USGS
science for a changing world

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

Groundwater Quality in the Eastern Lake Ontario Basin, New York, 2008

Open-File Report 2011–1074

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

Cover. Photographs from the shores of Lake Ontario near Oswego. (photos by H.J. Zajd, Jr., 2010)

Groundwater Quality in the Eastern Lake Ontario Basin, New York, 2008

By Amy J. Risen and James E. Reddy

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

Open-File Report 2011–1074

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

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2011

Suggested citation:
Risen, A.J., and Reddy, J.E., 2011, Groundwater quality in the Eastern Lake Ontario Basin, New York, 2008: U.S. Geological Survey Open-File Report 2011–1074, 32 p., at http://pubs.usgs.gov/of/2011/1074.

Contents

Figures

Tables

Conversion Factors, Datum, and Abbreviations

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
million gallons (Mgal)	3,785	cubic meter (m^3)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
	Radioactivity	
picocurie per liter (pCi/L)	0.037	becquerel per liter (Bq/L)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F= (1.8×°C) +32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C= (°F-32)/1.8$$

Vertical coordinate information is referenced to North American Vertical Datum of 1929 (NAVD 29).

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

Laboratory reporting level (LRL). Generally equal to twice the yearly determined long-term method detection level (LTMDL). The LRL controls false negative error. The probability of falsely reporting a nondetection for a sample that contained an analyte at a concentration equal to or greater than the LRL is predicted to be less than or equal to 1 percent. The value of the LRL will be reported with a “less than” remark code for samples in which the analyte was not detected. The National Water Quality Laboratory collects quality-control data from selected analytical methods on a continuing basis to determine LTMDLs and to establish LRLs. These values are reevaluated annually based on the most current quality-control data, and, therefore, may change (Childress and others, 1999).

List of Acronyms

AMCL	Alternative maximum contaminant level
CFU/mL	Colony forming units per milliliter
CIAT	2-Chloro-4-isopropylamino-6-amino-s-triazine (also called deethylatrazine)
cICP-MS	Collision/reaction cell inductively coupled plasma-mass spectrometry
ESA	Ethanesulfonic acid
GC-MS	Gas chromatography-mass spectrometry
GWSI	Ground-water site inventory
HA	Health Advisory for drinking water
HPC	Heterotrophic plate count
HPLC-MS	High-performance liquid chromatography-mass spectrometry
ICP-AES	Inductively coupled plasma-atomic emission spectrometry
ICP-MS	Inductively coupled plasma-mass spectrometry
ICP-OES	Inductively coupled plasma-optical emission spectrometry
LC-MS	Liquid chromatography-mass spectrometry
LRL	Laboratory Reporting Level
MCL	Maximum Contaminant Level
MTBE	Methyl-*tert*-butyl ether
µg/L	micrograms per liter
µm	micrometer
µS/cm	microsiemens per centimeter
mg/L	milligrams per liter
NWQL	USGS National Water Quality Laboratory
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OA	Oxanilic acid
OGRL	USGS Organic Geochemistry Research Laboratory
OIET	2-Hydroxy-4-isopropylamino-6-ethylamino-s-triazine (also called hydroxyatrazine)
pCi/L	picocuries per liter
Pt-Co units	Platinum-cobalt units
SMCL	Secondary Maximum Contaminant Level
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	Volatile organic compound

This page has been left blank intentionally.

Groundwater Quality in the Eastern Lake Ontario Basin, New York, 2008

By Amy J. Risen and James E. Reddy

Abstract

Water samples were collected from nine production wells and nine private residential wells in the Eastern Lake Ontario Basin of New York from August through October 2008 and analyzed to characterize the chemical quality of groundwater. The wells were selected to provide adequate spatial coverage of the 3,225-square-mile study area; areas of greatest groundwater use were emphasized. Eight of the 18 wells sampled, were screened in sand and gravel aquifers, and 10 were finished in bedrock aquifers. The samples were collected and processed by standard U.S. Geological Survey procedures and were analyzed for 223 physical properties and constituents, including major ions, nutrients, trace elements, radon-222, pesticides, volatile organic compounds (VOCs), and indicator bacteria.

Water quality in the study area is generally good, but concentrations of some constituents exceeded current or proposed Federal or New York State drinking-water standards; these were: color (2 samples), pH (1 sample), sodium (5 samples), chloride (1 sample), aluminum (2 samples), iron (5 unfiltered samples), manganese (3 samples), radon-222 (13 samples), and bacteria (4 samples). Dissolved-oxygen concentrations in samples from wells finished in sand and gravel [median 3.8 milligrams per liter (mg/L)] were greater than those from wells finished in bedrock (median less than 0.7 mg/L). The pH of all samples was typically neutral or slightly basic (median 7.4); the median water temperature was 11.3 degrees Celsius (°C). The ions with the highest concentrations were bicarbonate (median 174 mg/L) and calcium (median 24.1 mg/L). Groundwater in the basin ranges from soft to moderately hard [less than or equal to 120 mg/L as $9CaCO_{30}$] and median hardness was 90 mg/L as $CaCO_3$. Concentrations of nitrate plus nitrite in samples from sand and gravel wells (median concentration 0.42 mg/L as nitrogen) were generally higher than those in samples from bedrock wells (median <0.04 mg/L as nitrogen). The trace elements with the highest concentrations were strontium [median 138 micrograms per liter (µg/L)], barium (median 38.2 µg/L) and iron (median 44 µg/L). Radon-222 activities were generally high [median 500 picocuries per liter (pCi/L)]; 72 percent of all samples exceeded a proposed U.S. Environmental Protection Agency (USEPA) drinking-water standard of 300 pCi/L. Five pesticides and pesticide degradates were detected among 6 samples at concentrations of 0.03 µg/L or less; most were herbicides or their degradates. Six VOCs were detected among 9 samples at concentrations of 1.2 µg/L or less; these included 3 trihalomethanes, benzene, toluene, and xylenes. Total coliform bacteria were detected in 3 samples, and the heterotrophic plate count exceeded the USEPA maximum contaminant level (MCL) of 500 colony forming units in one sample. Fecal coliform bacteria, including *Escherichia coli*, were not detected in any sample.

Introduction

Section 305(b) of the Federal Clean Water Act Amendments of 1977 requires that states monitor and report biennially on the chemical quality of surface water and groundwater in the state boundaries (U.S. Environmental Protection Agency, 1997). The U.S. Geological Survey (USGS) in 2002, in cooperation with the New York State Department of Environmental Conservation (NYSDEC), developed a program to evaluate groundwater quality throughout the major river basins in New York on a rotating basis. The work parallels the NYSDEC Rotating Intensive Basin Study program, which evaluates surface-water quality in 2 or 3 of the 14 major river basins in the State each year. The groundwater-quality program began in 2002 with a pilot study in the Mohawk River Basin (Butch and others, 2003). Groundwater-quality sampling was completed in the Chemung River Basin in 2003 (Hetcher-Aguila, 2005); the Lake Champlain (Nystrom, 2006) and Susquehanna River Basins in 2004 (Hetcher-Aguila and Eckhardt, 2006); the St. Lawrence (Nystrom, 2007a), Delaware (Nystrom, 2007b), and Genesee River Basins (Eckhardt and others, 2007) in 2005; the Mohawk River Basin (Nystrom, 2008) and western New York (Niagara and Allegheny River Basins, and tributaries to Lake Erie and western Lake Ontario) (Eckhardt and others, 2008) in 2006; and the Upper Hudson River Basin (Nystrom, 2009) and Central New York (Oswego, Seneca, and Oneida River Basins) (Eckhardt and others, 2009) in 2007. Sampling in the Eastern Lake Ontario Basin, the Chemung River Basin, and the Lower Hudson River Basin (Nystrom, 2010) were completed in 2008.

Groundwater characteristics are affected by the geology and the land use of the area. Shallow wells that tap sand and gravel aquifers are susceptible to contamination by several kinds of compounds, including volatile organic compounds (VOCs), pesticides, deicing chemicals, and nutrients from upgradient highways, industrial, agricultural, and residential areas. The movement of these contaminants to the water table through the soils and surficial sand and gravel can be relatively rapid. Bedrock wells that tap sandstone and shale aquifers in rural upland areas are generally less susceptible to contamination from industrial and urban sources, which are mainly in the valleys; but bedrock wells in lowland areas underlain by carbonate rock (limestone and dolostone) may be more vulnerable to contamination from surface runoff because infiltration rates and groundwater flow can be relatively rapid through solution features in the rock. Agricultural land upgradient of wells may be a potential source of contamination from fertilizers, pesticides, and fecal waste from livestock; lawns and residential septic systems also are a potential source of these contaminants. In addition to anthropogenic contaminants, the aquifers contain naturally derived elements that may diminish water quality, such as sodium, chloride, sulfate, iron, manganese, and trace elements such as arsenic; some also may contain hydrogen sulfide, methane, and radon gases from deep-lying sources.

Purpose and Scope

This report presents the findings of the 2008 study in the Eastern Lake Ontario Basin, in which 18 groundwater-quality samples were collected from August through October 2008. This report (1) describes the hydrogeologic setting and the methods of site selection, sample collection, and chemical analysis, and (2) discusses the analytical results for physical properties and concentrations of major ions, nutrients, trace elements and radionuclides, pesticides, volatile organic compounds (VOCs), and indicator bacteria. Information about the sampled wells and results of the analyses are presented in the appendix (tables A1 through A9).

Study Area

The 3,225-square mile (mi^2) study area includes all or parts of 6 counties in north-central New York (fig. 1). The study area encompasses the Eastern Lake Ontario Basin (between the Oswego River Basin and the St. Lawrence River Basin), and includes the Mid-Northern Lake Ontario Basin, the Black River Basins and the Chaumont River-Perch River Basin (fig. 1, table 1).

Physiography, Land Use, and Precipitation

The western part of the study area lies in the Lake Ontario Lowlands physiographic province (fig. 1, table A1). The central part lies in the Tug Hill Uplands, and the eastern part lies in the Adirondack Uplands. Forest and pasture dominate the lowland western parts of the study area (fig. 2); where most of the population is located. The Tug Hill region is mostly undeveloped forest and wetland. The Adirondack Uplands area is steep forest land and has numerous lakes. The Watertown and Oswego metropolitan areas are in the western part of the study area.

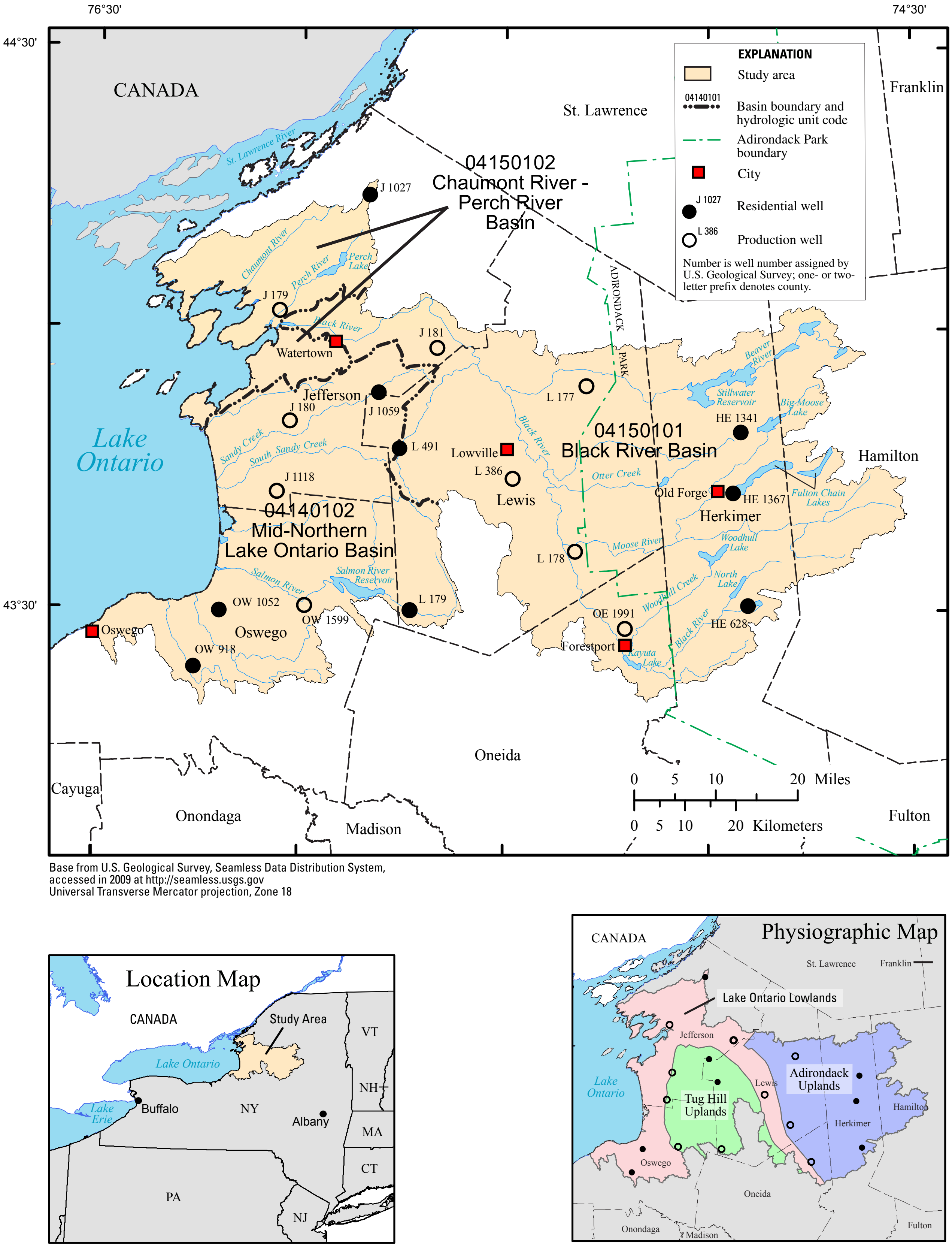
Land-surface elevations range from about 250 feet (ft) at Lake Ontario to about 3,000 ft in the Adirondack Uplands. The climate is humid, and air temperature in the lowlands is moderated by Lake Ontario. The Tug Hill Uplands and the Adirondacks receive substantially more precipitation than the Lake Ontario lowlands, primarily because of lake-effect snow in the winter months. Virtually all groundwater in the area originates as precipitation, which ranges from about 36 inches per year (in/yr) in the western areas to about 48 in/yr in the central and eastern areas; the Tug Hill Upland may receive up to 60 in/yr. About 30 percent of the annual precipitation infiltrates the land surface and recharges the sand and gravel and bedrock aquifers (Randall, 2001).

Glacial Deposits

Glacially derived deposits are generally observed throughout the Eastern Lake Ontario Basin of New York (fig. 3). Glaciers scoured the hills and valleys of New York and left a thin mantle of till on top of the bedrock in upland areas and morainal deposits of fine-grained, poorly sorted material that formed valley plugs and low ridges (Cadwell and Muller, 1986). During the subsequent period of deglaciation, meltwater streams deposited layers of stratified drift (fluvial sands and gravels) in front, on top, beneath, and alongside glaciers, to form deposits that are seen today as outwash plains, eskers, kettles, kames, and kame terraces. In some areas near Lake Ontario, sequences of beach sands were deposited along the shores of glacial lakes. These water-borne deposits of sand and gravel, where saturated with groundwater, now form important aquifers in the Lake Ontario Lowlands and in an area in the western side of the Adirondacks near Forestport. Glacial meltwaters also deposited fine-grained sediments in proglacial lakes, where the meltwaters settled to form deposits of lacustrine clays, silts, and fine sands with limited permeability. Recent alluvium covers some of the glacial deposits and forms floodplains along the larger streams and rivers and on the terraces along the shore of Lake Ontario. The glacial deposits in the study area are described in detail by Fairchild (1928), Coates (1966), Waller and Ayer (1975), Miller (1982, 1988, 1990), Miller and others (1989), Zarriello (1993), Randall (2001), and Kontis and others (2004).

Bedrock

The bedrock aquifers in the western and central parts of the study area (fig. 4) consist of gently dipping, interbedded sedimentary units of shale, siltstone, sandstone, limestone,



Base from U.S. Geological Survey, Seamless Data Distribution System, accessed in 2009 at http://seamless.usgs.gov
Universal Transverse Mercator projection, Zone 18

Figure 1. Pertinent geographic features of study area in the Eastern Lake Ontario Basin of New York, and locations of the 18 wells sampled in 2008. (Well data are given in table A1, at end of report.)

Table 1. Area and population of the Eastern Lake Ontario Basin of New York study area.

[Locations are shown in figure 1]

Drainage basin	Hydrologic unit code	Area (square miles)	Population[1]
Black River	04150101	1,903	40,961
Chaumont River-Perch River	04150102	350	55,892
Mid-Northern Lake Ontario	04140102	972	52,824

[1] 2000 Census (U.S. Department of Commerce, 2000).

and dolostone of Ordovician and Silurian age (Broughton and others, 1962; Isachsen and others, 2000). A band of carbonate-rock aquifers— mostly limestone with some interbedded shale and dolostone—extend south eastward from Watertown around the Tug Hill area to Forestport. The bedrock east of Oswego, including the Tug Hill Uplands is mostly sandstone and siltstone. Bedrock in the Adirondack Uplands is a complex mixture of metamorphosed igneous and sedimentary rock.

Population and Water Supply

Most of the study area is predominantly rural, but includes several small cities such as Watertown, Oswego, Lowville, and Old Forge (fig. 1). Total population of the study area in 2000 was about 150,000 (U.S. Department of Commerce, 2000). Production wells supply about 12 million gallons per day (Mgal/d) of water for commercial and domestic use in the study area (New York State Department of Health, 2007a).

Several small cities such as Watertown and Oswego tap reservoirs and lakes for their water supply, but many rural communities rely on community water-system (production) wells that tap groundwater from bedrock or from surficial deposits of sand and gravel. Most homeowners that live in rural areas have private wells that tap local surficial deposits or bedrock. Waller and Ayer (1975) estimated that about 13 percent of water use in the Black River Basin was derived from groundwater sources.

The most productive aquifers in the study area are the glacial and alluvial deposits of sand and gravel (fig. 3). Miller and others (1989) estimated that the Tug Hill glacial-drift aquifer supplies more than 2 Mgal/d to 7 municipal water systems in Oswego and Jefferson Counties. Waller and Ayers (1975) estimated that wells in the sand and gravel deposits along some river valleys in the Adirondack region could potentially yield more than 100 gallons per minute (gal/min).

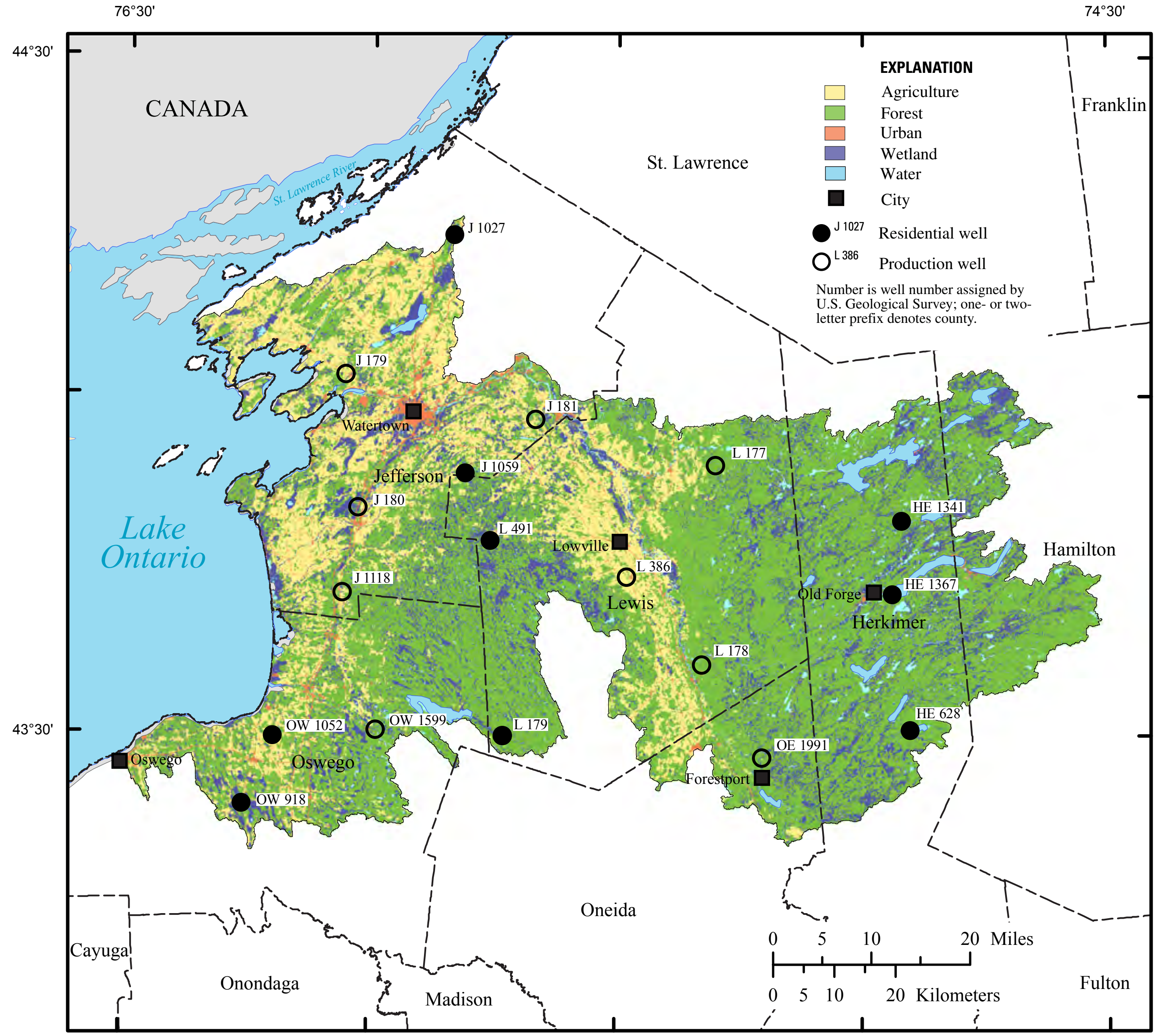
Till deposits cover much of the upland areas, but are typically thin, relatively impermeable, and yield little water to wells. Lacustrine silt and clay beds are in most large valleys but yield little or no water to wells; however, the silt and clay beds may confine and protect productive sand and gravel aquifers that lie beneath. Bedrock aquifers (fig. 4) are used for water supply where sand and gravel aquifers are absent, typically in upland areas. The bedrock aquifers in the study area may yield water of poorer chemical quality than the surficial aquifers; for example, the carbonate rock aquifers typically yield very hard water, and shale bedrock aquifers near Lake Ontario may yield salty water (Kantrowitz, 1970; Crain, 1975).

Methods

The methods used in this study, including (1) well-selection criteria, (2) sampling methods, and (3) analytical methods, were designed to maximize data precision, accuracy, and comparability. Groundwater-sample collection and processing followed standard USGS procedures as documented in the National Field Manual for the Collection of Water-Quality Data (U.S. Geological Survey, variously dated). Samples were analyzed by documented methods at the USGS National Water Quality Laboratory (NWQL) in Denver, Colo., the USGS Organic Geochemistry Research Laboratory (OGRL) in Lawrence, Kans., and New York State Department of Health (NYSDOH)-certified laboratories.

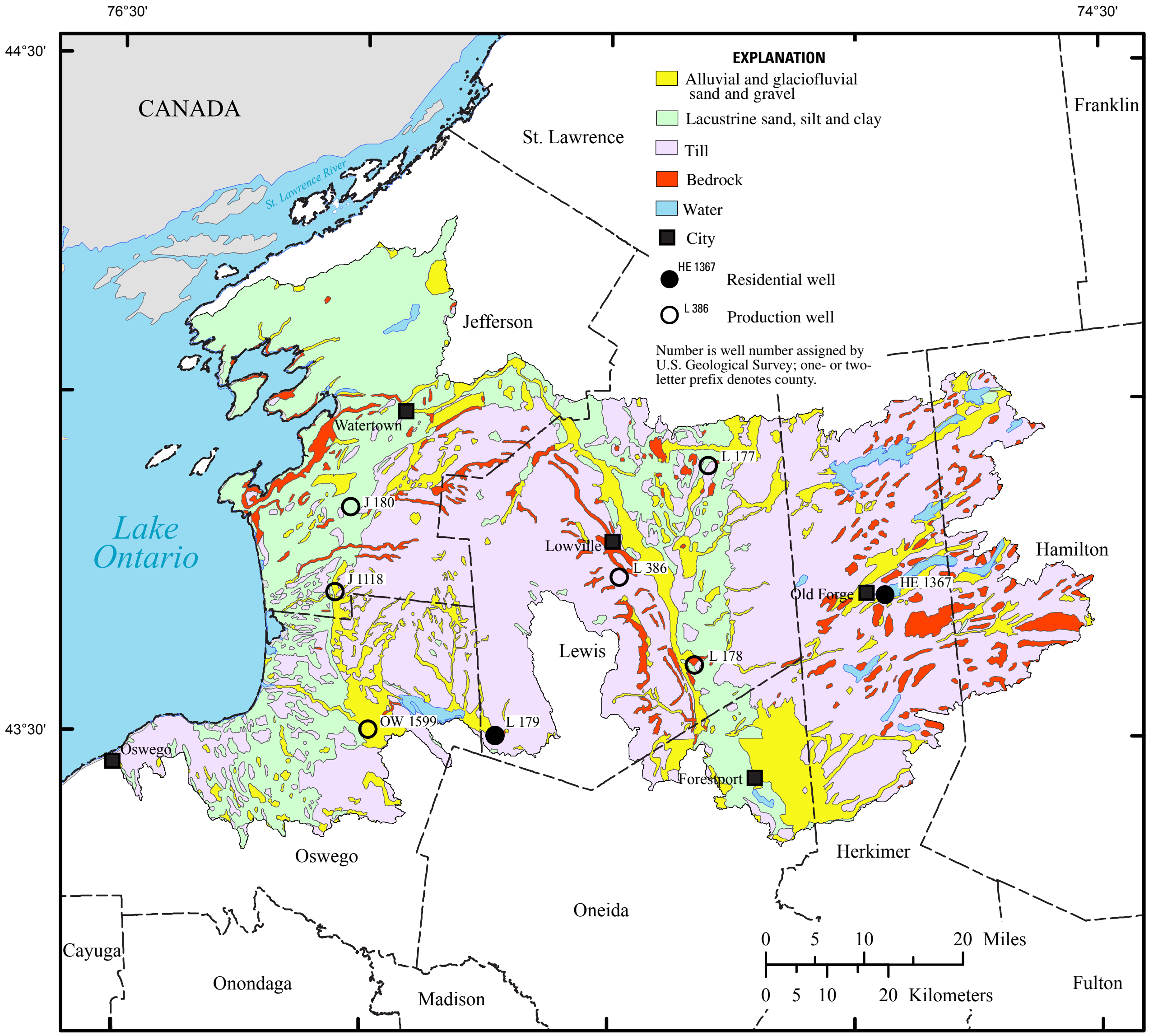
Site Selection

A total of 18 wells were selected for sample collection. Wells were selected to provide adequate spatial coverage of the basin; areas of greatest groundwater use were emphasized. The study did not target specific municipalities, industries, or agricultural practices. The sites selected for sampling represent a combination of the four predominant land-use categories-agriculture, urban, forest, and wetland. Eight wells were finished in sand and gravel aquifers (fig. 3) and ranged from 17 to 88 ft deep (table A1); production wells that tap sand and gravel have slotted screens; whereas, most residential wells that tap sand and gravel simply have an open-ended steel casing. Ten wells were finished in bedrock aquifers (fig. 4) and ranged from 58 to 700 ft deep (table A1); these wells typically have steel casing set into open boreholes in competent rock, and water yields are obtained from flow through bedrock fractures to the well. The eight wells that tap sand and gravel consisted of 6 production wells and 2 private residential wells; the 10 bedrock wells consisted of 3 production wells and 7 private residential wells. Sampling was done from August through October 2008. The water samples were analyzed for 223 physical properties and constituents. Three samples—two



Base from U.S. Geological Survey, Seamless Data Distribution System,
accessed in 2009 at http://seamless.usgs.gov
Universal Transverse Mercator projection, Zone 18

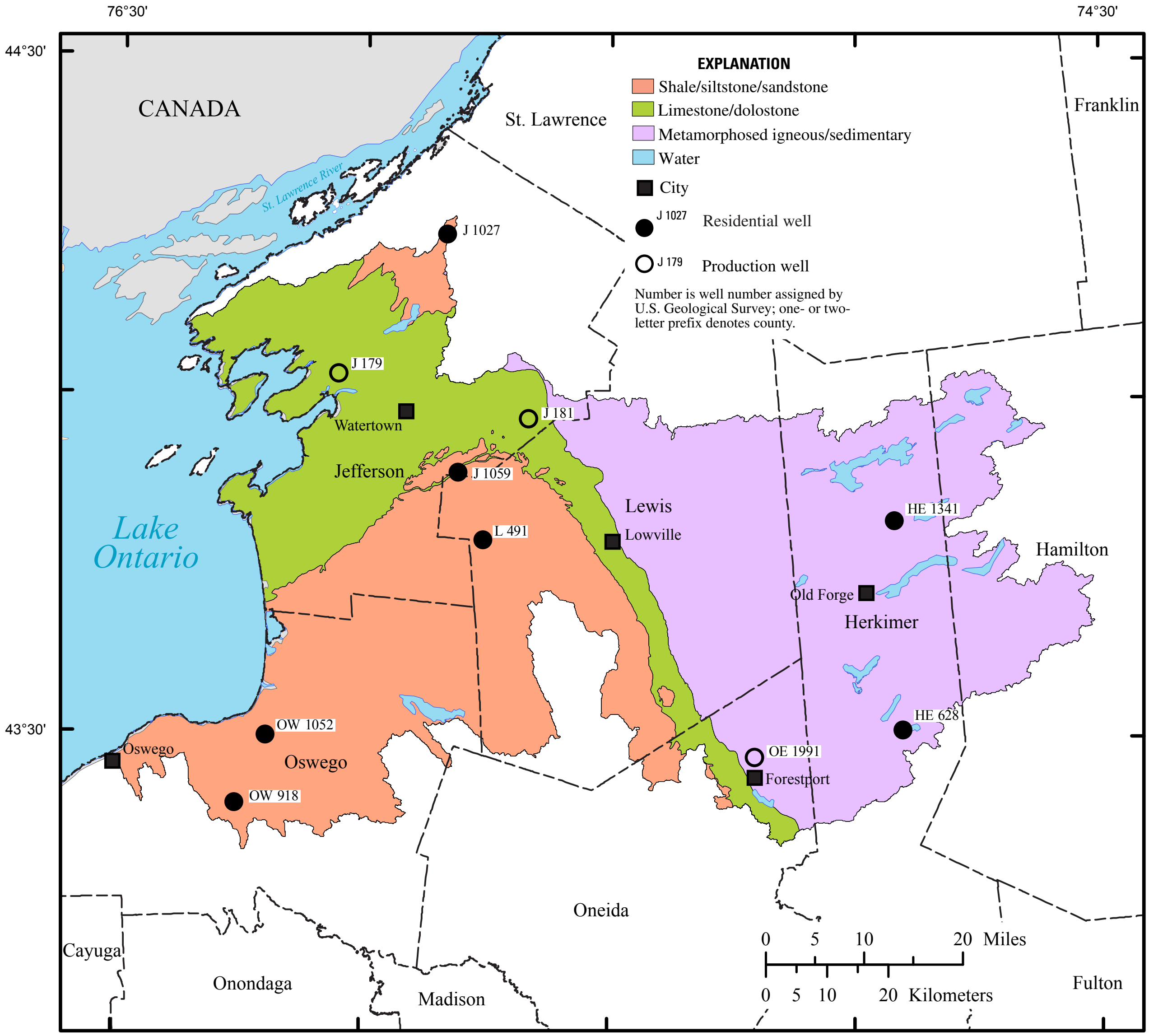
Figure 2. Land use in the Eastern Lake Ontario Basin of New York study area and locations of the 18 wells sampled in 2008. (Well data are given in table A1, at end of report.)



Base from U.S. Geological Survey, Seamless Data Distribution System,
accessed in 2009 at http://seamless.usgs.gov
Universal Transverse Mercator projection, Zone 18

Surficial Geology from New York State Museum, 1:250,000

Figure 3. Surficial geology of the Eastern Lake Ontario Basin of New York study area and locations of the eight wells screened in sand and gravel aquifers that were sampled in 2008. (Well data are given in table A1, at end of report.)



Base from U.S. Geological Survey, Seamless Data Distribution System,
accessed in 2009 at http://seamless.usgs.gov
Universal Transverse Mercator projection, Zone 18

Bedrock Geology from New York State Museum, 1:250,000

Figure 4. Generalized bedrock geology of the Eastern Lake Ontario Basin of New York study area and locations of the 10 wells completed in bedrock that were sampled in 2008. (Well data are given in table A1, at end of report.)

field blanks and one replicate sample—were collected for quality assurance and quality control, as required for the Federal 305(b) program.

The wells were identified through (1) the USGS Ground-Water Site Inventory (GWSI) database, (2) the NYSDEC Water-Well Reporting Program, or (3) information from State and County health departments. The Water-Well Reporting Program was implemented in 2000 to collect information on well construction, geology, and yield for newly drilled wells throughout New York from licensed well drillers; the resulting database provides useful information for groundwater studies. A letter requesting permission to sample the water was sent to owners of residential wells that were identified as potential sampling sites; the letter described the project and included a questionnaire asking the location of the well, the most convenient times for sampling, any safety concerns around the well, and other information. Production wells were identified through the NYSDOH and by local water managers of villages and cities throughout the study area. The water managers were sent a project description and a questionnaire similar to those sent to residential well owners. Well owners who responded favorably were contacted by telephone to clarify information about the wells and to arrange sampling dates.

Sampling Methods

Sampling was done at all sites as follows: the well pump was turned on (many of the production wells were pumped for at least 1 hour prior to sampling) and the well was purged by running to waste for at least 20 minutes, or until at least one well-casing volume of water had passed the sampling point. Domestic wells that had been used recently required removal of less than three well-casing volumes (U.S. Geological Survey, 2006). A raw-water tap between the well and the pressure tank was opened, and the water was allowed to flush for several minutes. During this time, a visual evaluation of the area surrounding the well was conducted to identify potential sources of contamination that could affect the well water. Samples were collected from the raw-water tap to avoid all water-treatment systems and to ensure that the water collected was representative of the aquifer. The raw-water samples were collected prior to any disinfection treatments. A Teflon discharge line was then connected to the tap, and samples were analyzed with a multiprobe meter for physical properties (temperature, specific conductance, dissolved-oxygen concentration, and pH). After the measurements of these properties had stabilized, a second Teflon discharge line with a stainless-steel quick-connect fitting was connected to the first Teflon discharge line and was directed into a sample-collection chamber mounted on a plastic box; this chamber was used to minimize sample exposure to dust and other potential sources of contamination. Bottles were filled in the chamber according to standard USGS field methods (U.S. Geological Survey, 2006).

The analyses for physical properties, most trace elements and metals, acid-neutralizing capacity, organic carbon, radon-222, VOCs, and phenols were done on unfiltered water samples to obtain total whole-water concentrations. Dissolved concentrations of nutrients, major inorganic constituents, three metals, and pesticides were obtained from filtered samples. Concentrations of iron and manganese in unfiltered samples were compared with those in filtered samples to obtain the difference between the total and dissolved concentrations (table A6). Sulfuric acid was added to the samples collected for phenol analysis, hydrochloric acid was added to samples collected for total organic carbon and VOC analyses, and nitric acid was added to some of the samples collected for trace-element analyses to prevent sample degradation. Samples collected for dissolved inorganic-compound analyses were filtered through a 0.45-micrometer (µm) cellulose capsule filter that was attached to the Teflon discharge line inside the sample-collection chamber; samples for pesticide analysis were filtered through a 0.7-µm furnace-baked glass-fiber plate filter by the methods of Wilde and others (2004).

All Teflon discharge lines were cleaned in the laboratory before each sampling day and in the field between each sample collection. New sample-chamber bags were used at each sampling site. Samples for radon analysis were obtained through an in-line septum chamber with a disposable syringe to avoid atmospheric contamination. Samples for bacterial analysis were collected in sterile containers provided by the bacteriological laboratory; the connection of the sampling tube to the well tap was not sterilized. The samples were stored on ice in coolers and delivered directly, or shipped by overnight delivery to laboratories for analysis.

Analytical Methods

Samples were analyzed for 223 physical properties and constituents, including inorganic constituents, nutrients, trace elements, radionuclides, pesticides and pesticide degradates, VOCs, and bacteria. Physical properties such as water temperature, pH, dissolved oxygen concentration, and specific conductance were measured at the sampling site. Inorganic constituents, nutrients, trace elements, radon-222, pesticides and pesticide degradates, and VOCs were analyzed at the USGS NWQL in Denver, Colo.; additional pesticide and pesticide degradates were analyzed at the USGS OGRL in Lawrence, Kans. Total organic carbon and phenolic compounds were analyzed at a private laboratory in Melville, N.Y., and indicator bacteria were analyzed at a private laboratory in Watertown, N.Y.; both laboratories are certified by NYSDOH.

Anion concentrations were measured by ion-exchange chromatography, and cation concentrations were measured by inductively coupled plasma-atomic emission spectrometry (ICP-AES), as described in Fishman (1993). Nutrients were analyzed by colorimetry, as described by Fishman (1993), and Kjeldahl digestion with photometric finish, as described by Patton and Truitt (2000). Mercury concentrations were measured through cold vapor–atomic fluorescence spectrometry according to methods described by Garbarino and Damrau (2001). Arsenic, chromium, and nickel analyses used collision/reaction cell inductively coupled plasma-mass spectrometry (cICPMS) as described by Garbarino and others (2006). The remaining trace elements were analyzed by ICP-AES (Struzeski and others, 1996), inductively coupled plasma-optical emission spectrometry (ICP-OES), and inductively coupled plasma-mass spectrometry (ICP-MS) (Garbarino and Struzeski, 1998). In-bottle digestions for trace-element analyses described by Hoffman and others (1996) were followed. Radon-222 was measured through liquid-scintillation counting (ASTM International, 2006).

Samples for pesticide analyses were processed as described by Wilde and others (2004). Pesticides and pesticide-degradates were analyzed at the NWQL through gas chromatography-mass spectrometry (GC-MS) and high-performance liquid chromatography-mass spectrometry (HPLC-MS), as described by Zaugg and others (1995), Furlong and others (2001), and Sandstrom and others (2001). Acetamide pesticide parent compounds and degradation-product analyses were done by liquid chromatography-mass spectrometry (LC-MS) at the USGS OGRL according to methods described by Lee and Strahan (2003). VOCs were analyzed by GC-MS by using methods described by Connor and others (1998).

Concentrations of total organic carbon were measured by method SW-846 9060 (U.S. Environmental Protection Agency, 2004), and total phenolic compounds were analyzed by U.S. Environmental Protection Agency (USEPA) method 420.2 (U.S. Environmental Protection Agency, 1983). Indicator bacteria samples were tested for total coliform, fecal coliform, and *Escherichia coli* (*E. coli*) through Standard Method 9222 (American Public Health Association, 2005). A heterotrophic plate count test (SM 9215 B) also was done.

In addition to the 18 groundwater samples, one blank sample and two sequential replicate samples were collected for quality assurance. Nitrogen-purged VOC/pesticide-grade blank water and inorganic-grade blank water supplied by the USGS-NWQL were used for a laboratory equipment blank before environmental-sample collection began. The water for unfiltered constituents was run through a piece of the Teflon tubing used for sampling; water for filtered-water constituents was pumped through the Teflon tubing into cleaned, preconditioned filters. Samples were acidified in the same manner as environmental well-water samples. The only constituent that exceeded laboratory reporting levels (LRLs) in the blank was sample color, which was measured at 2 platinum-cobalt units. The differences from the sequential replicate samples were less than 5 percent for all constituent detections more than the LRL in the replicate samples except for color, zinc, and heterotrophic plate count, which were detected in one replicate sample at levels close to the LRL, where small differences in concentration make large relative percent-concentration differences.

Groundwater Quality

The 18 samples were analyzed for 223 constituents and physical properties. More than half (158) of these were not detected above the LRLs in any sample (appendix table A2). Results for the remaining 65 constituents and properties that were detected are in the appendix. The categories are as follows: physical properties (table A3), inorganic constituents (table A4), nutrients and total organic carbon (table A5), trace elements and radon-222 (table A6), pesticides (table A7), VOCs (table A8), and bacterial water-quality indicators (table A9). Some concentrations were reported as “estimated.” Estimated concentrations are typically reported where the detected value is less than the established LRL, or when recovery of a compound has been shown to be highly variable (Childress and others, 1999). Analytical results for selected constituents were compared with Federal and New York State drinking-water standards, which are typically identical. The standards include Maximum Contaminant Levels (MCLs), Secondary Maximum Contaminant Levels (SMCLs), and Health Advisories (HAs) established by the USEPA (U.S. Environmental Protection Agency, 2002; 2004; 2006) and the NYSDOH (New York State Department of Health, 2007b). MCLs are enforceable standards that specify the highest level of a contaminant that is allowed in public drinking water supplies; MCLs are not enforceable for private homeowner wells but are presented here as a guideline for evaluation of the water results. SMCLs are nonenforceable guidelines based on cosmetic and aesthetic criteria, such as taste and odor. HAs are estimates of acceptable drinking water levels for contaminants that can affect human health; HAs are nonenforceable guidelines that provide technical guidance for water use.

The quality of the sampled groundwater was generally acceptable, although at 10 wells the concentrations of some constituents exceeded recommended MCLs, SMCLs, or HAs set by the USEPA (U.S. Environmental Protection Agency, 2006) and the NYSDOH (New York State Department of Health, 2007b). Most of the wells tested exceeded the USEPA proposed MCL for radon-222, which is generated from the natural decay of uranium. Other MCL exceedances generally involve taste or odor and included excessive hardness, aluminum, chloride, iron, manganese, and sodium. These water-quality problems typically develop from natural interactions of water and rock minerals in the subsurface.

Physical Properties

The temperature of the water ranged from 8.6º Celsius (C) to 16.6ºC; the median was 10.6ºC for sand and gravel wells and 12.2ºC for bedrock wells. The pH of the samples (table A3) ranged from 6.5 to 9.1; the median was pH 7.0 for sand and gravel wells and pH 7.8 for bedrock wells. One bedrock well had a pH of 9.1 that is outside the accepted USEPA SMCL range of pH 6.5 to 8.5 (U.S. Environmental

Protection Agency, 2006). Specific conductance of the samples ranged from 49 to 1,760 microsiemens per centimeter (µS/cm); the median was 156 µS/cm for sand and gravel wells and 576 µS/cm for bedrock wells. Dissolved-oxygen concentrations ranged from less than 0.4 mg/L to 9.5 milligrams per liter (mg/L): the median was 3.8 mg/L for sand and gravel wells and 0.7 mg/L for bedrock wells. The color of the samples range from less than 1 platinum-cobalt (Pt-Co) unit to 15 Pt-Co units. The median was 2 Pt-Co units for sand and gravel wells and 5 Pt-Co units for bedrock wells. Two samples (one sand and gravel and one bedrock) had a water color that equaled the USEPA SMCL and the NYSDOH MCL of 15 Pt-Co units. The odor of hydrogen sulfide gas, which may occur in the absence of oxygen, was noted by field personnel in water from 3 bedrock wells.

Major Ions

The cations that were detected in the highest concentrations were calcium, magnesium, and sodium (tables 2 and A4). Calcium concentrations ranged from 1.59 to 99.2 mg/L, and magnesium concentrations ranged from 0.31 to 70.6 mg/L; calcium and magnesium contribute to water hardness. Sodium concentrations ranged from 1.30 to 223 mg/L, and five samples exceeded the USEPA HA, which recommends that sodium concentrations in drinking water not exceed 60 mg/L. This HA for sodium is not federally enforceable but is intended as a guideline for consumers (U.S. Environmental Protection Agency, 2002; 2006).

The anions that were detected in the highest concentrations were bicarbonate (alkalinity), chloride, and sulfate (tables 2 and A4). Bicarbonate concentrations ranged from 20 to 368 mg/L (as $CaCO_3$). Chloride concentrations ranged from 0.45 to 368 mg/L, and the USEPA SMCL and the NYSDOH MCL of 250 mg/L for chloride was exceeded in one bedrock well sample. Sulfate concentrations ranged from 1.01 mg/L to 53.6 mg/L.

Water hardness in the basin ranged from 5 to 510 mg/L as $CaCO_3$, and the median hardness was 90 mg/L as $CaCO_3$. Many of the samples (12 out of 18) were soft to moderately hard (less than 120 mg/L as $CaCO_3$); and 6 wells yielded water that was very hard (greater than 180 mg/L as $CaCO_3$) (Hem, 1985). Wells finished in bedrock were generally more hard (median 103 mg/L as $CaCO_3$) than those finished in sand and gravel (median 71 mg/L as $CaCO_3$).

Table 2. Summary statistics for concentrations of major ions in sand and gravel aquifers and bedrock aquifers in the Eastern Lake Ontario Basin of New York, 2008.

[Concentrations are in milligrams per liter. All samples represent filtered water; --, not applicable; E, estimated]

Constituent	Drinking water standard	Number of samples exceeding standard	Sand and gravel (8 samples)			Bedrock (10 samples)		
			Minimum	Median	Maximum	Minimum	Median	Maximum
Cations								
Calcium	--	--	5.24	24.1	99.2	1.59	25.1	97.3
Magnesium	--	--	1.24	3.47	9.16	0.31	7.73	70.6
Potassium	--	--	0.23	0.74	1.66	0.85	2.24	6.67
Sodium	[a]60	5	1.30	2.42	30.5	2.98	69	223
Anions								
Bicarbonate	--	--	20	84	343	39	248	368
Chloride	[b]250	1	0.73	1.98	35	0.45	81.8	368
Fluoride	[c]2.0–[b]2.2	0	<0.08	E0.09	0.28	0.16	0.54	1.65
Sulfate	[b,c]250	0	3.23	5.89	14.6	1.01	14.35	53.6
Hardness, mg/L as $CaCO_3$			18	71	270	5	103	510
Alkalinity, mg/L as $CaCO_3$			16	68.5	281	32	203	302
Residue on evaporation, mg/L			45	92	374	51	326	935

[a] US Environmental Protection Agency (USEPA) Drinking Water Advisory Taste Threshold.

[b] New York State Department of Health (NYSDOH) Maximum Contaminant Level.

[c] USEPA Secondary Maximum Contaminant Level.

Nutrients and Organic Carbon

Nitrate and ammonia were the predominant nutrients present in the groundwater samples (tables 3 and A5); nitrite and organic nitrogen concentrations were negligible in most samples. Nitrate plus nitrite concentrations ranged from less than 0.04 (the LRL) to 8.31 mg/L as nitrogen (N); the median concentration was 0.42 mg/L in samples from sand and gravel wells and less than 0.04 mg/L in samples from bedrock wells. The nitrate MCL of 10 mg/L (as N) was not exceeded in any sample, and the concentrations in 6 samples were less than the LRL. Nitrite was detected in only one sample at a concentration of 0.013 mg/L as N; the concentration of nitrite did not exceed the MCL (1 mg/L as N) in any sample. Ammonia concentrations ranged from less than 0.020 (the LRL) to 1.10 mg/L as N. Orthophosphate was detected in 14 samples, but concentrations were typically low; the maximum concentration was 0.067 mg/L as phosphorus (P). Total organic carbon was detected in 11 samples; concentrations ranged from less than 1.0 mg/L (the LRL) to 3.2 mg/L.

Trace Elements and Radon-222

The elements detected in the highest concentrations were aluminum, barium, boron, iron, lithium, manganese, and strontium. Aluminum, barium, boron, lithium, and strontium were generally present at higher concentrations in bedrock wells compared to sand and gravel wells (tables 4 and A6). Aluminum concentrations ranged from the LRL of less than 4 micrograms per liter (µg/L) to 234 µg/L; the USEPA SMCL (50 µg/L) was exceeded in samples from two bedrock wells. Barium concentrations ranged from an estimate of the LRL of less than 0.6 µg/L to 250 µg/L. Boron concentrations ranged from 3.4 to 628 µg/L. Iron concentrations in filtered samples ranged from the LRL of less than 4 µg/L to 902 µg/L; the USEPA SMCL and the NYSDOH MCL for iron (300 µg/L) was exceeded in 4 filtered samples. Lithium concentrations ranged from an estimate of 0.5 µg/L to 311 µg/L. Manganese concentrations in filtered samples ranged from the LRL of less than 0.2 µg/L to 1,480 µg/L; the USEPA SMCL for manganese (50 µg/L) was exceeded in 3 filtered samples, and the NYSDOH MCL (300 µg/L) was exceeded in one filtered sample. Boron, lithium, molybdenum, strontium, and thallium were detected but no MCLs have been established for these elements.

Some trace elements were detected less frequently or at lower concentrations. Drinking-water standards for antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, selenium, thallium, uranium, and zinc were not exceeded; additionally mercury and silver were not detected in any sample (table A2). Cobalt and nickel were detected but no MCLs have been established for cobalt and nickel.

Radon-222 was detected in every sample (table A6), and activity ranged from 62 to 3,150 pCi/L. The median activity was 565 pCi/L in samples from sand and gravel wells and 266 pCi/L in samples from bedrock wells. The proposed MCL of 300 pCi/L for radon-222 in drinking water was exceeded in 13 samples, but the proposed Alternate Maximum Contaminant Level (ACML) of 4,000 pCi/L was not exceeded. The AMCL is the proposed allowable activity of radon in raw-water samples where the State has implemented mitigation programs to address the health risks of radon in indoor air. The proposed MCL and AMCL for radon are under review and have not been adopted (U.S. Environmental Protection Agency, 2004; 2006).

Table 3. Summary statistics for concentrations of major ions in sand and gravel aquifers and bedrock aquifers in the Eastern Lake Ontario Basin of New York, 2008.

[Concentrations are in milligrams per liter. All samples represent filtered water; --, not applicable; E, estimated]

Constituent	Drinking water standard	Number of samples exceeding standard	Sand and gravel (8 samples)			Bedrock (10 samples)		
			Minimum	Median	Maximum	Minimum	Median	Maximum
Ammonia plus organic N, mg/L as N	--	--	<0.10	<0.14	0.11	<0.10	0.15	1.80
Ammonia, mg/L as N	--	--	<0.020	<0.020	0.102	<0.020	0.068	1.10
Nitrate plus nitrite, mg/L as N	[a,b]10	0	E0.03	0.42	8.31	<0.04	<0.04	0.60
Nitrite, mg/L as N	[a,b]1	0	<0.002	<0.002	<0.002	<0.002	<0.002	0.013
Orthophosphate, mg/L as P	--	--	E0.005	<0.006	0.015	<0.006	0.009	0.067
Total organic carbon, unfiltered, mg/L	--	--	<1.0	1.0	1.8	<1.0	1.2	3.2

[a] US Environmental Protection Agency (USEPA) Drinking Water Advisory Taste Threshold.

[b] New York State Department of Health (NYSDOH) Maximum Contaminant Level.

Table 4. Summary statistics for concentrations of trace elements and radon-222 in sand and gravel aquifers and bedrock aquifers in the Eastern Lake Ontario Basin of New York, 2008.

[All concentrations are in micrograms per liter except as noted. All samples unfiltered except as noted. pCi/L, picocuries per liter; --, not applicable; E, estimated; <, less than; M, measured but not quantified]

Constituent	Drinking water standard	Number of samples exceeding standard	Sand and gravel (8 samples)			Bedrock (10 samples)		
			Minimum	Median	Maximum	Minimum	Median	Maximum
Aluminum	[c]50	2	<4	<5	9	<4	7	234
Antimony	[a,b]6	0	<0.1	<0.2	<0.4	<0.1	<0.1	E 0.1
Arsenic	[a]10	0	<0.20	<0.60	1.8	<0.60	<0.60	4.8
Barium	[a,b]2,000	0	1.1	8.0	45.7	<0.6	84.4	250
Beryllium	[a,b]4	0	<0.02	<0.03	<0.04	<0.02	<0.04	<0.04
Boron, filtered	--	--	3.4	6.3	19	3.9	50	628
Cadmium	[a,b]5	0	<0.01	<0.04	E 0.01	<0.01	<0.01	0.01
Chromium	[a,b]100	0	<0.40	<0.40	E 0.40	<0.40	<0.40	2.2
Cobalt	--	--	<0.04	E 0.07	E 0.08	<0.04	<0.04	0.60
Copper	[c]1,000	0	<4.0	<4.0	27.0	<1.2	2.9	12.5
Iron, filtered	[b,c]300	4	<4	<8	902	<8	<8	808
Iron	[b,c]300	5	<6	12	1,580	E 5	77	955
Lead	[d]15	0	0.09	0.56	5.15	E 0.03	0.26	1.27
Lithium	--	--	E 0.5	0.9	2.4	2.1	22	311
Manganese, filtered	[c]50–[b]300	3 - 1	<0.2	0.6	1,480	<0.4	6.8	68.9
Manganese	[c]50–[b]300	3 - 1	<0.4	<0.8	1,160	<0.4	11.3	79.7
Molybdenum	--	--	E 0.1	0.1	0.3	M	0.7	2.2
Nickel	--	--	<0.12	0.30	1.3	0.21	0.40	1.9
Selenium	[a,b]50	0	<0.08	<0.08	E 0.08	<0.08	<0.08	0.14
Silver	[a,b]100	0	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Strontium	--	--	21.6	44	169	22.2	859	5,070
Thallium	--	--	<0.08	<0.10	<0.12	<0.08	<0.08	E 0.04
Zinc	[b,c]5,000	0	<2.0	4.5	75.9	<2.0	3.2	7.2
Radon-222, pCi/L	[e]300	13	410	565	1,290	62	266	3,150
Uranium	[a]30	0	<0.020	0.131	0.231	<0.020	0.320	1.35

[a] US Environmental Protection Agency (USEPA) Maximum Contaminant Level.

[b] New York State Department of Health (NYSDOH) Maximum Contaminant Level.

[c] USEPA Secondary Maximum Contaminant Level.

[d] USEPA Treatment Technique.

[e] USEPA Proposed Maximum Contaminant Level.

Pesticides

Five pesticides and related compounds (including three pesticide degradates) were detected in water from six wells (table A7), but none of the concentrations exceeded MCLs. Four of the samples containing pesticides were from sand and gravel aquifers, and two were from bedrock aquifers. Caffeine, which is not a pesticide, is measured as part of the pesticide analyses and can be an indicator of human wastes, and was detected in one sample (table A7). The pesticide compound that was detected most frequently was CIAT (2-chloro-4-isopropylamino-6-amino-*s*-triazine, also called deethylatrazine) and was detected in four samples at estimated concentrations ranging from E0.002 to E0.003 µg/L. CIAT is a degradation product of the herbicide atrazine. The maximum concentration of any pesticide related product was 0.03 µg/L (metolachlor ESA, a degradation product of the herbicide metolachlor). Three pesticides and degradates were detected once: Metolachlor OA (a degradation product of metolachlor) (0.02 µg/L), *cis*-permethrin (estimate 0.001µg/L), and prometon (0.01 µg/L). No Federal MCLs currently (2010) have been established for pesticide degradation products, and no pesticide concentration exceeded USEPA or NYSDOH MCLs. These trace-level detections of pesticides are similar to those reported by Phillips and others (1999), Eckhardt and Stackelberg (1995), and Eckhardt and others (2001) from studies of pesticides in groundwater throughout New York State.

Volatile Organic Compounds and Phenolic Compounds

Six VOCs were detected in nine samples, three were from sand and gravel wells and six were from bedrock wells (table A8). Toluene was detected in one production well (J1118) and 5 residential wells: the maximum concentration was 0.3 µg/L. Benzene was detected in one residential bedrock well; the concentration was 0.2 µg/L. Xylene compounds were detected in one residential bedrock well; the concentration was estimated at 0.2 µg/L for the *meta* plus *para* isomers. Trichloromethane (chloroform) was detected in two production wells (J180 and J179) and two residential wells; the maximum concentration was 1.2 µg/L. Bromodichloromethane was detected in one residential bedrock well at 0.1 µg/L. These two compounds are called trihalomethanes and are typically formed as by-products when chlorine or bromine is used to disinfect water. The NYSDOH MCL of 80 µg/L for total trihalomethanes was not exceeded, however the MCL goal of zero for chloroform and bromodichloromethane was exceeded in four wells. Tetrachloromethane was detected in one residential bedrock well; the concentration was 0.3 µg/L. Phenolic compounds, which are semivolatile, were not detected in any sample (table A2). Methyl *tert*-butyl ether (MTBE), a gasoline additive that can infiltrate into groundwater from leaking fuel tanks, was not detected in any sample (table A2).

Bacteria

All samples were analyzed for total coliform, fecal coliform, *E. coli*, and heterotrophic bacteria. Total coliform was detected in three samples; fecal coliform and *E. coli* were not detected (table A9). Coliform bacteria were detected in one sample from a sand and gravel well and in two samples from bedrock wells; two of the samples were from private residential wells, and one was from a production well (OW 1599, fig. 1), which taps a sand and gravel aquifer. The NYSDOH and USEPA MCL for total coliform bacteria is exceeded when 5 percent of samples of finished water collected in 1 month test positive for total coliform (if 40 or more samples are collected per month) or when 2 samples are positive for total coliform (if fewer than 40 samples are collected per month). Heterotrophic plate counts (HPCs) ranged from less than 1 (absent) to 740 colony-forming units per milliliter (CFU/mL). The USEPA MCL for HPC is 500 CFU/mL, and 1 sample for a residential bedrock well exceeded this limit.

Summary

The USGS, in cooperation with the NYSDEC and the USEPA, began an assessment of groundwater quality in bedrock and sand and gravel aquifers throughout New York State in 2001. As a part of this assessment, water samples were collected at nine production wells and nine private residential wells in the Eastern Lake Ontario tributary basins from August through October 2008. Water samples were analyzed for 223 physical properties and constituents that included inorganic major ions, nutrients, organic carbon, trace elements, radon-222, pesticides, VOCs, phenolic compounds, and bacteria. The quality of the sampled groundwater was generally acceptable, although at 10 wells the concentrations of at least 1 constituent exceeded recommended MCLs, SMCLs, or HAs set by the USEPA and the NYSDOH. Of the 59 chemical constituents that were detected, 5 inorganic elements or ions exceeded Federal and State MCLs, SMCLs, or HAs at 8 wells; 2 types of bacteria were detected in concentrations that exceeded MCLs at 4 wells; color exceeded the USEPA SMCL and the NYSDOH MCL at 2 wells, and 1 well had a pH outside the accepted USEPA SMCL range. In addition, 2 organic chemicals detected had associated State reporting requirements at 2 wells, and the radioactive isotope radon-222 was detected at concentrations that exceed an USEPA proposed MCL at 13 wells.

The cations that were detected in the highest concentrations were calcium, magnesium, and sodium; the anions that were detected in the highest concentrations were bicarbonate, chloride, and sulfate. The predominant nutrients were nitrate and ammonia; no sample exceeded the MCL (10 mg/L as N) for nitrate. The Health Advisory for sodium in drinking water (60 mg/L) was exceeded in 5 of the 18 samples; and the Federal SMCL and State MCL for chloride (250 mg/L) was exceeded in 1 sample. Two samples had a water color that equaled the Federal SMCL and the State MCL (15 platinum-cobalt units).

The trace elements detected in the highest concentrations were aluminum, barium, boron, iron, lithium, manganese, and strontium; for all trace elements, only aluminum, iron, and manganese concentrations exceeded SMCLs. Aluminum was detected in 8 samples, and the SMCL (50 µg/L) was exceeded twice. Iron was detected in 10 of the 18 filtered samples, and the Federal SMCL and State MCL for iron (300 µg/L) was exceeded in 4 samples. Manganese was detected in 13 filtered samples; the USEPA SMCL (50 µg/L) was exceeded in 3 filtered samples and the State MCL (300 µg/L) was exceeded in 1 filtered sample. Barium was detected in 17 samples, but the Federal and State MCL (2,000 µg/L) was not exceeded. Boron, lithium, and strontium were each detected in all 18 samples, but no MCLs have been established for these elements. Radon-222 was detected in every sample; the proposed Federal MCL for radon-222 in drinking water (300 pCi/L) was exceeded in 13 samples, but the proposed AMCL (4,000 pCi/L) was not exceeded in any sample.

Five pesticides or degradates, were detected in water from 6 of the 18 wells; most of the concentrations were at or near the detection limits, and no concentration exceeded an MCL. Four of the samples containing pesticides were from sand and gravel aquifers, and two were from bedrock aquifers. Six VOCs were detected in nine samples, and no concentration exceeded an MCL. Two production wells tested positive for compounds that triggered a New York State Sanitary Code reporting requirement, prometon (a pesticide) and toluene (a VOC). Any detection of total coliform or fecal coliform bacteria is considered a potential violation of New York State MCLs; in this study, total coliform was detected in three samples; *E. coli* and fecal coliform were not detected. Heterotrophic plate counts exceeded the MCL of 500 CFU/mL in 1 sample.

References Cited

American Public Health Association, 2005, Standard methods for the examination of water and wastewater (21st ed.): Washington, D.C., American Public Health Association, American Water Works Association, and Water Environment Federation [variously paged].

ASTM International, 2006, D5072–98(2006), Standard test method for radon in drinking water: ASTM International, at http://www.astm.org.

Broughton, J.G., Fisher, D.W., Isachsen, Y.W., Rickard, L.V., and Offield, T.W., 1962, The geology of New York State: Albany, New York State Museum—Geological Survey, Map and Chart Series no. 5, 5 sheets, scale 1:250,000.

Butch, G.K., Murray, P.M., Hebert, G.J., and Weigel, J.F., 2003, Water Resources Data, New York, Water Year 2002: U.S. Geological Survey Water-Data Report, NY–02–1, p. 502–520.

Cadwell, D.H., and Muller, E.H., 1986, Surficial geologic map of New York: Albany, New York State Museum—Geological Survey, Map and Chart Series no. 40, 5 sheets, scale 1:250,000, digital compilation by Beckie Ugolini, 1998, from New York State Geological Survey 90-meter Digital Elevation Model.

Childress, C.J.O., Foreman, W.T., Connor, B.F., and Maloney, T.J., 1999, New reporting procedures based on long-term method detection levels and some considerations for interpretations of water-quality data provided by the U.S. Geological Survey National Water Quality Laboratory: U.S. Geological Survey Open-File Report 99–193, 19 p.

Coates, D.R., 1966, Glaciated Appalachian Plateau—Till shadows on hills: Science, v. 152, p. 1,617–1,619.

Connor, B.F., Rose, D.L., Noriega, M.C., Murtagh, L.K., and Abney, S.R., 1998, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of 86 volatile organic compounds in water by gas chromatography/mass spectrometry, including detections less than reporting limits: U.S. Geological Survey Open-File Report 97–829, 78 p.

Crain, L.J., 1975, Chemical quality of groundwater in the western Oswego River Basin: New York State Department of Environmental Conservation, Basin Planning Report ORB–3, 69 p.

Eckhardt, D.A., Hetcher, K.K., Phillips, P.J., and Miller, T.S., 2001, Pesticides and their metabolites in community water-supply wells of central and western New York, August 1999: U.S. Geological Survey Water-Resources Investigations Report 00–4128, 12 p.

Eckhardt, D.A., Reddy, J.E., and Shaw, S.B., 2009, Groundwater quality in central New York, 2007: U.S. Geological Survey Open-File Report 2009–1257, 40 p., at http://pubs.usgs.gov/of/2009/1257/.

Eckhardt, D.A., Reddy, J.E., and Tamulonis, K.L., 2007, Ground-water quality in the Genesee River Basin, New York, 2005–06: U.S. Geological Survey Open-File Report 2007–1093, 26 p., at http://pubs.usgs.gov/of/2007/1093/.

Eckhardt, D.A., Reddy, J.E., and Tamulonis, K.L., 2008, Ground-water quality in western New York, 2006: U.S. Geological Survey Open-File Report 2008–1140, 36 p., at http://pubs.usgs.gov/of/2008/1140/.

Eckhardt, D.A. and Stackelberg, P.E., 1995, Relation of ground-water quality to land use of Long Island, New York: Ground Water, v. 33, no. 6, p. 1,019–1,033.

Fairchild, H.L., 1928, Geologic story of the Genesee Valley and drainage history of central New York: Rochester, Gas and Electric News, July 1926 to July 1928.

Fishman, M.J., ed., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of inorganic and organic constituents in water and fluvial sediments: U.S. Geological Survey Open-File Report 93–125, 217 p.

Furlong, E.T., Anderson, B.D., Werner, S.L., Soliven, P.P., Coffey, L.J., and Burkhardt, M.R., 2001, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of pesticides in water by graphitized carbon-based solid-phase extraction and high-performance liquid chromatography/mass spectrometry: U.S. Geological Survey Water-Resources Investigations Report 01–4134, 73 p.

Garbarino, J.R., and Damrau, D.L., 2001, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of organic plus inorganic mercury in filtered and unfiltered natural water with cold vapor—Atomic fluorescence spectrometry: U.S. Geological Survey Water-Resources Investigation Report 01–4132, 16 p.

Garbarino, J.R., Kanagy, L.K., and Cree, M.E., 2006, Determination of elements in natural-water, biota, sediment and soil samples using collision/reaction cell inductively coupled plasma-mass spectrometry: U.S. Geological Survey Techniques and Methods, book 5, sec. B, chap.1, 88 p.

Garbarino, J.R., and Struzeski, T.M., 1998, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of elements in whole-water digests using inductively coupled plasma-optical emission spectrometry and inductively coupled plasma-mass spectrometry: U.S. Geological Survey Open-File Report 98–165, 101 p.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water Supply Paper 2254, 264 p.

Hetcher-Aguila, K.K., 2005, Ground-water quality in the Chemung River Basin, New York, 2003: U.S. Geological Survey Open-File Report 04–1329, 19 p., at http://ny.water.usgs.gov/pubs/of/of041329/.

Hetcher-Aguila, K.K. and Eckhardt, D.A., 2006, Ground-water quality in the upper Susquehanna River basin, New York, 2004–05: U.S. Geological Survey Open-File Report 06–1161, 20 p., at http://pubs.usgs.gov/of/2006/1161/.

Hoffman, G.L., Fishman, M.J., and Garbarino, J.R., 1996, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—In-bottle acid digestion of whole-water samples: U.S. Geological Survey Open-File Report 96–225, 28 p.

Isachsen, Y.W., Landing, Ed, Lauber, J.M., Rickard, L.V., and Rogers, W.B., 2000, Geology of New York—A simplified account (2nd ed.): Albany, N.Y., New York State Museum—Geological Survey, 294 p.

Kantrowitz, I.H., 1970, Chemical quality of ground water in the eastern Oswego River basin: New York State Department of Environmental Conservation, Basin Planning Report ORB–2, 129 p.

Kontis, A.L., Randall, A.D., and Mazzaferro, D.L., 2004, Regional hydrology and simulation of flow of stratified-drift aquifers in the glaciated northeastern United States: U.S. Geological Survey Professional Paper 1415–C. 156 p.

Lee, E.A. and Strahan, A.P., 2003, Determination of acetamide herbicides and their degradation products in water using online solid-phase extraction and liquid chromatography/mass spectrometry: U.S. Geological Survey Open-File Report 03–173, 17 p.

Miller, T.S., 1982, Geology and ground-water resources of Oswego County, New York: U.S. Geological Survey Water-Resources Investigations Report 81–60, 37 p.

Miller, T.S., 1988, Unconsolidated aquifers in upstate New York – Finger Lakes sheet: U.S. Geological Survey Water-Resources Investigations Report 87–4122, 1 sheet, scale 1:250,000.

Miller, T.S., 1990, Sand and gravel aquifers of Schuyler County, New York: U.S. Geological Survey Water-Resources Investigations Report 90–4073, 1 sheet, scale 1:48,000.

Miller, T.S., Sherwood, D.A., and Krebs, M.M., 1989, Hydrogeology and water quality of the Tug Hill Glacial Aquifer in northern New York: U. S. Geological Survey Water-Resources Investigations Report 88–4014, 60 p.

New York State Department of Health, 2007a, Public water systems – Codes, rules, and regulations: Troy, N.Y., Bureau of Public Water Supply Protection, accessed October 2007, at http://www.health.state.ny.us/environmental/water/drinking/part5/subpart5.htm.

New York State Department of Health, 2007b, Public water systems—Maximum Contaminant Levels: Troy, N.Y., Bureau of Public Water Supply Protection, accessed January 2009, at http://www.health.state.ny.us/nysdoh/water/part5/tables.htm.

Nystrom, E.A., 2006, Ground-water quality in the Lake Champlain basin, New York, 2004: U.S. Geological Survey Open-File Report 06–1088, 22 p., at http://pubs.usgs.gov/of/2006/1088/.

Nystrom, E.A., 2007a, Ground-water quality in the St. Lawrence River basin, New York, 2005–2006: U.S. Geological Survey Open-File Report 2007–1066, 33 p., at http://pubs.usgs.gov/of/2007/1066/.

Nystrom, E.A., 2007b, Ground-water quality in the Delaware River basin, New York, 2001 and 2005–2006: U.S. Geological Survey Open-File Report 2007–1098, 36 p., at http://pubs.usgs.gov/of/2007/1098/.

Nystrom, E.A., 2008, Ground-water quality in the Mohawk River basin, New York, 2006: U.S. Geological Survey Open-File Report 2008–1086, 33 p., at http://pubs.usgs.gov/of/2008/1086/.

Nystrom, E.A., 2009, Ground-water quality in the Upper Hudson River basin, New York, 2007: U.S. Geological Survey Open-File Report 2009–1240, 37 p., at http://pubs.usgs.gov/of/2009/1240/.

Patton, C.J., and Truitt, E.P., 2000, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of ammonium plus organic nitrogen by a Kjeldahl digestion method and an automated photometric finish that includes digest cleanup by gas diffusion: U.S. Geological Survey Open-File Report 00–170, 31 p.

Phillips, P.J., Eckhardt, D.A., Terracciano, S.A., and Rosenmann, L.R., 1999, Pesticides and their metabolites in wells of Suffolk County, New York, 1998: U.S. Geological Survey Water-Resources Investigations Report 99–4095, 12 p.

Randall, A.D., 2001, Hydrogeologic framework of stratified-drift aquifers in the glaciated Northeastern United States: U.S. Geological Survey Professional Paper 1415–B, 179 p.

Sandstrom, M.W., Stroppel, M.E., Foreman, W.T., and Schroeder, M.P., 2001, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of moderate-use pesticides and selected degradates in water by C-18 solid-phase extraction and gas chromatography/mass spectrometry: U.S. Geological Survey Water-Resources Investigations Report 01–4098, 70 p.

Struzeski, T.M., DeGiacomo, W.J., and Zayhowski, E.J., 1996, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of dissolved aluminum and boron in water by inductively coupled plasma-atomic emission spectrometry: U.S. Geological Survey Open-File Report 96–149, 17 p.

U.S. Department of Commerce, 2000, Redistricting Census 2000: Washington D.C., Bureau of the Census Geography Division, accessed January 2009, at http://www.census.gov/geo/www/index.html.

U.S. Environmental Protection Agency, 1983, Methods for chemical analysis of water and wastes: Washington, D.C., U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory Office of Research and Development, EPA 600/4–79-020, p. 420.2–1–5.

U.S. Environmental Protection Agency, 1997, Guidelines for preparation of the comprehensive state water quality assessments 305(b) reports and electronic updates: Washington, D.C., Office of Water, EPA 841–B–97–002A and EPA 841–B–97–002B, PL 95–217, 271 p.

U.S. Environmental Protection Agency, 2002, Drinking-water advisory—Consumer acceptability advice and health effects analysis on sodium: Washington, D.C., Office of Water, EPA 822–R–02–032, 34 p.

U.S. Environmental Protection Agency, 2004, Proposed radon in drinking water rule: Washington, D.C., Office of Water, accessed January 2009, at http://www.epa.gov/safewater/radon/proposal.html.

U.S. Environmental Protection Agency, 2006, Drinking water standards and health advisories: Washington, D.C., Office of Water, EPA 822–R–06–013, Oct. 2006, 12 p.

U.S. Geological Survey, [variously dated], National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chapters A1–A9, at http://pubs.water.usgs.gov/twri9A.

U.S. Geological Survey, 2006, Collection of water samples (ver. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A4, September, accessed March 4, 2010, at http://pubs.water.usgs.gov/twri9A4/.

Waller, R.M. and Ayer, G.R., 1975, Water resources of the Black River Basin, New York: U.S. Geological Survey in cooperation with New York State Department of Environmental Conservation . Basin Planning Report BRB–1, 205 p.

Wilde, F.D., Radtke, D.B., Gibs, Jacob, and Iwatsubo, R.T., eds., 2004, Processing of water samples: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A5 [variously paged].

Zarriello, P.J., 1993, Determination of the contributing area to six municipal groundwater supplies in the Tug Hill glacial aquifer of northern New York, with emphasis on the Lacona-Sandy Creek well field: U.S. Geological Survey Water-Resources Investigations Report 90–4145, 51 p.

Zaugg, S.D., Sandstrom, M.W., Smith, S.G., and Fehlberg, K.M., 1995, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of pesticides in water by C-18 solid-phase extraction and capillary-column gas chromatography with selective-ion monitoring: U.S. Geological Survey Open-File Report 95–181, 49 p.

Appendixes 1–9

Table A1. Information on wells sampled in Eastern Lake Ontario Basin, New York, 2008.

[Well locations are shown in figure 1. --, information not available]

Well number[1]	U.S. Geological Survey site identifier	Date sampled	Basin name[2]	Well type[3]	Well depth, feet below land surface	Casing depth, feet below land surface	Physiographic province
Sand and gravel wells							
HE 1367	434235074562201	8/27/2008	BR	R	88	87.5	Adirondack Upland
J 180	434840076014001	9/17/2008	MNO	P	20	15	Tug Hill Upland
J 1118	434239076032202	10/1/2008	MNO	P	30	22	Tug Hill Upland
L 177	435400075180001	9/24/2008	BR	P	33	28	Adirondack Upland
L 178	433700075220001	10/21/2008	BR	P	17	12	Adirondack Upland
L 179	432959075430801	10/22/2008	MNO	R	65	65	Tug Hill Upland
L 386	434400075282001	9/2/2008	BR	P	38	20	Lake Ontario Lowland
OW 1599	433027075591701	10/1/2008	MNO	P	56	46	Tug Hill Upland
Bedrock wells							
HE 628	433031074541401	9/3/2008	BR	R	285	170	Adirondack Upland
HE 1341	434904074552101	8/26/2008	BR	R	180	42	Adirondack Upland
J 179	440202076023201	9/10/2008	CPR	P	100	--	Lake Ontario Lowland
J 181	435800075400001	9/24/2008	BR	P	120	60	Lake Ontario Lowland
J 1027	441422075501801	9/9/2008	CPR	R	58	23	Lake Ontario Lowland
J 1059	435310075483801	9/10/2008	MNO	R	300	20	Tug Hill Upland
L 491	434713075452801	9/17/2008	BR	R	125	47	Tug Hill Upland
OE 1991	432652075121601	10/7/2008	BR	P	700	63	Adirondack Upland
OW 918	432346076152601	9/30/2008	MNO	R	70	32	Lake Ontario Lowland
OW 1052	432948076114501	9/23/2008	MNO	R	62	10	Lake Ontario Lowland

[1] Prefix denotes county: HE, Herkimer; J, Jefferson; L, Lewis; OE, Oneida; OW, Oswego; number is local well-identification number assigned by U.S. Geological Survey.

[2] BR, Black River; CPR, Chaumont River – Perch River; MNO, Mid-Northern Lake Ontario.

[3] P, Production well; R, Residential well.

Table A2. Compounds for which groundwater samples were analyzed but not detected.–

[USGS, U.S. Geological Survey]

USGS parameter code	Constituent	Laboratory reporting level[1], micrograms per liter
	Trace elements in unfiltered water	
71900	Mercury	0.010
01077	Silver, unfiltered	0.02–0.06
	Pesticides in filtered water	
04038	2-Chloro-6-ethylamino-4-amino-s-triazine (CEAT)	0.06–0.08
62850	2-[(2-Ethyl-6-methylphenyl)amino]-2-oxo-ESA	0.02
50355	2-Hydroxy-4-isopropylamino-6-ethylamino-s-triazine (OIET)	0.040–0.060
50470	2,4-D methyl ester	0.200–0.040
66496	2,4-D plus 2,4-D methyl ester	0.02
39732	2,4-D	0.02–0.06
38746	2,4-DB	0.02
82660	2,6-Diethylaniline	0.002–0.006
49308	3-Hydroxy carbofuran	0.040
49260	Acetochlor	0.006–0.02
61029	Acetochlor ethanesulfonic acid	0.02
61030	Acetochlor oxanilic acid	0.02
63782	Acetochlor second amide	0.02
62847	Acetochlor sulfynilacetic acid	0.02
49315	Acifluorfen	0.040
46342	Alachlor	0.005–0.006
50009	Alachlor ESA	0.02
62849	Alachlor ESA second amide	0.02
61031	Alachlor oxanilic acid	0.02
63781	Alachlor second amide	0.02
62848	Alachlor sulfynilacetic acid	0.02
49313	Aldicarb sulfone	0.08
49314	Aldicarb sulfoxide	0.060
49312	Aldicarb	0.12
34253	alpha-HCH	0.002–0.008
39632	Atrazine	0.007
82686	Azinphos-methyl	0.120
50299	Bendiocarb	0.04
82673	Benfluralin	0.004–0.014
50300	Benomyl	0.040–0.060
61693	Bensulfuron methyl	0.06
38711	Bentazon	0.04–0.06
04029	Bromacil	0.02–0.06
49311	Bromoxynil	0.12
04028	Butylate	0.002
49310	Carbaryl	0.04
49309	Carbofuran	0.020–0.040
61188	Chloramben methyl ester	0.10

Table A2. Compounds for which groundwater samples were analyzed but not detected.—Continued

[USGS, U.S. Geological Survey]

USGS parameter code	Constituent	Laboratory reporting level[1], micrograms per liter
	Pesticides in filtered water—Continued	
50306	Chlorimuron	0.080
38933	Chlorpyrifos	0.005–0.010
49305	Clopyralid	0.06
04041	Cyanazine	0.020–0.040
04031	Cycloate	0.02–0.04
49304	Dacthal monoacid	0.02–0.04
82682	DCPA	0.003–0.006
63778	Dechloroacetochlor	0.02
63777	Dechloroalachlor	0.02
63779	Dechlorodimethenamid	0.02
63780	Dechlorometolachlor	0.02
62170	Desulfinyl fipronil	0.012
39572	Diazinon	0.005
38442	Dicamba	0.04
49302	Dichlorprop	0.02–0.04
39381	Dieldrin	0.009
61951	Dimethenamid ethanesulfonic acid	0.02
62482	Dimethenamid oxanilic acid	0.02
61588	Dimethenamid	0.02
49301	Dinoseb	0.04
04033	Diphenamid	0.04
82677	Disulfoton	0.04
49300	Diuron	0.04
82668	EPTC	0.002
82663	Ethalfluralin	0.009
82672	Ethoprop	0.012–0.016
62169	Desulfinylfipronil amide	0.029
49297	Fenuron	0.04–0.06
62167	Fipronil sulfide	0.013
62168	Fipronil sulfone	0.024
62166	Fipronil	0.020–0.040
61952	Flufenacet ethanesulfonic acid	0.02
62483	Flufenacet oxanilic acid	0.02
62481	Flufenacet	0.02
61694	Flumetsulam	0.06
38811	Fluometuron	0.04
04095	Fonofos	0.010
63784	Hydroxyacetochlor	0.02
63783	Hydroxyalachlor	0.02
63785	Hydroxymetolachlor	0.02
64045	Hydroxydimethenamid	0.02

Table A2. Compounds for which groundwater samples were analyzed but not detected.—Continued

[USGS, U.S. Geological Survey]

USGS parameter code	Constituent	Laboratory reporting level[1], micrograms per liter
	Pesticides in filtered water—Continued	
50356	Imazaquin	0.04–0.06
50407	Imazethapyr	0.04–0.06
61695	Imidacloprid	0.060
39341	Lindane	0.006 – 0.014
38478	Linuron	0.02–0.04
39532	Malathion	0.016–0.020
38482	MCPA	0.04–0.06
38487	MCPB	0.06 – 0.20
50359	Metalaxyl	0.02 – 0.04
39415	Metalochlor	0.010–0.02
38501	Methiocarb	0.040
49296	Methomyl	0.120
82667	Methyl parathion	0.008
82630	Metribuzin	0.012–0.016
61697	Metsulfuron	0.14
82671	Molinate	0.002
61692	N-(4-Chlorophenyl)-N'-methylurea	0.06–0.12
82684	Napropamide	0.018
49294	Neburon	0.02
50364	Nicosulfuron	0.10
49293	Norflurazon	0.02–0.04
49292	Oryzalin	0.04
38866	Oxamyl	0.12
34653	p,p'-DDE	0.003
39542	Parathion	0.010–0.020
82669	Pebulate	0.004–0.016
82683	Pendimethalin	0.012
82664	Phorate	0.020–0.040
49291	Picloram	0.12
82676	Propyzamide	0.004
04024	Propachlor	0.006–0.02
62766	Propachlor ethanesulfonic acid	0.05
62767	Propachlor oxanilic acid	0.02
82679	Propanil	0.006–0.014
82685	Propargite	0.02–0.04
49236	Propham	0.040
50471	Propiconazole	0.04
38538	Propoxur	0.040–0.060
38548	Siduron	0.02–0.04
04035	Simazine	0.006–0.010
50337	Sulfometuron	0.060

Table A2. Compounds for which groundwater samples were analyzed but not detected.—Continued

[USGS, U.S. Geological Survey]

USGS parameter code	Constituent	Laboratory reporting level[1], micrograms per liter
	Pesticides in filtered water—Continued	
82670	Tebuthiuron	0.02
82665	Terbacil	0.018–0.040
82675	Terbufos	0.02
82681	Thiobencarb	0.010–0.016
82678	Triallate	0.006
49235	Triclopyr	0.08
82661	Trifluralin	0.006–0.012
	Volatile organic compounds, in unfiltered water	
34506	1,1,1-Trichloroethane	0.1
34496	1,1-Dichloroethane	0.1
34501	1,1-Dichloroethene	0.1
77652	1,1,2-Trichloro-1,2,2-trifluoroethane (CFC-113)	0.1
34536	1,2-Dichlorobenzene	0.1
32103	1,2-Dichloroethane	0.2
34541	1,2-Dichloropropane	0.1
34566	1,3-Dichlorobenzene	0.1
34571	1,4-Dichlorobenzene	0.1
34301	Chlorobenzene	0.1
77093	cis-1,2-Dichloroethene	0.1
32105	Dibromochloromethane	0.2
34668	Dichlorodifluoromethane	0.2
34423	Dichloromethane	0.2
81576	Diethyl ether	0.2
81577	Diisopropyl ether	0.2
34371	Ethylbenzene	0.1
78032	Methyl tert-butyl ether	0.2
50005	Methyl tert-pentyl ether	0.2
77135	o-Xylene	0.1
77128	Styrene	0.1
50004	tert-Butyl ethyl ether	0.1
34475	Tetrachloroethene	0.1
34546	trans-1,2-Dichloroethene	0.1
32104	Tribromomethane	0.2
39180	Trichloroethene	0.1
34488	Trichlorofluoromethane	0.2
39175	Vinyl Choride	0.2
32730	Total Phenolic Compounds	4.0

[1] Defined in “Conversion Factor” section.

Table A3. Physical properties of groundwater samples from Eastern Lake Ontario Basin, New York, 2008.

[Well locations are shown in figure 1. mg/L, milligrams per liter; <, less than; µS/cm, microsiemens per centimeter at 25° Celsius; (00080), National Water Information System (NWIS) parameter code; M, measured but not quantified. **Bold** values exceed one or more drinking-water standard]

Well number[1]	Water color, filtered, platinum cobalt units (00080)	Dissolved-oxygen concentration, field, mg/L (00300)	pH, field, standard units (00400)	Specific conductance, field, µS/cm (00095)	Water temperature, degrees Celsius (00010)	Hydrogen sulfide (71875)
Sand and gravel wells						
HE 1367	2	2.2	6.8	95	13.6	Absent
J 180	<1	4.0	7.1	647	11.0	Absent
J 1118	2	2.4	6.7	191	12.6	Absent
L 177	2	9.5	6.5	49	8.6	Absent
L 178	10	9.4	8.1	121	8.9	Absent
L 179	10	1.0	6.8	114	11.6	Absent
L 386	2	7.0	7.3	454	10.2	Absent
OW 1599	**15**	3.5	7.4	227	9.1	Absent
Bedrock wells						
HE 628	<1	4.3	8.3	77	11.8	Absent
HE 1341	<1	7.8	7.7	74	10.4	Absent
J 179	5	1.7	7.1	1,010	11.0	Absent
J 181	2	<.4	7.5	472	9.5	M
J 1027	8	<.4	7.1	457	16.5	M
J 1059	**15**	1.0	7.8	1,070	12.6	Absent
L 491	2	<.4	**9.1**	1,000	13.9	Absent
OE 1991	5	1.8	8.5	505	8.6	Absent
OW 918	10	<.4	7.4	1,760	14.9	Absent
OW 1052	5	<.4	8.5	646	16.6	M

[1] Prefix denotes county: HE, Herkimer; J, Jefferson; L, Lewis; OE, Oneida; OW, Oswego; number is local well-identification number assigned by U.S. Geological Survey.

Table A4. Concentrations of inorganic constituents in groundwater samples from Eastern Lake Ontario Basin, New York, 2008.

[Well locations are shown in figure 1. mg/L, milligrams per liter; (00900), USGS National Water Information System (NWIS) parameter code; $CaCO_3$, calcium carbonate. **Bold** values exceed one or more drinking-water standard]

Well number[1]	Hardness filtered, mg/L as $CaCO_3$, (00900)	Calcium, filtered, mg/L (00915)	Magnesium, filtered, mg/L (00925)	Potassium, filtered, mg/L (00935)	Sodium, filtered, mg/L (00930)	Acid-neutralizing capacity[2], unfiltered, mg/L as $CaCO_3$ (90410)	Alkalinity[2], filtered, mg/L as $CaCO_3$ (29801)
Sand and gravel wells							
HE 1367	38	10.5	2.88	0.89	2.83	41	41
J 180	270	99.2	6.24	1.56	30.5	280	281
J 1118	84	27.7	3.66	1.66	5.34	83	82
L 177	18	5.24	1.24	0.70	1.59	16	16
L 178	57	20.5	1.33	0.55	1.84	53	53
L 179	52	15.5	3.27	0.23	1.30	54	55
L 386	210	78.2	4.05	0.88	4.15	176	175
OW 1599	110	30.0	9.16	0.47	2.01	108	109
Bedrock wells							
HE 628	30	9.35	1.63	1.10	2.98	34	33
HE 1341	27	8.00	1.70	0.85	3.81	32	32
J 179	310	97.3	15.6	2.09	**84.7**	249	249
J 181	190	53.4	13.4	2.40	21.4	196	197
J 1027	230	72.2	11.4	1.84	3.85	209	209
J 1059	51	13.6	4.05	6.67	**215**	301	302
L 491	5	1.59	0.31	2.72	**223**	195	195
OE 1991	96	32.6	3.67	1.66	53.3	43	43
OW 918	510	87.9	70.6	5.77	**150**	279	280
OW 1052	110	17.6	14.8	4.89	**99.5**	250	252

Table A4. Concentrations of inorganic constituents in groundwater samples from Eastern Lake Ontario Basin, New York, 2008.—Continued

[Well locations are shown in figure 1. mg/L, milligrams per liter; (00900), USGS National Water Information System (NWIS) parameter code; $CaCO_3$, calcium carbonate. **Bold** values exceed one or more drinking-water standard]

Well number[1]	Bicarbonate,[3] filtered, mg/L as $CaCO_3$ (29805)	Chloride, filtered, mg/L (00940)	Fluoride, filtered, mg/L (00950)	Silica, filtered, mg/L (00955)	Sulfate, filtered mg/L (00945)	Residue on evaporation, at 180° Celsius, filtered, mg/L (70300)
Sand and gravel wells						
HE 1367	50	0.73	0.28	22.2	4.91	77
J 180	343	35.0	E .10	6.25	12.4	374
J 1118	100	5.61	< .08	5.94	6.14	106
L 177	20	1.23	0.13	12.7	5.63	45
L 178	65	1.76	E .10	11.8	5.20	72
L 179	67	0.83	< .08	6.77	3.23	70
L 386	214	11.6	E .07	6.75	14.6	291
OW 1599	133	2.19	< .08	7.77	7.45	121
Bedrock wells						
HE 628	40	0.45	0.31	15.2	3.75	55
HE 1341	39	0.81	0.59	21.6	2.98	51
J 179	304	166	0.21	6.18	19.9	575
J 181	240	24.4	0.49	8.64	17.8	261
J 1027	255	0.66	0.94	8.44	35.3	281
J 1059	368	150	1.09	8.44	1.01	600
L 491	238	225	1.65	6.55	1.40	593
OE 1991	52	112	0.42	13.4	17.1	287
OW 918	342	**368**	0.16	14.2	53.6	935
OW 1052	307	51.7	0.92	9.95	11.6	364

[1] Prefix denotes county: HE, Herkimer; J, Jefferson; L, Lewis; OE, Oneida; OW, Oswego; number is local well-identification number assigned by U.S. Geological Survey.

[2] Fixed-endpoint titration at pH 4.5.

[3] Calculated from alkalinity.

Table A5. Concentrations of nutrients and total organic carbon in groundwater samples from Eastern Lake Ontario Basin, New York, 2008.

[Well locations are shown in figure 1. mg/L, milligrams per liter; N, nitrogen; P, phosphorus; <, less than; (00623), National Water Information System (NWIS) parameter code; E, estimated value—constituent was detected in the sample but with low or inconsistent recovery]

Well number[1]	Ammonia plus organic nitrogen, filtered, mg/L as N (00623)	Ammonia, filtered, mg/L as N (00608)	Nitrate plus nitrite, filtered, mg/L as N (00631)	Nitrite, filtered, mg/L as N (00613)	Orthophosphate, filtered, mg/L as P (00671)	Total organic carbon, unfiltered, mg/L (00680)
Sand and gravel wells						
HE 1367	<0.14	<0.020	0.48	<0.002	0.015	1.8
J 180	<.14	<.020	0.51	<.002	<.006	1.4
J 1118	<.10	<.020	0.46	<.002	<.024	1.0
L 177	<.14	<.020	0.29	<.002	0.007	<1.0
L 178	<.10	<.020	0.37	<.002	E .008	<1.0
L 179	<.10	<.020	E .03	<.002	E .005	<1.0
L 386	<.14	<.020	8.31	<.002	<.006	1.1
OW 1599	0.11	0.102	0.17	<.002	E .005	<1.0
Bedrock wells						
HE 628	<.14	<.020	0.60	<.002	0.067	<1.0
HE 1341	<.14	<.020	0.50	<.002	0.012	1.2
J 179	0.15	E .012	0.12	0.013	0.021	3.2
J 181	0.15	0.096	<.04	<.002	E .004	1.4
J 1027	E .09	0.040	<.04	<.002	<.006	<1.0
J 1059	1.8	1.10	<.04	<.002	0.008	2.6
L 491	0.81	0.777	<.04	<.002	0.015	1.1
OE 1991	<.10	E .011	0.16	<.002	0.010	<1.0
OW 918	0.21	0.195	<.04	<.002	E .005	2.1
OW 1052	0.52	0.484	<.04	<.002	0.010	1.1

[1] Prefix denotes county: HE, Herkimer; J, Jefferson; L, Lewis; OE, Oneida; OW, Oswego; number is local well-identification number assigned by U.S. Geological Survey.

Table A6. Concentrations of trace elements and radon-222 in groundwater samples from Eastern Lake Ontario Basin, New York, 2008.

[Well locations are shown in figure 1. µg/L, micrograms per liter; (01105), USGS National Water Information System (NWIS) parameter code; <, less than; E, estimated value—constituent was detected in the sample but with low or inconsistent recovery. **Bold** values exceed one or more drinking-water standard]

Well number[1]	Aluminum, unfiltered, µg/L (01105)	Antimony, unfiltered, µg/L (01097)	Arsenic, unfiltered, µg/L (01002)	Barium, unfiltered, µg/L (01007)	Beryllium, unfiltered, µg/L (01012)	Boron, filtered, µg/L (01020)	Cadmium, unfiltered, µg/L (01027)	Chromium, unfiltered, µg/L (01034)
Sand and gravel wells								
HE 1367	<4	<0.1	<0.60	1.6	<0.04	3.4	<0.01	E 0.28
J 180	<4	<.1	<.60	45.7	<.04	18	E .01	<.40
J 1118	<6	<.4	<.20	11.5	<.02	10	<.06	<.40
L 177	<4	<.1	<.60	1.1	<.04	4.1	<.01	E .40
L 178	<6	<.4	<.20	1.5	<.02	4.6	<.06	<.40
L 179	9	<.4	1.0	5.0	<.02	6.0	<.06	<.40
L 386	<4	<.1	<.60	19.8	<.04	19	<.01	<.40
OW 1599	<6	<.4	1.8	37.3	<.02	6.6	<.06	<.40
Bedrock wells								
HE 628	E 3	<.1	<.60	<.6	<.04	3.9	<.01	2.2
HE 1341	<4	<.1	<.60	E .6	<.04	4.4	<.01	0.40
J 179	11	E .1	<.60	109	<.04	40	<.01	<.40
J 181	<4	<.1	<.60	127	<.04	150	<.01	<.40
J 1027	<4	<.1	E .36	59.8	E .03	34	<.01	<.40
J 1059	**115**	<.1	<.60	250	<.04	332	<.01	<.40
L 491	16	<.1	<.60	39.1	<.04	600	0.01	<.40
OE 1991	8	<.4	2.1	49.4	<.02	33	<.06	<.40
OW 918	6	<.1	4.8	142	<.04	60	<.01	<.40
OW 1052	**234**	<.1	0.84	153	<.04	628	<.01	E .39

Table A6. Concentrations of trace elements and radon-222 in groundwater samples from Eastern Lake Ontario basin, New York, 2008.—Continued

[Well locations are shown in figure 1. µg/L, micrograms per liter; (01105), USGS National Water Information System (NWIS) parameter code; <, less than; E, estimated value—constituent was detected in the sample but with low or inconsistent recovery. **Bold** values exceed one or more drinking-water standard]

Well number[1]	Cobalt, unfiltered, µg/L (01037)	Copper, unfiltered, µg/L (01042)	Iron, filtered, µg/L (01046)	Iron, unfiltered, µg/L (01045)	Lead, unfiltered, µg/L (01051)	Lithium, unfiltered, µg/L (01132)	Manganese, filtered, µg/L (01056)	Manganese, unfiltered, µg/L (01055)
				Sand and gravel wells				
HE 1367	<0.04	2.9	<8	46	1.42	1.9	0.8	2.0
J 180	E .02	2.6	<8	E 3	0.57	1.0	<.4	<.8
J 1118	<.10	<4.0	17	17	0.29	0.8	0.3	E .3
L 177	0.06	27.0	<8	7	0.09	0.8	<.4	<.8
L 178	<.10	4.0	<4	<14	0.56	0.7	<.2	<.4
L 179	E .07	<4.0	**902**	**1,580**	5.15	E .5	**1,480**	**1,160**
L 386	<.04	9.6	<8	<6	0.55	2.4	<.4	<.8
OW 1599	E .08	<4.0	**830**	**976**	1.46	2.1	**287**	**287**
				Bedrock wells				
HE 628	<.04	2.0	<8	42	0.13	2.1	<.4	0.9
HE 1341	<.04	2.8	E 6	17	0.20	3.1	0.6	1.4
J 179	0.18	3.0	24	80	**0.56**	6.3	11.5	19.9
J 181	<.04	12.5	<8	E 5	E .03	30.2	2.1	2.0
J 1027	0.60	<1.2	**788**	**817**	0.20	6.1	24.6	27.1
J 1059	E .03	8.7	<8	171	**1.27**	294	18.9	29.5
L 491	<.04	<1.2	E 5	74	**E .04**	311	2.1	2.7
OE 1991	<.10	<4.0	8	E 8	0.40	14.0	0.2	<.4
OW 918	0.05	E 1.2	**808**	**955**	**0.33**	29.6	**68.9**	**79.7**
OW 1052	0.17	8.6	E 7	**938**	**0.31**	127	19.9	23.0

Table A6. Concentrations of trace elements and radon-222 in groundwater samples from Eastern Lake Ontario Basin, New York, 2008.—Continued

[Well locations are shown in figure 1. µg/L, micrograms per liter; (01105), USGS National Water Information System (NWIS) parameter code; <, less than; E, estimated value—constituent was detected in the sample but with low or inconsistent recovery. **Bold** values exceed one or more drinking-water standard]

Well number[1]	Molybdenum, unfiltered, µg/L (01062)	Nickel, unfiltered, µg/L (01067)	Selenium, unfiltered, µg/L (01147)	Strontium, unfiltered, µg/L (01082)	Thallium, unfiltered, µg/L (01059)	Radon-222, unfiltered, picocuries per liter (pCi/L) (82303)	Uranium, (natural), unfiltered, µg/L (28011)	Zinc, unfiltered, µg/L (01092)
Sand and gravel wells								
HE 1367	0.3	<0.12	<0.08	35.0	<0.08	**1,290**	0.142	6.2
J 180	E .1	0.34	E .08	169	<.08	**420**	0.231	E 1.7
J 1118	E .1	1.3	E .07	54.0	<.12	**550**	0.033	7.4
L 177	0.1	E .08	<.08	21.6	<.08	**630**	0.062	<2.0
L 178	0.1	E .15	<.12	38.5	<.12	**580**	0.189	<2.0
L 179	0.1	0.46	<.12	24.7	<.12	**410**	<.020	2.8
L 386	E .1	0.33	<.08	152	<.08	**420**	0.172	8.7
OW 1599	0.2	0.28	<.12	49.0	<.12	**610**	0.120	75.9
Bedrock wells								
HE 628	2.2	0.21	0.14	22.2	<.08	**3,150**	0.837	E 1.5
HE 1341	1.4	0.29	E .05	22.4	<.08	**1,330**	0.378	E 1.6
J 179	0.5	1.9	0.09	805	**E .04**	62	0.437	3.3
J 181	0.8	1.0	0.13	2,370	<.08	66	<.020	<2.0
J 1027	0.6	0.83	<.08	5,070	<.08	**620**	0.263	3.1
J 1059	M	0.37	<.08	859	**<.08**	83	0.027	3.3
L 491	0.1	0.23	<.08	123	**<.08**	75	<.020	<2.0
OE 1991	1.9	0.26	<.12	1,110	<.12	**1,120**	1.35	6.1
OW 918	0.8	0.45	<.08	1,550	**<.08**	**450**	1.25	3.7
OW 1052	0.4	0.43	<.08	487	**<.08**	83	0.039	7.2

[1] Prefix denotes county: HE, Herkimer; J, Jefferson; L, Lewis; OE, Oneida; OW, Oswego; number is local well-identification number assigned by U.S. Geological Survey.

Table A7. Concentrations of pesticides detected in groundwater samples from Eastern Lake Ontario Basin, New York, 2008.

[Well locations are shown in figure 1. µg/L, micrograms per liter; <, less than; (04040), USGS National Water Information System (NWIS) parameter code; CIAT, 2-Chloro-4-isopropylamino-6-amino-s-triazine; OIET, 2-Hydroxy-4-isopropylamino-6-ethylamino-s-triazine; ESA, ethanesulfanic acid; E, estimated value—constituent was detected in the sample but with low or inconsistent recovery]

Well number[1]	CIAT, filtered, µg/L (04040)	cis-Permethrin, filtered, ug/L (82687)	Metolachlor ESA, filtered, µg/L (61043)	Metolachlor OA, filtered, µg/L (61044)	Prometon filtered, µg/L (04037)	Caffeine filtered ug/L (50305)
Sand and gravel wells						
HE 1367	<0 .014	< 0.010	<0.02	<0.02	<0 .01	<0 .060
J 180	E .003	<.010	0.03	0.02	<.01	<.060
J 1118	E .003	<.014	<.02	<.02	<.01	<.080
L 177	E .002	<.010	<.02	<.02	<.01	<.060
L 178	<.014	<.014	<.02	<.02	<.01	<.080
L 179	<.014	<.014	<.02	<.02	<.01	E .010
L 386	<.014	E .001	<.02	<.02	<.01	<.060
OW 1599	<.014	<.014	<.02	<.02	<.01	<.080
Bedrock wells						
HE 628	<.014	<.010	<.02	<.02	<.01	<.060
HE 1341	<.014	<.010	<.02	<.02	<.01	<.060
J 179	E .003	<.010	<.02	<.02	0.01	<.060
J 181	<.014	<.010	0.03	<.02	<.01	<.060
J 1027	<.014	<.010	<.02	<.02	<.01	<.060
J 1059	<.014	<.010	<.02	<.02	<.01	<.060
L 491	<.014	<.010	<.02	<.02	<.01	<.060
OE 1991	<.014	<.014	<.02	<.02	<.01	<.080
OW 918	<.014	<.010	<.02	<.02	<.01	<.060
OW 1052	<.014	<.010	<.02	<.02	<.01	<.060

[1] Prefix denotes county: HE, Herkimer; J, Jefferson; L, Lewis; OE, Oneida; OW, Oswego; number is local well-identification number assigned by U.S. Geological Survey.

Table A8. Concentrations of volatile organic compounds in groundwater samples from Eastern Lake Ontario Basin, New York, 2008.

[Well locations are shown in figure 1. µg/L, micrograms per liter; m + p, *meta* plus *para*; <, less than; (34506), USGS National Water Information System parameter code; E, estimated value—constituent was detected in the sample but with low or inconsistent recovery.]

Well number[1]	Bromodichloro-methane, unfiltered, µg/L (32101)	Trichloro-methane, unfiltered, µg/L (32106)	Tetrachloro-methane, unfiltered, ug/L (32102)	Benzene unfiltered, µg/L (34030)	Toluene, unfiltered, µg/L (34010)	m + p Xylene, unfiltered, µg/L (85795)
Sand and gravel wells						
HE 1367	<0.1	< 0.1	< 0.2	< 0.1	< 0.1	< 0.2
J 180	<.1	0.1	<.2	<.1	<.1	<.2
J 1118	<.1	<.1	<.2	<.1	0.1	<.2
L 177	<.1	<.1	<.2	<.1	<.1	<.2
L 178	<.1	<.1	<.2	<.1	<.1	<.2
L 179	<.1	<.1	<.2	<.1	0.1	<.2
L 386	<.1	<.1	<.2	<.1	<.1	<.2
OW 1599	<.1	<.1	<.2	<.1	<.1	<.2
Bedrock wells						
HE 628	<.1	0.3	<.2	<.1	<.1	<.2
HE 1341	<.1	<.1	<.2	<.1	<.1	<.2
J 179	<.1	0.6	<.2	<.1	<.1	<.2
J 181	<.1	<.1	<.2	<.1	<.1	<.2
J 1027	<.1	<.1	<.2	<.1	<.1	<.2
J 1059	0.1	1.2	0.3	0.2	0.3	E .2
L 491	<.1	<.1	<.2	<.1	0.1	<.2
OE 1991	<.1	<.1	<.2	<.1	<.1	<.2
OW 918	<.1	<.1	<.2	<.1	0.1	<.2
OW 1052	<.1	<.1	<.2	<.1	0.2	<.2

[1] Prefix denotes county: HE, Herkimer; J, Jefferson; L, Lewis; OE, Oneida; OW, Oswego; number is local well-identification number assigned by U.S. Geological Survey.

Table A9. Concentrations of bacteria in unfiltered groundwater samples from Eastern Lake Ontario Basin, New York, 2008.

[Well locations are shown in figure 1. mL, milliliter; <, less than; CFU, colony-forming unit; (61213), National Water Information System (NWIS) parameter code. **Bold** values exceed one or more drinking-water standard]

Well number[1]	Total coliform colonies per 100 mL (61213)	Fecal coliform colonies per 100 mL (61215)	*Escherichia coli,* colonies per 100 mL (31691)	Heterotrophic plate count, CFUs per mL (31692)
Sand and gravel wells				
HE 1367	<1	<1	<1	<1
J 180	<1	<1	<1	12
J 1118	<1	<1	<1	8
L 177	<1	<1	<1	2
L 178	<1	<1	<1	<1
L 179	<1	<1	<1	260
L 386	<1	<1	<1	6
OW 1599	1	<1	<1	6
Bedrock wells				
HE 628	2	<1	<1	6
HE 1341	1	<1	<1	140
J 179	<1	<1	<1	3
J 181	<1	<1	<1	1
J 1027	<1	<1	<1	21
J 1059	<1	<1	<1	30
L 491	<1	<1	<1	740
OE 1991	<1	<1	<1	<1
OW 918	<1	<1	<1	1
OW 1052	<1	<1	<1	130

[1] Prefix denotes county: HE, Herkimer; J, Jefferson; L, Lewis; OE, Oneida; OW, Oswego; number is local well-identification number assigned by U.S. Geological Survey.

Prepared by the Pembroke Publishing Service Center.

For additional information write to:
New York Water Science Center
U.S. Geological Survey
30 Brown Rd.
Ithaca, NY 14850

Information requests:
(518) 285-5602
or visit our Web site at:
http://ny.water.usgs.gov

Risen and Reddy—**Groundwater Quality in the Eastern Lake Ontario Basin, New York, 2008**—Open-File Report 2011–1074