	<5	<7	<8
N8007	<1	<1	<2	<3	<5	<5	<4	<3
N7785	<1	<1	<2	<3	<4	<5	<7	<8
N8497	<1	<1	<2	<3	<4	<5	<7	<1
N8957	<1	<1	<1	<3	<3	<3	<4	<4
N8526	<2	7	<2	<3	<4	<4	<4	<5
N7561	<1	8	<1	<3	<6	<3	<3	<4
N8525	<2	10	<2	<3	<4	<4	<4	<5
N7500	<1	<1	<2	<3	<5	<5	<4	<3
N8321	<1	<1	<2	<3	<4	<5	<7	<8
N4450	<1	<1	<2	<3	<4	<5	<7	<8
N4448	<1	<1	<2	<3	<4	<5	<7	<8
N5322	<1	<1	<2	<3	<4	<5	<7	<8
N3465	<1	<1	<2	<3	<4	<5	<7	<8

Appendix 3C. Concentrations of volatile organic compounds in water samples from network wells screened in the deep aquifer zone, Nassau and Suffolk Counties, Long Island, N.Y.--continued

Well number	Trichloro-fluoro-methane, total (µg/L)	1,2-Trans-dichloro-ethene, total (µg/L)	1,1-Dichloro-ethane, total (µg/L)	Chloroform, total (µg/L)	1,1,-Trichloro-ethane, total (µg/L)	Carbon tetra-chloride, total (µg/L)	Trichloro-ethylene, total (µg/L)	Dichloro-bromo-methane, total (µg/L)
UNSEWERED SUBURBAN AREA								
S37351	<1	<11	<2	<1	<1	<1	<1	<2
S36791	<1	<11	<2	<1	<1	<1	<1	<2
S42225	<1	<3	<4	<1	1	<1	<1	<1
S18058	<1	<3	<4	<1	<1	<1	<1	<1
S75454	<1	<3	<4	<1	<1	<1	<1	<1
S24769	<1	<4	<6	<1	<1	<1	<1	<1
S45638	<1	<6	<2	<1	<1	<1	<1	<1
S74284	<1	<4	<6	<1	<1	<1	<1	<1
S22015	<1	<3	<4	<1	<1	<1	<1	<1
S29776	<1	<3	<4	<1	<1	<1	<1	<1
S34021	<1	<3	<4	<1	<1	<1	<1	<1
S33006	<1	<11	<2	<1	<1	<1	<1	<2
S21134	<1	<6	<2	<1	<1	<1	<1	<1
S19057	<1	<6	<2	<1	2	<1	1	<1
S35007	<1	<6	<2	<1	<1	<1	<1	<1
S29962	<1	<6	<2	<1	<1	<1	1	<1
S74285	<1	<4	<6	<1	<1	<1	<1	<1
S22548	<1	<6	<2	<1	<1	<1	<1	<1
S26248	<1	<6	<2	<1	<1	<1	<1	<1

Well number	1,1,2-Trichloro-ethane, total (µg/L)	Tetrachloro-ethylene, total (µg/L)	Bromoform, total (µg/L)	Benzene, total (µg/L)	Toluene, total (µg/L)	Chloro-benzene, total (µg/L)	Ethyl-benzene, total (µg/L)	Xylene, total, water whole tot rec (µg/L)
UNSEWERED SUBURBAN AREA								
S37351	<1	<1	<2	<3	<5	<5	<4	<3
S36791	<1	<1	<2	<3	<5	<5	<4	<3
S42225	<2	<1	<2	<3	<3	<3	<3	<4
S18058	<2	<1	<2	<3	<3	<3	<3	<4
S75454	<2	<1	<2	<3	<3	<3	<3	<4
S24769	<1	<1	<1	<3	<4	<4	<5	<7
S45638	<1	<1	<1	<3	<6	<3	<3	<4
S74284	<1	<1	<1	<3	<4	<4	<5	<7
S22015	<2	<1	<2	<3	<3	<3	<3	<4
S29776	<2	<1	<2	<3	<3	<3	<3	<4
S34021	<2	<1	<2	<3	<3	<3	<3	<4
S33006	<1	<1	<2	<3	<5	<5	<4	<3
S21134	<1	<1	<1	<3	<6	<3	<3	<4
S19057	<1	<1	<1	<3	<6	<3	<3	<4
S35007	<1	<1	<1	<3	<6	<3	<3	<4
S29962	<1	<1	<1	<3	<6	<3	<3	<4
S74285	<1	<1	<1	<3	<4	<4	<5	<7
S22548	<1	<1	<1	<3	<6	<3	<3	<4
S26248	<1	<1	<1	<3	<6	<3	<3	<4

APPENDIX 4

Analysis of depth to water and estimated traveltimes of ground water.

ANALYSIS OF DEPTH TO WATER AND ESTIMATED TRAVELTIMES OF GROUND WATER

One-way analysis of variance on rank-transformed depth-to-water and traveltime data were used to examine differences in (1) depth to water among study areas, and (2) traveltimes among study areas for each depth zone. The null hypothesis for these tests states that the mean ranks are equal for all study areas; rejection of the null hypotheses indicates that at least one mean rank differs significantly from the others. If the null hypothesis was rejected by the ANOVA test, indicating that at least one mean depth to water or traveltime-rank value differed from another, Tukey's honest significant difference test (Tukey's test) was used to determine which means differed. Results indicate that the median thickness of the unsaturated zone in the unsewered suburban area is significantly greater than those in the agricultural or undeveloped areas and that median traveltimes within the shallow zones of the three suburban areas are significantly shorter than those within the agricultural or undeveloped areas (fig A-1). The effect of these differences is probably minimal because (1) the greater thickness of the unsaturated zone in the unsewered area is offset by the longer ground-water traveltimes within the agricultural and undeveloped areas, and (2) land use in the agricultural and undeveloped areas has undergone little change through time; thus, the effects of land use on water quality in these areas probably are accurately represented. Results of Tukey's test for the intermediate-depth zone indicates that mean traveltime ranks are equal among all areas except the unsewered suburban area, in which traveltimes are longer than those in the long-term-sewered suburban area (fig. A-1). Results of Tukey's test for the deep zone indicates that mean traveltime ranks are equal among the three suburban areas (fig. A-1).

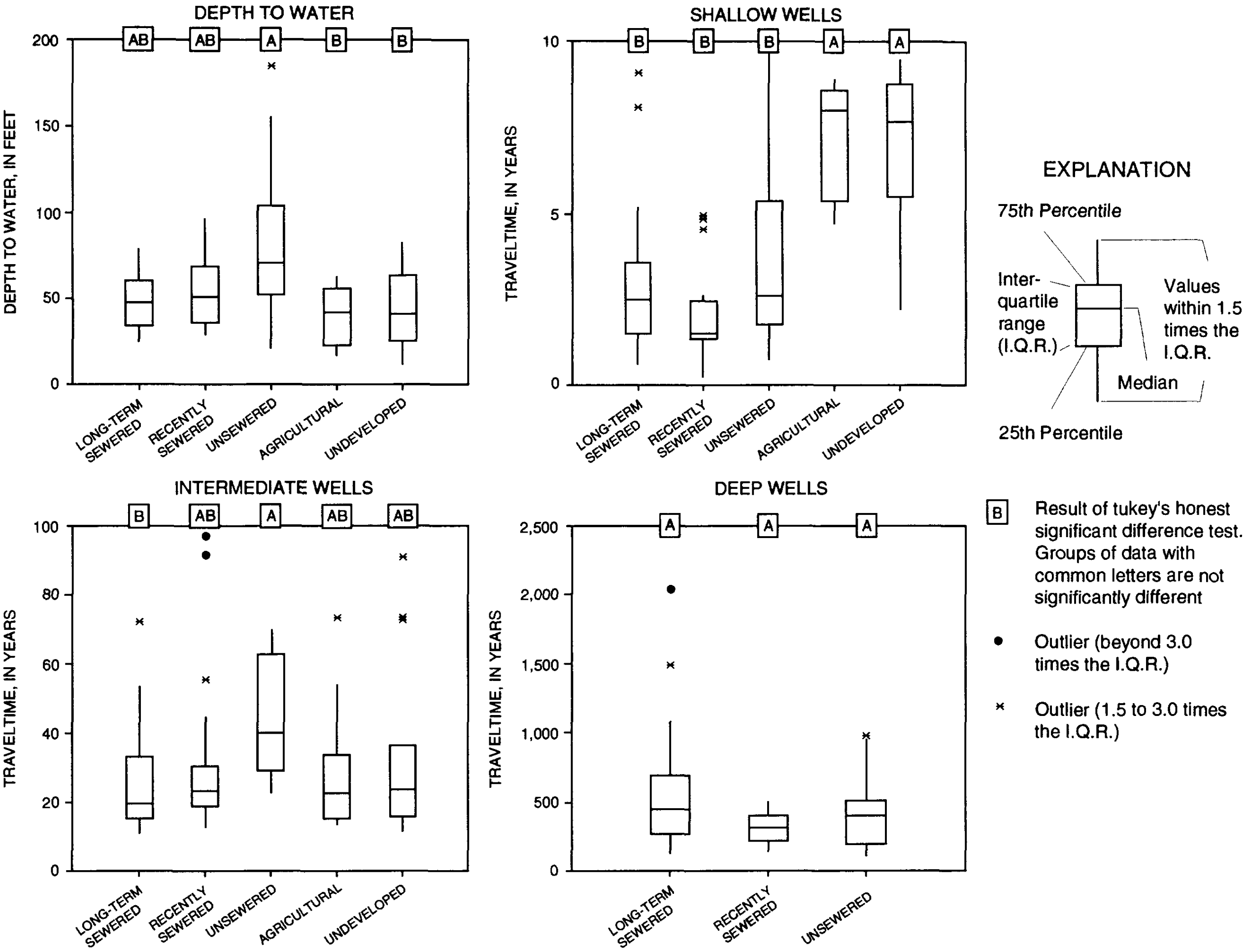

Figure A1. Depth to water and estimated traveltime of ground water from water table to well screens in all depth zones of each study area.