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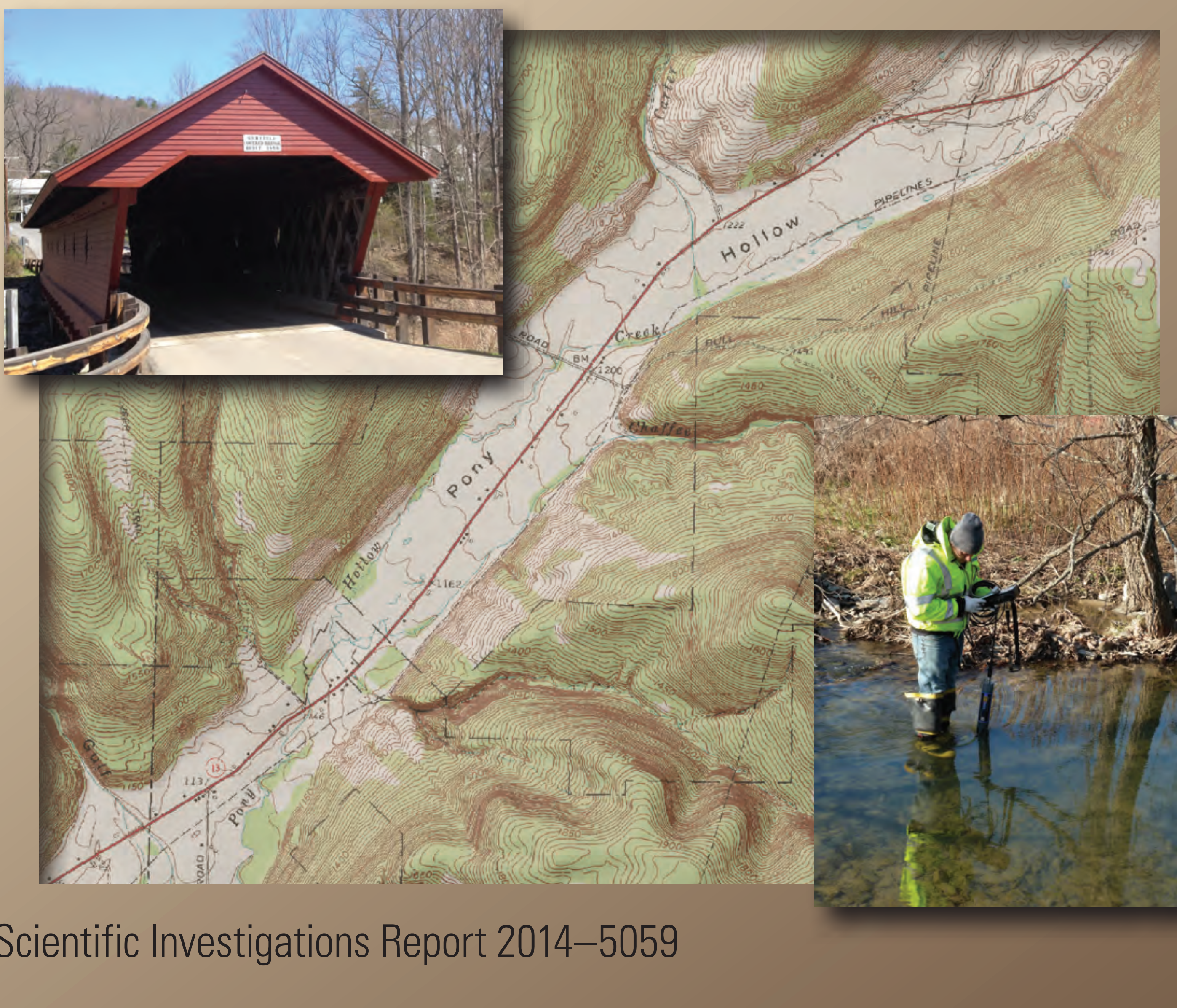
Hydrogeology and Water Quality of the Stratified-Drift Aquifer in the Pony Hollow Creek Valley, Tompkins County, New York



Scientific Investigations Report 2014–5059

U.S. Department of the Interior
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Cover. 1. Newfield Bridge is a wooden covered bridge over Cayuga Creek. It is in Newfield in Tompkins County, New York. It is one of 29 covered bridges in New York State. It was added to the National Register of Historic Places in 2000.

2. Brett Hayhurst, USGS, Ithaca N.Y., taking water-quality samples in Pony Hollow Creek, northeast of Cayuta, on December 13, 2011.

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By Edward F. Bugliosi, Todd S. Miller, and Richard J. Reynolds

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

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2014

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Conversion Factors and Datum

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Volume	
gallon (gal)	3.785	liter (L)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

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

$$°F=(1.8\times°C)+32$$

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

$$°C=(°F-32)/1.8$$

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

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

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

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 either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Abbreviations

EPA	U.S. Environmental Protection Agency
HA	health advisory
H/V	horizontal-to-vertical
MCL	maximum contaminant level
NWIS	National Water Information System
NWQL	National Water Quality Laboratory
NYSDEC	New York State Department of Environmental Conservation
SMCL	secondary maximum contaminant level
USGS	U.S. Geological Survey

Hydrogeology and Water Quality of the Stratified-Drift Aquifer in the Pony Hollow Creek Valley, Tompkins County, New York

By E. F. Bugliosi, Todd S. Miller, and Richard Reynolds

Abstract

The lithology, areal extent, and the water-table configuration in stratified-drift aquifers in the northern part of the Pony Hollow Creek valley in the Town of Newfield, New York, were mapped as part of an ongoing aquifer mapping program in Tompkins County. Surficial geologic and soil maps, well and test-boring records, light detection and ranging (lidar) data, water-level measurements, and passive-seismic surveys were used to map the aquifer geometry, construct geologic sections, and determine the depth to bedrock at selected locations throughout the valley. Additionally, water-quality samples were collected from selected streams and wells to characterize the quality of surface and groundwater in the study area.

Sedimentary bedrock underlies the study area and is overlain by unstratified drift (till), stratified drift (glaciolacustrine and glaciofluvial deposits), and recent post glacial alluvium. The major type of unconsolidated, water-yielding material in the study area is stratified drift, which consists of glaciofluvial sand and gravel, and is present in sufficient amounts in most places to form an extensive unconfined aquifer throughout the study area, which is the source of water for most residents, farms, and businesses in the valleys.

A map of the water table in the unconfined aquifer was constructed by using (1) measurements made between the mid-1960s through 2010, (2) control on the altitudes of perennial streams at 10-foot contour intervals from lidar data collected by Tompkins County, and (3) water surfaces of ponds and wetlands that are hydraulically connected to the unconfined aquifer. Water-table contours indicate that the direction of groundwater flow within the stratified-drift aquifer is predominantly from the valley walls toward the streams and ponds in the central part of the valley where groundwater then flows southwestward (down valley) toward the confluence with the Cayuta Creek valley. Locally, the direction of groundwater flow is radially away from groundwater mounds that have formed beneath upland tributaries that lose water where they flow on alluvial fans on the margins of the valley. In some places, groundwater that would normally flow toward streams is intercepted by pumping wells.

Surface-water samples were collected in 2001 at four sites including Carter, Pony Hollow (two sites), and Chafee Creeks, and from six wells throughout the aquifer. Calcium dominates the cation composition and bicarbonate dominates the anion composition in groundwater and surface-water samples and none of the common inorganic constituents collected exceeded any Federal or State water-quality standards. Groundwater samples were collected from six wells all completed in the unconfined sand and gravel aquifer. Concentrations of calcium and magnesium dominated the ionic composition of the groundwater in all wells sampled. Nitrate, orthophosphate, and trace metals were detected in all groundwater samples, but none were more than U.S. Environmental Protection Agency or New York State Department of Health regulatory limits.

Introduction

In 2009, the U.S. Geological Survey (USGS) began an appraisal of the stratified-drift aquifer in the Pony Hollow Creek valley in Tompkins County, New York. This study is a continuation of a series of hydrogeologic appraisals of the stratified-drift aquifers in Tompkins County, done in cooperation with the County and Towns within the county (fig. 1). The hydrogeology for much of the study area was characterized by Miller and Pitman (2012) in a cooperative study with the New York State Department of Environmental Conservation (NYSDEC) of the Cayuta Creek Valley, to which the Pony Hollow Creek valley is tributary. These reports provide a foundation for wellhead protection programs, water-resource management and planning, and groundwater remediation activities in upstate New York. Additionally, State, county, municipal, and other governmental agencies are requesting hydrogeologic information that will help decision makers evaluate the potential effects of gas drilling and hydraulic fracturing operations on aquifers that supply potable water. As the major sources of potable groundwater in Tompkins County, stratified-drift aquifers need to be delineated and their basic hydrogeologic characteristics determined.

The Pony Hollow Creek valley, in southwestern Tompkins County, is slightly more than 4-miles (mi)-long, trends northeast-southwest, and is a tributary to the 23-mi-long Cayuta Creek valley to the southwest, within the north-central part of the glaciated Appalachian Plateau in central New York (fig. 2). Pony Hollow Creek initially flows southwest out of wetland areas about 3 mi southwest of Newfield, New York, where a regional, low-relief, surface-water divide separates areas of northward drainage to Lake Ontario and southward drainage to the Susquehanna River Basin (not shown).

The physiography of the Pony Hollow Creek valley is described in detail by Miller and Pitman (2012). The valley is generally surrounded by rounded hills of moderate relief several hundred feet above the valley floor. The Pony Hollow Creek valley is one of many examples of bedrock troughs that extend southward from the Finger Lakes to the northern rim of the Appalachian Plateau (fig. 2). Glacial meltwaters and post-glacial streams deposited large amounts of stratified drift composed of coarse-grained sediments (sand and gravel) in the main valleys, forming extensive aquifers that provide the sole sources of water for most residents, farms, and businesses in the valleys.

Purpose and Scope

This report summarizes the hydrogeology of the stratified-drift aquifer in the Pony Hollow Creek valley in the southwestern part of Tompkins County, New York. The report includes maps that depict the aquifer extent, locations of wells, and results of horizontal-to-vertical (H/V) ambient-noise seismic surveys, nature of surficial deposits, and water-table configuration. The report also summarizes the quality of surface water and groundwater in the valley sampled from selected streams and wells. A table of well data is included in appendix 1.

Data Sources and Methods

Most of the aquifer geometry information and well and hydraulic data are from Miller and Pitman (2012). The Miller and Pitman (2012) report includes a 1:24,000-scale surficial-deposits map, subsurface data including well- and test-drilling records, and results from H/V ambient-noise seismic surveys (a geophysical method used to estimate the thickness of sediment over bedrock). Sources of well and test-boring data include previous USGS groundwater studies by Miller and Karig (2010) and Miller and Pitman (2012), the USGS National Water Information System (NWIS), and the NYSDEC Water Well Drillers Registration Program (well records from 2000 to 2010). Well data are in Appendix 1.

Well, test-boring, and seismic data (fig. 3), and surficial-deposits data were used to define and map the extent of the aquifers, determine the aquifer lithology and degree of confinement, depict the stratigraphy in two geohydrologic sections, and determine the depth to bedrock and thickness of unconsolidated valley-fill deposits at selected locations. Most well and test-boring records included groundwater-level measurements that were used along with altitudes of stream channels and ponds determined from light detection and ranging (lidar) data to construct a generalized water-table map of the aquifer (Miller and Pitman, 2012).

Wells and Well Locations

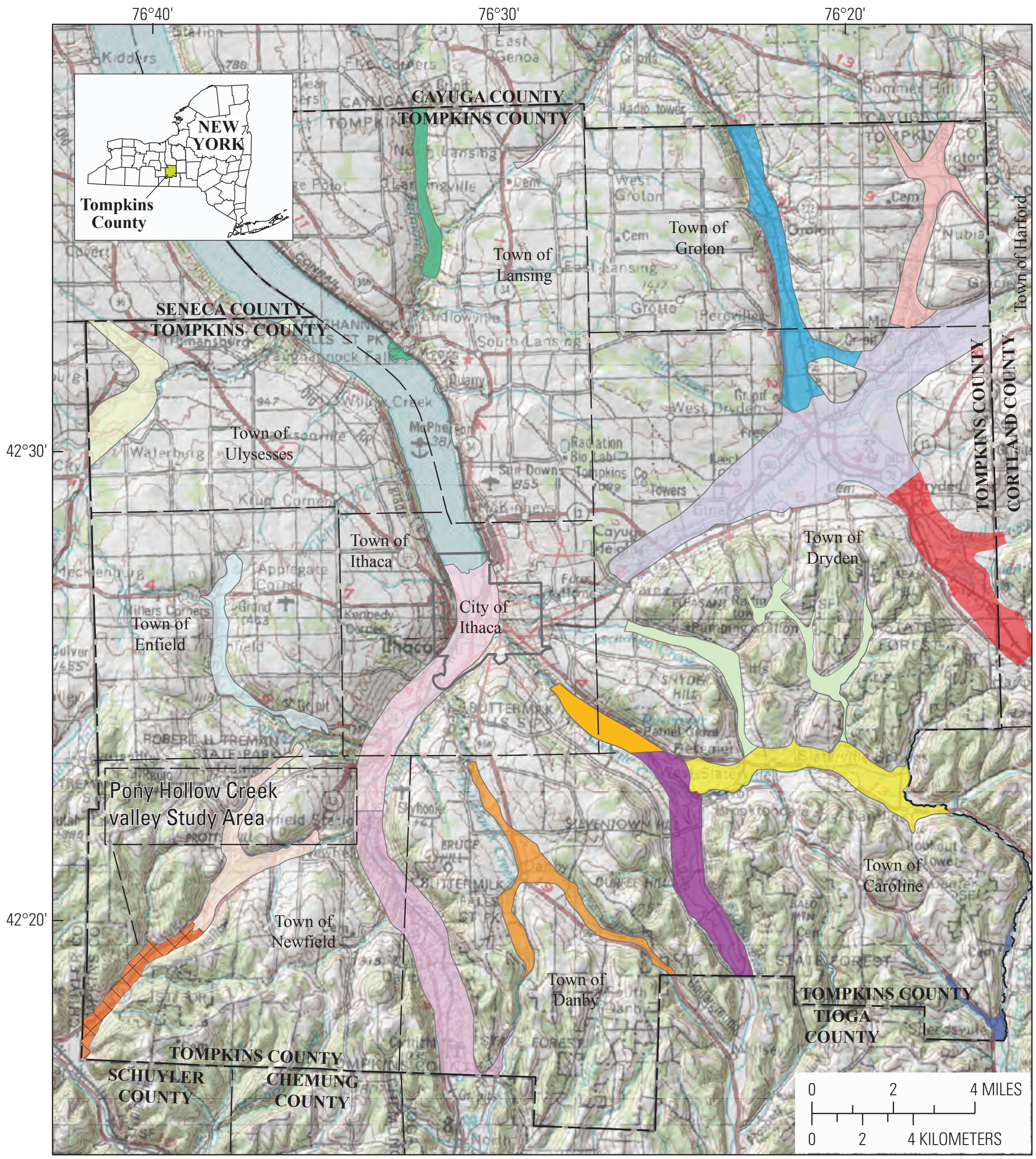
A total of 18 well and associated test-boring records were compiled for this study (fig. 3 and Appendix 1). The locations of wells from the NYSDEC Water Well Drillers Registration Program were field checked by USGS personnel (Miller and Pitman, 2012). The altitudes of land surface at the wells were determined from lidar data. Water-level measuring points were referenced to the lidar data with an accuracy of 1 foot (ft).

Bedrock and Surficial Deposits

Bedrock in the study area consists of Upper to Middle Devonian shale that is overlain by unconsolidated deposits including till, glaciolacustrine and glaciofluvial deposits, and recent alluvium (fig. 4) (Rickard and Fisher, 1970). Bedrock crops out at land surface along the flanks of many of the valleys and on hilltops (Miller and Pitman, 2012). The regional dip of the strata is southward at 40 to 60 feet per mile (ft/mi); at subregional scales, however, the strata are warped into shallow open folds with axes trending east to northeast, which result in local variations in dip and, in some places, reversal of dip (Miller and Pitman, 2012).

The Pony Hollow Creek valley follows one of a group of predominant lineaments (linear structural features) that are faults or suspected faults in Tompkins County (fig. 4) (Miller and Pitman, 2012, fig.3), which controlled the development of the Pony Hollow Creek valley. The drainage pattern of tributaries in the Pony Hollow Creek valley is consistent with the underlying regional, orthogonal fracture pattern in this area, and is distinct from the more dendritic drainage pattern of the surrounding hillsides. Faults and fractures are found throughout the study area and bedrock uplands, and in some places locally enhance the secondary permeability of the rock, acting as conduits through which groundwater may flow (Fountain and Jacobi, 2000; Miller and Pitman, 2012).

The study area has undergone several major glaciations during the Pleistocene Epoch, which began 2.6 million years ago and ended about 12,000 years before present (Fullerton,



Base from U.S. Geological Survey digital Line graph, scale 1:250,000

Aquifers mapped by T.S. Miller (2000)

EXPLANATION

Aquifer reaches

- Cascadilla Creek valley and upland Sixmile Creek valley
- Enfield Creek valley
- Lower Cayuga Inlet valley
- Lower Fall Creek valley
- Lower Sixmile Creek valley (towns of Dryden and Ithaca)
- Owasco Inlet valley
- Lower Sixmile Creek and Willseyville Creek valleys (town of Caroline)

Aquifer reaches, continued

- Pony Hollow Creek valley (this study)
- Salmon Creek/Myers Point/Locke Creek
- Taughannock Creek valley and delta
- Upper Buttermilk Creek and Danby Creek valleys
- Upper Cayuga Inlet valley
- Upper Fall Creek valley
- Upper Sixmile Creek and West Branch Owego Creek valleys
- Virgil Creek, Dryden Lake, and Owego Creek valleys
- West Branch Cayuga Inlet and Fish Kill valleys
- West Branch Owego Creek valley and tributaries

Figure 1. Locations of 17 unconsolidated-aquifer reaches in Tompkins County, New York.

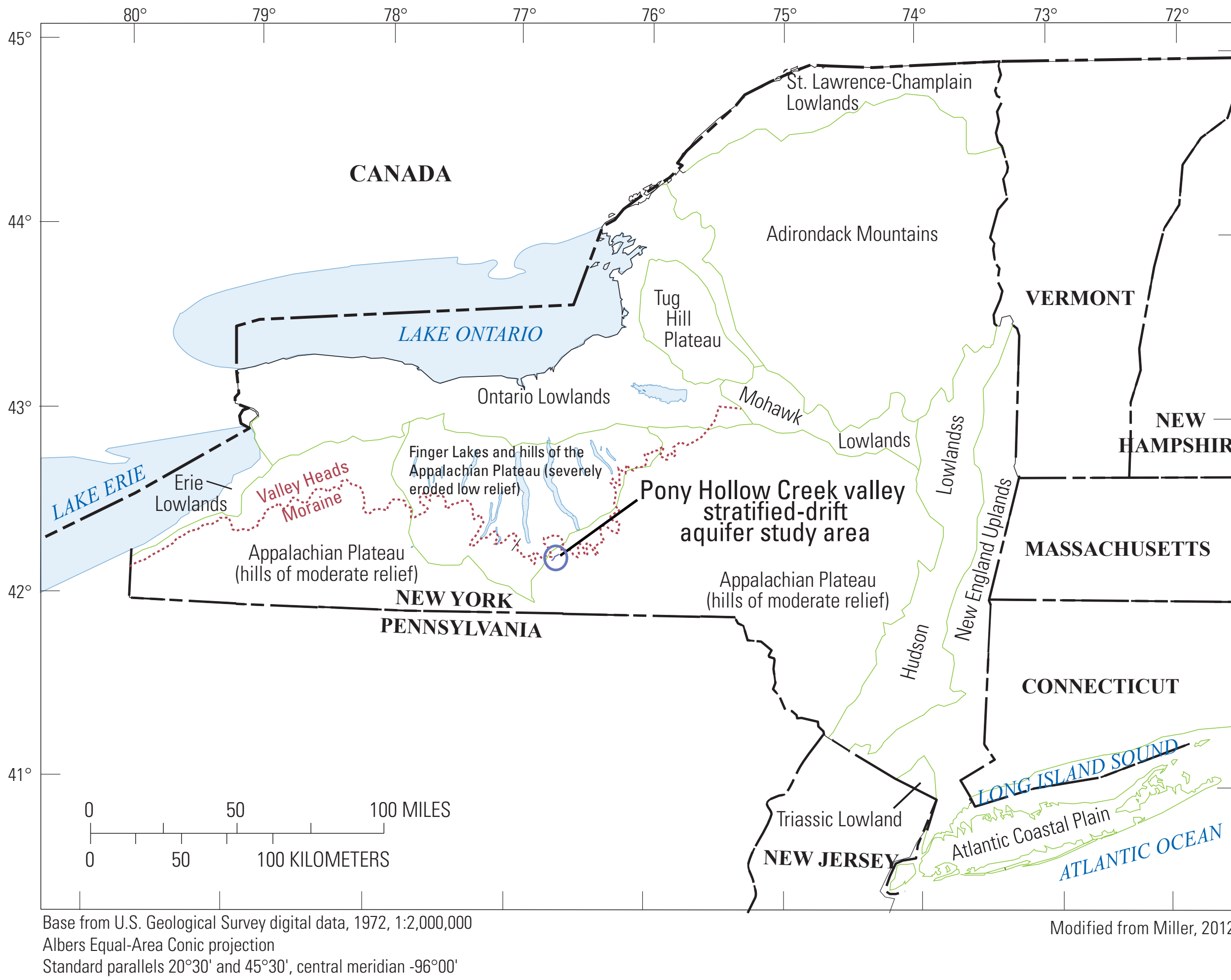
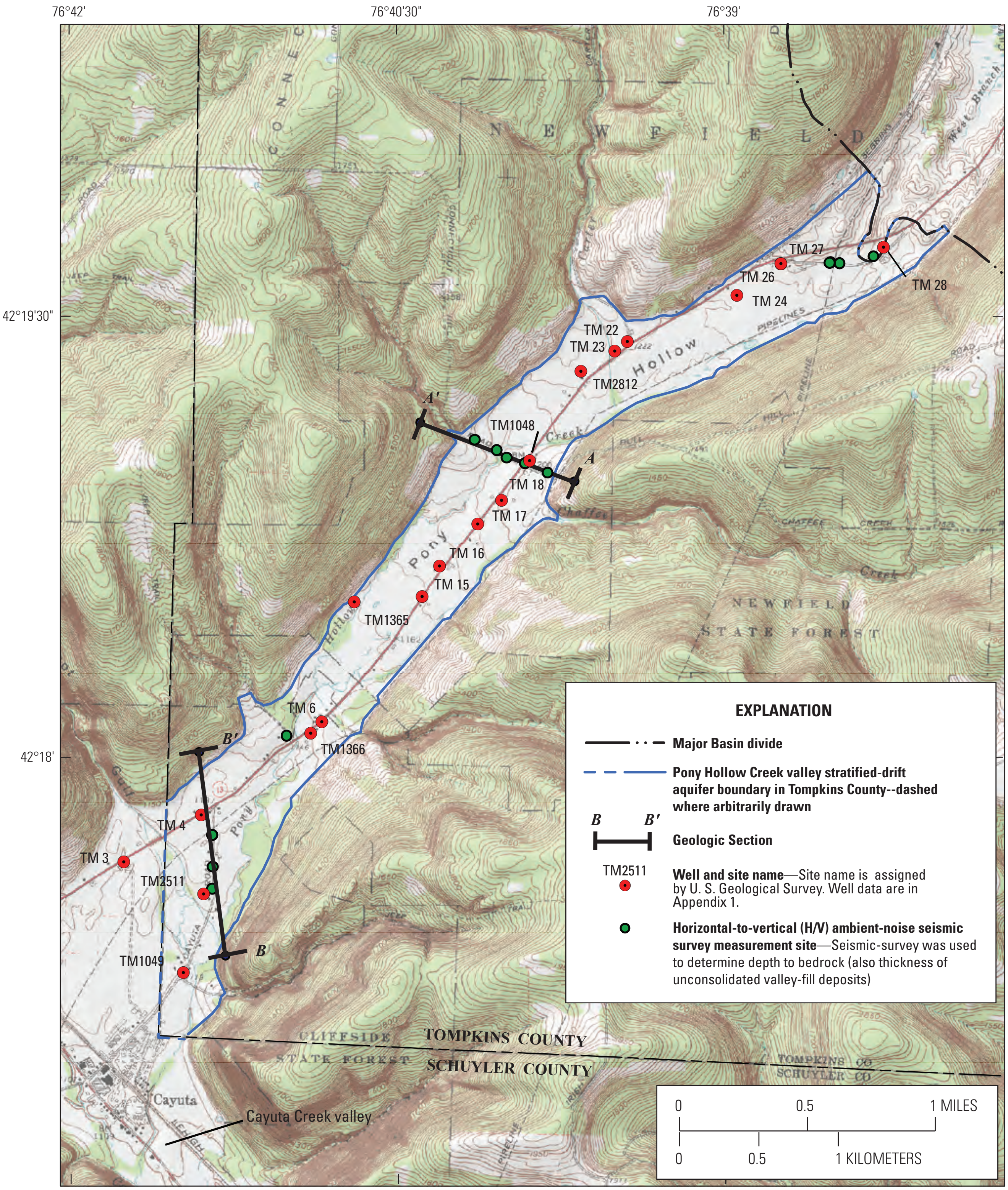


Figure 2. Physiographic regions of New York and location of the Pony Hollow Creek valley stratified-drift aquifer study area, New York.

1980). Most glacial sediments in the Pony Hollow Creek valley were deposited during the end of the most recent (Wisconsin) glacial epoch, from about 20,000 to 11,850 years ago. These sediments are composed mainly of unstratified and stratified glacial drift.

The unstratified glacial drift in the study area consists of till in the uplands that directly overlies bedrock, and is the sole unconsolidated deposit (fig. 5) in the uplands. Till typically has low hydraulic conductivity and therefore, does not form any extensive aquifer in this area (Miller and Pitman, 2012). In contrast, stratified-drift deposits consisting of glaciofluvial, glaciolacustrine, and recent deposits (alluvial sand and gravel, and swamp and marsh sediments) are the major unconsolidated deposits present in the Pony Hollow Creek valley (fig. 5) (Miller and Pitman, 2012). Additionally, fluvial sediments were deposited by glacial meltwaters as the ice retreated and then by post-glacial streams. Glaciofluvial and alluvial deposits form the unconfined aquifer throughout the study area (fig. 4). The geologic framework that forms the aquifer in the Pony Hollow Creek valley is depicted in two geohydrologic sections spanning the valley [(section *A–A′* one-half way down the valley and section *B–B′* towards the southern end of the valley (fig. 6)]. The prevalence of alluvial deposits in many places indicates that post-glacial erosion of the uplands contributed a large volume of sediment that has accumulated in the valleys (Miller and Pitman, 2012). The thickness of the unconsolidated deposits in the Pony Hollow Creek valley ranges from 22-85 ft (based on well depth and casing depth)—the depth to bedrock ranges between 23-100 ft at three wells in the valley (appendix 1).

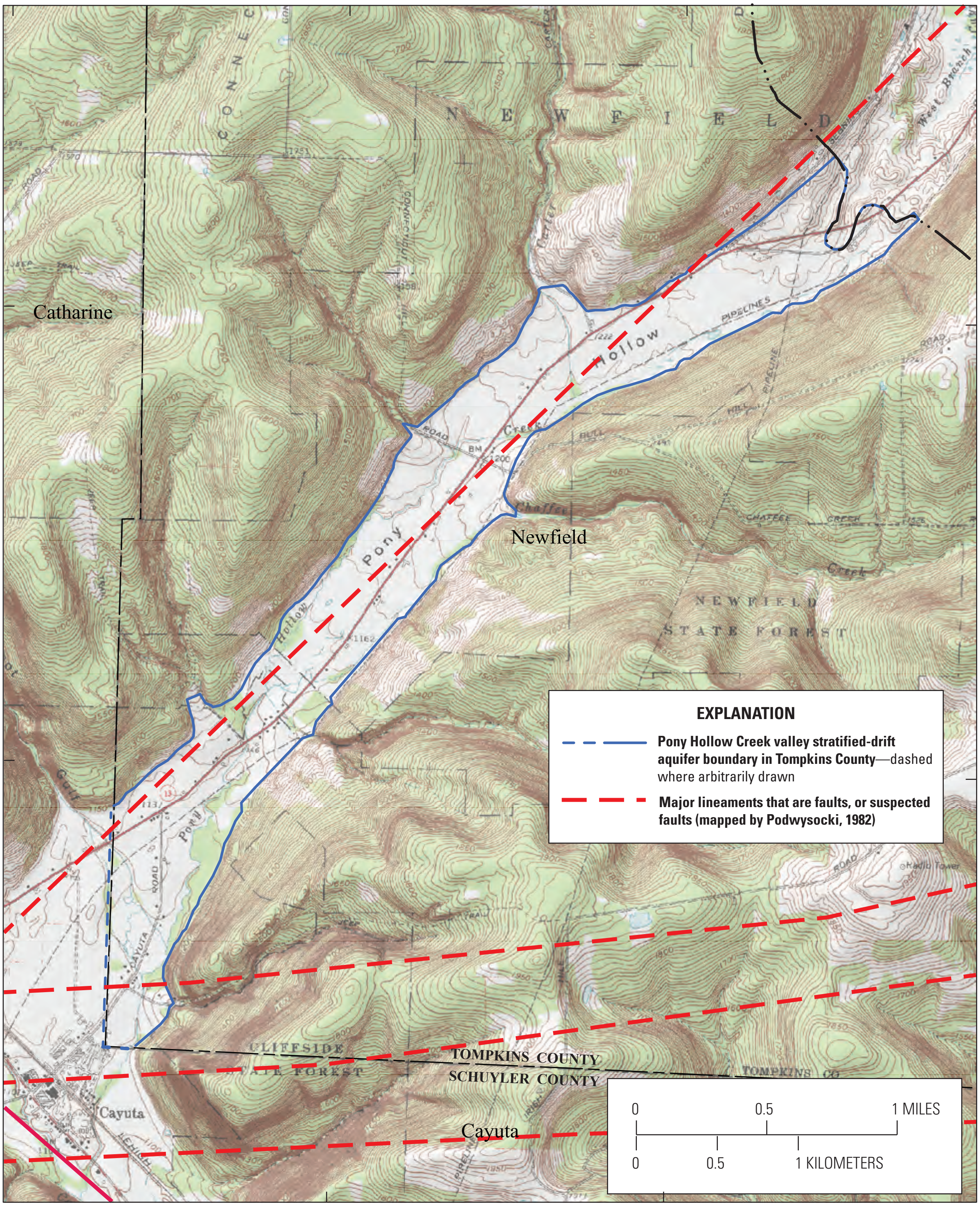
In the 4-mi-long Pony Hollow Creek valley, outwash, kame, and post-glacial alluvial sediments are the predominant deposits (fig. 5). In the northern part of the valley a kame morainal deposit blends into outwash sand and gravel to the southwest and then into mostly alluvium, southwest to the mouth of the valley and the confluence with the larger Cayuta Creek valley near the border between Schuyler County and Tompkins County where some inwash sand and gravel were locally deposited (fig. 5). The kame end moraine makes a low-relief, major-basin drainage divide crossing the valley



Base from U.S. Geological Survey, Seamless Data Distribution System, accessed in 2009 at http://seamless.usgs.gov, Universal Transverse Mercator (UTM) projection, Zone 18. Shading from 30-meter Digital Elevation Model accessed in 2009 at http://nationalmap.gov/elevation.html#data, UTM, Zone 18.

Modified from MIller and Pittman, 2012

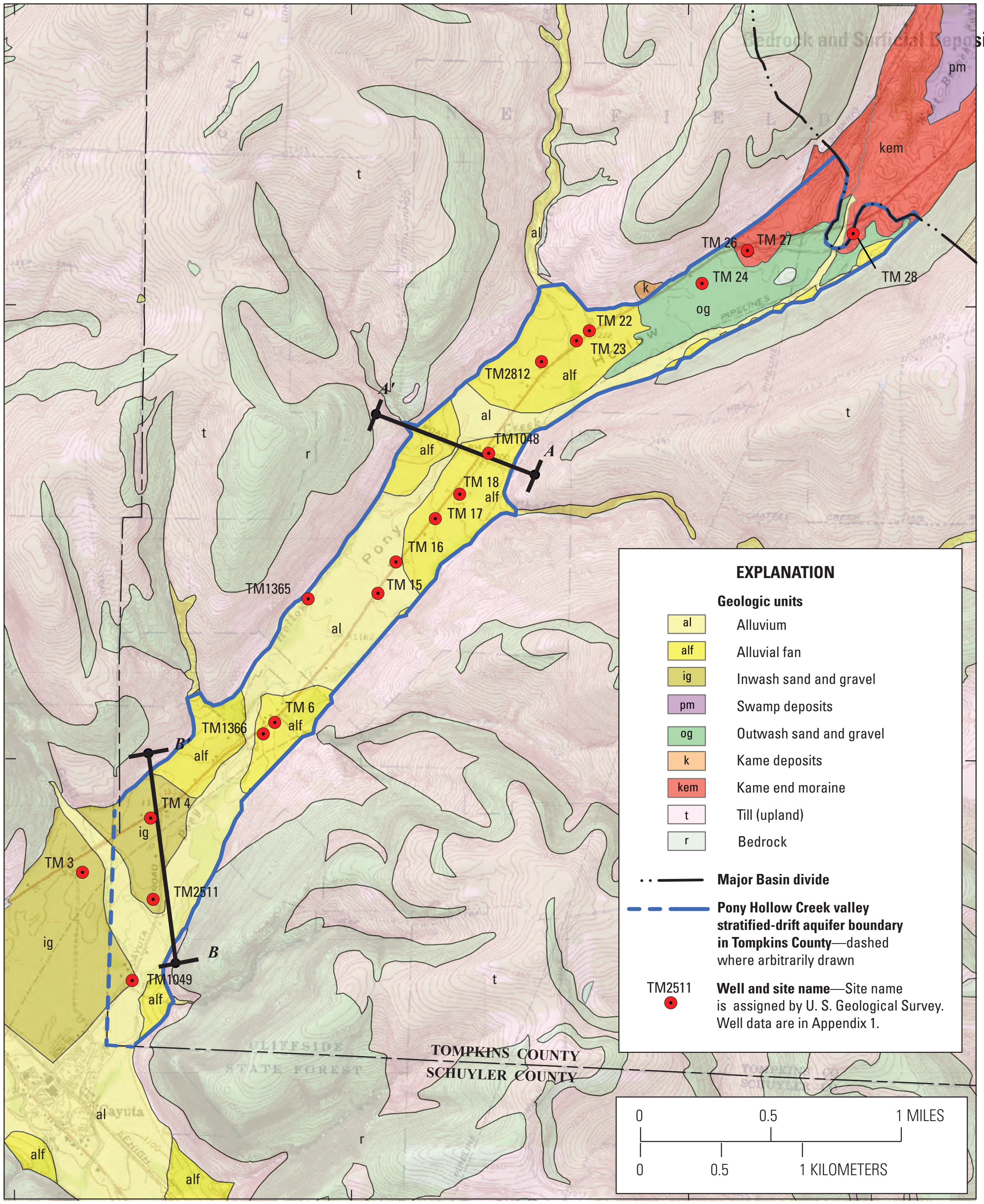
Figure 3. Well and seismic-survey locations and geologic-section locations in the Pony Hollow Creek valley stratified-drift aquifer, Tompkins County, New York.



Base from U.S. Geological Survey, Seamless Data Distribution System, accessed in 2009 at http://seamless.usgs.gov, Universal Transverse Mercator (UTM) projection, Zone 18. Shading from 30-meter Digital Elevation Model accessed in 2009 at http://nationalmap.gov/elevation.html#data, UTM, Zone 18.

(Map modified from Miller and Pitman, 2012; Lineaments mapped by Podwysocki and others, 1982)

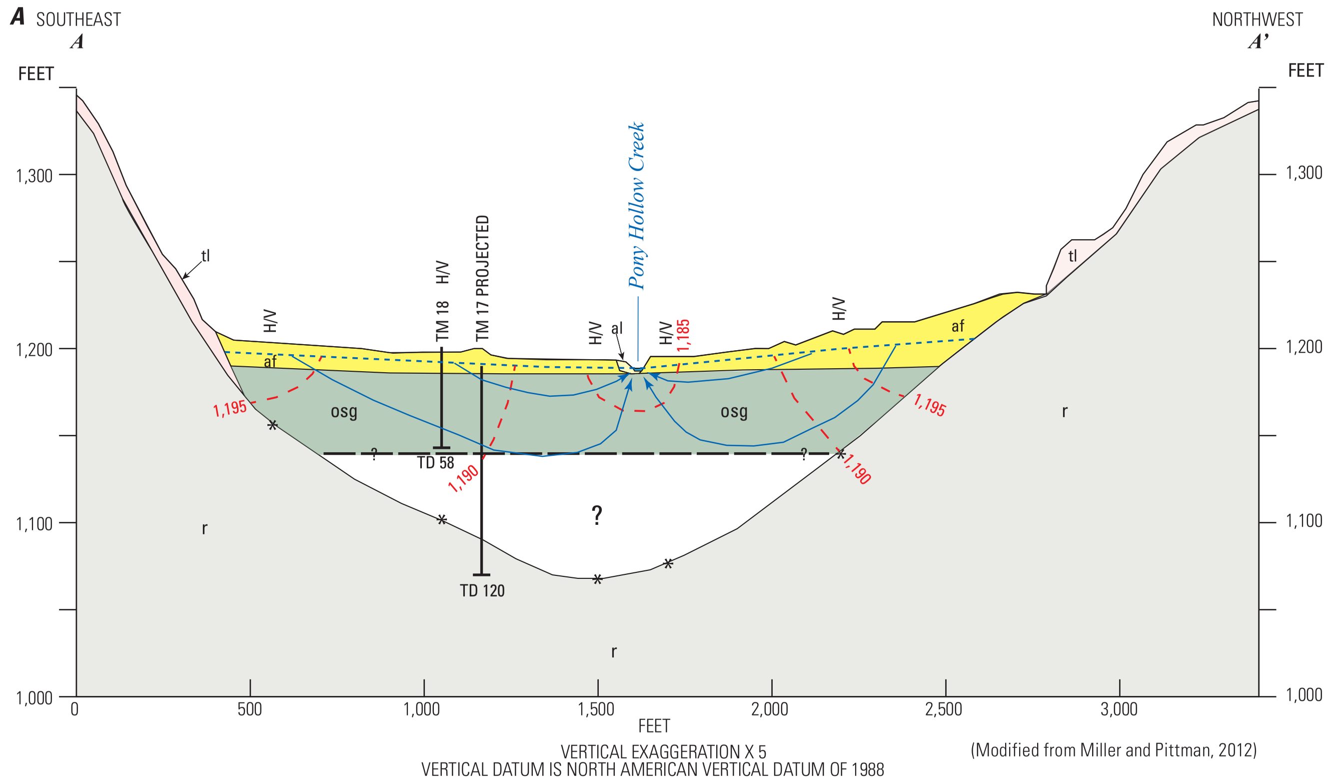
Figure 4. Location of Pony Hollow Creek valley stratified-drift aquifer and major lineaments that are faults or suspected faults in Tompkins County, New York.



Base from U.S. Geological Survey, Seamless Data Distribution System, accessed in 2009 at http://seamless.usgs.gov, Universal Transverse Mercator (UTM) projection, Zone 18. Shading from 30-meter Digital Elevation Model accessed in 2009 at http://nationalmap.gov/elevation.html#data, UTM, Zone 18.

Modified from Miller and Pitman, 2012)

Figure 5. Bedrock and surficial deposits in the Pony Hollow Creek valley stratified-drift aquifer, Tompkins County, New York.



EXPLANATION

Alluvial deposits of Holocene age

al — **Channel and flood-plain alluvium**—Stream-deposited gravel, sand, silt, and clay. Forms part of the unconfined aquifer.

af — **Alluvial-fan deposits**—A complex of gravel, sand, silt, and clay deposited as fans by upland tributaries where they join the main valley. Forms part of the unconfined aquifer.

Glaciofluvial deposits of Wisconsin age

osg — **Outwash sand and gravel**—Chiefly sand and gravel beneath terrace remnants; as valley trains and beneath outwash plains; as fans and aprons; as delta topset beds. Forms the main part of the unconfined aquifer in the valley.

Till of late Wisconsin age

tl — **Till deposits in the uplands (mostly lodgment till)**—Consists of subangular to angular clasts (fine pebbles to boulders) embedded in a matrix consisting chiefly of calcareous loam, silt loam, sandy loam, sandy clay loam, or silty clay loam.

Devonian-age rocks

r — **Bedrock**—Mostly Devonian-age shales and siltstones, and with some fine-grained sandstones, limestones and dolostones units. Beds are gently folded and have a regional dip to the south from 40 to 60 feet per mile.

TM 18 / TD 58 — **Well and site name**—Site name is assigned by the U.S. Geological Survey. TM = Tompkins County, number following TM is sequential well number, and TD = total depth (in feet) of well.

H/V * — **Horizontal-to-vertical ambient-noise seismic measurement**—Asterisk denotes computed bedrock surface.

Geologic contacts

Accurately to approximately located

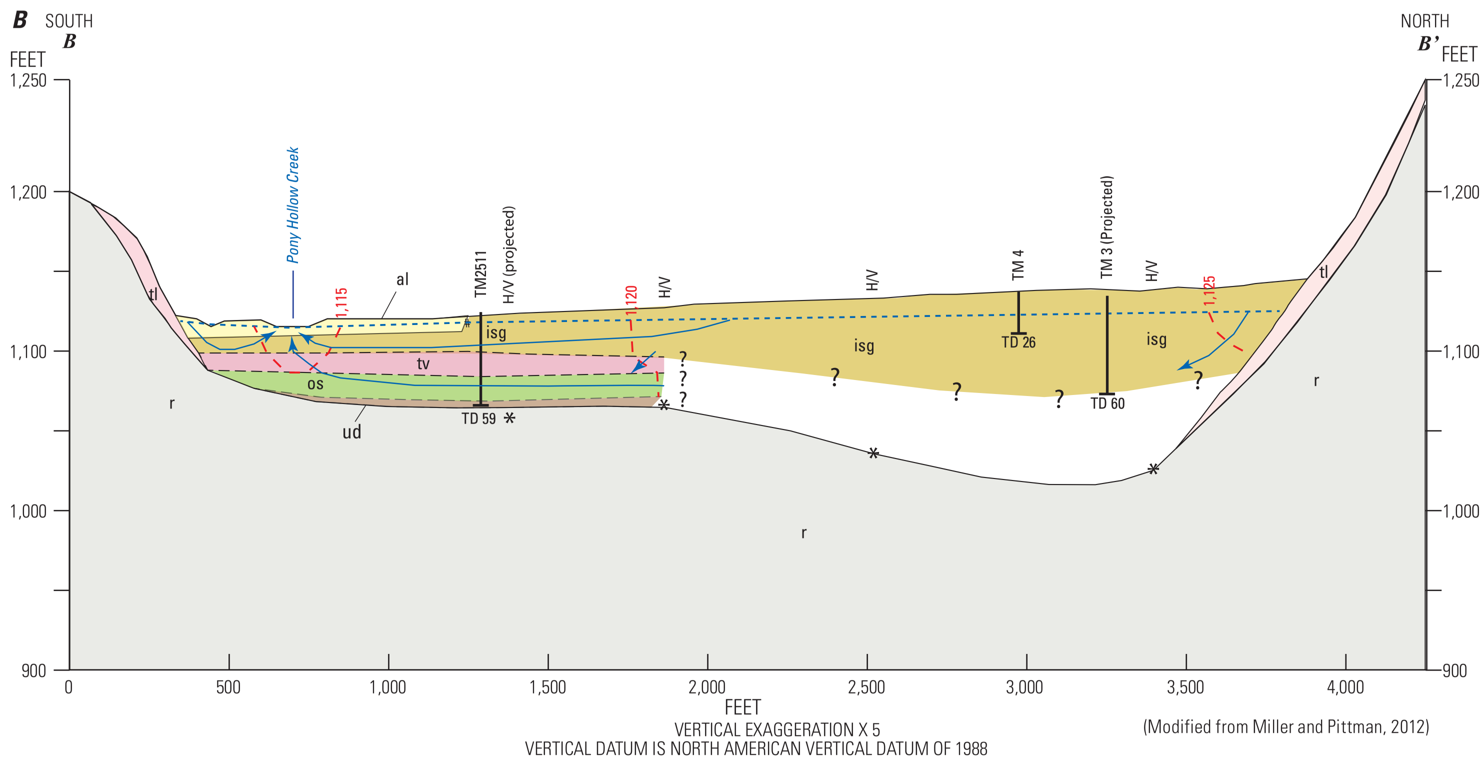
? ? ? ? Unknown

Hydrologic symbols

Water table

1,190 — **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells. Contour interval 5 feet. Datum is NAVD 88. Arrow shows general direction of groundwater flow.

Figure 6. A. Geohydrologic section A–A' across the Pony Hollow Creek valley along Connecticut Hill Road; and B. section B–B' across Pony Hollow Creek valley, along Cayuta Road Tompkins County, New York, (modified from Miller and Pitman, 2012). Section location shown on figure 5.



EXPLANATION

Alluvial deposits of Holocene age

al — **Channel and flood-plain alluvium**—Stream-deposited gravel, sand, silt, and clay. Forms upper part of the unconfined aquifer

Alluvial deposits of Wisconsin and Holocene age

isg — **Inwash sand and gravel**—Chiefly sand and gravel that were transported by upland tributary streams or outlets to proglacial lakes and that were deposited in the valley. Forms main part of the unconfined aquifer

Glaciofluvial deposits of Wisconsin age

os — **Outwash sand**—Chiefly sand or sand and silt containing scattered pebbles. Forms upper part of a confined aquifer where overlain by till, otherwise, it forms an unconfined aquifer where not confined

ud — **Undifferentiated alluvial sand and gravel (unknown origin)**—Forms lower part of a confined aquifer where overlain by till, otherwise, it forms an unconfined aquifer where not confined

Till of late Wisconsin age

tv — **Till deposits in valley fill (valley facies)**—Till that typically consists of subangular to rounded clasts (fine pebbles to coarse cobbles) embedded in a fine-grained matrix. Sometimes this unit may be misidentified as till (referred to by drillers as hardpan) where it actually may be dirty gravel. Forms a confining unit, where present

tl — **Till deposits in the uplands (mostly lodgment till)**—Consists of subangular to angular clasts (fine pebbles to boulders) embedded in a matrix consisting chiefly calcareous loam, silt loam, sandy loam, sandy clay loam, or silty clay loam

Devonian-age rocks

r — **Bedrock**—Mostly Devonian-age shales and siltstones, and with some fine-grained sandstones, limestones and dolostones units. Beds are gently folded and have a regional dip to the south from 40 to 60 feet per mile

TM2511 / TD 59 — **Well and site name**—Site name is assigned by the U.S. Geological Survey. TM = Tompkins County, number following TM is sequential well number, and TD = total depth (in feet) of well

H/V * — **Horizontal-to-vertical ambient-noise seismic measurement**—Asterisk denotes computed depth to bedrock

Geologic contacts

Accurately to approximately located

Inferred

? ? ? ? Unknown

Hydrologic symbols

Water table

1,190 — **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells. Contour interval 5 feet. Datum is NAVD 88. Arrow shows general direction of groundwater flow

Figure 6. A. Geohydrologic section A–A′ across the Pony Hollow Creek valley along Connecticut Hill Road; and B. section B–B′ across Pony Hollow Creek valley, along Cayuta Road Tompkins County, New York. (modified from Miller and Pitman, 2012), Section location shown on figure 5.—continued

floor, separating northward and southward major drainages (fig. 3). The divide defines the headwaters for water draining northward to Cayuga Lake (fig. 1) and then Lake Ontario (fig. 2), and that draining southward to Cayuta Creek and then to the Susquehanna River (not shown).

Groundwater Levels and Flow

In the Pony Hollow Creek valley, groundwater levels refer to the altitude of the water table (or hydraulic head) in the stratified-drift aquifer (fig. 6). Groundwater flows from high to low hydraulic head and perpendicular to the head gradient. A water-table map was constructed by using water-level measurements made in wells from the 1960s to 2011 (appendix 1), lidar data (where available) that were used to determine altitudes of perennial streams at 10-ft intervals, and altitudes of large ponds and wetlands (fig. 7).

Groundwater flows perpendicular to the water-table contours in the stratified-drift aquifer in Pony Hollow Creek (fig.7). Flow is generally down valley and from the sides of the valley walls towards Pony Hollow Creek in most of the valley, at which point most groundwater discharges to the creek (Miller and Pitman, 2012). Where upland tributary streams lose water over the alluvial fans in the valleys, a localized groundwater mound forms beneath the streams and groundwater flow is radially away from the tributary channel and toward the main stream in the valley (Miller and Pitman, 2012) (fig. 7).

The water-table map in figure 7 was created by using groundwater-level measurements that were recorded at different times of the year from the 1960s to 2011 (Miller and Pitman, 2012). This approach was deemed reasonable because there were no measured long-term changes in water levels during this period (Miller and Pitman, 2012) and because the contour interval presented is large enough (20 ft) to take into account seasonal fluctuations in this area (which are normally less than 20 ft) without having the contours be inaccurate. There are no large public water-supply wells or commercial or industrial wells in the study area that would discharge large quantities of water from the aquifer and affect water levels. Additionally, the number of homeowner wells in the study area has remained relatively stable for the last 50 years, so no large changes in average water levels in the aquifer over that period would likely occur. In addition, the average annual fluctuation of the water table in the stratified-drift aquifers in the Pony Hollow Creek valley typically ranges from 5 to 10 ft, which is the same or smaller than the contour interval on the map (20 ft).

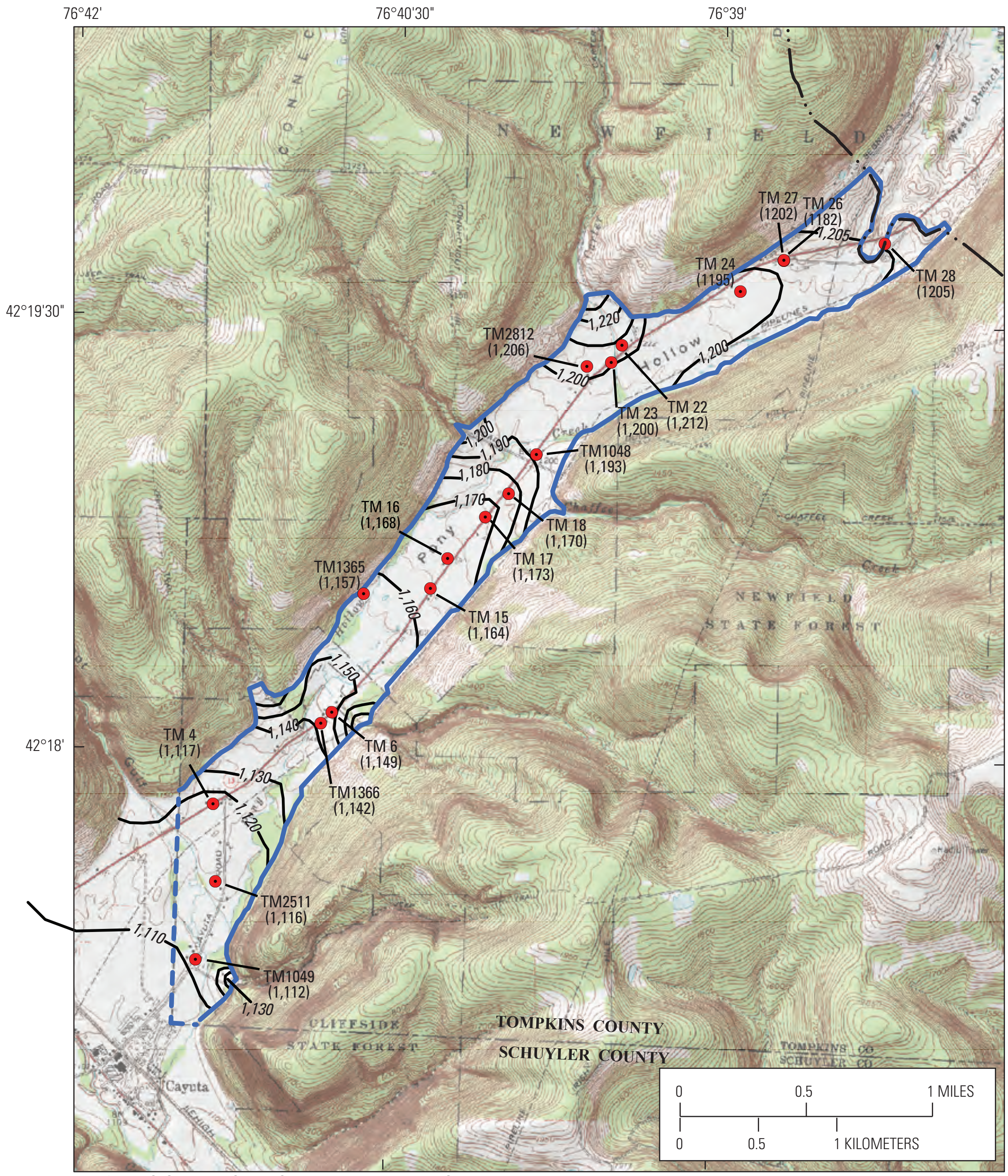
Annual water-table fluctuations (about 5 ft) are smaller near discharge areas, such as streams, and largest (about 10 ft) where greater amounts of recharge occur, such as along the valley walls and beneath alluvial fans (Miller and Pitman, 2012). In areas adjacent to gaining streams and large surface-water bodies such as lakes, ponds, and wetlands, the altitude of the water table reflects the water level of the surface-water body. Annual water-levels are normally affected by changes in the amounts of recharge, such as precipitation or snowmelt, but only locally change the relation of groundwater and surface-water levels in the study area (Miller and Pitman, 2012). Because there are no long-term water-level trends in the area and the annual fluctuation of groundwater levels is less than the contour interval (fig. 7), the water table map is a useful representation of long-term, average-annual groundwater levels and the general directions of groundwater flow (Miller and Pitman, 2012).

Water Quality

Water samples were collected to characterize the chemical quality of surface water at seasonal low flow or at average base flow when streamflow is mainly groundwater discharge and the quality of groundwater from wells in the study area. Field measurements were made for pH, specific conductance, and water temperature for surface-water and groundwater samples using a YSI-6920 multi-parameter meter that was maintained and calibrated according to standard USGS protocol (U.S. Geological Survey, variously dated). The concentrations of 40 constituents in surface-water samples and 44 constituents in groundwater samples were measured, including major inorganic ions, nutrients, trace metals, and dissolved gases.

On December 13, 2011, surface-water samples were collected from four sites in the Town of Newfield, including (1) Carter Creek at State Route 13 near Cayuta (station ID-01515583), (2) Pony Hollow Creek at State Route 13 northeast of Cayuta (station ID-01515586), (3) Chaffee Creek at State Route 13 near Cayuta (station ID- 01515592), and (4) Pony Hollow Creek at Morrell Road at Cayuta (station ID- 01515615) (fig.8). All surface-water samples were collected by an equal-width-increment sampling method using a USGS DH-59 sampler with 1-liter Teflon bottles using standard USGS water-quality sampling methods and equipment (U.S. Geological Survey, variously dated). Standard USGS procedures also were used to clean sampling equipment. Final rinsing of equipment was with pesticide-grade water—a high purity water.

Groundwater samples were collected from six residential domestic wells (fig. 8) on December 14 and 15, 2011. Groundwater samples were collected from residential domestic wells at a place in the water-delivery system before any filtration, water softeners, or purifiers to capture the native groundwater. Water in the home was allowed to run to void the well of at least 3 casing volumes of water, and samples were collected using Teflon fittings, hoses, and bottles only when physical properties (pH, specific conductance, and temperature) had stabilized. As done for the surface-water



Base from U.S. Geological Survey, Seamless Data Distribution System, accessed in 2009 at http://seamless.usgs.gov, Universal Transverse Mercator (UTM) projection, Zone 18. Shading from 30-meter Digital Elevation Model accessed in 2009 at http://nationalmap.gov/elevation.html#data, UTM, Zone 18.

(Modififed from Miller and Pittman, 2012)

EXPLANATION

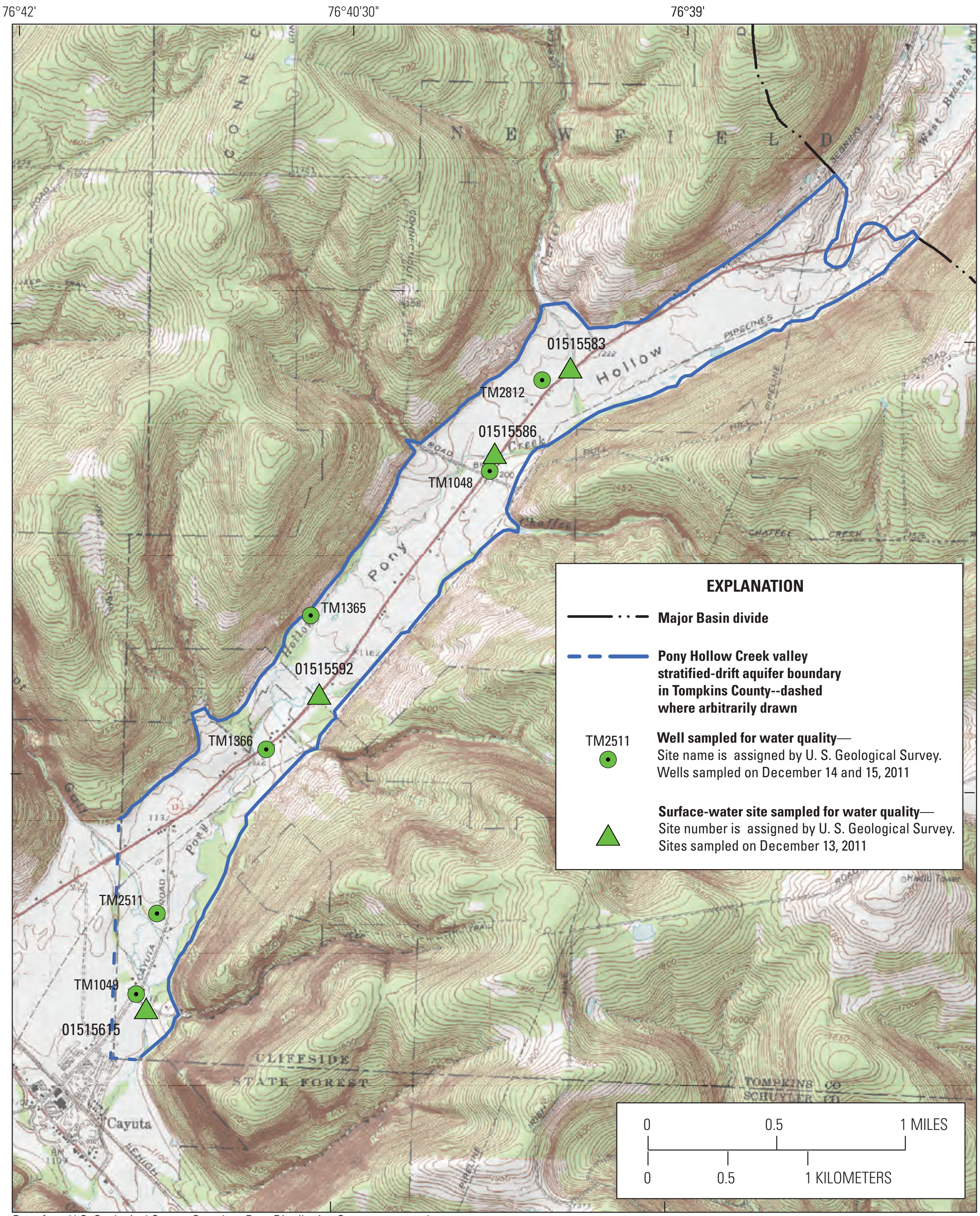
Major Basin divide

Pony Hollow Creek valley stratified-drift aquifer boundary in Tompkins County—dashed where arbitrarily drawn

1,010 **Generalized water-table altitude**—Shows approximate altitude of the water level in the unconfined aquifer in the Pony Hollow Creek valley derived from measurements made from historic groundwater-level data throughout several decades and during all seasons (1960s to 2011), and from approximate surface-water altitudes estimated from light detection and ranging (lidar) data, where available; and in areas where lidar data were unavailable, as indicated on 1:24,000-scale topographic maps; therefore, the contours are an approximation and reflect a generalized conception of the water table in this area. Contour interval 10 feet. Datum is North American Vertical Datum of 1988.

TM2511 (1,120) **Well and site name**—Site name is assigned by U. S. Geological Survey. Well data are in Appendix 1. Number in parenthesis is water-level altitude.

Figure 7. Water-level measurements and water-table surface contours in the Pony Hollow Creek valley Tompkins County, New York. (modified from Miller and Pitman, 2012).



Base from U.S. Geological Survey, Seamless Data Distribution System, accessed in 2009 at http://seamless.usgs.gov, Universal Transverse Mercator (UTM) projection, Zone 18. Shading from 30-meter Digital Elevation Model accessed in 2009 at http://nationalmap.gov/elevation.html#data, UTM, Zone 18.

Figure 8. Location of stream sites and wells sampled in the Pony Hollow Creek valley, Tompkins County, New York, December 13–15, 2011.

equipment, standard cleaning procedures (U.S. Geological Survey, variously dated) were followed with rinsing by pesticide-grade water.

All samples were analyzed by the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado. The NWQL participates satisfactorily in the USGS Standard Reference Water Sample Program and in a blind sample program. Analytical results for selected constituents are compared with Federal and State drinking-water standards. The standards include maximum contaminant levels (MCLs), secondary maximum contaminant levels (SMCLs), and health advisories (HAs) established by the U.S. Environmental Protection Agency (EPA; U.S. Environmental Protection Agency, 2006).

Surface Water

Four surface-water samples were collected by USGS personnel on December 13, 2011, during seasonal base-flow conditions. These surface-water samples were collected in December because of logistics and because winter samples can reflect base flow conditions provided snowmelt and surface-water contributions are at a minimum. If these conditions are met, winter base-flow conditions can be an approximation of the chemical quality of groundwater because streamflow during this time is composed largely of groundwater discharging into streams with little snowmelt or surface runoff. In addition, microbial activity, which can alter the concentrations of some constituents through contact with air and stream biota, is at a minimum in December. For example, microbial activity (associated with algal growth in the streams during warm seasons) can change dissolved oxygen concentrations or use the nitrogen in the water, potentially causing a decrease in nitrate concentrations (Miller and Pitman, 2012). However, the quality of surface water on December 13, 2011, may not reflect extreme base flow conditions because groundwater discharge to the streams likely was diluted by a small amount of surface runoff from snowmelt and local rainfall. Because air temperatures at the nearest weather station (Freeville 1 NE; National Weather Service station no. 303050) were in the lower 40-to upper 50-degree range, and there was about 0.5 inch of rainfall in the area for the preceding week, it is probable that overland runoff into the streams somewhat diluted the groundwater discharge with surface water and snowmelt. Thus, the samples may not reflect only groundwater input to the streams. Field measurements of pH, dissolved oxygen, specific conductance, and temperature, and the results of laboratory analyses are presented in table 1.

Physiochemical Properties

The pH of surface-water samples ranged from 7.5 to 7.7, with a median value of 7.6 (table 1); pH values for all 4 samples were within the accepted EPA SMCL range of 6.5 to 8.5 (U.S. Environmental Protection Agency, 2006). Specific conductance of the samples ranged from 62 to 152 microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C), with a median value of 105 µS/cm.

Common Inorganic Constituents

The cation detected in the greatest concentration was calcium, which ranged from 6.76-18.8 milligrams per liter (mg/L), with a median value of 12.6 mg/L (table 1). Magnesium concentrations ranged from 2.26 to 4.49 mg/L, with a median of 3.2 mg/L. Calcium and magnesium contribute to water hardness, which ranged from 26.2 to 65.9 mg/L as calcium carbonate ($CaCO_3$), with a median of 45.3 mg/L. Sodium concentrations ranged from 2.2 to 5.29 mg/L, with a median value of 3.12 mg/L. Potassium concentrations ranged from 0.52 to 0.803 mg/L, with a median value of 0.652 mg/L.

The anion detected in the greatest concentration was bicarbonate (Bicarbonate values were calculated from alkalinity concentrations, which are given in milligrams per liter of $CaCO_3$ and are reported as calcium carbonate)—the concentrations ranged from 23.4 to 66.2 mg/L, with a median value of 25.4 mg/L (table 1). Chloride concentrations ranged from 1.49 to 7.47 mg/L, with a median value of 3.20 mg/L. Sulfate concentrations ranged from 8.62 to 10.6 mg/L, with a median value of 9.71 mg/L. Silica concentrations ranged from 6.09 to 6.49 mg/L, with a median value of 6.17 mg/L. Fluoride concentrations were all below the detection limit of 0.04 mg/L. None of the inorganic major constituents collected from surface-water sites in the study area exceeded any Federal or State water-quality standards (table 1).

Nutrients

Nitrate plus nitrite, hereafter referred to as nitrate (N) was the predominant nitrogen species present in all nutrient samples of surface water, ranging from less than the detection limit of 0.04 mg/L to 0.656 mg/L as nitrogen (table 1). Elevated concentrations of nitrogen can cause excessive plant and algal growth in streams, depleting oxygen and stressing organisms in their aquatic habitat— it also is a human health concern when the concentration is more than 10 mg/L (U.S. Environmental Protection Agency, 2006). However, the concentration of nitrate in the four surface-water samples is considered to be very low. Orthophosphate concentrations were detected at the reporting limit (0.005 mg/L as phosphorus) in three of the surface-water samples, whereas results from the fourth sample indicated a concentration of 0.014 mg/L. None of the surface-water samples exceeded Federal or State drinking-water standards for nitrate or nitrite (table 1).

Table 1. Physical properties and concentrations of inorganic constituents, nutrients, and dissolved gases in surface-water samples in the Pony Hollow Creek valley, Tompkins County, New York, December 13, 2011.

[Sampling site location is shown in figure 8. USGS, U.S. Geological Survey; NWIS, National Water Information System; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitorgen; NO_2, nitrite; NO_3, nitrate; ft³/s, cubic feet per second; <, less than; --, not analyzed; XX, not available]

Physical properties		USGS station:	Carter Creek at State Route 13 near Cayuta	Pony Hollow Creek northeast of Cayuta	Chaffee Creek at State Route 13 near Cayuta	Pony Hollow Creek at Morrell Road at Cayuta	Drinking water standard	Median value
		Date sampled:	12/13/2011	12/13/2011	12/13/2011	12/13/2011		
		Station number:	01515583	01515586	01515592	01515615		
	NWIS parameter code	Units						
Dissolved oxygen (field)	00300	mg/L	14.1	13.6	11.6	13.0	XX	13.3
pH (field)	00400	pH	7.60	7.50	7.60	7.70	6.5–8.5[c]	7.60
Specific conductance (field)	00095	µS/cm	62.0	64.5	145	152	XX	105
Water temperature	00010	Celsius	0.43	0.74	3.60	3.04	XX	1.89
Concentrations of chemical constituents								
Common ions								
Hardness, filtered, as $CaCO_3$	00900	mg/L	26.2	26.8	63.7	65.9	XX	45.3
Calcium, filtered	00915	mg/L	6.76	6.84	18.4	18.8	XX	12.6
Magnesium, filtered	00925	mg/L	2.26	2.31	4.28	4.49	XX	3.23
Potassium, filtered	00935	mg/L	0.20	0.52	0.78	0.80	XX	0.65
Sodium, filtered	00930	mg/L	2.24	2.20	4.00	5.29	60[a]	3.12
Alkalinity, filtered, as $CaCO_3$	29801	mg/L	20.7	20.9	54.4	54.3	250[c]	37.6
Bicarbonate, filtered	29805	mg/L	25.2	25.5	23.4	66.2	XX	25.4
Bromide, filtered	71870	mg/L	< 0.010	< 0.010	< 0.010	< 0.010	XX	
Chloride, filtered	00940	mg/L	1.49	1.61	4.78	7.47	XX	3.20
Fluoride, filtered	00950	mg/L	< 0.04	< 0.04	< 0.04	< 0.04	2.2[b]	
Silica, filtered	00955	mg/L	6.19	6.09	6.15	6.49	XX	6.17
Sulfate, filtered	00945	mg/L	8.62	8.92	10.5	10.6	250[c]	9.71
Dissolved solids, at 180 °C	70300	mg/L	35.0	37.0	78.0	91.0	XX	57.5
Nutrients								
Ammonia + organic N, filtered	00623	mg/L	< 0.07	0.07	0.10	< 0.07	XX	0.09
Ammonia, as N, filtered	00608	mg/L	< 0.010	--	0.01	0.01	XX	0.01
Nitrate+nitrite, as N, filtered	00631	mg/L	0.058	< 0.04	0.389	0.66	10[a,b]	0.66
Nitrite, as N, filtered	00613	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	1[a,b]	< 0.001
Orthophosphate, as P, filtered	00671	mg/L	0.005	0.005	0.014	0.005	XX	0.005
Dissolved gases								
Carbon dioxide, unfiltered	00405	mg/L	1.10	--	2.90	--	XX	2.00
Stream discharge								
Discharge, instantaneous	00061	ft³/s	3.93	4.42	2.28	15.0	XX	4.18

[a]U.S. Environmental Protection Agency (USEPA) drinking water advisory taste threshold.

[b]New York State Department of Health maximum contaminant level.

[c]USEPA secondary maximum contaminant level.

Trace Elements

Trace elements detected in at least one surface-water sample included aluminum, antimony, arsenic, barium, boron, chromium, cobalt, iron, lead, lithium, manganese, molybdenum, nickel, strontium, uranium, and zinc (table 2). The trace elements detected in the greatest concentrations were aluminum, barium, boron, iron, lithium, manganese, and strontium. No samples exceeded Federal or State MCLs (table 2). Aluminum concentrations ranged from 6.35 to 9.48 µg/L, with a median value of 7.3 µg/L. Arsenic concentrations ranged from 0.128 to 0.180 µg/L, with a median of 0.158 µg/L (table 2). Barium concentrations ranged from 15.4 to 34.7 µg/L, with a median of 21.6 µg/L. Boron concentrations ranged from 7 to 14 µg/L, with a median of 8.89 µg/L. An MCL has not yet been established for boron. Iron concentrations ranged from 6.88 to 30.7 µg/L, with a median of 17.2 µg/L. Lead was detected in all four surface-water samples, ranging from 0.047 to 0.108 µg/L, with a median value of 0.074 µg/L, which is well below the EPA MCL of 15 µg/L. Lithium concentrations ranged from 0.438 to 1.49 µg/L, with a median of 0.895 µg/L. An MCL has not yet been established for lithium. Strontium concentrations ranged from 26.9 to 46.4 µg/L, with a median of 34.4 µg/L. An MCL has not yet been established for strontium. Uranium concentrations ranged from 0.004 to 0.042 µg/L, with a median of 0.021 µg/L. No samples exceeded the EPA MCL of 30 µg/L.

Groundwater

Groundwater samples were collected from six wells, all of which were completed in the unconfined sand and gravel aquifer in the Pony Hollow Creek valley (locations shown on fig. 8). All of these wells were drilled domestic wells that supplied private residences. Field measurements were made of pH, specific conductance, dissolved oxygen, and water temperature. Samples were analyzed for inorganic major ions, nutrients, dissolved gases, and trace metals by the USGS NWQL in Denver, Colorado. Results of these chemical analyses are tabulated in tables 3 and 4.

The wells that were sampled ranged from 26 to 59 ft deep. The pH of the samples ranged from 7.1 to 8.2, with a median value of 7.8 (table 3); no pH measurement was outside the EPA SMCL range of 6.5 to 8.5 (table 3). Specific conductance values of the samples ranged from 185 to 339 µS/cm at 25°C, with a median value of 275 µS/cm.

Inorganic Major Ions

Major ions in samples exceeded no Federal or State drinking-water health advisory standards (table 3). The cation that was detected in the greatest concentration was calcium, ranging from 28 to 46.4 mg/L, with a median value of 43.5 mg/L (table 3). Magnesium concentrations ranged from 5.94 to 10.7 mg/L, with a median value of 8.47 mg/L. Calcium and magnesium contribute to water hardness as $CaCO_3$, which ranged from 94.6 to 160 mg/L, with a median value of 144. mg/L. Three of the six sampled wells yielded water with a hardness of 150 mg/L or greater, which is classified as “hard”; the hardness of the three remaining samples ranged from 94.6 mg/L (moderately hard) to 137 mg/L (hard) (Hem, 1985).

Sodium concentrations ranged from 2.35 to 9.34 mg/L, with a median value of 4.71 mg/L (table 3) for the six wells sampled. The median concentration of 4.71 mg/L of sodium in these six residential domestic wells is lower than the median concentration of sodium of 12 mg/L detected in domestic wells completed in the glacial aquifers in the northern United States (Mullaney and others, 2009).

The anion detected in the greatest concentration was bicarbonate, ranging from 107 to 167 mg/L, with a median value of 151 mg/L (table 3). Bicarbonate values were calculated from alkalinity concentrations, which are given in milligrams per liter of $CaCO_3$ (calcium carbonate). Sulfate concentrations ranged from 8.41 to 18.8 mg/L, with a median value of 12 mg/L. Alkalinity, which results from dissolution of carbonate minerals such as those composing limestone and dolomite and is a measure of the capacity of water to neutralize acid, was measured by the USGS NWQL in Denver, Colorado using a fixed-endpoint titration method. Alkalinity concentrations ranged from 88 to 137 mg/L as $CaCO_3$, with a median of 124 mg/L. Alkalinity lower than 100 mg/L can be corrosive under low-pH conditions, and alkalinity greater than 150 mg/L can cause scale (lime) buildup in plumbing (Mechenich and Andrews, 2004). Chloride concentrations ranged from 2.69 to 21.5 mg/L, with median value of 6.56 mg/L (table 3), which is substantially lower than the median concentration of 12 mg/L that was detected in domestic wells that tap the glacial aquifers in the northern United States (Mullaney and others, 2009).

Calcium with some sodium and magnesium generally dominate the cation composition; bicarbonate and, in a few samples, chloride dominate the anion composition in samples from this study area and in most samples from stratified-drift aquifers in Tompkins County. The water chemistry in the stratified-drift aquifers throughout Tompkins County is similar because the geologic settings of all the areas are similar.

Nutrients

Groundwater samples from each of the six residential domestic wells were analyzed for several nitrogen and phosphorus species (table 3). Nitrate was present in all six wells, and had concentrations ranging from 0.355 to 1.17 mg/L, with a median value of 0.713 mg/L. These nitrate concentrations are well below the EPA MCL of 10 mg/L (U.S. Environmental Protection Agency, 2006), and are considered low for unconfined sand and gravel aquifers which are typically affected by nitrate sources such as septic systems and fertilizer use.

Table 2. Concentrations of trace metals in surface-water samples from the Pony Hollow Creek valley, Tompkins County, New York, December 13, 2011.

[Sampling site location is shown in figure 1. USGS, U.S. Geological Survey; NWIS, National Water Information System; µg/L, micrograms per liter; <, less than; XX, not available]

Trace metals		USGS station:	Carter Creek at State Route 13 near Cayuta	Pony Hollow Creek northeast of Cayuta	Chaffee Creek at State Route 13 near Cayuta	Pony Hollow Creek at Morrell Road at Cayuta	Drinking water standard	Median value
		Date sampled:	12/13/2011	12/13/2011	12/13/2011	12/13/2011		
		Station number:	01515583	01515586	01515592	01515615		
	NWIS parameter code	Units	Concentrations of chemical constituents					
Aluminum, filtered	01106	µg/L	7.00	6.35	7.60	9.48	50a	7.30
Antimony, filtered	01095	µg/L	0.029	< 0.027	< 0.027	< 0.027	6b,c	0.029
Arsenic, filtered	01000	µg/L	0.140	0.128	0.180	0.175	10b	0.158
Barium, filtered	01005	µg/L	15.8	15.4	34.7	27.4	2,000b,c	21.6
Beryllium, filtered	01010	µg/L	< 0.006	< 0.006	< 0.006	< 0.006	4b,c	< 0.006
Boron, filtered	01020	µg/L	7.00	7.48	14.0	10.3	XX	8.89
Cadmium, filtered	01025	µg/L	< 0.016	< 0.016	< 0.016	< 0.016	5b,c	< 0.016
Chromium, filtered	01030	µg/L	0.070	0.086	0.110	0.107	100b,c	0.097
Cobalt, filtered	01035	µg/L	0.040	0.040	0.071	0.080	XX	0.056
Copper, filtered	01040	µg/L	< 0.80	< 0.80	< 0.80	< 0.80	1,000a	< 0.80
Iron, filtered	01046	µg/L	10.6	6.88	23.8	30.7	300a,b	17.2
Lead, filtered	01049	µg/L	0.071	0.077	0.047	0.108	15d	0.074
Lithium, filtered	01130	µg/L	0.520	0.438	1.27	1.49	XX	0.895
Manganese, filtered	01056	µg/L	0.550	1.09	12.7	17.9	50a–300c	6.90
Molybdenum, filtered	01060	µg/L	0.026	0.023	0.033	0.034	XX	0.030
Nickel, filtered	01065	µg/L	0.200	0.195	0.280	0.31	XX	0.240
Selenium, filtered	01145	µg/L	< 0.030	< 0.030	< 0.030	< 0.030	50b,c	< 0.030
Silver, filtered	01075	µg/L	< 0.005	< 0.005	< 0.005	< 0.005	100b,c	< 0.005
Strontium, filtered	01080	µg/L	27.2	26.9	41.5	46.4	XX	34.4
Uranium, natural, unfiltered	22703	µg/L	0.004	0.005	0.037	0.042	30b	0.021
Zinc, filtered	01090	µg/L	< 1.40	< 1.40	26.5	2.20	5,000a,c	14.4

[a]U.S. Environmental Protection Agency (USEPA) secondary maximum contaminant level.

[b]USEPA maximum contaminant level.

[c]New York State Department of Health (NYSDOH) maximum contaminant level.

[d]USEPA drinking-water-regulation standard for lead revised in 2007. (*http://water.epa.gov/drink/contaminants/basicinformation/lead.cfm*)

[e]USEPA proposed maximum contaminant level.

Table 3. Physical properties and concentrations of inorganic constituents, nutrients, and dissolved gases in groundwater samples from unconsolidated aquifers in the Pony Hollow Creek valley, Tompkins County, New York, December 14–15, 2011.

[Sampling site location is shown in figure 1. USGS, U.S. Geological Survey; NWIS, National Water Information System; mg/L, milligrams per liter; µS/cm at 25 °C, microsiemens per centimeter at 25 degrees Celsius; <, less than; XX, not available]

Physical properties	NWIS parameter code	Units	TM1365	TM1366	TM2511	TM2812	TM1048	TM1049	Drinking water standard	Median value
		Date sampled:	12/14/2011	12/14/2011	12/15/2011	12/14/2011	12/15/2011	12/15/2011		
		Station number:	421833 076403901	421833 076403801	421732 076411701	421921 076393701	421902 076395101	421717 076412301		
			Values of physical properties							
Aquifer type			S&G, unconf	S&G, unconf	S&G, unconf	S&G, unconf	S&G, unconf	S&G, unconf		
Well depth, below land surface	72008	ft	38.0	47.0	59.0	30.0	40.0	26.0		39.0
Dissolved oxygen (field)	00300	mg/L	3.7	3.1	2.6	6.2	7.6	4.0	XX	3.85
pH (field)	00400	pH	7.8	8.2	7.8	7.1	7.6	7.8	6.5–8.5[c]	7.80
Specific conductance (field)	00095	µS/cm at 25 °C	308	208	339	185	253	298	XX	275
Water temperature	00010	Celsius	10.7	9.5	9.2	10.8	9.8	10.9	XX	10.3
Concentrations of chemical constituents										
Common ions										
Hardness, filtered, as $CaCO_3$	00900	mg/L	154	105	160	94.6	137.0	150	XX	144
Calcium, filtered	00915	mg/L	45.4	31.0	46.4	28.0	41.6	45.4	XX	43.5
Magnesium, filtered	00925	mg/L	9.8	6.8	10.7	5.9	8.1	8.9	XX	8.47
Potassium, filtered	00935	mg/L	0.9	0.7	0.9	1.0	0.6	0.9	XX	0.88
Sodium, filtered	00930	mg/L	8.2	3.1	9.3	3.3	2.4	6.1	60[a]	4.71
Alkalinity, filtered, as $CaCO_3$	29801	mg/L	132	97.0	127	88.0	120	137	250[c]	124
Bicarbonate, filtered,	29805	mg/L	161	118	155	107	146	167	XX	151
Bromide, filtered	71870	mg/L	0.0	< 0.1	0.0	0.0	0.0	0.0	XX	0.0
Chloride, filtered	00940	mg/L	14.3	3.1	21.5	2.7	3.7	9.4	XX	6.56
Fluoride, filtered	00950	mg/L	0.1	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	2.2[b]	0.05
Silica, filtered	00955	mg/L	8.1	6.9	7.5	7.4	7.2	7.8	XX	7.48
Sulfate, filtered	00945	mg/L	12.6	12.1	18.8	8.4	10.2	11.8	250[c]	12.0
Dissolved solids, at 180 °C	70300	mg/L	182	128	188	100	141	170	XX	156

Table 3. Physical properties and concentrations of inorganic constituents, nutrients, and dissolved gases in groundwater samples from unconsolidated aquifers in the Pony Hollow Creek valley, Tompkins County, New York, December 14–15, 2011.—Continued

[Sampling site location is shown in figure 1. USGS, U.S. Geological Survey; NWIS, National Water Information System; mg/L, milligrams per liter; μS/cm at 25 °C, microsiemens per centimeter at 25 degrees Celsius; <, less than; XX, not available]

Physical properties		USGS station:	TM1365	TM1366	TM2511	TM2812	TM1048	TM1049	Drinking water standard	Median value
		Date sampled:	12/14/2011	12/14/2011	12/15/2011	12/14/2011	12/15/2011	12/15/2011		
		Station number:	421833 076403901	421833 076403801	421732 076411701	421921 076393701	421902 076395101	421717 076412301		
	NWIS parameter code	Units	Values of physical properties							
Nutrients										
Ammonia, filtered	71846	mg/L	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	XX	< 0.013
Ammonia, as N, filtered	00608	mg/L	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	XX	< 0.010
Nitrate, as N, NO_2+NO_3, filtered	00631	mg/L	1.01	0.390	0.753	0.400	1.17	0.713	10a,b	0.71
Nitrite, as N, filtered	00613	mg/L	0.001	0.001	.005	0.0	0.0	0.0	1a,b	0.002
Orthophosphate, as P, filtered	00671	mg/L	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	XX	
Dissolved gases										
Methane, unfiltered	85574	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	XX	<0.001
Dissolved nitrogen gas, unfiltered	00597	mg/L	26.1	23.4	24.4	27.2	28.8	21.9	XX	25.3
Argon, unfiltered	82043	mg/L	0.865	0.811	0.815	0.862	0.928	0.772	XX	0.84
Carbon dioxide, unfiltered	00405	mg/L	4.10	1.50	3.90	12.2	5.9	4.20	XX	4.15
Dissolved oxygen gas, unfiltered	62971	mg/L	2.40	0.400	0.700	6.40	6.3	0.6	XX	1.55

[a]U.S. Environmental Protection Agency (USEPA) drinking water advisory taste threshold.

[b]New York State Department of Health maximum contaminant level.

[c]USEPA secondary maximum contaminant level.

Nitrite was detected in all six wells, but at very small concentrations, ranging from 0.001 to 0.005 mg/L, with a median value of 0.002 mg/L. All results of nitrite analyses were below the EPA MCL of 1 mg/L (U.S. Environmental Protection Agency, 2006). Ammonia (filtered, as nitrogen) concentrations from all six wells were less than 0.013 mg/L. Orthophosphate was not detected above the reporting limit of 0.004 mg/L in any of the six groundwater samples (table 3).

Trace Elements

Trace elements detected in every sample included aluminum, antimony, arsenic, barium, boron, chromium, cobalt, copper, iron, lithium, manganese, molybdenum, nickel, selenium, strontium, uranium, and zinc (table 4). The trace elements detected in the greatest concentrations were barium, boron, iron, lithium, manganese, and strontium. No

Table 4. Concentrations of trace metals in groundwater samples from the the Pony Hollow Creek valley, Tompkins County, New York, December 14–15, 2011.

[Sampling site locations are shown in figure 1. USGS, U.S. Geological Survey; NWIS, National Water Information System; µg/L, micrograms per liter; <, less than; XX, not available]

Trace metals	NWIS parameter code	Units	TM1365 (12/14/2011; 421833 076403901)	TM1366 (12/14/2011; 421833 076403801)	TM2511 (12/15/2011; 421732 076411701)	TM2812 (12/14/2011; 421921 076393701)	TM1048 (12/15/2011; 421902 076395101)	TM1049 (12/15/2011; 421717 076412301)	Drinking water standard	Median value
			Concentrations of chemical constituents							
Aluminum, filtered	01106	µg/L	< 2.20	< 2.20	< 2.20	3.50	< 2.20	< 2.20	50[a]	3.50
Antimony, filtered	01095	µg/L	< 0.027	< 0.027	0.05	< 0.027	< 0.027	< 0.027	6[b,c]	0.05
Arsenic, filtered	01000	µg/L	0.20	0.17	0.36	0.05	0.10	0.17	10[b]	0.17
Barium, filtered	01005	µg/L	41.2	37.4	77.4	24.6	23.4	46.6	2,000[b,c]	39.3
Beryllium, filtered	01010	µg/L	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	4[b,c]	< 0.006
Boron, filtered	01020	µg/L	14.0	11.0	12.0	12.0	10.0	13.0	XX	12.0
Cadmium, filtered	01025	µg/L	< 0.016	< 0.016	< 0.016	< 0.016	< 0.016	< 0.016	5[b,c]	< 0.016
Chromium, filtered	01030	µg/L	0.28	0.24	0.14	0.12	0.27	0.21	100[b,c]	0.23
Cobalt, filtered	01035	µg/L	0.04	0.03	0.06	0.25	0.04	0.10	XX	0.05
Copper, filtered	01040	µg/L	4.80	13.90	1.20	< 0.80	6.40	< 0.80	1,000[a]	5.60
Iron, filtered	01046	µg/L	< 3.2	< 3.2	< 3.2	19.90	< 3.2	< 3.2	300[a,b]	19.9
Lead, filtered	01049	µg/L	0.17	0.15	0.09	< 0.025	2.39	0.03	15[d]	0.15
Lithium, filtered	01130	µg/L	7.09	3.38	7.35	2.29	3.15	4.21	XX	3.80
Manganese, filtered	01056	µg/L	1.03	0.91	4.51	3.04	0.92	3.10	50[a]–300[c]	2.04
Molybdenum, filtered	01060	µg/L	0.13	0.04	0.17	0.02	0.02	0.05	XX	0.04
Nickel, filtered	01065	µg/L	0.33	0.22	0.39	0.24	0.38	0.36	XX	0.35
Selenium, filtered	01145	µg/L	0.06	0.07	0.10	< 0.03	0.06	0.06	50[b,c]	0.06
Silver, filtered	01075	µg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	100[b,c]	< 0.005
Strontium, filtered	01080	µg/L	89.3	64.3	88.0	57.7	49.6	80.3	XX	72.3
Uranium, natural, unfiltered	22703	µg/L	0.16	0.09	0.26	0.04	0.07	0.11	30[b]	0.10
Zinc, filtered	01090	µg/L	1.90	1.90	6.30	< 1.40	9.00	< 1.40	5,000[a,c]	4.10

[a]U.S. Environmental Protection Agency (USEPA) secondary maximum contaminant level.

[b]USEPA maximum contaminant level.

[c]New York State Department of Health (NYSDOH) maximum contaminant level.

[d]USEPA drinking-water-regulation standard for lead revised in 2007. (http://water.epa.gov/drink/contaminants/basicinformation/lead.cfm)

[e]USEPA proposed maximum contaminant level.

samples exceeded Federal or State MCLs. All aluminum concentrations, except one (3.5 µg/L), were less than 2.2 µg/L. Arsenic concentrations ranged from 0.05 to 0.36 µg/L, with a median value of 0.17 µg/L (table 4). All of the arsenic values are less than the EPA MCL for arsenic of 10 µg/L. Barium concentrations ranged from 23.4 to 77.4 µg/L, with a median of 39.3 µg/L. Boron concentrations ranged from 10 to 14 µg/L, with a median of 12 µg/L; an MCL has not been established for boron. Iron concentrations in five of the wells were all less than the detection limit of 3.2 µg/L; only data from one well (TM 2812) showed a measurable value of 19.9 µg/L. Lead was detected in five out of six samples, ranging from <0.025-2.39 µg/L, but none exceeded the EPA MCL (15 µg/L). Lithium concentrations ranged from 2.29–7.35 µg/L, with a median of 3.80 µg/L; an MCL has not been established for lithium. Strontium concentrations ranged from 49.6-89.3 µg/L, with a median of 72.3 µg/L; an MCL has not been established for strontium. Uranium concentrations ranged from 0.042–0.264 µg/L, with a median of 0.102 µg/L; no samples exceeded the EPA MCL of 30 µg/L.

Dissolved Gases

A suite of dissolved gases, including methane, nitrogen, argon, carbon dioxide, and dissolved oxygen (O^2)were collected to determine the concentrations of these gases in groundwater. Methane concentrations were below the detection limit (table 3) and nitrogen was between 21 and 26 mg/L. Dissolved oxygen concentrations were between 0.4 and 6.4 mg/L. Dissolved oxygen concentrations, in concert with NO_3^-, MN^{2+}, Fe^{2+}, and SO_4^{2-} concentrations, can suggest either reducing or oxidation conditions in groundwater—a concentration below 0.5 mg/L suggests reducing conditions normally found in confined aquifer systems (McMahon and others, 2009). All but one well had dissolved oxygen concentrations above 0.5 mg/L suggesting an unconfined aquifer. However, one well, TM1366, was less than 0.4 mg/L for dissolved oxygen concentration, but nevertheless, the sample was from the unconfined aquifer in the Pony Hollow Creek valley, as determined from well records and the immediate stratigraphy and water levels.

Summary

The Pony Hollow Creek valley aquifer was previously mapped in 2009 in cooperation with the New York State Department of Environmental Conservation. This project incorporates additional hydrogeologic information and water-quality data, collected from 2009 to 2011, that builds on the previously published report. Geologic materials in the study area include sedimentary bedrock, unstratified drift (till), stratified drift (glaciolacustrine and glaciofluvial deposits), and post-glacial alluvium. Stratified drift, consisting of sand and gravel, is the major component of the valley fill and forms an extensive unconfined aquifer in the study area. The unconfined aquifer is the source of water for most residents, farms, and businesses in the Pony Hollow Creek valley.

The water-table contours indicate that the general direction of groundwater flow within the Pony Hollow Creek valley stratified-drift aquifer is predominantly from the valley walls toward the main stream, where groundwater discharges from the aquifer system to the stream. Locally, where upland tributary streams lose water over the alluvial fans in the valley, a groundwater mound forms beneath the stream, and the direction of groundwater flow is radially away from the tributary channel.

On December 13, 2001, four surface-water samples were collected during average base flow conditions, including (1) Carter Creek at State Route 13 near Cayuta, (2) Pony Hollow Creek at State Route 13 northeast of Cayuta, (3) Chaffee Creek at State Route 13 near Cayuta, and (4) Pony Hollow Creek at Merrell Road at Cayuta. During December 14 and 15, 2011, groundwater samples were collected from six residential domestic wells. Calcium dominates the cation composition and bicarbonate dominates the anion composition in the groundwater and surface-water samples, and none of the common inorganic constituents collected exceeded any Federal or State water-quality standards.

In surface-water samples, calcium and manganese concentrations ranged from 6.76 to 18.8 and 2.26 to 4.49 milligrams per liter (mg/L), respectively; concentrations of bicarbonate and chloride ranged from 23.4 to 66.2 and 1.49 to 7.47 mg/L, respectively. Nitrate in surface-water samples ranged from less than the detection limit of 0.04 to 0.656 mg/L as nitrogen, and only one orthophosphate concentration (0.014 mg/L) was detected above the reporting limit (0.005 mg/L as phosphorus). The trace elements detected in surface-water samples in the greatest concentrations were aluminum, barium, boron, iron, lithium, manganese, and strontium.

Concentrations of calcium and magnesium in groundwater samples ranged from 28 to 46.4 and 5.94 to 10.7 mg/L, respectively; concentrations of bicarbonate and sulfate ranged from 107 to 167 and 8.41 to 18.8 mg/L, respectively. Nitrate was present in all six sampled wells, and had concentrations ranging from 0.355 to 1.17 mg/L. Orthophosphate was not detected above the reporting limit of 0.004 mg/L in any of the six groundwater samples. Trace elements detected in every sample included aluminum, antimony, arsenic, barium, boron, chromium, cobalt, copper, iron, lithium, manganese, molybdenum, nickel, selenium, strontium, uranium, and zinc. None of the analytes exceeded any State of Federal drinking-water standards

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Appendix 1. Records of selected wells in Pony Hollow Creek valley, Tompkins County, New York.

[S&G, sand and gravel; WQ, water quality--, no data; ft, feet; in, inches; gal/min, gallons per minute; LSD, land-surface datum:,WL, water level. Sources of data are New York State Department-meetnof Environmental Conservation Water Well Drillers Registration Program and USGS data files. Land surface datum (LSD) equivalent to altitude of land surface, which is established using lidar data.]

Site number	Site name	Date drilled	Well depth (ft)	Depth of casing (ft)	Casing diameter (in)	Altitude land surface (ft)	Aquifer type	Water level below land surface (ft)	Altitude water level (ft)	Date water level measured	Depth to bedrock (ft)	Altitude top of bedrock (ft)	Reported yield (gal/min)	Remarks
421739076414001	TM 3	1/1/1964	60	0	0	1,131	S&G	--	--	--	--	--	--	assumed to be unconsolidated
421739076414001	TM 4	6/1/1980	26	26	6	1,136	Gravel	18.5	1,118	8/9/1980	--	--	--	--
421808076405101	TM 6	5/1/1959	14	14	2	1,159	S&G	10	1,149	6/21/1967	--	--	6	Well located in cellar below LSD 8”.
421834076402101	TM 15	5/31/1960	41	41	6	1,168	S&G	4	1,164	6/1/1967	--	--	50	--
421841076401601	TM 16	6/1/1967	38	40	6	1,173	Gravel	5	1,168	4/21/1981	--	--	30	--
421849076460601	TM 17	--	120	100	6	1,188	Shale	15	1,173	4/21/1981	100	1,088	30	Drilled late 1800’s; yield rough guess.
421854076395901	TM 18	6/1/1962	58	58	6	1,200	S&G	30	1,170	6/1/1967	--	--	18	3.5 gal/min at 56.5 ft, 18 gal/min at 58 ft. Gravel.
421925076392901	TM 22	4/24/1968	22	24	6	1,221	S&G	9	1,212	4/24/1968	--	--	15	Gravel except 19–20’ medium to coarse sand.
421927076392601	TM 23	6/1/1938	59	60	6	1,222	S&G	24.6	1,200	8/15/1967	--	--	--	Original well 33 ft went dry in 1938 redrilled; highly variable WL depth.
421932076385601	TM 24	5/5/1981	41	43	1	1,224	Gravel	29.5	1,195	5/5/1981	--	--	--	0-20 gravel, 20–22 silty gravel, 22–35 gravel, 35–42 ft silty gravel.
421944076394501	TM 26	6/1/1979	160	80	6	1,242	Shale	60	1,182	6/1/1979	80	1,168	5	Till (“clay with stones”) 0–80′ interval.

Appendix 1. Records of selected wells in Pony Hollow Creek valley, Tompkins County, New York.—Continued

[S&G, sand and gravel; WQ, water quality--, no data; ft, feet; in, inches; gal/min, gallons per minute; LSD, land-surface datum:,WL, water level. Sources of data are New York State Depart-meetnof Environmental Conservation Water Well Drillers Registration Program and USGS data files. Land surface datum (LSD) equivalent to altitude of land surface, which is established using lidar data.]

Site number	Site name	Date drilled	Well depth (ft)	Depth of casing (ft)	Casing diameter (in)	Altitude land surface (ft)	Aquifer type	Water level below land surface (ft)	Altitude water level (ft)	Date water level measured	Depth to bedrock (ft)	Altitude top of bedrock (ft)	Reported yield (gal/min)	Remarks
421944076394502	TM 27	6/1/1979	70	70	6	1,242	S&G	40	1,202	12/30/1899	--	--	30	Wells go dry in August. Discontinuous gravel seams.
421949076381601	TM 28	6/1/1965	85	85	6	1,245	Gravel	40	1,205	5/5/1981	--	--	--	0–85 ft gravel, high yield.
421902076395101	TM1048	6/30/1950	40	35	6	1,199	S&G	5.3	1,194	12/15/2011	--	--		WQ sample taken. Well 4.9 ft below below land surface in concrete pit.
421717076412301	TM1049	--	26	26	6	1,119	S&G	6.8	1,112	12/15/2011	--	--		WQ sample taken. Well 4.9 ft below below land surface in concrete pit.
421833076403801	TM1366	9/10/2001	47	47	6	1,150	S&G	15	1,135	9/10/2001	--	--	15	0–47 ft S&G.
421732076411701	TM2511	5/13/2008	59	59	6	1,125	Sand	9	1,116	5/13/2008	--	--	12	0-25 gravel. 25–41 till, 41–58 sand, 58–59 ft coarse sand.
421921076393701	TM2812	10/12/2010	30	30	6	1,214	S&G	10	1,204	10/12/2010	--	--	3	S&G.

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