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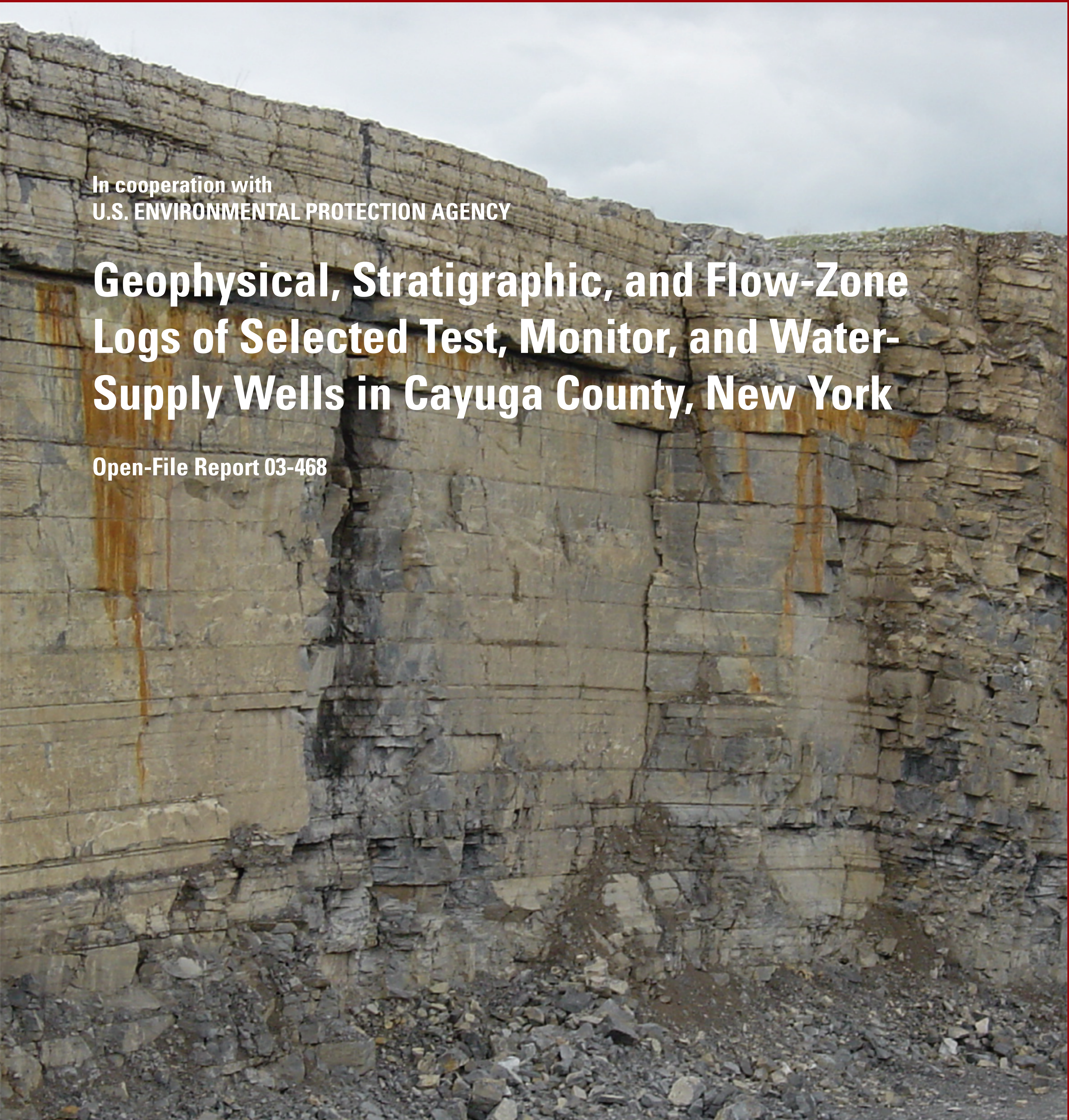

In cooperation with
U.S. ENVIRONMENTAL PROTECTION AGENCY

Geophysical, Stratigraphic, and Flow-Zone Logs of Selected Test, Monitor, and Water-Supply Wells in Cayuga County, New York

Open-File Report 03-468

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Conversion Factors and Datum

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
gallon per minute (gal/min)	3.785	liter per minute
	Gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)

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

˚C = (˚F - 32) / 1.8

Vertical coordinate information is referenced to the National Geodetic Vertical Datum 1929 (NGVD 1929). Altitude, as used in this report, refers to distance above the vertical datum.

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

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Abstract

Volatile-organic compounds have been detected in water sampled from more than 50 supply wells between the City of Auburn and Village of Union Springs in Cayuga County, New York, and the area was declared a Superfund site in 2002. In 2001-04, geophysical logs were collected from 37 test, monitor, and water-supply wells as a preliminary part of the investigation of volatile-organic compound contamination in the carbonate-bedrock aquifer system. The geophysical logs included gamma, induction, caliper, wellbore image, deviation, fluid resistivity and temperature, and flowmeter. The geophysical logs were analyzed along with core samples and outcrops of the bedrock to define the stratigraphic units and flow zones penetrated by the wells. This report describes the logging methods used in the study and presents the geophysical, stratigraphic, and flow-zone logs.

Introduction

Volatile-organic compounds (VOCs) have been detected in water sampled from more than 50 supply wells between the City of Auburn and Village of Union Springs in Cayuga County, N. Y. (fig. 1). More than 300 wells were sampled in the area by the Cayuga County Environmental Health Department, New York State Department of Environmental Conservation (NYSDEC), New York State Department of Health, and U. S. Environmental Protection Agency (USEPA) following the detection of VOCs in the Union Springs supply wells. The area was declared a Superfund site and listed on the National Priorities List (http://www.epa.gov/superfund/sites/npl/) in 2002.

In 2001- 04, the U.S. Geological Survey (USGS) and the USEPA collected geophysical logs from selected test, monitor, and water-supply wells as a preliminary part of the investigation of VOC contamination in the carbonate-bedrock aquifer system in Cayuga County. The USGS analyzed the geophysical logs along with core samples and outcrops of the bedrock to define the stratigraphic units and flow zones penetrated by the wells. This report describes the logging methods used in the study and presents the geophysical, stratigraphic, and flow-zone logs.

Study Area

The study area occupies 7 mi^2 between Auburn and Union Springs in central Cayuga County, N. Y. (fig. 1). The area is underlain by till of varying thickness; and carbonate, clastic, and evaporite bedrock units of Silurian and Devonian age that regionally dip southward at about 50 ft/mi (Kantrowitz, 1970). The area is part of the Finger Lakes region and lies between Owasco Lake to the east and Cayuga Lake to the west (fig. 1). The local topography consists of gently rolling hills with altitude ranging from about 800 ft above sea level in the south-central part of the study area to about 485 ft above sea level near Cayuga Lake.

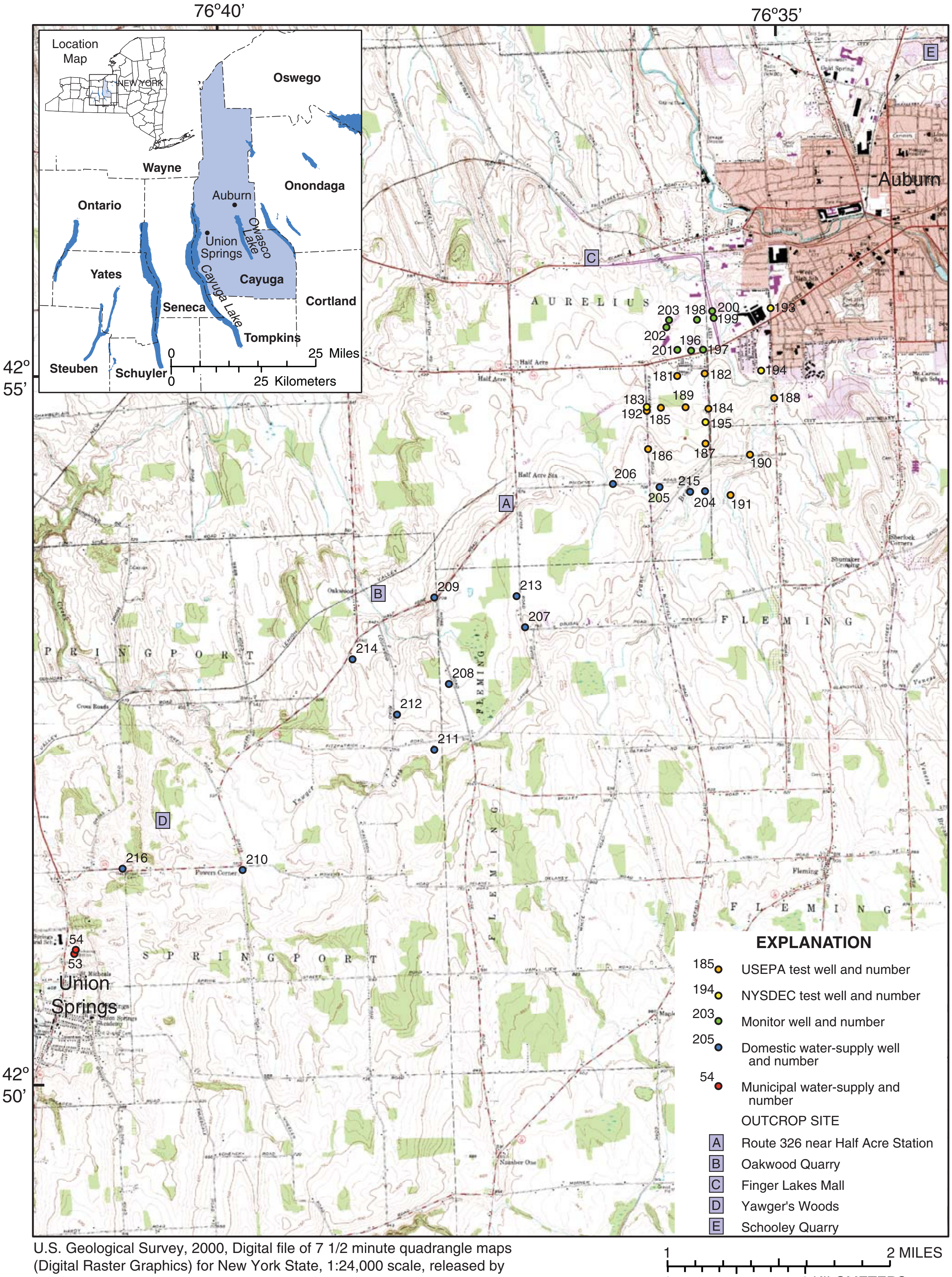
Acknowledgments

The authors thank the following individuals for their cooperation and assistance:

Donald Bussey, John Harmon, Isabel Rodrigues, Alan Humphrey, and John DiMartino of the USEPA; Charles Ver Straeten of the New York State Geological Survey; Kenneth Woodruff of Lockheed Martin/REAC; Kevin Kelly and Carl Cuipylo of the NYSDEC; Eileen O'Connor, Mary Jump, Nick Colas, and Bruce Natale of Cayuga County; Edward Trufant and Robert Kneaskern of the Village of Union Springs; Paul Hare of the General Electric Company; and all the residents who graciously allowed access to their wells.

Description of Wells

Geophysical logs were collected from 37 wells -- 15 test wells, 7 monitor wells, 13 domestic water-supply wells, and two municipal water-supply wells. Core samples from two of the test wells were described and an additional core-sample description was obtained from a monitor-well installation. The well locations are shown in figure 1. Construction and water-level information for the wells at the time of logging are given in table 1, and the types and source of geophysical logs and core-sample descriptions collected from the wells are given in table 2.



U.S. Geological Survey, 2000, Digital file of 7 1/2 minute quadrangle maps (Digital Raster Graphics) for New York State, 1:24,000 scale, released by New York Department of Environmental Conservation

Figure 1. Location of study area and selected wells and outcrops in Cayuga County, N.Y.

Seven wells (181, 182, 183, 184, 186, 187, and 188) were constructed by the USEPA as test wells with open hole below steel casing that terminates near the top of bedrock. Four wells (185, 189, 190, and 191) were constructed by the USEPA as test wells with open hole below steel casing that terminates near the water level in the well. Four wells (192-195) were constructed by the NYSDEC as test wells with multiple, telescopic steel casings and an open-hole interval near the bottom. Eight wells (196-203) were constructed by an industrial facility owner as monitor wells with a grouted PVC casing and a screened and sand-packed interval near the bottom. Thirteen wells (204-216) were constructed as domestic water-supply wells; the wells were completed as open hole below steel casing that terminates near the top of bedrock; except for well 216, which was cased more than 100 ft into bedrock. Wells 53 and 54 were constructed as municipal water-supply wells with open hole below steel casing that terminates near the top of bedrock.

Description of Logs

The geophysical, stratigraphic, and flow-zone logs collected from the wells are presented in the appendix. The geophysical, stratigraphic, and flow-zone logs are also available upon request in ASCII file format and in WellCad Reader[1] format with the WellCad Reader program from the USGS office in Troy, N. Y. (http://ny.usgs.gov). WellCad Reader allows the logs to be displayed, tabulated, and printed at user-specified vertical scales. The video-camera logs are not presented but are available for viewing on DVD at the USGS office in Troy, N. Y. The core samples from wells 181 and 186 are available for inspection at the USGS office in Ithaca, N.Y.

Geophysical Logs

The geophysical logs include gamma, electromagnetic induction, caliper, wellbore image, deviation, fluid, and flowmeter. The types and sources of geophysical logs collected in each well are listed in table 2. The caliper logs were collected by mechanical and acoustical methods. Wellbore-image logs were collected with video cameras and acoustic and optical televiewers. Deviation logs were collected with three-axis fluxgate magnetometers and inclinometers included as part of the televiewer tools. Fluid logs entailed fluid-resistivity and temperature measurements. Flowmeter logs were collected by heat-pulse and electromagnetic methods. Applications of geophysical logs in ground-water studies are described by Keys (1990). The geophysical logs used in this investigation are described briefly below.

Gamma logs measure the gamma radiation of rocks surrounding the wellbore. Major natural gamma emitters are uranium, thorium, and daughter products of potassium 40. Units with relatively high gamma radiation when compared to other lithologic units include shales, bentonites, and other argillaceous units, as well as phosphate-rich zones. The gamma tool has a vertical resolution of 1 to 2 ft. Gamma logs collected in open holes and through steel and PVC casing were the primary logs used for lithologic identification and stratigraphic correlation.

Electromagnetic-induction logs measure the electrical conductivity of the rocks and water surrounding the wellbore. Electrical conductivity measurements are affected by the argillaceous content and porosity of the rocks and by the dissolved-solids concentration of the water. The electromagnetic-induction tool has a vertical resolution of 2 ft and generally is not affected by the electrical conductivity of the water in wellbores that have a diameter less than 8 inches.

Mechanical- and acoustic-caliper logs record the diameter of the wellbore. Changes in wellbore diameter are related to drilling and construction procedures and competency of lithologic units, fractures, and solution features. Mechanical-caliper logs were collected with a spring-loaded, three-arm averaging tool; acoustic-caliper logs were calculated from acoustic travel times collected with the acoustic-televiewer tool. Caliper logs were used in the delineation of fractures, solution features, and lithology; and to confirm or determine well and casing depths and diameters.

Video-camera logs record an optical "fisheye" view of the wellbore and can be collected above the water level, and below where the water is clear. Video-camera logs were used to directly view well and casing conditions, bedding and lithologic contacts, fractures, solution features, and cascading water from flow zones above the water level.

Optical-televiewer logs record a 360-degree magnetically oriented optical image of the wellbore wall (Williams and Johnson, 2004). Optical-televiewer logs can be collected above the water level, and below it where the water is clear. Features nearly as small as the vertical sampling interval (from 0.005 to .008 ft) were identified. Optical-televiewer logs were used to characterize bedding and lithology, fractures, solution features, and staining related to flow zones.

Acoustic-televiewer logs record a 360-degree magnetically oriented acoustic image of the wellbore wall. Acoustic-televiewer logs can be collected in clear or murky water. Features with widths greater than 0.01 ft were identified. Acoustic-televiewer logs were used to characterize bedding and lithology, fractures, solution features, and wellbore-wall rugosity.

Deviation logs measure the inclination and direction of the well from vertical. Inclination generally is measured within ± 0.5 degree and direction within ± 2 degrees. Deviation logs indicated that all the open-hole wells were inclined less than 3

[1]The use of trade, product, or firm names in this report is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Table 1. Location, construction, and water-level information for selected wells in Cayuga County, N.Y.
[Dashes indicate no measurement. Locations are shown on fig. 1]

Well No.[1]	Latitude[2]	Longitude[2]	Land-surface Altitude[3]	Well Depth[4]	Well Diameter[5]	Casing Depth[6]	Casing Type[7]	Water Level Date	Water Level Depth[8]
Muncipal water-supply wells									
53	425056.7	764122.3	442	120(210)	8	18	Steel	11/13/02	31.05
54	425058.4	764121.6	447	160	8	20	Steel	-	-
Test wells									
181	425456.8	763554.8	658.25	187	4	13	Steel	4/14/04	64.05
182	425458.0	763538.6	659.39	205	4	19	Steel	12/13/01	116.20
183	425443.0	763611.3	670.17	195	4	8	Steel	12/10/01	126.62
184	425443.7	763537.2	671.71	211	4	14	Steel	12/12/01	130.90
185	425443.7	763603.5	675.05	210	4	102	Steel	7/9/02	111.68
186	425426.8	763610.2	719.46	261	4	32	Steel	10/24/01	179.12
187	425429.5	763538.4	691.28	250	4	13.5	Steel	3/12/04	114.27
188	425448.5	763500.9	679.10	242	4	19	Steel	3/10/04	98.01
189	425444.1	763549.9	662.75	202	4	103	Steel	7/10/02	100.42
190	425425.3	763513.7	702.52	262	4	142	Steel	3/11/04	126.51
191	425408.7	763524.0	712.6	190(250)	4	150	Steel	7/11/02	157.68
192	425443.3	763611.3	670.5	310	8	290	Steel	10/16/01	129
193	425525.1	763503.8	643.3	198.5	8	180	Steel	10/16/01	76
194	425459.6	763508.4	665.7	285	8	266	Steel	10/16/01	110
195	425438.2	763538.7	681.7	311	8	290	Steel	10/16/01	133
Monitor wells									
196	425507.2	763547.4	636.9	100	1.25	70	PVC	-	-
197	425507.7	763540.8	643.0	100	2	69	PVC	7/16/02	77.03
198	425519.8	763544.4	638.8	96	2	81	PVC	7/16/02	63.35
199	425520.7	763535.2	630.1	130	2	85	PVC	7/16/02	56.32
200	425523.5	763536.01	629.1	130	2	100	PVC	7/16/02	54.43
201	425507.4	763555.0	639.4	100	2	85	PVC	7/17/02	56.66
202	425516.5	763601.3	628.1	100	2	85	PVC	7/17/02	50.88
203	425519.5	763559.9	627.0	100	2	85	PVC	7/18/02	50.75
Domestic water-supply wells									
204	425410.1	763538.2	737.74	222	6	64.5	Steel	8/26/02	194.46
205	425411.4	763603.4	718.54	222	6	40	Steel	8/27/02	176.93
206	425412.3	763629.3	691.58	204	6	25	Steel	8/28/02	154.08
207	425313.3	763716.4	760	322	6	29	Steel	9/23/02	255.98
208	425249.6	763758.0	720	269	6	16	Steel	9/24/02	228.10
209	425324.7	763807.0	705	243	6	30	Steel	9/25/02	213.99
210	425132.2	763950.01	588	178(187)	6	32	Steel	10/8/02	150.30
211	425222.7	763805.3	711	273(305)	6	25	Steel	10/10/02	256.40
212	425236.7	763826.4	671	240	6	16	Steel	10/11/02	220.16
213	425325.9	763721.4	734	289	6	53	Steel	10/8/02	222.81
214	425258.9	763851.6	640	162(182)	6	20	Steel	11/12/02	156.78
215	425409.7	763546.4	725	221	6	40	Steel	11/14/02	186.25
216	425131.8	764056.6	492	120	6	112	Steel	10/7/02	81.20

Explanation

[1]County sequential number assigned by U.S. Geological Survey (USGS), prefix Cy for Cayuga County not shown

[2]Degrees, minutes, seconds, and tenths of seconds; North American Datum 1983

[3]Land-surface altitude, in feet above sea level; National Geodetic Vertical Datum 1929, altitudes to the nearest foot estimated from USGS 1:24,000 topographic map

[4]Depth of well, in feet below land-surface altitude; reported drilled depth presented in parentheses if not reached during logging because of blockage

[5]Diameter of well, in inches

[6]Depth of casing, in feet below land surface

[7]Type of casing material

[8]Depth to water level, in feet below land surface; depths to the nearest foot are reported or estimated from fluid logs

Table 2. Types and sources of geophysical logs and core-sample descriptions collected from selected wells in Cayuga County, N. Y.

[Locations are shown in figure 1. Dashes indicate not available. Source: LM/R, Lockheed Martin/REAC, USGS, U.S. Geological Survey, DUNN, Dunn Geoscience, SWDC, Seneca Well Drillers Corporation.]

Well No.	Type of logs											
	Gamma	Cond[1]	Mech Cal[2]	Acou Cal[3]	Video[4]	ATV[5]	OTV[6]	Fl Res[7]	Temp[8]	HPFM[9]	EMFM[10]	Core[11]
Municipal water-supply wells												
53	USGS	-	USGS	USGS	SWDC	USGS	USGS	USGS	USGS	USGS	USGS	-
54	-	-	-	-	SWDC	-	-	-	-	-	-	-
Test wells												
181	USGS	-	USGS	USGS	LM/R	USGS	USGS	USGS	USGS	USGS	USGS	USGS
182	USGS	-	USGS	USGS	LM/R	USGS	USGS	USGS	USGS	USGS	-	-
183	USGS	-	LM/R	USGS	LM/R	USGS	-	LM/R	LM/R	USGS	-	-
184	USGS	-	LM/R	USGS	LM/R	USGS	USGS	LM/R	LM/R	USGS	-	-
185	USGS	USGS	LM/R	USGS	-	USGS	-	USGS	USGS	USGS	USGS	-
186	USGS	-	LM/R	USGS	LM/R	USGS	-	LM/R	LM/R	-	USGS	USGS
187	USGS	-	USGS	USGS	LM/R	USGS	USGS	USGS	USGS	USGS	-	-
188	USGS	-	USGS	USGS	LM/R	USGS	USGS	USGS	USGS	-	USGS	-
189	LM/R	USGS	LM/R	USGS	-	USGS	-	USGS	USGS	USGS	-	-
190	USGS	-	USGS	USGS	LM/R	USGS	-	USGS	USGS	USGS	-	-
191	USGS	-	USGS	-	-	-	-	USGS	USGS	-	-	-
192	LM/R	-	-	-	-	-	-	LM/R	LM/R	-	-	-
193	LM/R	-	-	-	-	-	-	LM/R	LM/R	-	-	-
194	LM/R	-	-	-	-	-	-	LM/R	LM/R	-	-	-
195	LM/R	-	-	-	-	-	-	LM/R	LM/R	-	-	-
Monitor wells												
196	-	-	-	-	-	-	-	-	-	-	-	DUNN
197	USGS	USGS	-	-	-	-	-	-	-	-	-	-
198	USGS	USGS	-	-	-	-	-	-	-	-	-	-
199	USGS	USGS	-	-	-	-	-	-	-	-	-	-
200	USGS	USGS	-	-	-	-	-	-	-	-	-	-
201	USGS	USGS	-	-	-	-	-	-	-	-	-	-
202	USGS	USGS	-	-	-	-	-	-	-	-	-	-
203	USGS	USGS	-	-	-	-	-	-	-	-	-	-
Domestic water-supply wells												
204	USGS	-	USGS	USGS	-	USGS	USGS	USGS	USGS	USGS	-	-
205	USGS	-	USGS	USGS	-	USGS	USGS	USGS	USGS	USGS	-	-
206	USGS	-	USGS	USGS	-	USGS	USGS	USGS	USGS	USGS	-	-
207	USGS	-	USGS	USGS	-	USGS	USGS	USGS	USGS	USGS	-	-
208	USGS	-	USGS	USGS	-	USGS	USGS	USGS	USGS	USGS	-	-
209	USGS	-	USGS	USGS	-	USGS	USGS	USGS	USGS	USGS	-	-
210	USGS	-	USGS	USGS	-	USGS	-	USGS	USGS	USGS	USGS	-
211	USGS	-	USGS	USGS	-	USGS	-	USGS	USGS	USGS	-	-

Table 2. (Continued) Types and sources of geophysical logs and core-sample descriptions collected from selected wells in Cayuga County, N. Y.

Type of logs

Well No.	**Gamma**	**Cond**[1]	**Mech Cal**[2]	**Acou Cal**[3]	**Video**[4]	**ATV**[5]	**OTV**[6]	**Fl Res**[7]	**Temp**[8]	**HPFM**[9]	**EMFM**[10]	**Core**[11]
212	USGS	-	USGS	USGS	-	USGS	-	USGS	USGS	USGS	-	-
213	USGS	-	USGS	USGS	-	USGS	-	USGS	USGS	USGS	-	-
214	USGS	-	USGS	USGS	-	USGS	USGS	USGS	USGS	USGS	-	-
215	USGS	-	USGS	USGS	-	USGS	USGS	USGS	USGS	USGS		-
216	USGS	-	USGS	USGS	-	USGS	-	USGS	USGS	-	USGS	USGS

Explanation

[1]Electromagnetic-induction conductivity
[2]Mechanical three-arm caliper
[3]Acoustic caliper
[4]Fisheye video camera
[5]Acoustic televiewer
[6]Optical televiewer
[7]Fluid resistivity
[8]Temperature
[9]Heat-pulse flowmeter
[10]Electromagnetic flowmeter
[11]Core-sample description

degrees from vertical except for well 211, which was inclined 8 degrees from vertical.

Fluid-resistivity logs record the electrical resistivity of water in the wellbore. Electrical resistivity is inversely related to the concentration of dissolved solids in the water. Slope changes in fluid-resistivity logs may indicate zones of inflow to or outflow from the wellbore. Fluid-resistivity logs were used to delineate possible changes in wellbore flow.

Temperature logs record the temperature of air and water in the wellbore. Temperature gradients smaller than the geothermal gradients may indicate intervals of wellbore flow. Temperature logs were used to delineate the water level and possible changes in wellbore flow, including cascading water.

Heat-pulse and electromagnetic flowmeter logs record the direction and rate of vertical flow in the wellbore. Vertical flow occurs in wells that penetrate more than one flow zone under differing hydraulic head. Flow in the wellbore is from zones of higher head to zones of lower head. The heat-pulse flowmeter (Hess, 1982) measures the traveltime of a thermal pulse between a set of upper and lower thermisters. The electromagnetic flowmeter (Young and Peterson, 1995) measures fluid velocity based on Faraday's Law, which states that the flow of an electrically conductive fluid through an induced magnetic field generates a voltage gradient that is proportional to the fluid's velocity. The heat-pulse and electromagnetic flowmeters were used with flexible rubber diverters fitted to the nominal wellbore diameter. The heat-pulse flowmeter, which was used in a stationary mode, has a measurement range of 0.005 to 1 gal/min. The electromagnetic flowmeter, which was used in stationary and trolling modes, has a measurement range of 0.05 to 10 gal/min.

Stratigraphic Logs

The stratigraphic logs delineate the geologic formations and members penetrated by the wells. The stratigraphy of central New York has been described by Harris (1905), Luther (1910), Oliver (1954), Rickard (1962, 1975, and 1989), Demicco and others (1992), Brett and Ver Straeten (1994), and Brett and others (2000). The stratigraphic units penetrated by test wells 181 and 186 were identified by characterization and correlation of the core samples and gamma logs. The stratigraphic units penetrated by the other wells were identified by characteristic signatures in the gamma logs; supporting information from the optical televiewer was used where available.

The wells penetrate limestones, dolostones, shales, sandstones, and evaporites of Silurian to Devonian age. The identified stratigraphic units of Silurian age, in ascending order, are the Camillus Formation; the Fiddlers Green, Forge Hollow and Oxbow Members of the Bertie Formation or Group; the Cobleskill Formation; and lower part of the Chrysler Member of the Rondout Formation. The Camillus shale and Fiddlers Green dolostone, although not penetrated by wells 181 and 186, were identified in wells 192 to 195 from characteristic gamma signatures observed in logs from local gas wells that were obtained from the NYSDEC. The presence of the Akron Formation, which may interfinger locally with the Cobleskill limestone as an equivalent dolomitized facies (Brett and others, 2000), and which may be penetrated by some wells, could not be confirmed through the geophysical log analysis.

The identified stratigraphic units of Devonian age, in ascending order, are the upper part of the Chrysler Member of the Rondout Formation; the Olney Member of the Manlius Formation; the Edgecliff, Nedrow, Moorehouse, and Seneca Members of the Onondaga Formation; the Union Springs, Cherry Valley, and Oatka Creek Members of the Marcellus Formation; and the Mottville and Delphi Station Members of the Skaneateles Formation. The Mottville shale and sandstone and Delphi Station shale, although not penetrated by wells 181 and 186, were identified from their inferred thickness and gamma signature. The lower part of the Mottville is exposed along Route 326, about 0.25 mi south of Half Acre Station (site A, fig. 1).

The Oriskany Formation and Springvale Member of the Bois Blanc Formation, in central New York, are discontinuously present between the Manlius and Onondaga Formations (Brett and others, 2000). The Oriskany sandstone and Springvale sandstone and shale are not present in cores from wells 181, 186, or 196, nor in exposures at the Oakwood quarry (site B, fig. 1) or along Routes 5 and 20 near the Finger Lakes mall (site C, fig. 1). A 5-ft thick section of Oriskany sandstone is present at the Yawger`s Woods outcrop (site D, fig. 1) described by Luther (1910). At the Schooley quarry (site E, fig. 1), no Oriskany sandstone is present but a thin discontinuous bed of the Springvale with its characteristic phosphate nodules is present. Clasts of reworked phosphate nodules from the Springvale are present at the base of the Edgecliff Member of the Onondaga in core from wells 186 and 196 and in exposures at the Oakwood and Schooley quarries and along Routes 5 and 20 near the Finger Lakes mall. The Oriskany and Springvale were not identified through the geophysical log analysis but relatively thin sections of these units may be penetrated by some of the wells (typically less than one ft).

Repeated statigraphic sections were identified within the Manlius Formation in well 205, Manlius and Onondaga Formations in well 212, and Onondaga and Marcellus Formations in well 215. The repeated sections are probably the result of localized thrust faults similar to that described by Conkin and Conkin (1984) at the Seneca Stone quarry near Fayette, 8 mi west of the study area.

Flow-Zone Logs

The flow-zone logs define the distribution and relative hydraulic head of fracture-flow zones penetrated by 11 of the test wells and 15 water-supply wells. Zones of inflow to and outflow from the wellbore under ambient conditions were defined by the integrated analysis of the caliper, wellbore-image, flowmeter, and fluid logs.

Water levels presented in table 1 and included with the flow-zone logs were measured on the days in which the geophysical logs were collected. Water levels in those wells in which the logging spanned multiple days were measured on the days on which the flowmeter logs were collected. The water levels are composite values that reflect the transmissivity-weighted average of the hydraulic heads of the flow zones open to the wells (Bennett and others, 1982). Zones of inflow had heads higher than the composite water level, and zones of outflow had heads lower than the composite water level.

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Appendix

Geophysical, stratigraphic, and flow-zone logs of selected wells in Cayuga County, N.Y.

Explanation

Depth	Depth, in feet below land surface, scale 1:100 (1 foot equals 100 feet)
Age	Geologic age
Form	Geologic formation
Mmb	Geologic member
Gamma	Gamma radiation, in counts per second
Cond	Electromagnetic-induction conductivity, in millisiemens per meter
Mech Cal	Mechanical three-arm caliper, in inches
Acou Cal	Acoustic caliper, in inches
ATV	Acoustic televiewer, orientation in degrees from true North; NO indicates not oriented
OTV	Optical televiewer, orientation in degrees from true North
Fl Res	Fluid resistivity, in ohms per meter; NC indicates not calibrated
Temp	Temperature, in degrees Fahrenheit; NC indicates not calibrated
HPFM	Heat-pulse flowmeter, in gallons per minute; flows plotted at the displayed limit exceed measurement range
EMFM	Electromagnetic flowmeter, in gallons per minute; flows plotted at the displayed limit exceed measurement range
Flow Zone	Black line indicates the base of casing; blue line indicates the composite water level; red line indicates a flow zone with lower hydraulic head than the composite water level; yellow line indicates a flow zone with higher hydraulic head than the composite water level
Litho	Lithology, lithologic patterns presented below