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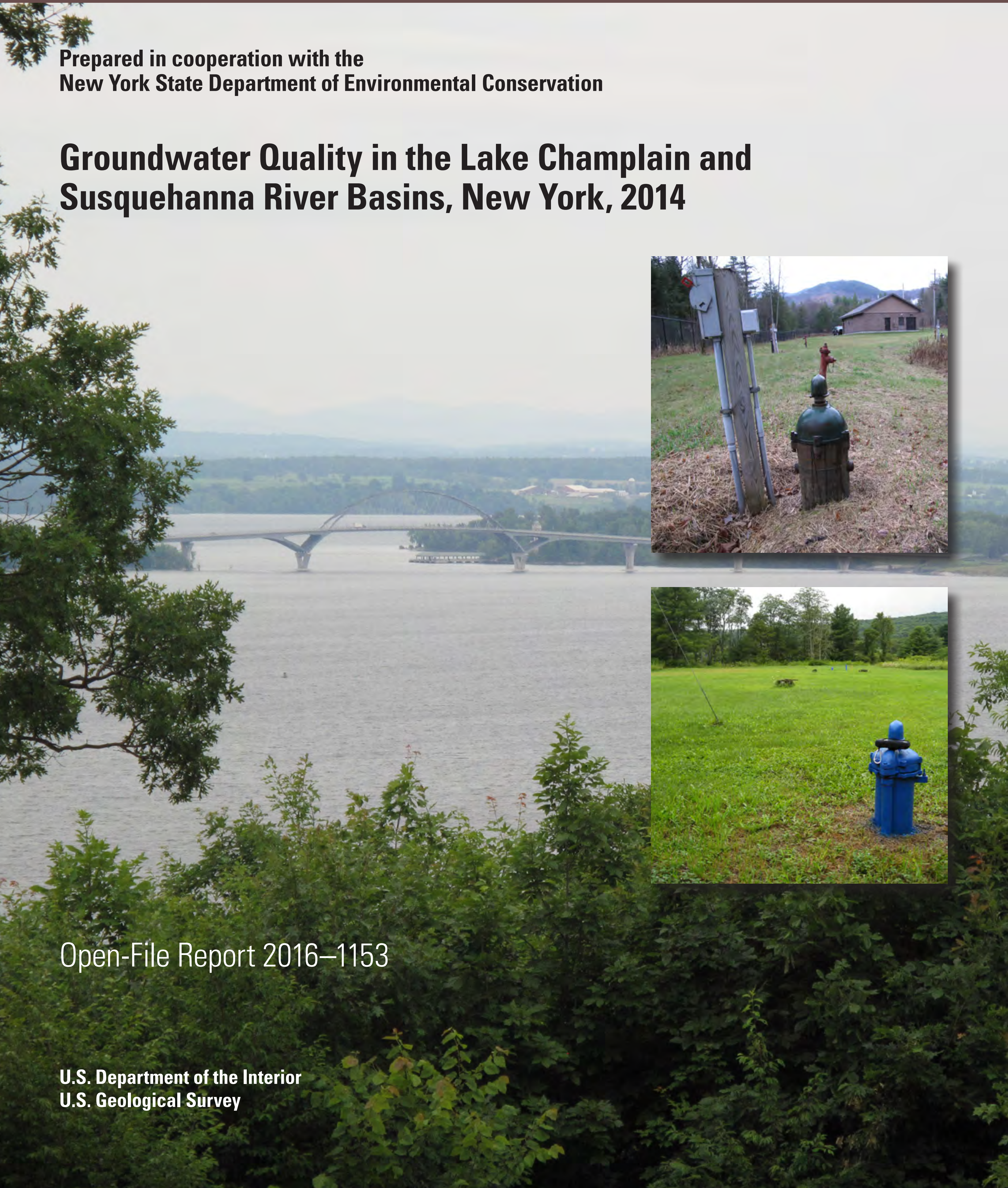
Groundwater Quality in the Lake Champlain and Susquehanna River Basins, New York, 2014



Open-File Report 2016–1153

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

Cover.
Background. View of the Champlain Bridge over Lake Champlain from a domestic well in Essex County, New York.
Top. Setting of a production well in Essex County.
Bottom. Setting of a production well in Otsego County, N.Y.; photograph by James E. Reddy, U.S. Geological Survey.

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Contents

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon (gal)	3.785	liter (L)
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:

$$°F = (1.8 \times °C) + 32.$$

Datum

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

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

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

Supplemental Information

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (μS/cm at 25 °C).

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

Abbreviations

AMCL	alternative maximum contaminant level
CFU	colony-forming units
CH_4	methane
CIAT	2-chloro-4-isopropylamino-6-amino-*s*-triazine
CO_2	carbon dioxide
EPA	U.S. Environmental Protection Agency
GC–MS	gas chromatography-mass spectrometry
ICP–AES	inductively coupled plasma-atomic emission spectrometry
LRL	laboratory reporting level
MCL	maximum contaminant level
MTBE	methyl *tert*-butyl ether
NWIS	National Water Information System
NWQL	National Water Quality Laboratory
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
SDWS	secondary drinking-water standards
THM	trihalomethane
USGS	U.S. Geological Survey
VOC	volatile organic compound

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Abstract

In a study conducted by the U.S. Geological Survey in cooperation with the New York State Department of Environmental Conservation, groundwater samples were collected from 6 production wells and 7 domestic wells in the Lake Champlain Basin and from 11 production wells and 9 domestic wells in the Susquehanna River Basin in New York. All samples were collected from June through December 2014 to characterize groundwater quality in these basins. The samples were collected and processed using standard procedures of the U.S. Geological Survey and were analyzed for 148 physiochemical properties and constituents, including dissolved gases, major ions, nutrients, trace elements, pesticides, volatile organic compounds, radionuclides, and indicator bacteria.

The Lake Champlain Basin study area covers the 3,050 square miles of the basin in northeastern New York; the remaining part of the basin is in Vermont and Canada. Of the 13 wells sampled in the Lake Champlain Basin, 6 are completed in sand and gravel, and 7 are completed in bedrock. Groundwater in the Lake Champlain Basin was generally of good quality, although properties and concentrations of some constituents—fluoride, iron, manganese, dissolved solids, sodium, radon-222, total coliform bacteria, fecal coliform bacteria, and *Escherichia coli* bacteria—sometimes equaled or exceeded primary, secondary, or proposed drinking-water standards. The constituent most frequently detected in concentrations exceeding drinking-water standards (5 of 13 samples) was radon-222.

The Susquehanna River Basin study area covers the entire 4,522 square miles of the basin in south-central New York; the remaining part of the basin is in Pennsylvania. Of the 20 wells sampled in the Susquehanna River Basin, 11 are completed in sand and gravel, and 9 are completed in bedrock. Groundwater in the Susquehanna River Basin was generally of good quality, although properties and concentrations of some constituents—pH, chloride, sodium, dissolved solids, iron, manganese, aluminum, arsenic, barium, gross-α radioactivity, radon-222, methane, total coliform bacteria, and fecal coliform bacteria—sometimes equaled or exceeded primary, secondary, or proposed drinking-water standards. As in the Lake Champlain Basin, the constituent most frequently detected in concentrations exceeding drinking-water standards (13 of 20 samples) was radon-222.

Introduction

Groundwater is used as a source of drinking water by approximately one-quarter of the more than 19 million population of New York State (Kenny and others, 2009; U.S. Census Bureau, 2016). In 2002, the U.S. Geological Survey (USGS), 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 program parallels the NYSDEC Rotating Integrated Basin Studies Program (http://www.dec.ny.gov/chemical/30951.html), which evaluates surface-water quality on a 5-year cycle by sampling in 2 or 3 of the 14 major river basins in the State each year. This program also supports NYSDEC's responsibilities under section 305(b) of the Federal Water Pollution Control Act Amendments of 1972 (Clean Water Act) to report on the chemical quality of groundwater within New York (U.S. Environmental Protection Agency, 1997). The groundwater-quality program began with a pilot study in the Mohawk River Basin in 2002 and has continued throughout upstate New York (upstate refers to New York State north of New York City) since then (table 1). Sampling completed in 2008 represents the conclusion of the first round of groundwater-quality sampling throughout upstate New York State. Groundwater-quality sampling was conducted in 2014 in the Lake Champlain and Susquehanna River Basins, beginning the third round of groundwater-quality sampling for this program.

Objective and Approach

The objective of the groundwater-quality monitoring program is to quantify and report on ambient groundwater quality in bedrock and glacial-drift aquifers in upstate New York. Using consistent, standardized methods, groundwater-quality samples were collected from existing domestic and production wells, equipped with permanently installed pumps. Wells were selected to represent an approximately equal number of domestic and production wells, to represent an approximately equal number of bedrock and glacial-drift wells, and to provide a representative geographic distribution of samples with emphasis on areas of greatest groundwater

Table 1. Previous groundwater-quality studies and reports of the rotating-basin groundwater monitoring program in New York.

[Reports listed in **bold** indicate the previous groundwater-quality studies in the Lake Champlain Basin and the Susquehanna River Basin]

Study area	Year	Report	Reference
Mohawk River Basin	2002	Water-Data Report NY–02–1	Butch and others, 2003
Chemung River Basin	2003	Open-File Report 2004–1329	Hetcher-Aguila, 2005
Lake Champlain Basin	2004	Open-File Report 2006–1088	Nystrom, 2006
Susquehanna River Basin	2004	Open-File Report 2006–1161	Hetcher-Aguila and Eckhardt, 2006
Delaware River Basin	2005	Open-File Report 2007–1098	Nystrom, 2007a
Genesee River Basin	2005	Open-File Report 2007–1093	Eckhardt and others, 2007
St. Lawrence River Basin	2005	Open-File Report 2007–1066	Nystrom, 2007b
Mohawk River Basin	2006	Open-File Report 2008–1086	Nystrom, 2008
Western New York	2006	Open-File Report 2008–1140	Eckhardt and others, 2008
Central New York	2007	Open-File Report 2009–1257	Eckhardt and others, 2009
Upper Hudson River Basin	2007	Open-File Report 2009–1240	Nystrom, 2009
Chemung River Basin	2008	Open-File Report 2011–1112	Risen and Reddy, 2011a
Eastern Lake Ontario Basin	2008	Open-File Report 2011–1074	Risen and Reddy, 2011b
Lower Hudson River Basin	2008	Open-File Report 2010–1197	Nystrom, 2010
Lake Champlain Basin	2009	Open-File Report 2011–1180	Nystrom, 2011
Susquehanna River Basin	2009	Open-File Report 2012–1045	Reddy and Risen, 2012
Delaware River Basin	2010	Open-File Report 2011–1320	Nystrom, 2012
Genesee River Basin	2010	Open-File Report 2012–1135	Reddy, 2012
St. Lawrence River Basin	2010	Open-File Report 2011–1320	Nystrom, 2012
Mohawk River Basin	2011	Open-File Report 2013–1021	Nystrom and Scott, 2013
Western New York	2011	Open-File Report 2013–1095	Reddy, 2013
Central New York	2012	Open-File Report 2014–1226	Reddy, 2014
Upper Hudson River Basin	2012	Open-File Report 2014–1084	Scott and Nystrom, 2014
Chemung River Basin	2013	Open-File Report 2015–1168	Scott and others, 2015
Eastern Lake Ontario Basin	2013	Open-File Report 2015–1168	Scott and others, 2015
Lower Hudson River Basin	2013	Open-File Report 2015–1168	Scott and others, 2015

use. Approximately 20 percent of samples were collected from wells that previously have been sampled as part of the cycle of studies. Samples were analyzed for a broad suite of constituents, including physiochemical properties and concentrations of dissolved gases, major ions, nutrients, trace elements, pesticides, volatile organic compounds (VOCs), radionuclides, and indicator bacteria. The resulting dataset will be used to establish a groundwater-quality baseline for New York State that characterizes naturally occurring and ambient conditions and to identify long-term trends. The data are made available through the USGS National Water Information System (NWIS; http://nwis.waterdata.usgs.gov/ny/nwis/qw) and published reports.

Groundwater-quality samples were collected in the Lake Champlain Basin in 2004–05, 2009, and 2014, and in the Susquehanna River Basin in 2004–05, 2009, and 2014. In 2014, from June through December, 13 environmental samples and 1 quality-assurance sample were collected in the Lake Champlain Basin. Twenty environmental samples and two quality-assurance samples were collected in the Susquehanna River Basin. Three of the Lake Champlain Basin wells sampled in 2014 were also sampled as part of this cycle of studies in 2009 (Nystrom, 2011); two of those wells were also sampled in the 2004–05 cycle of this study (Nystrom, 2006). Three of the Susquehanna River Basin wells were also sampled as part of this cycle of studies in 2009 (Reddy and Risen, 2012); one of those wells was also sampled in the 2004–05 cycle of this study (Hetcher-Aguila and Eckhardt, 2006).

Purpose and Scope

This report presents the findings of the 2014 groundwater-quality study in the Lake Champlain Basin and the Susquehanna River Basin. Thirteen samples from the Lake Champlain Basin and 20 samples from the Susquehanna River Basin were collected from June through December 2014. The report (1) describes the hydrogeologic setting, the methods of site selection, wells that were sampled, sample collection, and chemical analysis; (2) presents discussions of the analytical results; (3) presents comparisons of analytical results to drinking-water-quality guidelines, and (4) presents comparisons of the results of this study with results for selected wells in the study areas that were sampled in 2004–05 and 2009 (Hetcher-Aguila and Eckhardt, 2006; Nystrom, 2006, 2011; Reddy and Risen, 2012).

Hydrogeologic Setting

The study areas discussed in this report cover more than 7,500 square miles (mi^2), or 14 percent of New York State, and represent a wide range of geologic, hydrologic, and topographic settings, and land uses. Bedrock lithology ranges from complex mixtures of crystalline, metamorphic, and carbonate rock in the Lake Champlain Basin to primarily shale and sandstone with some carbonate rock in the Susquehanna Basin. Surficial material in the study areas mainly consists of glacial and alluvial deposits.

Lake Champlain Basin

The Lake Champlain Basin encompasses 8,250 mi^2 in New York, Vermont, and Quebec, Canada. The groundwater-monitoring study area includes only the 3,050-mi^2 part of the Lake Champlain Basin that lies within New York (fig. 1). The study area includes parts of five counties—Clinton, Essex, Franklin, Warren, and Washington (fig. 1). Major tributaries to Lake Champlain in New York include the Ausable River, Saranac River, Salmon River, Great Chazy River, Boquet River, La Chute River, and Mettawee River; large lakes in the basin include Lake Champlain and Lake George. The Champlain Canal connects Lake Champlain to the Hudson River at Fort Edward.

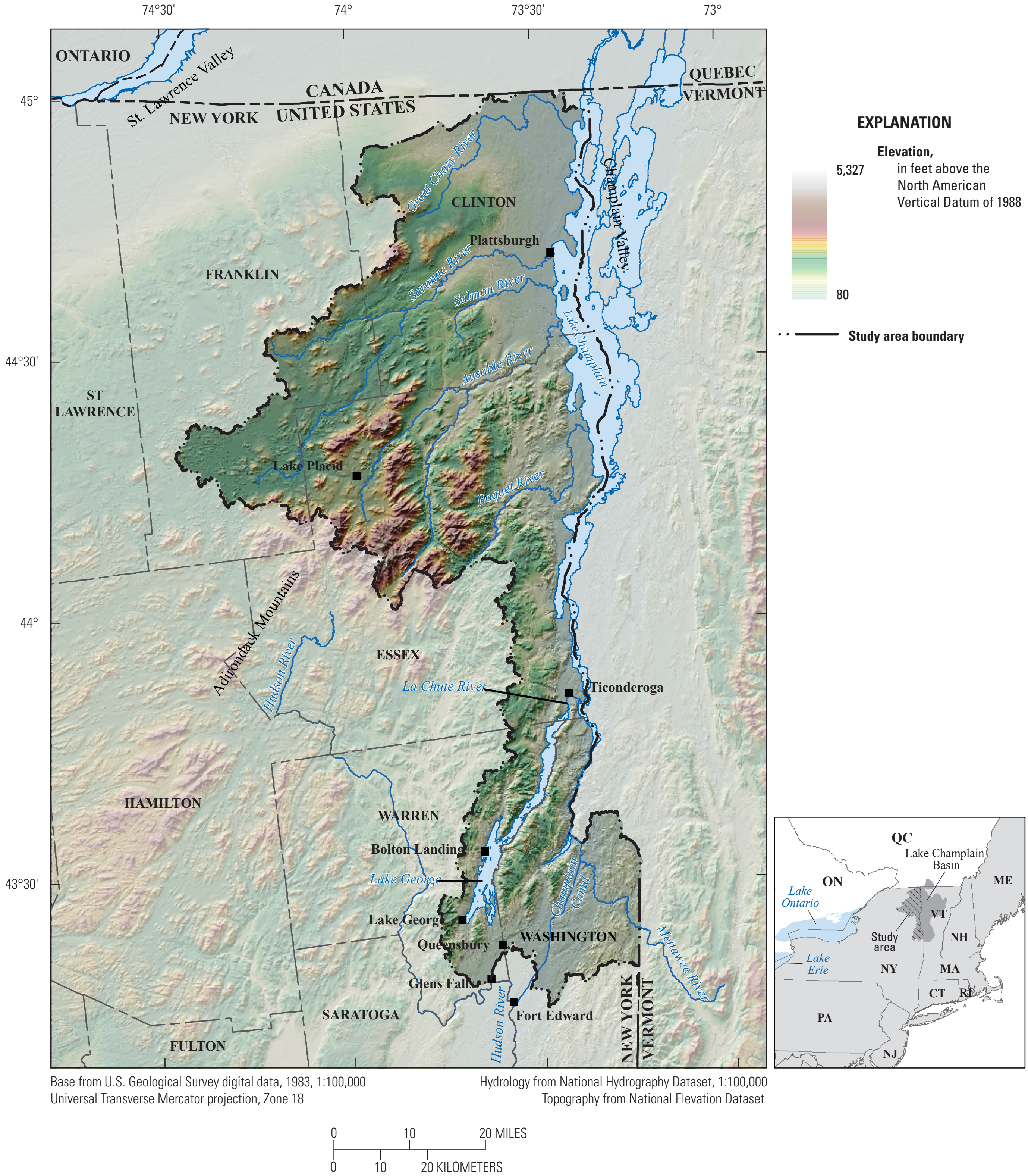
The highest elevations in the Lake Champlain Basin study area are more than 5,000 feet (ft) above the North American Vertical Datum of 1988 (NAVD 88) on the western edge of the basin, in the Adirondack Mountains (fig. 1). The lowest elevations in the basin are at Lake Champlain (about 100 ft above NAVD 88). Precipitation throughout the Lake Champlain Basin falls mostly as rain. Precipitation in the Lake Champlain Valley lowland areas averages about 35 inches per year (in/yr), whereas precipitation in the cooler Adirondack Mountains averages about 45 in/yr (Giese and Hobba, 1970). Urban centers and adjacent developed areas in the Lake Champlain Basin study area include Glens Falls, Queensbury, and Plattsburgh (fig. 1). Land use in the basin is primarily forested, especially in the upland areas, with urban and agriculture uses mainly in valleys and other low-lying areas (Vogelmann and others, 2001).

Bedrock in the Lake Champlain Basin study area (fig. 2) is mainly crystalline rock with small areas of carbonate rock, sandstone, and shale. The Adirondack Mountains are underlain mainly by crystalline metamorphic rock, including granitic gneiss, meta-anorthosite, and olivine metagabbro (Isachsen and others, 2000). The Champlain and St. Lawrence Valleys are underlain by sandstone, carbonate rocks (including limestone and dolostone), shale, and metamorphosed clastic rocks (Isachsen and others, 2000). Yields from bedrock wells in the study area vary greatly, but the carbonate units generally produce the greatest yields, and the crystalline units generally produce the smallest (Giese and Hobba, 1970). The surficial material throughout the study area (fig. 3) was deposited primarily during the Pleistocene epoch when the Wisconsinan glaciers covered most of the northeastern United States (Isachsen and others, 2000). Till, which was directly deposited by the glaciers, discontinuously overlies bedrock in the uplands (fig. 3). Lacustrine sand, silt, and clay underlie much of the lowlands bordering Lake Champlain. Ice contact and outwash sand and gravel, which were deposited by glacial meltwater, and recent alluvium, underlie the larger stream and river valleys. Till and lacustrine deposits generally yield low amounts of water, whereas saturated sand and gravel deposits form the most productive aquifers in the study area (Giese and Hobba, 1970).

Susquehanna River Basin

The Susquehanna River Basin study area encompasses 4,522 mi^2 in south-central New York, north of the Pennsylvania border. The study area contains parts of 14 counties, including most of Cortland, Chenango, Otsego, Broome, and Tioga Counties; and parts of Tompkins, Schuyler, Chemung, Onondaga, Madison, Oneida, Herkimer, Schoharie, and Delaware Counties (fig. 4). Major tributaries to the Susquehanna River include the Chenango River, Tioughnioga River, Unadilla River, Otselic River, Nanticoke River, Owego Creek, Catatonk Creek, Cayuta Creek, Genegantslet Creek, Butternut Creek, Wharton Creek, Ouleout Creek, Otego Creek, Cherry Valley Creek, Schenevus Creek, and Charlotte Creek (fig. 4). The Susquehanna River Basin ultimately drains into the Chesapeake Bay watershed (fig. 4).

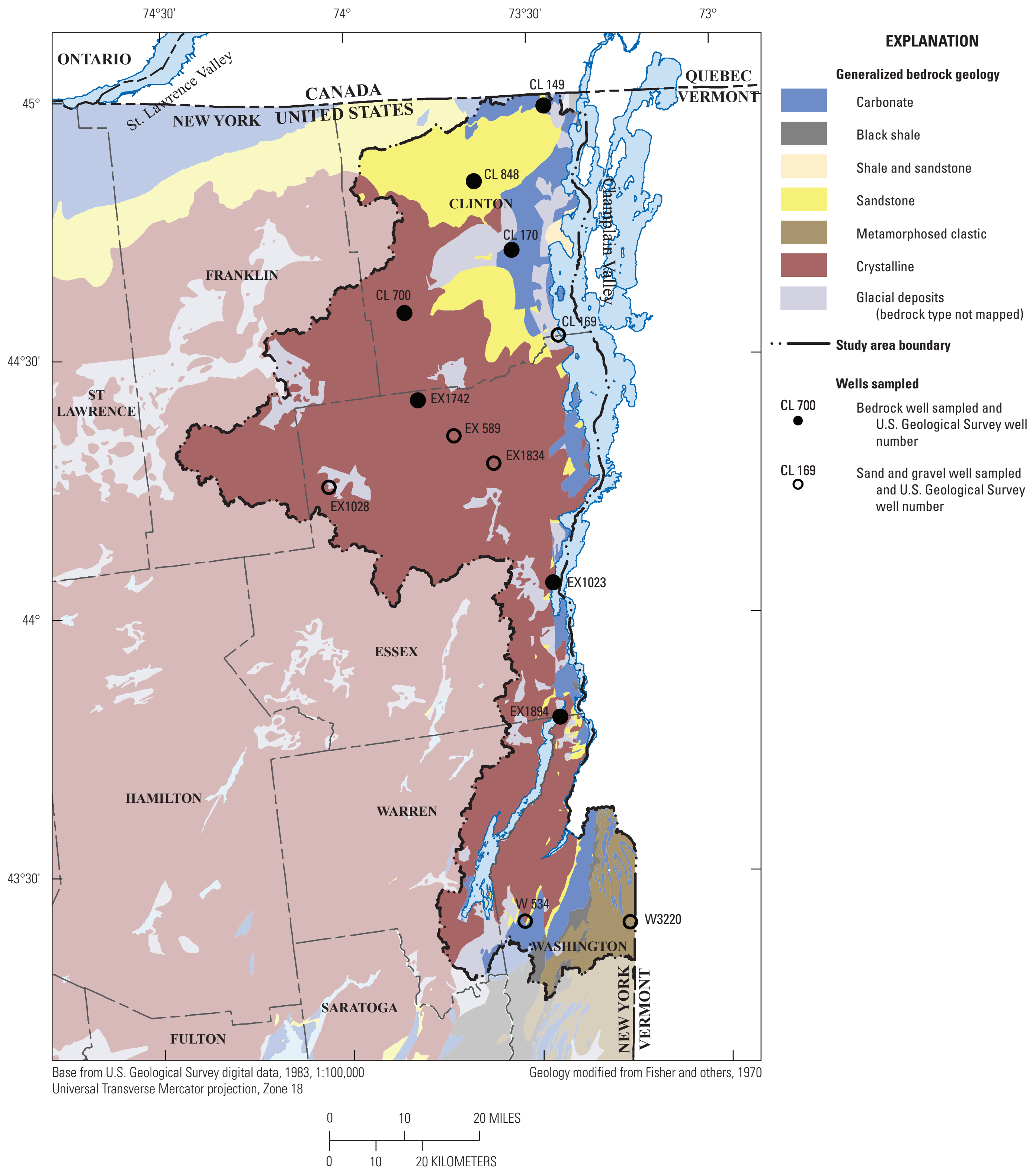
The highest elevations in the Susquehanna River Basin study area are more than 2,700 ft above NAVD 88 in the western Catskill Mountains (fig. 4). The lowest elevations in the study area are about 750 ft above NAVD 88, near the downstream end of the Susquehanna River valley (fig. 4). Precipitation in the Susquehanna River Basin averages around 40 in/yr (Randall, 1996). Land use in the study area is predominantly rural, although it contains the small cities of Oneonta, Binghamton, Norwich, and Cortland (fig. 4). Most of the developed areas are within the Susquehanna, Unadilla, Chenango, and Tioughnioga River valleys (fig. 4). The main valley of the Susquehanna River trends northeast to southwest and is about 1 mile wide in most places.



Base from U.S. Geological Survey digital data, 1983, 1:100,000
Universal Transverse Mercator projection, Zone 18

Hydrology from National Hydrography Dataset, 1:100,000
Topography from National Elevation Dataset

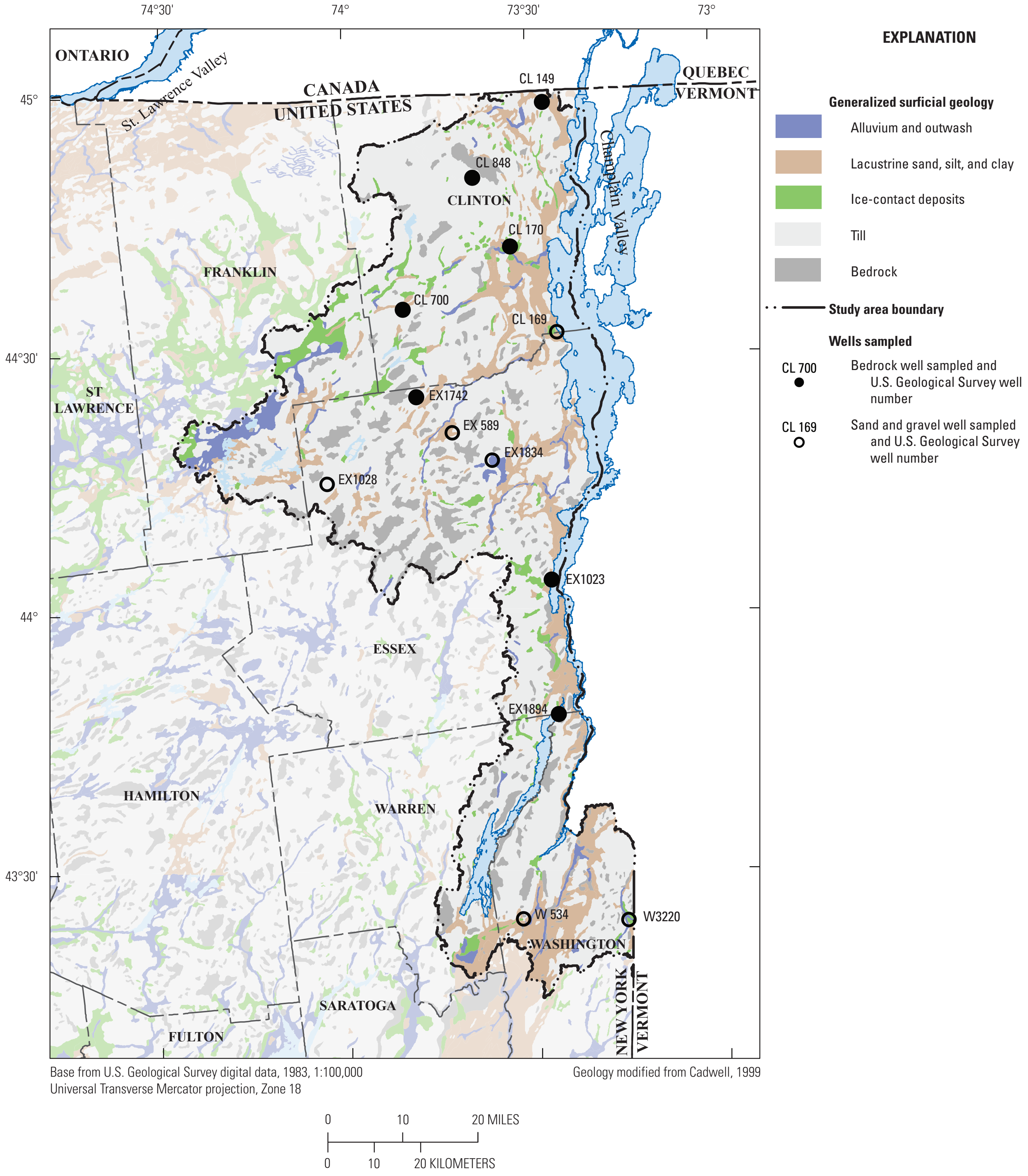
Figure 1. Topography and geography of the Lake Champlain Basin, New York.



Base from U.S. Geological Survey digital data, 1983, 1:100,000
Universal Transverse Mercator projection, Zone 18

Geology modified from Fisher and others, 1970

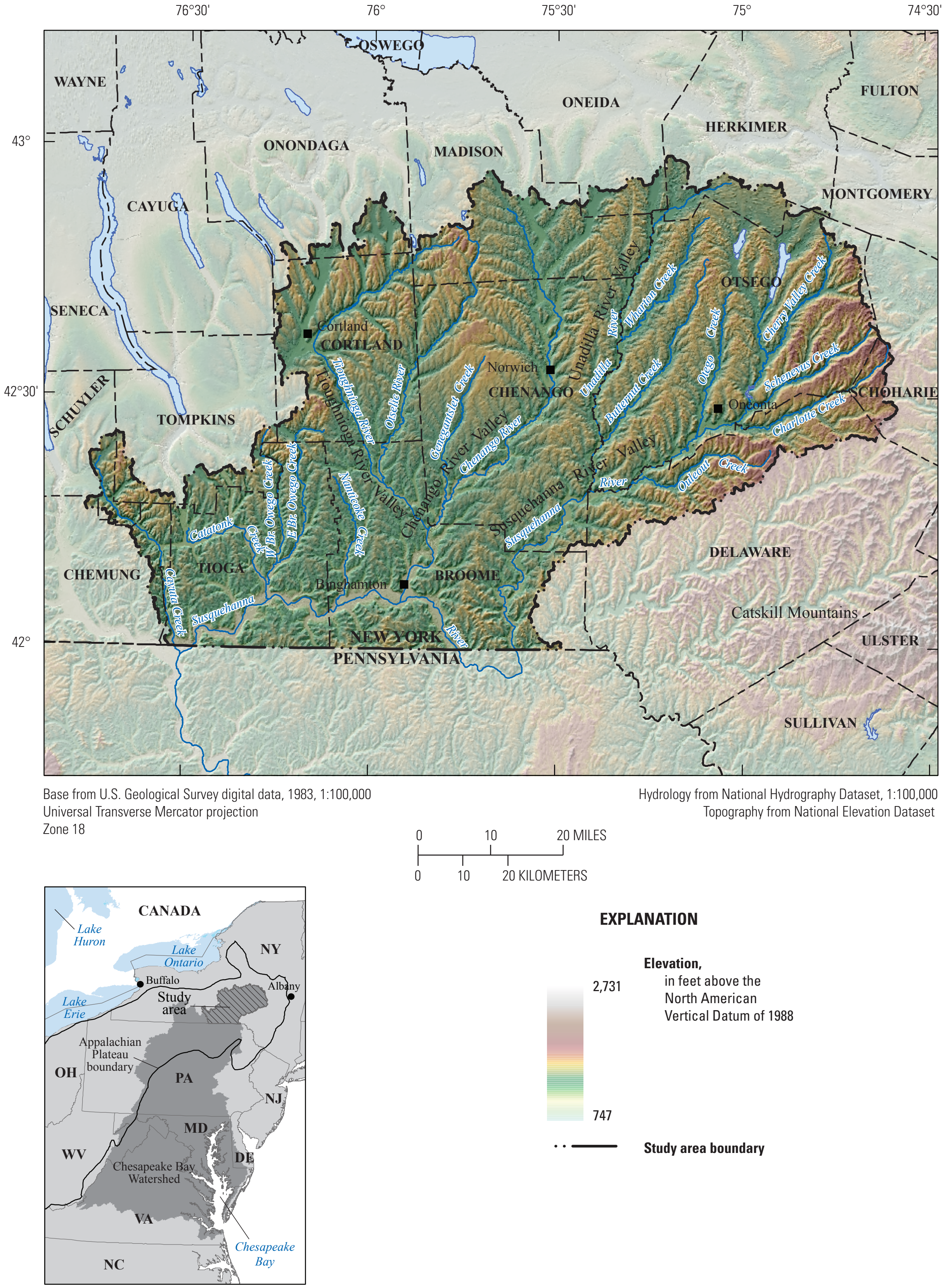
Figure 2. Generalized bedrock geology of the Lake Champlain Basin, New York, and locations of wells sampled in 2014.



Base from U.S. Geological Survey digital data, 1983, 1:100,000
Universal Transverse Mercator projection, Zone 18

Geology modified from Cadwell, 1999

Figure 3. Generalized surficial geology of the Lake Champlain Basin, New York, and locations of wells sampled in 2014.



Base from U.S. Geological Survey digital data, 1983, 1:100,000
Universal Transverse Mercator projection
Zone 18

Hydrology from National Hydrography Dataset, 1:100,000
Topography from National Elevation Dataset

Figure 4. Topography and geography of the Susquehanna River Basin, New York.

Bedrock in the Susquehanna River Basin (fig. 5) mainly consists of fractured shale and sandstone; small areas in the northern part of the basin consist of fractured and solutioned limestone and dolostone (Reddy and Risen, 2012). The surficial material throughout the Susquehanna River Basin was deposited primarily during the Pleistocene epoch when the Wisconsinan glaciers covered most of the northeastern United States (Isachsen and others, 2000). Till, which was directly deposited by the glaciers, discontinuously overlies bedrock in the uplands (fig. 6). Ice contact and outwash sand and gravel and lacustrine sand, silt, and clay were deposited mainly in valleys. Recent alluvium overlies the glacial deposits in the flood plains of the larger streams and rivers (Randall, 2001; Coates, 1966).

Methods of Investigation

Well selection criteria, sampling methods, and 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, n.d.). Samples were analyzed at the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado, and other certified laboratories using published methods.

Well Selection

The 33 wells selected for sampling (figs. 2 and 5) represent forested, developed, and agricultural areas (table 2). The final selection of each well was based on the availability of well construction data and hydrogeologic information for the well and its surrounding area. The study did not target specific municipalities, industries, or agricultural practices. Wells were selected to represent an approximately equal number of domestic and production wells.

The domestic wells were selected on the basis of information from the NYSDEC Water Well Program, which began in 2000. The program requires that licensed well drillers file a report with NYSDEC containing basic information about each well drilled, such as well and casing depth, diameter, yield, and a driller’s log. Evaluation of well completion report data identified several hundred wells as potential sampling sites; well owners were sent a letter requesting permission to sample the well and a questionnaire about the well. Well owners who granted permission were contacted later by phone to verify well information and to arrange for sampling.

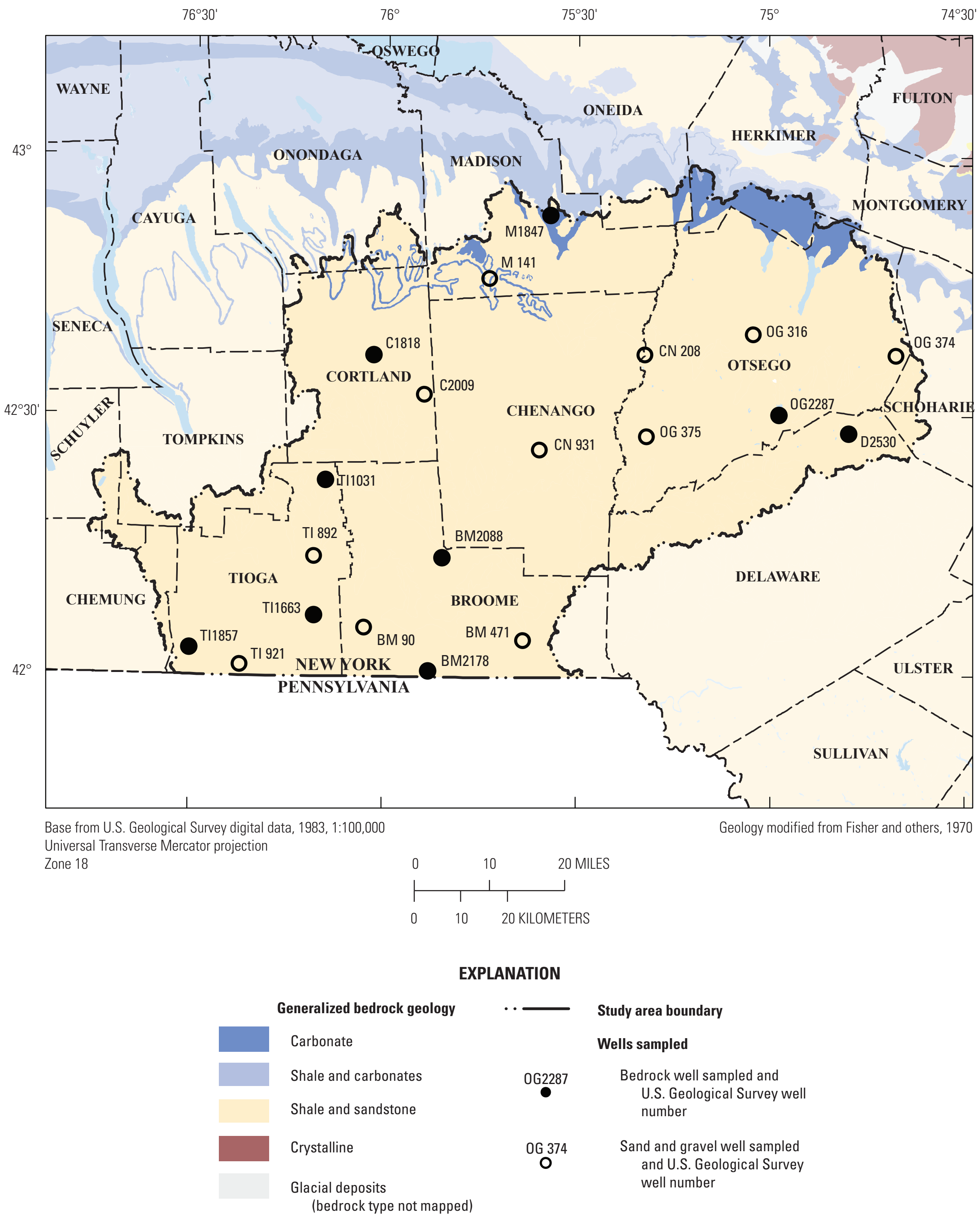
Production wells considered for sampling were identified through the U.S. Environmental Protection Agency (EPA) Safe Drinking Water Information System, the New York State Department of Health (NYSDOH) Drinking Water Protection Program, and the NYSDEC Water Well Program. Town officials and (or) water managers were sent letters requesting permission to sample a well, and followup phone calls were made to arrange a time for sampling. Well information, such as depth, was provided by water managers if a well completion report was unavailable. The aquifer type indicated for sampled wells was assigned through evaluation of driller’s logs and published geologic maps, including Fisher and others (1970) and Cadwell (1999).

The characteristics of the wells sampled, the USGS-assigned county well numbers of production and domestic wells, and the type of land cover surrounding each well are listed in table 2. The depths of the wells and the aquifer units from which samples were collected are summarized in tables 2 and 3. Three Lake Champlain Basin wells sampled in 2014 (CL 149, EX 589, and W 534) were also sampled in 2009 (Nystrom, 2011); two of those wells (CL 149 and W 534) were sampled as part of the 2004–05 round of the study as well (Nystrom, 2006). Three Susquehanna River Basin wells sampled in 2014 (BM 90, OG 316, and TI 892) were also sampled in 2009 (Reddy and Risen, 2012); one of those wells (BM 90) was sampled as part of the 2004–05 round of the study, as well (Hetcher-Aguila and Eckhardt, 2006). Domestic wells that are completed in sand and gravel aquifers are generally finished with open-ended casing so that groundwater enters the well only through the end of the casing (thus, the casing depth and well depth for domestic sand and gravel wells listed in table 2 are the same). Production wells, however, are typically completed with a well screen to maximize the well yield; the difference between the casing depth and the well depth in table 2 is the approximate screened interval for these wells. In some cases, however, smaller yielding production wells are completed open-ended in sand and gravel aquifers with no screen (that is, W3220). Bedrock wells, both domestic and production, are completed with a surface casing cemented several feet into competent bedrock, and the balance of the well is completed as an open hole in bedrock. In bedrock wells, groundwater moves mainly through bed partings, joints, and other fractures in the rock towards the wellbore under pumping conditions.

Sampling Methods

Water-quality samples were collected and processed in accordance with documented USGS protocols (U.S. Geological Survey, 2006). The samples were collected before any water treatment system to be representative of the native aquifer water. Samples from domestic wells were collected from a spigot near the pressure tank; samples from production wells were collected at the spigot or faucet used for collection of raw water samples by water managers.

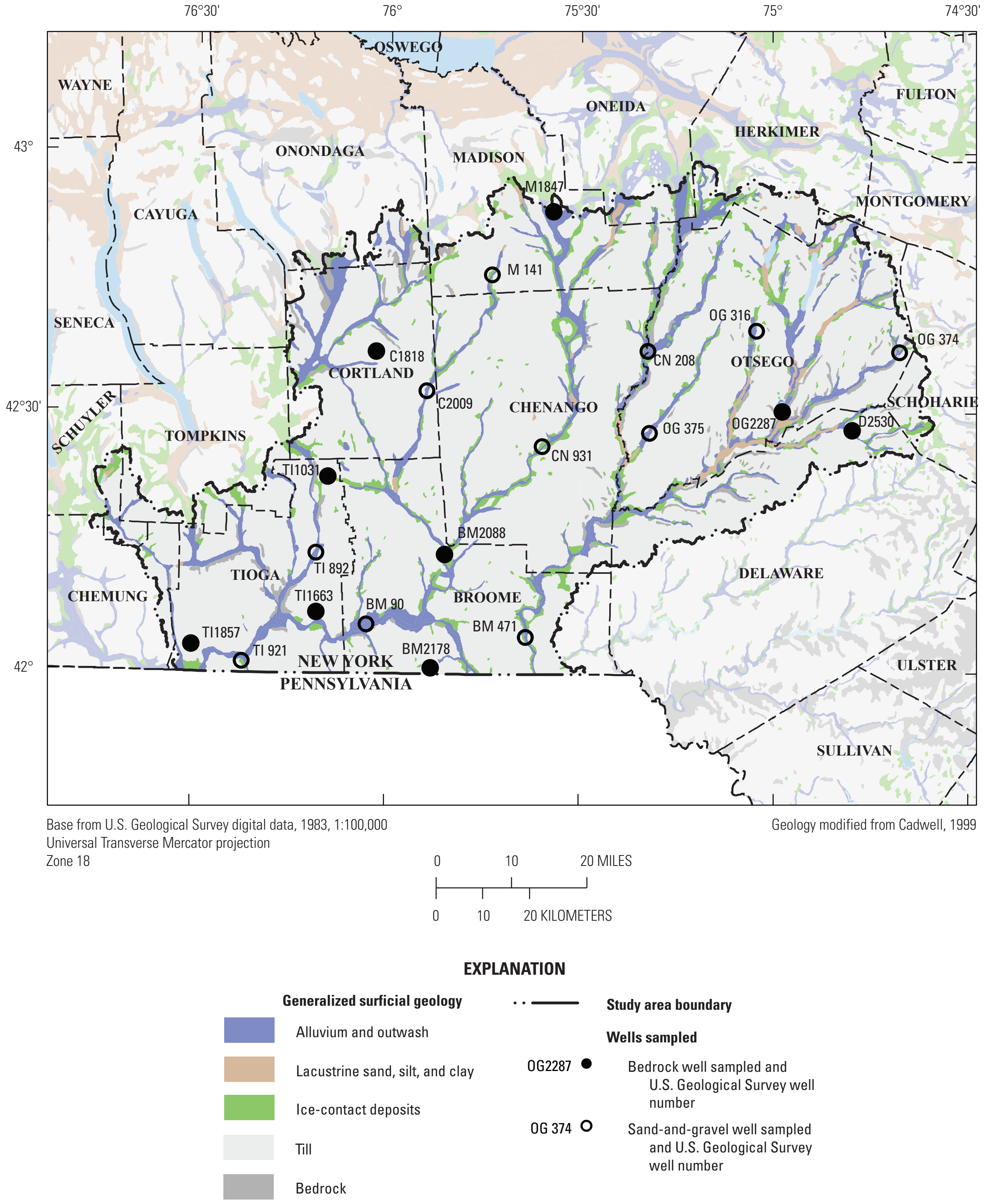
Samples were collected from garden hose thread spigots at all sites where possible. Domestic wells were purged by pumping groundwater to waste for at least 20 minutes at pumping rates ranging from about 2 to 5 gallons per minute (gal/min) or until at least one well casing volume of water had passed the sampling point. Wells that had been used recently required removal of less than three well casing



Base from U.S. Geological Survey digital data, 1983, 1:100,000
Universal Transverse Mercator projection
Zone 18

Geology modified from Fisher and others, 1970

Figure 5. Generalized bedrock geology of the Susquehanna River Basin, New York, and locations of wells sampled in 2014.



Base from U.S. Geological Survey digital data, 1983, 1:100,000
Universal Transverse Mercator projection
Zone 18

Geology modified from Cadwell, 1999

Figure 6. Generalized surficial geology of the Susquehanna River Basin, New York, and locations of wells sampled in 2014.

Table 2. Description of wells from which water samples were collected in the Lake Champlain and Susquehanna River Basins, New York, 2014.

[—, unknown; well types: P, production; D, domestic. Land-cover categories: D, developed; F, forested; A, agricultural; W, open water; WL, wetlands. Well locations are for the Lake Champlain Basin are shown in figures 2 and 3, and for the Susquehanna River Basin, in figures 5 and 6]

Well number[1]	Station identification number	Date sampled (mm/dd/yyyy)	Well depth, in feet below land surface	Casing depth, in feet below land surface	Well type	Bedrock type	Land cover,[2] as percentage by category, within 0.5-mile radius surrounding the well				
							D	F	A	W	WL
Lake Champlain Basin											
Sand and gravel wells											
CL 169	443249073263001	10/6/2014	185	—	P		12	51		25	12
EX 589	442101073425601	10/28/2014	67.1	55	P		4	74	9		13
EX1028	441521074030701	7/9/2014	79	79	D			96			4
EX1834	441743073361901	7/9/2014	84	80	D		5	94	1		
W 534	432428073311501	7/1/2014	140	—	P		8	34	51		7
W3220	432407073152001	7/1/2014	18	18	P		51	22	16		10
Bedrock wells											
CL 149	445939073275102	10/8/2014	137	—	P	Sandstone	56	8	28		8
CL 170	444203073325801	10/7/2014	220	—	P	Carbonate	27	22	31		21
CL 700	443526073502601	6/30/2014	100	40	D	Crystalline	10	72	11	3	4
CL 848	445104073390001	11/24/2014	350	20	D	Sandstone	5	76	9		9
EX1023	440350073270501	6/24/2014	805	20	D	Crystalline	8	41	7	43	
EX1742	442513073481601	12/9/2014	255	105	D	Crystalline	2	96	2		
EX1894	434819073262101	6/23/2014	445	80	D	Crystalline	11	12	3	73	
Susquehanna River Basin											
Sand and gravel wells											
BM 90	420540076030701	7/10/2014	160	145	P		79	2	2	12	5
BM 471	420417075382801	7/28/2014	117	107	P		43	25	21	5	7
C2009	423236075540301	8/4/2014	120	105	P		19	30	42		9
CN 208	423731075193901	8/11/2014	360	—	P		36	8	33	3	20
CN 931	422618075360001	8/14/2014	111	80	P		37	34	22	1	6
M 141	424601075440801	7/23/2014	70	62.3	P		13	31	55		1
OG 316	423938075024001	7/7/2014	43.6	37	P		15	26	45		14
OG 374	423718074401501	7/29/2014	70	—	P		26	36	32		6
OG 375	422753075191901	8/13/2014	93.5	83.6	P		18	19	51		12
TI 892	421350076110301	7/9/2014	180	—	P		26	45	27		2
TI 921	420123076221601	7/21/2014	66	56	P		46	8	27	9	10
Bedrock wells											
BM2088	421348075505701	7/30/2014	149	63	D	Shale and sandstone	10	71	11	5	3
BM2178	420040075530601	8/12/2014	160	48.5	D	Shale and sandstone	2	80	16		2
C1818	423710076015301	7/22/2014	120	86.5	D	Shale and sandstone	2	83	16		
D2530	422809074473901	7/30/2014	80	45.5	D	Shale and sandstone	11	59	28		2
M1847	425325075342201	7/28/2014	142	20	D	Limestone	8	52	36		3
OG2287	423024074583101	8/5/2014	270	252.5	D	Shale and sandstone	18	59	1	20	1
TI1031	422237076092001	8/6/2014	180	45.5	D	Shale and sandstone	6	69	16		9
TI1663	420702076105301	8/18/2014	100	23	D	Shale and sandstone	2	70	28		
TI1857	420303076300701	7/21/2014	125	44	D	Shale and sandstone	4	61	35		

[1] Prefix denotes county: BM, Broome; C, Cortland; CL, Clinton; CN, Chenango; D, Delaware; EX, Essex; M, Madison; OG, Otsego; TI, Tioga; W, Washington. Number is local well identification number assigned by the U.S. Geological Survey.

[2] Determined from the National Land Cover Database (Vogelmann and others, 2001).

Table 3. Summary of 33 wells from which water samples were collected in the Lake Champlain and Susquehanna River Basins, New York, 2014.

Basin and type of well	Number of wells		
	Production	Domestic	Total
Lake Champlain Basin			
Wells completed in sand and gravel (depth 18 to 185 feet below land surface)	4	2	6
Wells completed in bedrock (depth 100 to 805 feet below land surface)	2	5	7
All well types	6	7	13
Susquehanna River Basin			
Wells completed in sand and gravel (depth 43.6 to 360 feet below land surface)	11	0	11
Wells completed in bedrock (depth 80 to 270 feet below land surface)	0	9	9
All well types	11	9	20
All basins	**17**	**16**	**33**

volumes (U.S. Geological Survey, 2006). At least three well casings of water were pumped from production wells before sampling; several were pumped for 1 hour or more prior to sampling, typically at rates of about 100 gal/min. During well purging, notes about the well, surrounding land, and land use were recorded, including a global positioning system measurement of latitude and longitude. Field measurements of water temperature, pH, specific conductance, and dissolved oxygen concentration were recorded at the site using portable instruments (U.S. Geological Survey, n.d.).

The flow rate for sample collection was adjusted to less than 0.5 gal/min when possible. The sampling tube was then connected to a sample collection chamber constructed of a polyvinyl chloride frame and a clear plastic chamber bag, the purpose of which is to minimize the possibility of any airborne contaminants getting into the water samples. The tubing and spigot attachment equipment for each sample were precleaned (U.S. Geological Survey, 2006).

Samples were collected and preserved in the sampling chamber according to standard USGS procedures (U.S. Geological Survey, 2006). Samples for nutrient, major ion, and some trace element analyses were filtered through disposable (one-time use) 0.45-micrometer (µm) pore-size polyether sulfone capsule filters that were preconditioned in the laboratory with 3 liters (L) of deionized water on the day of sample collection and stored on ice until use in the field. Samples for pesticide analyses were filtered through baked 0.7-µm pore-size glass-fiber filters. Ultrapure nitric acid preservation was required for trace element samples, except mercury, which was preserved with ultrapure hydrochloric acid. Hydrochloric acid was added to samples analyzed for volatile organic compounds (VOCs) to reduce the sample pH below 2.0 and kill bacteria that might degrade VOCs. Samples for major cation analysis and some samples for radiochemical analysis were preserved with ultrapure nitric acid. Acid preservative was added after the collection of other samples to avoid the possibility of cross contamination by the acid preservative; for example, samples preserved with nitric acid were acidified after the collection of samples for nutrient analysis. Water samples for radon analysis were collected through a septum chamber with a glass syringe, according to standard USGS procedures (U.S. Geological Survey, 2006). Bottles containing water samples for the analysis of dissolved gases were filled and sealed while submerged in a beaker of well water to prevent exposure to the atmosphere. Samples for bacterial analysis were collected in accordance with NYSDEC and NYSDOH protocols (Clesceri and others, 1998), except that the tap from which each water sample was collected was not flame sterilized. Water samples for bacterial analysis were collected in sterilized bottles provided by the NYSDOH-certified analyzing laboratory. After collection, all water samples except those for radiochemical analyses were chilled to 4 degrees Celsius (°C) or less and were kept chilled until delivery to the analyzing laboratory. Bacterial samples were hand delivered to the analyzing laboratory within 6 hours of collection; all other samples were shipped by overnight delivery to the designated laboratories.

Analytical Methods

Samples were measured for 148 physiochemical properties and constituents, including dissolved gases, major ions, nutrients, trace elements, pesticides, pesticide degradates, VOCs, radionuclides, and bacteria. Water temperature, pH, dissolved oxygen concentration, and specific conductance were measured at the sampling site. Major ions, nutrients, total organic carbon, trace elements, radon-222, pesticides, pesticide degradates, and VOCs were analyzed at the USGS NWQL in Denver, Colorado. Selected dissolved gases were analyzed at the USGS Chlorofluorocarbon Laboratory in Reston, Virginia. Gross-α and gross-β radioactivities were analyzed at Test America in Richland, Washington. Samples were analyzed for indicator bacteria at one of the following

NYSDOH-certified laboratories: Lake Champlain Basin samples were analyzed at the Darren Freshwater Institute in Bolton Landing, N.Y.; Susquehanna River Basin samples were analyzed at Community Science Institute in Ithaca, N.Y.

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). Color was determined by visual comparison using method I–1250–85 (Fishman and Friedman, 1989). Nutrients were analyzed by colorimetry, as described by Fishman (1993), and Kjeldahl digestion with photometric finish, as described by Patton and Truitt (2000). Total organic carbon samples were analyzed by high temperature combustion and catalytic oxidation for measurement by infrared detection according to Standard Method 5310B (Clesceri and others, 1998). Mercury concentrations were measured through cold vapor-atomic fluorescence spectrometry according to methods described by Garbarino and Damrau (2001). Arsenic, chromium, and nickel were analyzed by use of collision/reaction cell inductively coupled plasma-mass spectrometry, 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, and inductively coupled plasma-mass spectrometry (Garbarino and Struzeski, 1998). Procedures for in-bottle digestions for trace element analyses described by Hoffman and others (1996) were followed. Radon-222 activities were measured through liquid scintillation counting (ASTM International, 2006). Samples for pesticide analyses were processed as described by Wilde and others (2004) and were analyzed using gas chromatography-mass spectrometry (GC–MS) and high-performance liquid chromatography-mass spectrometry, as described by Zaugg and others (1995), Furlong and others (2001), and Sandstrom and others (2001). VOCs were analyzed by GC–MS using methods described by Connor and others (1998).

Gross-α and gross-β radioactivities were measured according to EPA method 900.0 (U.S. Environmental Protection Agency, 1980). Carbon dioxide (CO_2) and methane (CH_4) concentrations were measured through gas chromatography with flame ionization detection; dissolved nitrogen gas and argon concentrations were measured using gas chromatography with thermal conductivity detection (Busenberg and others, 1998). Indicator bacteria samples were tested for total coliforms, fecal coliforms (also known as thermotolerant coliforms), and *Escherichia coli (E. coli)* using membrane filtration and standard method 9222; a heterotrophic plate count test (SM 9215 B) also was done (Clesceri and others, 1998).

Quality-Control Samples

In addition to the 33 groundwater samples, 2 field blank samples and 1 replicate sample were collected for quality assurance. Silica, ammonia, and ammonia plus organic nitrogen were detected in one or both field blank samples. In the field blank collected in the Lake Champlain Basin and the field blank collected in the Susquehanna River Basin, silica was measured at 0.033 milligram per liter (mg/L) and 0.045 mg/L, respectively (laboratory reporting level [LRL] for silica is 0.036 mg/L). The minimum silica concentration detected in the environmental samples was 4.02 mg/L. In one field blank, collected in the Lake Champlain Basin, ammonia was measured at a concentration of 0.012 mg/L as nitrogen (N; LRL for ammonia is 0.010 mg/L). One environmental sample had an ammonia concentration less than 0.012 mg/L as N. This sample was given a “V” remark code in the associated tables and discussion within the text. “V” remark codes indicate that a value may be affected by contamination; the analyte was detected in environmental samples and the associated blanks. In the Susquehanna River Basin field blank, ammonia plus organic nitrogen was measured at 0.19 mg/L as N (LRL for ammonia plus organic nitrogen as N is 0.14 mg/L). Six environmental samples had ammonia plus organic nitrogen detections less than 0.19 mg/L as N. These six samples were given “V” remark codes in associated tables and discussion within the text. Two environmental samples collected in the Susquehanna River Basin (BM 90 and OG 316) were collected using the equipment used in the Lake Champlain Basin. Therefore, detections in these two samples were evaluated in the context of the Lake Champlain Basin field blank analysis. The ammonia plus organic nitrogen concentration of 0.10 mg/L as N at OG 316 was not given a “V” code because there was no detection in the blank sample collected with the Lake Champlain Basin equipment. The variability between replicate samples was less than 20 percent for all constituents with the exception of low level gross-β activity.

Groundwater Quality

Many of the constituents for which the groundwater samples were analyzed were not detected in any sample. Some concentrations are reported as “E” (for estimated). Estimated concentrations are typically reported when 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). Concentrations of some constituents (table 4) exceeded maximum contaminant levels (MCLs) or secondary drinking-water standards (SDWS) set by the EPA (U.S. Environmental Protection Agency, 2009) or NYSDOH (New York State Department of Health, 2011) or proposed alternative MCLs set by the EPA (U.S. Environmental Protection Agency, 1999). MCLs are enforceable standards for finished water in public water supplies; they are not enforceable for private homeowner wells but are presented here as a standard for evaluation of the water-quality results. SDWS are nonenforceable drinking-water standards that typically relate to aesthetic concerns such as taste, odor, or staining of plumbing fixtures. Well owners were notified promptly if any constituent exceeded EPA or NYSDOH

Table 4. Constituents that exceeded primary and (or) secondary drinking-water standards in groundwater samples collected in the Lake Champlain and Susquehanna River Basins, New York, 2014.

[Well locations for the Lake Champlain Basin are shown in figures 2 and 3, and for the Susquehanna River Basin, in figures 5 and 6. P, production well; D, domestic well; —, not applicable; pAMCL, proposed alternative maximum contaminant level; pMCL, proposed maximum contaminant level; f, in filtered water; u, in unfiltered water]

Well number[1]	Well type	Bedrock type	Constituents that exceeded drinking-water standards
Lake Champlain Basin			
Sand and gravel wells			
CL 169	P	—	Total coliforms,[2,3,4] radon[5] (pAMCL)
EX 589	P	—	—
EX1028	D	—	—
EX1834	D	—	—
W 534	P	—	—
W3220	P	—	—
Bedrock wells			
CL 149	P	Sandstone	Iron (f,u),[3,6] manganese (f,u),[6] dissolved solids,[6] sodium[7]
CL 170	P	Carbonate	Radon[5] (pAMCL)
CL 700	D	Crystalline	Manganese (f,u),[6] radon[5] (pAMCL)
CL 848	D	Sandstone	Radon[5] (pMCL)
EX1023	D	Crystalline	Total coliforms,[2,3,4] fecal coliforms,[2,3,4] *E. coli*,[2,3,4] radon[5] (pAMCL)
EX1742	D	Crystalline	—
EX1894	D	Crystalline	Total coliforms,[2,3,4] manganese (f,u),[3,6] fluoride[3,6]
Susquehanna River Basin			
Sand and gravel wells			
BM 90	P	—	Chloride,[3,6] iron (f,u),[3,6] manganese (f,u),[3,6] dissolved solids,[6] sodium[7]
BM 471	P	—	Dissolved solids,[6] sodium,[7] radon[5] (pAMCL)
C2009	P	—	Radon[5] (pAMCL)
CN 208	P	—	Manganese (f,u)[6]
CN 931	P	—	Radon[5] (pAMCL)
M 141	P	—	Radon[5] (pAMCL)
OG 316	P	—	Total coliforms,[2,3,4] radon[5] (pAMCL)
OG 374	P	—	pH,[6] sodium,[7] radon[5] (pAMCL)
OG 375	P	—	Manganese (f,u)[6]
TI 892	P	—	Radon[5] (pAMCL)
TI 921	P	—	pH,[6] radon[5] (pAMCL)

Table 4. Constituents that exceeded primary and (or) secondary drinking-water standards in groundwater samples collected in the Lake Champlain and Susquehanna River Basins, New York, 2014.—Continued

[Well locations for the Lake Champlain Basin are shown in figures 2 and 3, and for the Susquehanna River Basin, in figures 5 and 6. P, production well; D, domestic well; —, not applicable; pAMCL, proposed alternative maximum contaminant level; pMCL, proposed maximum contaminant level; f, in filtered water; u, in unfiltered water]

Well number[1]	Well type	Bedrock type	Constituents that exceeded drinking-water standards
Susquehanna River Basin—Continued			
Bedrock wells			
BM2088	D	Shale and sandstone	Barium,[2,3] chloride,[3,6] iron (f,u),[3,6] manganese (f,u),[3,6] dissolved solids,[6] gross-α radioactivity,[2,3] sodium,[7] methane[8]
BM2178	D	Shale and sandstone	Manganese (f,u),[6] radon[5] (pAMCL)
C1818	D	Shale and sandstone	Sodium,[7] radon[5] (pAMCL)
D2530	D	Shale and sandstone	Radon[5] (pAMCL)
M1847	D	Limestone	Total coliforms,[2,3,4] radon[5] (pAMCL)
OG2287	D	Shale and sandstone	Manganese (f,u)[6]
TI1031	D	Shale and sandstone	Arsenic,[2,3] iron (u),[3,6] manganese (u),[3,6] aluminum,[6] radon[5] (pAMCL)
TI1663	D	Shale and sandstone	Manganese (f,u),[3,6] radon[5] (pAMCL)
TI1857	D	Shale and sandstone	Manganese (f,u)[6]

[1] Prefix denotes county: BM, Broome; C, Cortland; CL, Clinton; CN, Chenango; D, Delaware; EX, Essex; M, Madison; OG, Otsego; TI, Tioga; W, Washington. Number is local well identification number assigned by the U.S. Geological Survey.

[2] U.S. Environmental Protection Agency (2009) maximum contaminant level.

[3] New York State Department of Health (2011) maximum contaminant level.

[4] Maximum contaminant level exceedances for bacteria in public drinking-water supplies are generally defined in terms of a certain number of positive samples per month on the basis of the number of samples collected.

[5] U.S. Environmental Protection Agency (1999) proposed maximum contaminant level of 300 picocuries per liter for areas that do not implement an indoor air radon mitigation program.

[6] U.S. Environmental Protection Agency (2009) secondary drinking-water standard.

[7] U.S. Environmental Protection Agency (2009) drinking-water advisory taste threshold.

[8] Methane concentration above recommended monitoring concentration (Eltschlager and others, 2001).

MCLs. Copies of the complete analytical results were mailed to each well owner.

The results of analyses of the 33 groundwater samples collected in the Lake Champlain Basin and Susquehanna River Basin collected during June through December 2014 are presented in tables 1–1 through 1–9. Of the 148 constituents and physiochemical properties analyzed for, 75 were not detected at levels greater than the LRLs in any sample (table 1–1). Results for the remaining 73 constituents and properties that were detected in the Lake Champlain Basin and Susquehanna River Basin are presented in tables 1–2 through 1–9.

Physiochemical Properties

Groundwater-quality samples were analyzed in the field for physiochemical properties, including water temperature, pH, specific conductance, and dissolved oxygen. Samples were collected for analysis of color. Qualitative assessment of the presence of hydrogen sulfide was noted. Results of analyses are reported in table 5 and in table 1–2. The number of samples that exceeded drinking-water standards for physiochemical properties are reported in table 6. No drinking-water standards exist for specific conductance, water temperature, and dissolved oxygen.

Most samples from the Lake Champlain Basin had a color of less than (<) 1 platinum-cobalt (Pt-Co) unit (tables 5, 6, and 1–2). Three samples, two from sand and gravel wells (W 534, W3220) and one from a bedrock well (CL 149) had color of 2 Pt-Co units. One sample from a bedrock well (CL 700) had color of 8 Pt-Co units (EPA SDWS is 15 Pt-Co units). Sample pH was typically near neutral (median of 7.8 for sand and gravel wells, median of 7.6 for bedrock wells) and ranged from 6.7 to 8.3. Specific conductance ranged from 70 to 1,220 microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C); the median specific conductance was 190 µS/cm at 25 °C for sand and gravel wells and 390 µS/cm at 25 °C for bedrock wells. Water temperature ranged from 7.5 to 16.4 °C; the median temperature was 8.6 °C for sand and gravel wells and 9.7 °C for bedrock wells. Hydrogen sulfide odor was not detected in any wells sampled in the Lake Champlain Basin.

Most samples from the Susquehanna River Basin had a detectable color (tables 5 and 1–2). Six samples, mostly from bedrock wells had colors of 5 Pt-Co units, one sample from a bedrock well (TI1031) had a color of 12 Pt-Co units. Sample pH was typically near neutral (median of 7.3 for sand and gravel wells, median of 7.6 for bedrock wells) and ranged from 6.3 to 8.4. The pH values for samples from sand and gravel wells OG 374 and TI 921 (6.4 and 6.3, respectively) were lower than the EPA SDWS range for pH. Specific conductance ranged from 199 to 7,980 µS/cm at 25 °C; the median specific conductance was 484 µS/cm at 25 °C for sand and gravel wells and 312 µS/cm at 25 °C for bedrock wells. Water temperature ranged from 9.1 to 16.1 °C; the median temperature was 11.3 °C for sand and gravel wells and 12.7 °C for bedrock wells. Hydrogen sulfide odor was detected in two sand and gravel wells (CN 208, OG 316) and one bedrock well (D2530).

Dissolved Gases

Dissolved oxygen was measured in the field. Groundwater-quality samples were analyzed for dissolved gases including CO_2, argon, nitrogen, and CH_4. Results are reported in tables 5 and 1–2. The concentrations of CO_2, argon, nitrogen gas, and CH_4 were determined twice for each site; therefore, the statistics given include two samples per well. These data are listed in table 1–2. No drinking-water standards exist for CO_2, argon, and nitrogen gas; however, the number of samples that exceeded drinking-water standards for CH_4 are reported in table 6.

In the Lake Champlain Basin, dissolved oxygen concentrations ranged from <0.3 to 11.2 mg/L (tables 5 and 1–2) and typically were greater in samples from sand and gravel wells (median 5.8 mg/L) than in samples from bedrock wells (median 0.6 mg/L). Median concentrations of dissolved gases in samples from sand and gravel wells were 21.24 mg/L for nitrogen, 2.4 mg/L for CO_2, 0.756 mg/L for argon, and <0.001 mg/L for CH_4. Median concentrations of dissolved gases in samples from bedrock wells were 25.55 mg/L for nitrogen, 6.9 mg/L for CO_2, 0.824 mg/L for argon, and <0.001 mg/L for CH_4.

In the Susquehanna River Basin, dissolved oxygen concentrations ranged from <0.3 to 5.9 mg/L (tables 5 and 1–2) and, similar to the Lake Champlain Basin were typically greater in samples from sand and gravel wells (median 3.1 mg/L) than in samples from bedrock wells (median 0.5 mg/L). Median concentrations of dissolved gases in samples from sand and gravel wells were 20.70 mg/L for nitrogen, 21.3 mg/L for CO_2, 0.738 mg/L for argon, and <0.001 mg/L for CH_4. Median concentrations of dissolved gases in samples from bedrock wells were 23.20 mg/L for nitrogen, 5.2 mg/L for CO_2, 0.812 mg/L for argon, and 0.017 mg/L for CH_4, which was detected in 9 of the 20 samples; six of those detections were at trace level. Although the EPA and NYSDOH do not have MCLs for CH_4, dissolved CH_4 concentrations greater than 28 mg/L can pose explosion hazards as a result of CH_4 accumulation in confined spaces. The U.S. Department of Interior, Office of Surface Mining recommends that CH_4 concentrations ranging from 10 to 28 mg/L in water signify an action level where the situation should be closely monitored; if the concentration increases, enclosed areas should be vented to prevent CH_4 gas buildup (Eltschlager and others, 2001). The concentrations of CH_4 in the two duplicate samples from bedrock well BM2088 were 61.0 mg/L and 50.5 mg/L, both of which were greater than safety threshold of 28 mg/L. Samples from two bedrock wells (C1818 and D2530) had concentrations of CH_4 ranging from 6.52 to 11.9 mg/L (tables 6 and 1–2), which exceeded the action level of 10 to 28 mg/L.

Table 5. Summary statistics for physiochemical properties of groundwater samples collected in the Lake Champlain and Susquehanna River Basins, New York, 2014.

[All concentrations are in unfiltered water. Values in **bold** indicate samples that exceed one or more drinking-water or safety standards. Pt-Co units, platinum-cobalt unit; mg/L, milligram per liter; µS/cm at 25 °C, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; <, value less than reporting level]

Constituent	All samples			Lake Champlain Basin						Susquehanna River Basin					
	All aquifers (33 samples)			Sand and gravel aquifers (6 samples)			Bedrock aquifers (7 samples)			Sand and gravel aquifers (11 samples)			Bedrock aquifers (9 samples)		
	Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum
Color, filtered, in Pt-Co units	<1	2	12	<1	<1	2	<1	<1	8	<1	<1	5	<1	5	12
Dissolved oxygen, in mg/L	<0.3	2.7	11.2	0.3	5.8	11.2	<0.3	0.6	11.2	0.3	3.1	5.9	<0.3	0.5	5.4
pH	**6.3**	7.6	8.4	7.4	7.8	8.3	6.7	7.6	8.1	**6.3**	7.3	8.0	6.8	7.6	8.4
Specific conductance, in µS/cm at 25 °C	70	358	7,980	70	190	443	88	390	1,220	266	484	1,540	199	312	7,980
Temperature, in °C	7.5	10.9	16.4	7.5	8.6	16.4	8	9.7	12.2	9.1	11.3	12.8	10.7	12.7	16.1
Carbon dioxide, in mg/L	0.5	7.2	74	0.6	2.4	18.1	1.1	6.9	74	1.4	21.3	72.2	0.5	5.2	35.9
Argon, in mg/L	0.536	0.774	1.013	0.582	0.756	0.811	0.753	0.824	1.013	0.715	0.738	0.783	0.536	0.812	0.888
Nitrogen gas, in mg/L	10.34	22.39	32.59	15.83	21.24	23.76	21.44	25.55	32.59	19.74	20.70	26.28	10.34	23.20	28.36
Methane, in mg/L	<0.001	<0.001	**61.0**	<0.001	<0.001	0.097	<0.001	<0.001	0.022	<0.001	<0.001	0.100	<0.001	0.017	**61.0**

Table 6. Drinking-water standards for physiochemical properties and dissolved gases and number of groundwater samples exceeding those standards collected in the Lake Champlain and Susquehanna River Basins, New York, 2014.

[All concentrations in unfiltered water. Pt-Co units, platinum-cobalt unit; mg/L, milligram per liter]

Constituent	Drinking-water standard	Number of samples exceeding drinking-water standards		
		All samples (33 samples)	Lake Champlain Basin (13 samples)	Susquehanna River Basin (20 samples)
Color, filtered, in Pt-Co units	[1]15	0	0	0
pH	[1]6.5–8.5	2	0	2
Methane, in mg/L	[2]28	1	0	1

[1] U.S. Environmental Protection Agency (2009) secondary drinking water standard.

[2] Methane recommended monitoring concentration (Eltschlager and others, 2001).

Major Ions and Dissolved Solids

Groundwater-quality samples were analyzed for anions, including bicarbonate, chloride, fluoride, silica, and sulfate; cations including calcium, magnesium, potassium, and sodium; alkalinity; hardness; and dissolved solids. Results are reported in tables 7 and 1–3. The number of samples that exceeded drinking-water standards for major ions and dissolved solids are reported in table 8. No drinking-water standards exist for calcium, magnesium, potassium, bicarbonate, silica, hardness, or alkalinity.

In the Lake Champlain Basin, the anions detected in the highest concentrations were bicarbonate (median concentration 100 mg/L in sand and gravel wells, 128 mg/L in bedrock wells) and sulfate (median concentration 8.20 mg/L in sand and gravel wells, 14.7 mg/L in bedrock wells; tables 7 and 1–3). The cations detected in the highest concentrations were calcium (median concentration 20.2 mg/L in sand and gravel wells, 36.0 mg/L in bedrock wells), magnesium (median concentration 5.46 mg/L in sand and gravel wells, 9.46 mg/L in bedrock wells), and sodium (median concentration 3.69 mg/L in sand and gravel wells, 8.57 mg/L in bedrock wells). The concentration of sodium in one sample (CL 149, 138 mg/L) exceeded the EPA drinking water advisory taste threshold of 60 mg/L; the concentration of fluoride in one sample (EX1894, 2.26 mg/L) exceeded the NYSDOH MCL of 2.2 mg/L and the EPA secondary drinking water standard of 2.0 mg/L. The concentrations of chloride and sulfate did not exceed established MCLs in any sample (tables 8 and 1–3).

For samples in the Lake Champlain Basin, three samples were classified as “soft” (0 to 60 mg/L as calcium carbonate, [$CaCO_3$]), five as “moderately hard” (61 to 120 mg/L as $CaCO_3$), two as “hard” (121 to 180 mg/L as $CaCO_3$) and three as “very hard” (greater than 180 mg/L as $CaCO_3$; Hem, 1985). The median hardness was 84.8 mg/L as $CaCO_3$ for sand and gravel wells, and 142 mg/L as $CaCO_3$ for bedrock wells; the maximum hardness was 321 mg/L as $CaCO_3$ (bedrock well, CL 149; table 1–3). Alkalinity ranged from 24 to 283 mg/L as $CaCO_3$; the median was 82 mg/L as $CaCO_3$ for sand and gravel wells, and 107 mg/L as $CaCO_3$ for bedrock wells. Dissolved solids concentrations ranged from 50 to 659 mg/L with a median of 116 mg/L for sand and gravel wells and 195 mg/L for bedrock wells. Dissolved solids concentration in one bedrock sample (CL 149, 659 mg/L) exceeded the EPA SDWS for total dissolved solids of 500 mg/L (tables 8 and 1–3).

In the Susquehanna River Basin, the anions detected with the highest concentrations were bicarbonate (median concentration 113 mg/L in sand and gravel wells, 119 mg/L in bedrock wells), and chloride (median concentration 59.2 mg/L in sand and gravel wells, 4.15 mg/L in bedrock wells; tables 7 and 1–3). The cations detected in the highest concentrations were calcium (median concentration 46.1 mg/L in sand and gravel wells, 30.2 mg/L in bedrock wells) and sodium (median concentration 30.5 mg/L in sand and gravel wells, 17.0 mg/L in bedrock wells). The concentration of sodium in 3 sand and gravel samples (BM 90, 103 mg/L; BM 471, 91.0 mg/L, and OG 374, 64.7 mg/L) and 2 bedrock samples (BM2088, 1,200 mg/L; and C1818, 80.6 mg/L) exceeded the EPA drinking water advisory taste threshold of 60 mg/L. The concentration of chloride in 1 sand and gravel sample (BM 90, 312 mg/L) and 1 bedrock sample (BM2088, 2,260 mg/L) exceeded the EPA MCL and the NYSDOH MCL of 250 mg/L. The concentrations of fluoride and sulfate did not exceed established MCLs in any sample (tables 8 and 1–3).

For samples in the Susquehanna River Basin, two samples were classified as “soft,” seven as “moderately hard,” six as “hard,” and five as “very hard.” The median hardness was 149 mg/L as $CaCO_3$ for sand and gravel wells and 100 mg/L as $CaCO_3$ for bedrock wells; and the maximum hardness was 794 mg/L as $CaCO_3$. Alkalinity ranged from 22 to 295 mg/L as $CaCO_3$; the median was 92 mg/L as $CaCO_3$ for sand and gravel wells, and 100 mg/L as $CaCO_3$ for bedrock wells. Dissolved solids concentrations ranged from 112 to 4,550 mg/L with a median of 278 mg/L for sand and gravel wells and 176 mg/L for bedrock wells. Dissolved solids concentration in two sand and gravel wells (BM 90, 1,080 mg/L; BM 471, 628 mg/L) and one bedrock sample (BM2088, 4,550 mg/L) exceeded the EPA SDWS for total dissolved solids of 500 mg/L (tables 8 and 1–3).

Table 7. Summary statistics for concentrations of major ions in groundwater samples collected in the Lake Champlain and Susquehanna River Basins, New York, 2014.

[All concentrations are in milligrams per liter in filtered water. Values in **bold** indicate samples that exceed one or more drinking-water or safety standard. °C, degrees Celsius; $CaCO_3$, calcium carbonate]

Constituent minimum		All samples			Lake Champlain Basin						Susquehanna River Basin					
		All aquifers (33 samples)			Sand and gravel aquifers (6 samples)			Bedrock aquifers (7 samples)			Sand and gravel aquifers (11 samples)			Bedrock aquifers (9 samples)		
		Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum
Cations	Calcium	6.60	37.1	241	7.97	20.2	61.9	11.8	36.0	104	25.0	46.1	175	6.60	30.2	241
	Magnesium	1.39	7.35	47.0	2.42	5.46	18.1	2.29	9.46	36.6	5.11	8.16	28.3	1.39	6.73	47.0
	Potassium	0.29	1.01	9.49	0.31	0.70	2.23	0.29	1.60	9.49	0.56	1.74	3.74	0.33	0.69	4.30
	Sodium	1.70	17.0	**1,200**	1.70	3.69	30.9	2.81	8.57	**138**	7.81	30.5	**103**	3.99	17.0	**1,200**
Anions	Bicarbonate	26	119	359	29	100	244	45	128	345	26	113	359	89	119	193
	Chloride	0.28	17.5	**2,260**	0.28	1.50	9.39	0.41	5.8	184	21.3	59.2	**312**	1.22	4.15	**2,260**
	Fluoride	0.02	0.07	**2.26**	0.03	0.04	0.27	0.04	0.11	**2.26**	0.02	0.04	0.08	0.07	0.22	0.34
	Silica	4.02	9.00	21.4	4.02	13.6	21.4	8.05	14.2	20.4	5.43	8.37	10.9	6.67	8.24	17.6
	Sulfate	0.08	10.7	95.8	6.53	8.20	16.8	7.04	14.7	95.8	8.47	14.5	38.8	0.08	10.7	29.9
Hardness as $CaCO_3$		22.2	119	794	29.9	84.8	229	38.9	142	321	83.5	149	554	22.2	100	794
Alkalinity as $CaCO_3$		22	99	295	24	82	217	37	107	283	22	92	295	73	100	162
Dissolved solids, dried at 180 °C		50	195	**4,550**	50	116	212	63	195	**659**	148	278	**1,080**	112	176	**4,550**

Table 8. Drinking-water standards for concentrations of major ions and number of groundwater samples exceeding those standards collected in the Lake Champlain and Susquehanna River Basins, New York, 2014.

[All concentrations are in milligrams per liter in filtered water. °C, degrees Celsius]

Constituent		Drinking-water standard	Number of samples exceeding drinking-water standards		
			All samples (33 samples)	Lake Champlain Basin (13 samples)	Susquehanna River Basin (20 samples)
Cations	Sodium	[1]60	6	1	5
Anions	Chloride	[2,3]250	2	0	2
	Fluoride	[4]4.0	0	0	0
		[2]2.2	1	1	0
		[3]2	1	1	0
	Sulfate	[2,3]250	0	0	0
Dissolved solids, dried at 180 °C		[3]500	4	1	3

[1] U.S. Environmental Protection Agency (2009) drinking water advisory taste threshold.

[2] New York State Department of Health (2011) maximum contaminant level.

[3] U.S. Environmental Protection Agency (2009) secondary drinking water standard.

[4] U.S. Environmental Protection Agency (2009) maximum contaminant level.

Nutrients and Total Organic Carbon

Groundwater-quality samples were analyzed for several nutrients, including ammonia plus organic nitrogen, ammonia, nitrate plus nitrite, nitrate, nitrite, and orthophosphate, as well as total organic carbon. Results are reported in tables 9 and 1–4. The number of samples that exceeded drinking-water standards for nitrate, nitrite, and nitrate plus nitrite are reported in table 10. No drinking-water standards exist for ammonia, orthophosphate, and total organic carbon.

The dominant nutrient detected in the Lake Champlain Basin was nitrate (tables 9 and 1–4). The concentrations of nitrate ranged from <0.039 to 1.58 mg/L as nitrogen (N) and were generally greater in samples from sand and gravel wells (median 0.482 mg/L as N) than in samples from bedrock wells (median 0.063 mg/L as N). The concentrations of nitrate and nitrate plus nitrite did not exceed the NYSDOH and EPA MCL of 10 mg/L as N in any sample (tables 10 and 1–4). The concentrations of ammonia ranged from <0.010 to 0.06 mg/L as nitrogen (N) and were similar in samples from sand and gravel wells and in samples from bedrock wells. Nitrite was detected in only 3 of 13 samples and did not exceed the NYSDOH and EPA MCL of 1 mg/L as N in any sample. Orthophosphate concentrations ranged from <0.004 to 0.109 mg/L as phosphorus (P). Total organic carbon was detected in 4 of the 13 samples; the maximum concentration was 1.8 mg/L.

The dominant nutrient detected in the Susquehanna River Basin was nitrate (tables 9 and 1–4). The concentration of nitrate ranged from <0.040 to 4.58 mg/L as N and was generally greater in samples from sand and gravel wells (median 1.44 mg/L as N) than in samples from bedrock wells (median <0.040 mg/L as N). The concentration of nitrate and nitrate plus nitrite did not exceed the NYSDOH and EPA MCL of 10 mg/L as N in any sample (tables 10 and 1–4). The concentration of ammonia ranged from <0.010 to 1.40 mg/L as N and was generally higher in samples from bedrock wells (median 0.052 mg/L as N) than in samples from sand and gravel wells (median <0.010 mg/L as N). Nitrite was detected in 6 of the 20 samples and did not exceed the NYSDOH and EPA MCL of 1 mg/L as N in any sample. Orthophosphate concentrations ranged from <0.004 to 0.127 mg/L as phosphorus (P). Total organic carbon was detected in 5 of the 20 samples; the maximum concentration was 1.2 mg/L.

Trace Elements

Twenty-five trace elements were analyzed for in filtered and (or) unfiltered groundwater-quality samples. Results are reported in tables 11 and 1–5. The number of samples that exceeded drinking-water standards for trace elements are reported in table 12. No drinking-water standards exist for boron, cobalt, lithium, molybdenum, nickel, and strontium.

In the Lake Champlain Basin, the trace elements present in the highest median concentrations in the samples were strontium (median 94.2 micrograms per liter [µg/L] in sand and gravel wells; median 437 µg/L in bedrock wells), iron (median 51.8 µg/L in unfiltered water from bedrock wells;

Table 9. Summary statistics for concentrations of nutrients in groundwater samples collected in the Lake Champlain and Susquehanna River Basins, New York, 2014.

[All concentrations in milligrams per liter in filtered water except as noted. N, nitrogen; P, phosphorus; <, less than]

Constituent	All samples			Lake Champlain Basin						Susquehanna River Basin					
	All aquifers (33 samples)			Sand and gravel aquifers (6 samples)			Bedrock aquifers (7 samples)			Sand and gravel aquifers (11 samples)			Bedrock aquifers (9 samples)		
	Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum
Ammonia plus organic N, as N	<0.07	<0.07	1.5	<0.07	<0.07	<0.07	<0.07	<0.07	0.15	<0.07	<0.07	0.33	<0.07	0.10	1.5
Ammonia (NH_3 + NH_4^+), as N	<0.010	<0.010	1.40	<0.010	<0.010	0.03	<0.01	<0.010	0.06	<0.010	<0.010	0.291	<0.010	0.052	1.40
Nitrate plus nitrite (NO_2 + NO_3), as N	<0.040	0.078	4.58	<0.040	0.482	1.43	<0.040	0.063	1.82	<0.040	1.44	4.58	<0.040	<0.040	1.76
Nitrate (NO_3), as N	<0.039	0.078	4.58	<0.039	0.482	1.43	<0.039	0.063	1.58	<0.039	1.44	4.58	<0.039	<0.040	1.76
Nitrite (NO_2), as N	<0.001	<0.001	0.240	<0.001	<0.001	0.001	<0.001	<0.001	0.240	<0.001	<0.001	0.001	<0.001	<0.001	0.002
Orthophosphate (PO_4), as P	<0.004	0.008	0.127	0.006	0.024	0.050	<0.004	0.008	0.109	<0.004	0.007	0.127	<0.004	0.006	0.092
Total organic carbon, unfiltered	<0.7	<0.7	1.8	<0.7	<0.7	0.9	<0.7	<0.7	1.8	<0.7	<0.7	1.1	<0.7	<0.7	1.2

Table 10. Drinking-water standards for concentrations of nutrients and number of groundwater samples exceeding those standards collected in the Lake Champlain and Susquehanna River Basins, New York, 2014.

[All concentrations in milligrams per liter in filtered water. N, nitrogen]

Constituent	Drinking-water standard	Number of samples exceeding drinking water standards		
		All samples (33 samples)	Lake Champlain Basin (13 samples)	Susquehanna River Basin (20 samples)
Nitrate plus nitrite ($NO_2 + NO_3$), as N	[1,2]10	0	0	0
Nitrate (NO_3), as N	[1,2]10	0	0	0
Nitrite (NO_2), as N	[1,2]1	0	0	0

[1] U.S. Environmental Protection Agency (2009) maximum contaminant level.

[2] New York State Department of Health (2011) maximum contaminant level.

7.0 µg/L in filtered water from bedrock wells), and boron (median 23 µg/L in filtered water from bedrock wells; median 6.6 µg/L in filtered water from sand and gravel wells; tables 11 and 1–5).

The concentrations of iron in one sample from a bedrock well (CL 149) exceeded the NYSDOH MCL and EPA SDWS of 300 µg/L in the filtered and unfiltered samples (497 µg/L in the filtered sample; 606 µg/L in the unfiltered sample; tables 12 and 1–5). Samples from three bedrock wells (CL 149, CL 700, and EX1894) had concentrations of manganese that exceeded the EPA SDWS of 50 µg/L in unfiltered and filtered samples. However, samples from these wells did not exceed the NYSDOH MCL of 300 µg/L. The maximum concentration of manganese was 216 µg/L in an unfiltered sample from bedrock well CL 700. Drinking-water standards for antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, selenium, silver, thallium, zinc, and uranium were not exceeded (tables 12 and 1–5). Antimony, cadmium, mercury, and silver were not detected in any of the 13 Lake Champlain Basin samples collected (tables 1–1 and 1–5).

In the Susquehanna River Basin, the trace elements present in the highest median concentrations in the samples were strontium (median 94 µg/L in sand and gravel wells, median 175 µg/L in bedrock wells), iron (median concentration 149 µg/L in unfiltered water from bedrock wells and 116 µg/L in filtered water from bedrock wells), barium (median 128 µg/L in bedrock wells, median 26.7 µg/L in sand and gravel wells), manganese (median concentration of 113 µg/L in unfiltered water from bedrock wells and 111 µg/L in filtered water from sand and gravel wells), and boron (median 90 µg/L in filtered water from bedrock wells, median 21 µg/L in filtered water from sand and gravel wells; tables 11 and 1–5).

The concentration of aluminum in one sample from a bedrock well (TI1031, 501 µg/L) exceeded the EPA SDWS of 50 to 200 µg/L (tables 12 and 1–5). The concentration of arsenic in two samples—one from sand and gravel well (BM 90, 10.4 µg/L) and one from bedrock well (TI1031, 14.3 µg/L)—exceeded the EPA MCL and NYSDOH MCL of 10 µg/L. The concentration of barium in one sample from a bedrock well (BM2088, 18,300 µg/L) exceeded the NYSDOH MCL and EPA MCL of 2,000 µg/L. Additionally, the concentration of strontium in BM2088 was 12,900 µg/L. The concentration of iron in three samples (2 bedrock wells and 1 sand and gravel) exceeded the NYSDOH MCL and EPA SDWS of 300 µg/L in unfiltered samples; the maximum iron concentration was 1,950 µg/L (TI1031). Two of the three samples also had concentrations of iron that exceeded the MCL and SDWS when filtered. The concentration of manganese in 9 of 20 samples from the Susquehanna River Basin (3 from sand and gravel wells, 6 from bedrock wells) exceeded the EPA SDWS of 50 µg/L in unfiltered samples; only 1 of the samples from those nine wells did not have an exceedance in the associated filtered sample. The concentration of manganese in four of these samples further exceeded the NYSDOH MCL of 300 µg/L. The maximum manganese concentration was 1,170 µg/L (BM 90). Drinking-water standards for antimony, beryllium, cadmium, chromium, copper, lead, mercury, selenium, silver, thallium, and zinc were not exceeded; antimony, cadmium, mercury, and silver were not detected in any of the 20 Susquehanna River Basin samples (tables 1–1 and 1–5).

Pesticides

Groundwater-quality samples were analyzed for 52 pesticides and (or) pesticide degradates. No concentrations exceeded established drinking-water standards set for pesticides and pesticide degradates. Results are reported in table 1–6.

In the Lake Champlain Basin, five pesticides and (or) pesticide degradates were detected at trace concentrations in five samples (table 1–6). Most of the pesticides detected were broadleaf herbicides or their degradates; an insecticide (disulfoton) was also detected. Three out of the 5 wells with pesticide detections are bedrock wells; 2 wells are production wells, and 3 are domestic. The most frequently detected pesticides were the degradate 2-chloro-4-isopropylamino-6-amino-*s*-triazine (CIAT; 4 samples), the pesticide atrazine

Table 11. Summary statistics for concentrations of trace elements in groundwater collected in the Lake Champlain and Susquehanna River Basins, New York, 2014.

[All concentrations in micrograms per liter in unfiltered water. Values in **bold** indicate samples that exceed one or more drinking-water or safety standard. <, less than]

Constituent	All samples			Lake Champlain Basin						Susquehanna River Basin					
	All aquifers (33 samples)			Sand and gravel aquifers (6 samples)			Bedrock aquifers (7 samples)			Sand and gravel aquifers (11 samples)			Bedrock aquifers (9 samples)		
	Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum
Aluminum	<3.8	<3.8	**501**	<3.8	<3.8	6.7	<3.8	<3.8	<3.8	<3.8	<3.8	<3.8	<3.8	<3.8	**501**
Antimony	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arsenic	<0.20	<0.28	**14.3**	<0.28	<0.28	1.1	<0.20	<0.28	0.51	<0.28	<0.28	**10.4**	<0.28	0.87	**14.3**
Barium	<0.25	27.0	**18,300**	<0.25	7.22	46.5	0.27	7.58	77.7	10.2	26.7	823	36	128	**18,300**
Beryllium	<0.02	<0.02	0.04	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.04
Boron, filtered	<2.0	23	458	<2.0	6.6	46	5.7	23	458	10	21	43	15	90	372
Cadmium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	<0.30	<0.30	1.3	<0.30	<0.65	0.84	<0.30	<0.40	1.3	<0.30	<0.30	<0.30	<0.30	<0.30	0.94
Cobalt	<0.05	<0.05	0.40	<0.05	<0.05	0.08	<0.05	<0.05	0.17	<0.05	<0.05	0.14	<0.05	<0.05	0.40
Copper	<0.80	1.9	19.1	<0.80	<0.82	13.7	<0.80	1.9	6.9	<0.80	2.4	16.4	<0.80	1.9	19.1
Iron, filtered	<4.0	9.4	**1,560**	<4.0	<4.5	18.3	<4.0	7.0	**497**	<4.0	5.0	**1,560**	13.1	116	**323**
Iron	<4.6	38.0	**1,950**	<4.6	7.6	88.7	<4.6	51.8	**606**	<4.6	8.6	**1,590**	48.5	149	**1,950**
Lead	<0.04	0.10	6.82	<0.04	0.06	0.33	0.06	0.10	0.25	<0.04	0.13	6.82	<0.04	0.13	1.58
Lithium	<0.22	5.74	1,510	<0.22	0.29	1.75	0.61	1.45	175	0.59	3.84	16.4	7.87	22.8	1,510
Manganese, filtered	<0.20	2.77	**1,150**	<0.20	0.32	31	<0.20	9.24	**214**	<0.20	0.73	**1,150**	2.77	**111**	**511**
Manganese	<0.20	2.4	**1,170**	<0.4	0.70	32.7	<0.4	10.7	**216**	<0.20	0.79	**1,170**	2.22	**113**	**482**
Mercury	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Molybdenum	<0.05	0.19	9.68	<0.05	0.20	9.68	0.14	0.76	5.08	<0.05	0.06	0.4	0.06	0.22	0.59
Nickel	<0.20	<0.80	1.0	<0.20	<0.20	0.62	<0.20	<0.20	0.66	<0.20	0.4	0.95	<0.20	<0.20	1.0
Selenium	<0.100	<0.100	0.358	<0.100	<0.100	0.103	<0.100	<0.100	<0.100	<0.100	<0.100	0.358	<0.100	<0.100	<0.400
Silver	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Strontium	23.2	125	12,900	24.4	94.2	278	23.2	437	1,190	59.8	94	484	82.6	175	12,900
Thallium	<0.06	<0.06	0.11	<0.06	<0.06	<0.06	<0.06	<0.06	0.08	<0.06	<0.06	0.11	<0.06	<0.06	0.08
Zinc	<2.0	2.8	44.2	<2.0	2.4	6.6	<2.0	2.6	7.6	<2.0	5.1	21.9	<2.0	<8.0	44.2
Uranium	<0.014	0.118	1.78	0.025	0.210	0.438	0.042	0.765	1.78	<0.014	0.162	1.22	<0.014	0.037	0.104

Table 12. Drinking-water standards for concentrations of trace elements and number of groundwater samples exceeding those standards collected in the Lake Champlain and Susquehanna River Basins, New York, 2014.

[All concentrations in micrograms per liter in unfiltered water]

Constituent	Drinking-water standard	Number of samples exceeding drinking water standards		
		All samples (33 samples)	Lake Champlain Basin (13 samples)	Susquehanna River Basin (20 samples)
Aluminum	[1]50–200	1	0	1
Antimony	[2,3]6	0	0	0
Arsenic	[2,3]10	2	0	2
Barium	[2,3]2,000	1	0	1
Beryllium	[2,3]4	0	0	0
Cadmium	[2,3]5	0	0	0
Chromium	[3,3]100	0	0	0
Copper	[1]1,000	0	0	0
Iron, filtered	[1,3]300	3	1	2
Iron	[1,3]300	4	1	3
Lead	[4]15	0	0	0
Manganese, filtered	[3]300 [1]50	3 11	0 3	3 8
Manganese	[3]300 [1]50	4 11	0 3	4 8
Mercury	[2,3]2	0	0	0
Selenium	[2,3]50	0	0	0
Silver	[1,3]100	0	0	0
Thallium	[2,3]2	0	0	0
Zinc	[1,3]5,000	0	0	0
Uranium	[2,3]30	0	0	0

[1] U.S. Environmental Protection Agency (2009) secondary drinking water standard.

[2] U.S. Environmental Protection Agency (2009) maximum contaminant level.

[3] New York State Department of Health (2011) maximum contaminant level.

[4] U.S. Environmental Protection Agency (2009) treatment technique.

(3 samples), and the pesticide metolachlor (3 samples). The pesticide detected at the highest concentration (0.053 µg/L) was atrazine. More than one pesticide was detected in several samples. One sample (EX1023) had detections of four pesticides, one sample (W3220) had detections of three pesticides, and two samples (CL 700 and EX1894) had detections of two pesticides.

In the Susquehanna River Basin, atrazine, a broadleaf herbicide, and CIAT, a degradate of atrazine were detected at trace concentrations in five samples (table 1–6). Most of the wells with pesticide detections were sand and gravel production wells (four of five); the remaining well was a bedrock domestic well. CIAT was detected in all five of the samples with a pesticide detection; atrazine was detected in two of those wells with pesticide detections (C2009, TI 892). The pesticide detected at the highest concentration (estimated 0.010 µg/L) was CIAT.

Volatile Organic Compounds

Groundwater-quality samples were analyzed for 34 VOCs. No concentration exceeded established drinking-water standards set for VOCs. Results are reported in table 1–7.

In the Lake Champlain Basin, VOCs were detected in samples from one sand and gravel well (EX 589) and one bedrock well (CL 149; table 1–7). The VOCs detected were the gasoline additive methyl *tert*-butyl ether (MTBE) and the solvent 1,1-dichloroethene. MTBE was detected in the sand and gravel production well CL 149 (0.8 µg/L), and 1,1-dichloroethene was detected in the bedrock production well EX 589 (0.1 µg/L).

In the Susquehanna River Basin, eight VOCs were detected in samples from three sand and gravel wells (BM 90, OG 374, and TI 921) and two bedrock wells (C1818 and TI1031; table 1–7). The VOCs detected included three trihalomethanes (THMs, which are a byproduct formed when chlorine or bromine are used as disinfectants; trichloromethane [chloroform], dibromochloromethane, and tribromomethane), four solvents (1,1,1-trichloroethane, 1,1-dichloroethane, bromodichloro-methane, and *cis*-1,2-dichloroethene), and one refrigerant (tetrachloromethane). The VOC detected at the highest concentration was tribromomethane (7.0 µg/L) in a sample from a bedrock well (TI1031). The sample from bedrock well C1818 contained detectable concentrations of five VOCs: bromodichloromethane, tribromomethane, dibromochloromethane, tribromomethane, and tetrachloromethane.

Radionuclides

Groundwater-quality samples were analyzed for radon-222 activity, gross-α activity and gross-β activity. Radon is currently (2016) not regulated in drinking water, however, the EPA has proposed a two-part standard for radon-222 in drinking water: (1) a 300-picocuries per liter (pCi/L) MCL for areas that do not implement an indoor-air radon-222 mitigation program and (2) an alternative MCL (AMCL) of 4,000 pCi/L for areas that do implement an indoor-air radon-222 mitigation program (U.S. Environmental Protection Agency, 1999). The EPA and NYSDOH MCLs for gross-β are both for 4 millirems per year, a dosage determination that requires knowledge of the specific radionuclide sources. The activity units (picocuries per liter) that were used to measure gross-β radioactivity in this study are not comparable to dosage units (millirems per year) without determination of the nuclide sources; therefore, it is not possible to determine whether any of the samples exceeded the MCL for gross-β radioactivity. Results are reported in table 1–8.

In the Lake Champlain Basin, gross-α activity ranged from non-detectable levels to 3.7 pCi/L; the median activity was less than the detection level (tables 13 and 1–8). No samples exceeded the NYSDOH and EPA MCLs of 15 pCi/L for gross-α activity (tables 14 and 1–8). Gross-β activities ranged from non-detectable levels to 11.4 pCi/L; the median gross-β activity was 1.9 pCi/L for sand and gravel wells and 3.7 pCi/L for bedrock wells. Radon-222 activities in the water samples ranged from 109 to 6,300 pCi/L; the median activity was 183 pCi/L for sand and gravel wells, and 480 pCi/L for bedrock wells. The highest gross-β, and radon-222 activities were in a sample from one well, CL 848 (11.4 pCi/L; 6,300 pCi/L, respectively), that is completed in sandstone bedrock. The second highest radon-222 activity was from a well completed in crystalline bedrock (CL 700; 3,800 pCi/L). Radon-222 activities in 5 of the 13 Lake Champlain Basin samples exceeded the proposed MCL of 300 pCi/L; the radon-222 activity in one sample (CL 848) exceeded the proposed AMCL of 4,000 pCi/L.

In the Susquehanna River Basin, gross-α activity ranged from non-detectable levels to 45 pCi/L; the median activity was less than the detection level (tables 13 and 1–8). The gross-α activity of bedrock well BM2088 (45 pCi/L) exceeded the NYSDOH and EPA MCLs of 15 pCi/L. Gross-β activities ranged from non-detectable levels to 37 pCi/L. Radon-222 activities in the groundwater samples ranged from 58 to 1,240 pCi/L; the medians were 670 pCi/L in sand and gravel wells, and 350 in bedrock wells. The highest radon-222 activity was in a sample from a sand and gravel well (TI 921, 1,240 pCi/L). The two highest radon-222 activities in bedrock samples were from wells completed in shale and sandstone (BM2178, 1,150 pCi/L; TI1663, 1,080 pCi/L). Radon-222 activities in 13 of the 20 Susquehanna River Basin samples exceeded the proposed MCL of 300 pCi/L; no samples exceeded the proposed AMCL of 4,000 pCi/L (tables 14 and 1–8).

Bacteria

Groundwater-quality samples were analyzed for fecal indicator bacteria, including total coliform bacteria, fecal coliform bacteria, and *E. coli* bacteria. Heterotrophic plate count was also determined. Heterotrophic plate count is used to assess the overall bacterial load in the sample, which in conjunction with fecal indicator bacteria, allows for inferring potential sources of contamination. The NYSDOH and EPA MCLs for total coliform bacteria are exceeded when 5 percent of samples of finished water collected in 1 month test positive for total coliforms (if 40 or more samples are collected per month) or when two samples of finished water test positive for total coliforms (if fewer than 40 samples are collected per month). Results are reported in table 1–9.

In the Lake Champlain Basin, total coliform bacteria were detected in one sample from a sand and gravel well (CL 169) and two samples from bedrock wells (EX1023 and EX1894; table 1–9). Well EX1023 had a total coliform bacteria detection of 24 colony-forming units per 100 milliliters (CFU/100 mL). Fecal coliform bacteria (12 CFU/100 mL) and *E. coli* bacteria were detected in bedrock well EX1023, exceeding the EPA and NYSDOH MCLs for both fecal coliform and *E. coli* bacteria (NYSDOH and EPA MCLs are any positive result). The heterotrophic plate count ranged from <1 to 18 colony-forming units per milliliter (CFU/mL); no Lake Champlain Basin samples exceeded the EPA MCL of 500 CFU/mL for heterotrophic plate count.

In the Susquehanna River Basin, total coliform bacteria were detected in 1 sample from a sand and gravel well (OG 316, 13 CFU/100 mL) and 1 sample from a bedrock well (M1847, 30 CFU/100 mL; table 1–9). Fecal coliforms and *E. coli* bacteria were not detected in any samples from the Susquehanna River Basin. The heterotrophic plate count ranged from <1 to 421 CFU/mL; no samples exceeded the EPA MCL for heterotrophic plate count.

Table 13. Summary statistics for activities of radionuclides in groundwater samples collected in the Lake Champlain and Susquehanna River Basins, New York, 2014.

[All activities in picocuries per liter in unfiltered water. Values in **bold** indicate samples that exceed one or more drinking-water or safety standard. <, less than]

Constituent	All samples			Lake Champlain Basin						Susquehanna River Basin					
	All aquifers (33 samples)			Sand and gravel aquifers (6 samples)			Bedrock aquifers (7 samples)			Sand and gravel aquifers (11 samples)			Bedrock aquifers (9 samples)		
	Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum
Gross-α radioactivity	<0.427	<1.38	**45**	<0.427	<0.872	3.7	<0.536	<1.70	3.1	<0.441	<1.26	<2.41	<0.854	<1.38	**45**
Gross-β radioactivity	<1.14	2.0	280	<1.32	1.9	3.7	<1.16	3.7	11.4	<1.14	1.9	5.5	<1.14	1.6	280
Radon-222	58	**470**	**6,300**	109	183	**570**	172	**480**	**6,300**	58	**670**	**1,240**	161	**350**	**1,150**

Table 14. Drinking-water standards for activities of radionuclides and number of groundwater samples exceeding those standards collected in the Lake Champlain and Susquehanna River Basins, New York, 2014.

[All activities are in unfiltered water. Activity units (in picocuries per liter [pCi/L]) used to measure gross-β radioactivity in this study are not comparable to dosage units (in millirems per year [mrem/yr]). —, not applicable]

Constituent	Drinking-water standard	Number of samples exceeding drinking water standards		
		All samples (33 samples)	Lake Champlain Basin (13 samples)	Susquehanna River Basin (20 samples)
Gross-α radioactivity, in pCi/L	[1,2]15	1	0	1
Gross-β radioactivity, in mrem/yr	[1,2]4	—	—	—
Radon-222, in pCi/L	[3]300	18	5	13
	[4]4,000	1	1	0

[1] U.S. Environmental Protection Agency (2009) maximum contaminant level.

[2] New York State Department of Health (2011) maximum contaminant level.

[3] U.S. Environmental Protection Agency (2009) proposed maximum contaminant level.

[4] U.S. Environmental Protection Agency (2009) proposed alternative maximum contaminant level.

Comparison of Results From Wells Sampled in 2004–05, 2009, and 2014

A subset of six wells sampled in 2014 was previously sampled in 2009; of those six wells, three were also sampled in 2004–05. Of the 148 physical properties, organic compounds, and inorganic compounds analyzed for in 2014 and 2009, 140 were also analyzed for in 2004–05. Note that the NWQL annually updates the LRLs for all analytes based on method performance during the previous year of analysis. Therefore, reporting levels and the determination of whether a concentration is considered "estimated" changes annually, and concentrations of compounds could differ for this reason between 2004–05, 2009, and 2014. The rules for determining and adjusting LRLs and long-term method detection levels are outlined by the USGS Branch of Quality Systems (U.S. Geological Survey, 1999a,b). Results are reported in tables 2–1 through 2–8.

Three of the Lake Champlain Basin wells sampled in 2014 (wells EX 589, W 534, and CL 149) were sampled previously in 2009; W 534 and CL 149 were sampled in 2004–05, as well. Overall, physiochemical properties exhibited little to no change for these wells (table 2–1); however, for CL 149, color was substantially lower in 2014 (2 Pt-Co units) than in 2009 (20 Pt-Co units) and 2004–05 (15 Pt-Co units). Concentrations of nutrients, major ions, dissolved gases (2009 and 2014 only), radon-222 activities, and most trace elements exhibited little to no change (tables 2–1 to 2–4 and 2–7). The concentration of iron in the filtered sample differed substantially in the CL 149 sample (2004–05, 543 mg/L; 2009 45.7 mg/L; and 2014, 497 mg/L; table 2–4). One pesticide degradate, CIAT, was detected in a sample from well W 534 in the 2009 sample (E0.001 µg/L) and the 2014 sample (E0.003 µg/L), however it was not detected in the 2004–05 sample (table 2–5). Six VOCs were detected in samples from three of the wells that were resampled. In 2009, several VOCs (all THMs) were detected in the sample from well CL 149, but were not detected in the 2004–05 or 2014 samples (table 2–6). MTBE was detected in samples from CL 149 in all three rounds of sampling; concentrations were very similar in samples across all three rounds. 1,1-dichloroethene was detected in samples from well EX 589 in 2009 and 2014; concentrations were similar across both rounds of sampling (table 2–6). Gross-α, gross-β, and radon-222 activities exhibited little to no change for these wells (table 2–7). Total coliform bacteria and fecal coliform bacteria were not detected in the samples from wells CL 149, EX 589, and W 534 in any of the rounds of sampling. The heterotrophic plate counts in all three wells were about the same across the 2 or 3 rounds of sampling (table 2–8).

Three of the Susquehanna River Basin wells sampled in 2014 (wells BM 90, OG 316, and TI 892) were sampled previously in 2009; BM 90 was sampled in the 2004–05 round, as well. Overall, physiochemical properties exhibited little to no change for these wells (table 2–1); however, for BM 90, color was substantially lower in 2014 (<1 Pt-Co units) than in 2009 (5 Pt-Co units) and 2004–05 (25 Pt-Co units). Also, dissolved oxygen from BM 90 was substantially lower in 2014 and 2009 (both 0.3 mg/L) than in 2004–05 (7.2 mg/L). Concentrations of nutrients, dissolved gases (2009 and 2014 only), most major ions, radon-222 activities, and most trace elements showed little change for each of the three wells (BM 90, OG 316, TI 892; tables 2–1 to 2–4 and 2–7). For some compounds, however, concentrations have been increasing during each subsequent round of sampling (2004–05, 2009, and 2014) in the sand and gravel production well BM 90.

Concentrations of sodium, chloride, and dissolved solids in samples from BM 90 have increased from 2004 to 2014 to levels that each exceeded the drinking-water standards (60, 300, and 500 mg/L, respectively; table 2–2). For well BM 90, sodium concentrations increased from 53.7 mg/L in 2004–05 to 70.4 mg/L in 2009 and to 103 mg/L in 2014, chloride concentrations increased from 140 mg/L in 2004–05 to 201 mg/L in 2009 and to 312 mg/L in 2014, and dissolved solids concentrations increased from 546 mg/L in 2004–05 to 736 mgL in 2009 and to 1,080 mg/L in 2014 (table 2–2). This upward trend in concentrations is also observed for several trace elements.

The concentrations of arsenic, barium, iron (in filtered and unfiltered samples), and manganese (in filtered and unfiltered samples) have substantially increased in samples collected from 2004–05 to 2009 and to 2014. Arsenic concentrations increased to levels that exceed drinking-water standards (maximum of 10.4 µg/L). Barium concentrations have increased from 508 µg/L (2004–05) to 823 µg/L (2014). Iron and manganese concentrations have exceeded drinking-water standards in filtered and unfiltered samples since 2004–05. However, concentrations of each seem to be increasing over time; for example, the concentration of iron (filtered) was 1,230 µg/L in 2004–05, 1,400 µg/L in 2009, and 1,560 µg/L in 2014. Similar trends have been exhibited for results in unfiltered iron samples and filtered and unfiltered manganese samples (table 2–4).

No pesticides or pesticide degradates were detected in any of the samples collected at BM 90. Samples from OG 316 and TI 892 each had detections of one pesticide and one degradate at trace levels. CIAT was detected in both the 2009 and 2014 samples from OG 316 and TI 892. Atrazine was detected in both the 2009 and 2014 samples from TI 892 but was detected only in the 2009 sample from OG 316 (table 2–5).

No VOCs were detected in any of the samples collected at TI 892. Four VOCs were detected in a 2004–05 sample from BM 90. Vinyl chloride and 1,1,1-trichloroethane were detected in the 2004–05 round of the study but not in 2009 or 2014. 1,1-dichloroethane and *cis*–1,2-dichloroethene were detected in samples in 2004–05, 2009, and 2014. Only one VOC, trichloromethane, was detected at OG 316, and it was detected only in the sample collected in 2009 (table 2–6). Total coliform bacteria and fecal coliform bacteria were not detected in the samples from wells BM 90 and TI 892 in any of the rounds of sampling; however, total coliform bacteria were detected (13 CFU/100 mL) in the 2014 round of sampling at OG 316. The heterotrophic plate counts in all three wells were about the same across the 2 or 3 rounds of sampling (table 2–8).

Summary

In a study conducted by the U.S. Geological Survey (USGS), in cooperation with the New York Department of Environmental Conservation, groundwater samples were collected during June through December 2014 from 13 wells in the Lake Champlain Basin and 20 wells in the Susquehanna River Basin to characterize the overall groundwater quality in each of these basins. Sample collection and analysis followed standard USGS procedures and other documented procedures. Samples were measured for physical properties and concentrations of dissolved gases, major ions, nutrients, trace elements, pesticides, volatile organic compounds (VOCs), radionuclides, and bacteria. About 45 percent (67 of 148) of constituents analyzed for were not detected at concentrations greater than the reporting levels in any of the samples.

The depths of sand and gravel wells sampled in the Lake Champlain Basin ranged from 18 to 185 feet (ft) below land surface; the depths of bedrock wells sampled ranged from 100 to 805 ft below land surface and are completed in clastic (sandstone), carbonate, or crystalline bedrock. Six of the 13 wells sampled are production wells, and the remaining 7 are domestic wells. The samples generally had few exceedances of State and (or) Federal drinking-water standards, although concentrations of some constituents—sodium, dissolved solids, fluoride, iron, manganese, radon-222, total and fecal coliform bacteria, and *Escherichia coli (E. coli)* bacteria—equaled or exceeded primary, secondary, or proposed drinking-water standards in 7 of the 13 wells sampled. The constituent most frequently detected in concentrations exceeding drinking-water standards was radon-222 (5 of 13 samples had activities equal to or greater than the U.S. Environmental Protection Agency [EPA] proposed maximum contaminant level (MCL) of 300 picocuries per liter [pCi/L]). The highest radon-222 activities were in samples from wells completed in bedrock.

In the Lake Champlain Basin, pH was typically near neutral. The groundwater was typically moderately hard, and the median dissolved solids concentration was 116 milligrams per liter (mg/L) in sand and gravel wells, and 195 mg/L in bedrock wells. The ions detected in the highest median concentrations were bicarbonate, sulfate, calcium, magnesium, and sodium. The dominant nutrient was nitrate; concentrations of nitrate and nitrite did not exceed established drinking-water standards. Strontium, manganese, iron, and boron were the trace elements with the highest median concentrations. Iron concentrations exceeded drinking-water standards in samples from one well; the maximum concentration was 606 µg/L. Manganese concentrations in three samples exceeded drinking-water standards. Five pesticides and pesticide degradates were detected in five samples; all were trace-level detections. Two samples had detections for a VOC. Radon-222 activities in 5 samples exceeded a proposed MCL; 1 sample exceeded the proposed alternative maximum contaminant level. Total coliform bacteria were detected in 3 samples, and 1 of those samples also had detections for fecal coliform bacteria and *E. coli* bacteria.

In the Susquehanna River Basin the depths of sand and gravel wells sampled ranged from 43.6 to 360 ft below land surface; the depths of bedrock wells that were sampled ranged from 80 to 270 ft below land surface. The bedrock wells are completed in clastic (shale and sandstone) or carbonate bedrock. Eleven of the 20 wells sampled are production wells, and 9 are domestic wells. The samples had several exceedances of State and (or) Federal drinking-water standards, and properties and concentrations of some constituents—pH, sodium, dissolved solids, chloride, iron, manganese, arsenic, aluminum, barium, gross-α radioactivity, radon-222, and total coliform bacteria—equaled or exceeded primary, secondary, or proposed drinking-water standards in all of the 20 wells sampled. The constituent most frequently detected in concentrations exceeding drinking-water standards was radon-222 (14 of 20 samples had activities equal to or greater than the EPA MCL of 300 pCi/L). The highest radon-222 activities were in samples from wells completed in sand and gravel.

In the Susquehanna River Basin, sample pH was typically near neutral. Methane was detected in 9 of the 20 samples; the action level was exceeded in samples from one well. The groundwater tended toward moderately hard to very hard, and the median dissolved solids concentration was 278 mg/L in sand and gravel wells and 176 mg/L in bedrock wells. The ions detected in the highest median concentrations were bicarbonate, calcium, sodium, and chloride. The dominant nutrient was nitrate; concentrations of nitrate and nitrite did not exceed established drinking-water standards. Strontium, iron, barium, manganese, and boron were the trace elements with the highest median concentrations. Aluminum, arsenic, iron, and manganese concentrations exceeded drinking-water standards in samples. One pesticide and one pesticide degradate were detected in five samples; all were trace-level detections. Eight VOCs were detected in five samples. Radon-222 activities in 13 of 20 samples exceeded a proposed MCL. Total coliform bacteria were detected in two samples, and fecal coliform bacteria and *E. coli* bacteria were not detected in any samples.

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Appendixes

Appendix 1. Results of Water-Sample Analyses, 2014

Appendix 2. Results of Water-Sample Analyses, 2004–05, 2009, and 2014

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