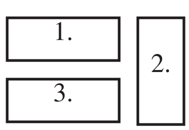
Recharge to Shale Bedrock at Averill Park, an Upland Hamlet in Eastern New York—An Estimate Based on Pumpage within a Defined Cone of Depression

Scientific Investigations Report 2008–5087

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

Cover.



1. Shale bedrock, exposed in excavation near Well 270. Shovel handle is 1.6 feet long.

2. Shale bedrock, exposed in drainage ditch along New York Route 43 near Well 137. Salt-laden winter highway runoff can readily infiltrate into bedrock here.

3. Dug well, excavated in shale bedrock in basement of house near Well 177. Arch is part of laid-stone basement wall. Water was seeping from fractures above the water surface in the well July 16, 2008.

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By Allan D. Randall and Anne J. Finch

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U.S. Geological Survey, Reston, Virginia: 2008

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Suggested citation:
Randall, A.D., and Finch, A.J., 2008, Recharge to shale bedrock at Averill Park, an upland hamlet in eastern New York—An estimate based on pumpage within a defined cone of depression: U.S. Geological Survey Scientific Investigations Report 2008–5087, 78 p., 3 pls., scale 1:24,000, online only.

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(In pocket)

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Conversion Factors, Datum and Acronyms

Multiply	By	To obtain
	Length	
inch	2.54	centimeter
inch	25.4	millimeter
foot	0.3048	meter
mile	1.609	kilometer
	Area	
acre	4,047	square meter
acre	0.4047	hectare
acre	0.4047	square hectometer
acre	0.004047	square kilometer
square foot	929.0	square centimeter
square foot	0.09290	square meter
square mile	259.0	hectare
square mile	2.590	square kilometer
	Volume	
gallon	3.785	liter
gallon	0.003785	cubic meter
	Flow rate	
foot per second	0.3048	meter per second
cubic foot per second	0.02832	cubic meter per second
gallon per minute	0.06309	liter per second
gallon per day	0.003785	cubic meter per day
gallon per day per acre	935	liter per day per square kilometer
gallon per day per square mile	1.46	liter per day per square kilometer

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

°F=(1.8 X °C) +32

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD29).

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 in milligrams per liter (mg/L).

List of Abbreviations and Acronyms

$CaCO_3$	Calcium carbonate
H_2S	Hydrogen sulfide
N	Nitrogen
USGS	U.S. Geological Survey

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Abstract

Water levels beneath parts of Averill Park, a residential hamlet in an upland area of till-mantled shale bedrock in east-central New York, have declined in response to increased withdrawals from new wells. Similar experiences in many upland localities in the northeastern United States have resulted in awareness that the rate of recharge to bedrock can be an important constraint on the density of new development in uplands. Recharge at Averill Park was calculated on the basis of careful estimation of pumpage within a defined cone of depression. The data-collection and recharge-estimation procedures documented herein could be applied in a variety of upland localities in support of community-planning studies.

Static water levels measured in 145 wells at Averill Park during the late summer of 2002 defined a 0.54-square-mile cone of depression within which ground-water discharge took place entirely as withdrawals from wells. Rates of withdrawal were estimated largely from surveys in similar neighborhoods a few miles away served by public water supply. Comparison of the water-level measurements in 2002 with measurements on other dates revealed localized declines that could be attributed to new housing developments or commercial demands, but also demonstrated that water levels in 2002 within the cone of depression had stabilized and were not declining persistently over time. Therefore, the current withdrawals were equated to recharge from infiltrating precipitation. Recharge within this area was estimated to average 104 gallons per day per acre, equivalent to 1.4 inches annually, and was sufficient to sustain a residential population of 1.9 persons per acre. This recharge rate is much lower than rates estimated from streamflow records for upland watersheds elsewhere in the northeastern United States. This rate is an average of an unknown larger rate in the 30 percent of the study area where bedrock is discontinuously overlain by less than 30 feet of till and an unknown smaller rate in the remainder of the area where bedrock is overlain by thick till in the form of drumlins. The spatial variation in rate of recharge is inferred from the fact that high heads and strong downward gradients in bedrock, and very hard water with high chloride concentrations caused by winter highway runoff, are largely restricted to the area of discontinuous, thin till.

Wells less than 180 feet deep and distant from highways typically yield water of moderate hardness (50–170 milligrams per liter as calcium carbonate) that is caused by dissolution of limestone fragments in the till. Some wells that are more than 180 feet deep yield very soft water (0–50 milligrams per liter) with high pH and high sodium concentrations resulting from ion exchange within the bedrock. Nearly all wells in some areas of thick till yield very soft water.

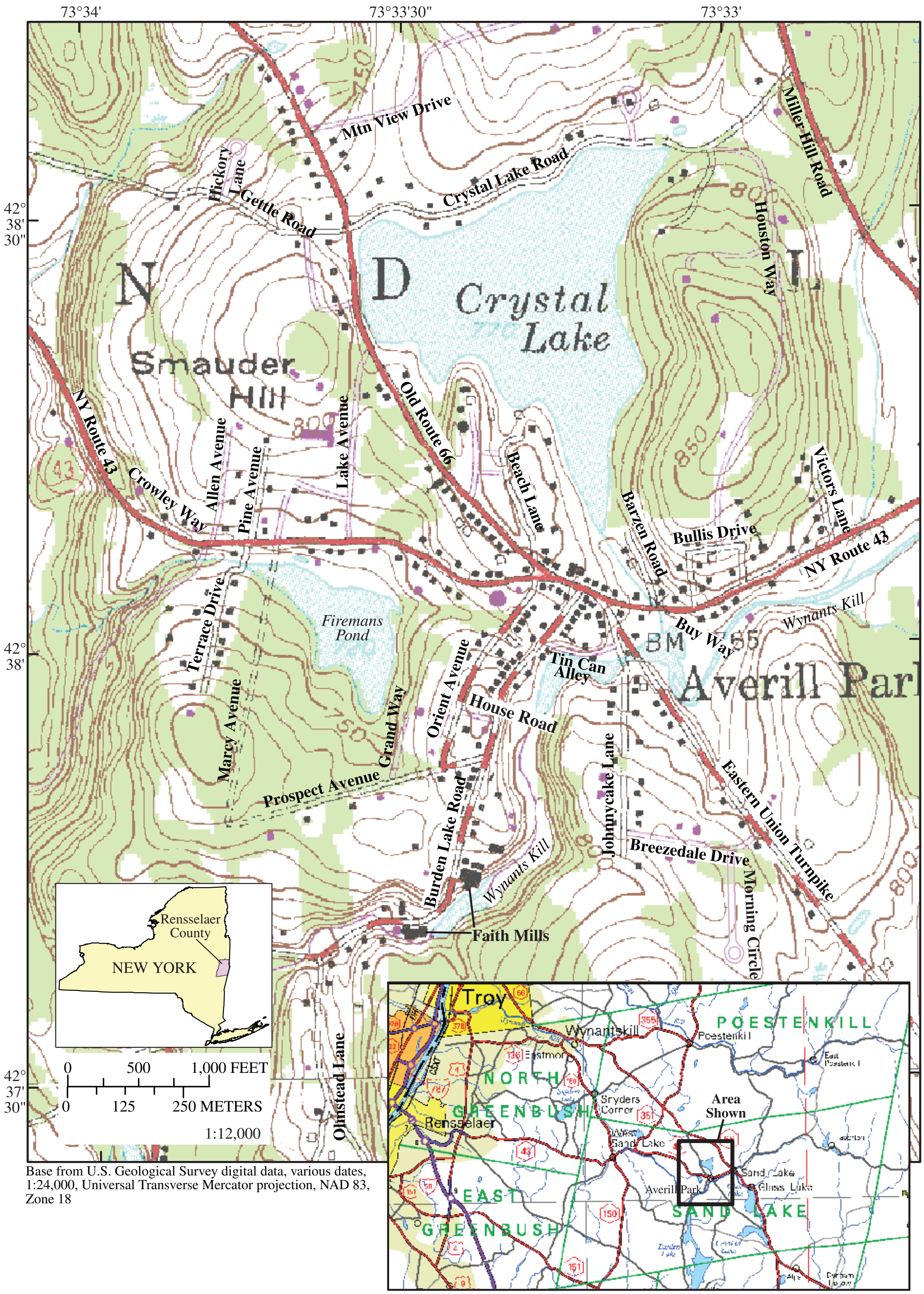
Most wells near the center of Averill Park yield less than 3 gallons per minute. The likelihood of obtaining an additional 2 gallons per minute or more by drilling deeper than 200 feet is calculated to be about 25 percent. Most wells west and southwest of the center yield at least 3 gallons per minute, and the liklihood of obtaining an additional 2 gallons per minute or more by drilling deeper than 200 feet is about 50 percent.

Introduction

Averill Park is one of several hamlets within the town of Sand Lake in south-central Rensselaer County, N.Y. (fig. 1). Averill Park is primarily residential but has a small commercial district near its center along New York Route 43. The Wynants Kill[1], one of the principal streams in Rensselaer County, drains 9.5 square miles where it flows through the hamlet.

During the 1970s and 1980s, many well owners at Averill Park occasionally experienced a loss of water pressure that required pump shutdowns lasting from a few minutes to several hours until the water level in the wells recovered. Some chose to deepen their wells or to drill new, deeper wells. These experiences, along with the export of wastewater from the hamlet through sewers after 1983, which was expected to reduce recharge, led to widespread public concern about the ability of the bedrock aquifer to meet the current demand for water or to supply new development. In 1987, the town government authorized an investigation of ground-water availability at Averill Park. That investigation entailed an inventory of the dimensions and history of wells

[1] "Kill", a Dutch word that means "creek," was applied to many streams in this region by 17th-century immigrants.



Base from U.S. Geological Survey digital data, various dates, 1:24,000, Universal Transverse Mercator projection, NAD 83, Zone 18

Figure 1. Topography and street names at Averill Park, Rensselaer County, New York.

at most homes, and resulted in a report (LaFleur, 1989) that included a map of water-level altitudes in 1988 and several graphs that linked water levels measured in 1988 with water levels in prior years as recalled or recorded by well owners or drillers. The graphs suggested steep declines in several places (LaFleur, 1989, pl. 7–14). The dates of the pre-1988 water levels differed from well to well, however, and the reliability of this information was uncertain; therefore, LaFleur (1989) recommended that additional water-level measurements be made in subsequent years to better define trends in water levels. The 1988 water-level map (LaFleur, 1989) depicted three coalesced cones of depression (localities in which water levels were depressed by pumping). If water levels in these localities were stable, the average rate of recharge to bedrock could be inferred to approximately equal the average rate of withdrawal from wells.

The rate of recharge to bedrock in the uplands can be a major constraint on density of development supplied by on-site wells, but few studies to date have documented recharge to bedrock in upland localities. To expand our knowledge of rates of recharge to upland bedrock, the U.S. Geological Survey (USGS) began an investigation in 1999 to delineate the coalesced cones of depression at Averill Park in detail and to ascertain whether water levels therein were persistently declining, or had stablilized in dynamic equilibrium with current withdrawals. If stability were evident, and if the rate of withdrawal could be accurately estimated by evaluating current demand, then the rate of recharge to bedrock in this locality could be computed. Similar studies of clusters of wells in a variety of other upland localities could eventually allow identification and quantification of the environmental factors that control rates of recharge to bedrock and development of regionalized estimates of those rates for planning purposes.

The purpose of this report is to summarize the methods and results of the investigation of recharge to bedrock at Averill Park. The report (1) describes the methods of data collection, (2) discusses recent water-level trends in relation to their probable causes, (3) describes the spatial variation in ground-water quality and its significance with respect to recharge, (4) documents other features of the hydrogeologic setting that affect pumpage and recharge, and (5) presents a computation of the rate of recharge to bedrock and discusses factors that constrain the significance of that rate. Well records and other pertinent data are included in appendices.

Geohydrologic Setting

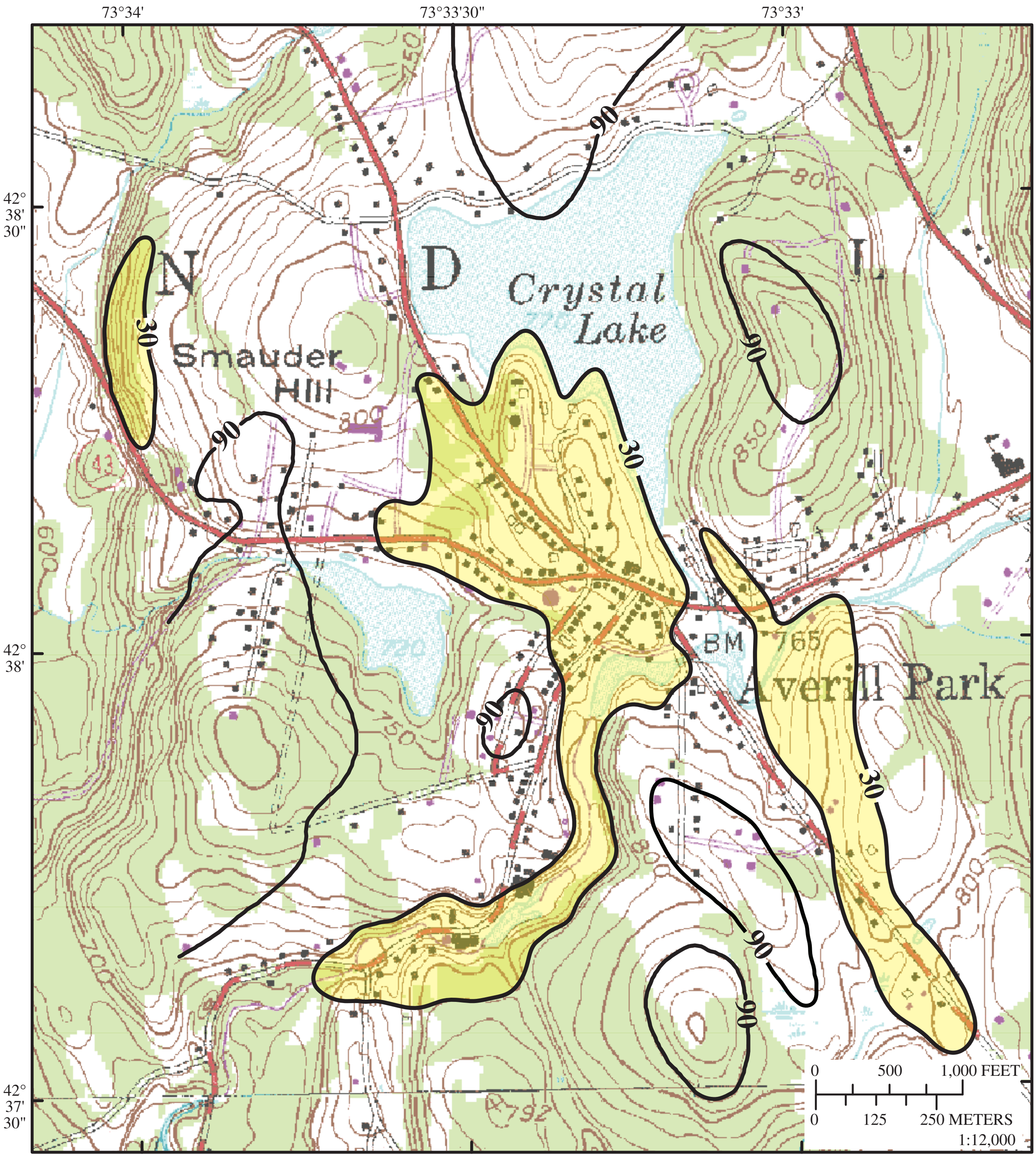
The study area at Averill Park (fig. 1) encompasses 1.5 square miles. The Wynants Kill, which flows through the hamlet, powered several cotton, wool, paper, and grist mills less than a mile downstream from the center of the hamlet during most of the 19th century (Lilly, 1999, 2005). Two small dams remain; the more recent was built in 1923 and was used until 1956 to generate electrical power for Faith Mills, the last mill on the Wynants Kill to close. The gateworks for these dams no longer function; the upper dam now impounds water only seasonally, and the lower, smaller dam spills continuously. Crystal Lake (fig. 1), a recreational highlight of the hamlet, was once a source of water storage for mills as far downstream as Troy (fig. 1, inset map). Nearly all buildings within the hamlet obtain water from private wells that penetrate bedrock. Sanitary sewers were installed in 1983 to eliminate the many persistent overflows from private septic systems on small lots with clayey soils.

Bedrock

The bedrock beneath Averill Park is the Nassau Formation (Fisher and others, 1970) of Cambrian age, which is more than 500 million years old and one of the oldest bedrock units in New York. The Nassau Formation consists largely of red and green shale, interbedded with thin layers of quartzite or hard sandstone that are mostly less than 2 inches thick (Ruedemann, 1930; LaFleur, 1989). Two massive, 40-to-50-foot-thick beds of hard sandstone lie within the Nassau Formation (Ruedemann, 1930, p. 83). The hard sandstone is similar to the Rensselaer Graywacke (or grit) that forms Taborton Mountain, a few miles east of Averill Park. Shale layers trend slightly east of north where exposed along the Wynants Kill near Burden Lake Road and along the southwest shore of Crystal Lake (pl. 1), and generally dip eastward at more than 70 degrees, although dips vary within some exposures. Geologic sections (Ruedemann, 1930) depict the Nassau Formation as tightly folded, with fold axes dipping steeply eastward. A fault, also dipping steeply eastward, has been mapped 4 miles south of Averill Park in the town of Nassau and was inferred by Isachsen and McKendree (1977) to extend northward near Eastern Union Turnpike and along the east shore of Crystal Lake.

Unconsolidated Deposits

The bedrock throughout most of the study area is overlain by lodgment till, a poorly permeable mixture of clay, silt, sand, and stones deposited by glacial ice and commonly referred to as “hardpan.” The till cover in a 0.15-square-mile area near the center of Averill Park, and in smaller areas along Eastern Union Turnpike and on the west slope of Smauder Hill (fig. 2), is less than 30 feet thick and is interrupted in many places by unobtrusive shale-bedrock outcrops. Greater thicknesses of till accumulated elsewhere around Averill Park as smooth, oval hills called drumlins, which were shaped by the glacier. Till beneath the crests of most of these drumlins is at least 90 feet thick. Locations of bedrock outcrops are indicated on plate 1; till thickness at any location can be estimated from plate 1 by subtracting the bedrock-surface contours from the land-surface contours.



Base from U.S. Geological Survey digital data, 1:24,000,
Universal Transverse Mercator projection, NAD 83, Zone 18

EXPLANATION

30 — Area within which till thickness is 0 to 30 feet. Bedrock crops out discontinuously within these areas

90 — Line along which till thickness is 90 feet

Figure 2. Thickness of till overlying bedrock at Averill Park, Rensselaer County, N.Y. (General location is shown in inset map in fig. 1.)

Sand and gravel was deposited by meltwater from the retreating glacier in the lowland that surrounds Sand Lake School, immediately east of the study area (pl. 1); in some places the sand and gravel is overlain by silt and clay. Sand and gravel of glacial origin may also underlie the alluvial sediment deposited by the modern Wynants Kill in a wide reach of the flood plain immediately upstream from Eastern Union Turnpike (LaFleur, 1965; LaFleur and others, 1995). A few feet of alluvial gravel, sand, and silt directly overlie bedrock downstream from Eastern Union Turnpike in a gorge where the Wynants Kill has incised through till into bedrock since the last glaciation (fig. 2).

The sand and gravel that underlies parts of the lowland around Sand Lake School is capable of yielding a few hundred gallons per minute to properly constructed wells and is a potential source of municipal or large commercial water supplies (LaFleur and others, 1995). The till that overlies bedrock elsewhere around Averill Park can yield small amounts of water to large-diameter dug wells. Dug wells 15 to 20 feet deep supplied water to nearly every house at Averill Park before 1940. A few dug wells were still in use in 2002, but nearly all residential and commercial buildings at Averill Park now obtain all or most of their water from drilled wells that penetrate the shale bedrock of the Nassau Formation.

Data Collection

The major components of data collection in this study were (1) a well inventory; (2) precise measurements of water levels in 2002 and 2005, supplemented by compilation of similar measurements in 1987–91 and 1997–2003; and (3) field measurements of specific conductance and hardness of ground water, and compilation of other available chemical data. The following sections describe the procedures used to collect and process these data. Minor components of data collection, including streamflow measurements at Averill Park and per-capita water consumption in nearby towns, are briefly described in conjunction with the results. The scope and procedures of data collection described herein were selected to accommodate local conditions; the same procedures could be replicated in studies of recharge to clusters of bedrock wells elsewhere if deemed appropriate for the specific setting.

Well Inventory

Copies of the well records compiled during the 1988 study (LaFleur, 1989) were made available. Some of these records incorporated reports on newly completed wells submitted by well drillers to the Rensselaer County Health Department. All of this information was updated during 1999–2001 by an interview with the owner and (or) occupants of each building regarding their experience with water availability and quality since 1988, number of residents, water-use practices, dimensions of any new or deepened wells, and why any new drilling was undertaken. Specific conductance and hardness of the water from each well were measured. Records of wells at 318 properties at or near Averill Park were compiled and are tabulated in appendix A; well locations are shown on plate 2 and are labeled with identification (ID) numbers that appear in the first column of appendix A. Well numbers 1 through 320 were assigned during the investigation by LaFleur (1989); numbers 2060 through 2117 were assigned during the present investigation.

The well records in appendix A and the recorded depths to static water level in appendix B were entered into the National Water Information System (a U.S. Geological Survey electronic database). Records of many other wells in the town of Sand Lake that were compiled by LaFleur and others (1995) are unpublished but available on a compact disk that accompanies copies of that report in two libraries, as explained in the “References cited” section herein.

Water-Level Measurements

A principal objective of this study was to measure the depth to water in many wells in the summer of 2002, and to adjust the measurements to a common date and datum for use in preparation of a map of water-level altitudes, from which directions of ground-water flow could be inferred and a cone of depression delineated to facilitate computation of recharge. A second objective was to remeasure the depth to water in 2002 in several wells that had been measured in 1988 in connection with an earlier study (LaFleur, 1989) to ascertain whether the cone of depression was stable or persistently becoming deeper over the years. Supplementary measurements in many wells were made in 2005 to document the water-level response to much wetter conditions than those experienced in 1988 and 2002.

Measurements in 1988

Depth to water was measured in 56 wells as part of the study described by LaFleur (1989), mostly between late June and early August 1988. Water levels were measured on other dates from 1987 through 1991 in some wells and more than once in some wells. Generally, each measurement was repeated several times over a 10- to 20-minute period. Measurements deemed to be static (fully recovered) were so noted, but many measurements were made when water levels were rising rapidly, an indication of recent pumping. The intent of the present study was to compare water-level measurements made in the summer of 1988 with those made in 2002, but nonstatic measurements in the summer of 1988 were ignored if a reliable static water level from another date was available. The most reliable static water-level measurements from 1987 through 1991 are compiled in appendix B; a few water levels recorded by drillers or well owners are included in appendix A.

Measurements in 2002

Depth to water was measured in 127 wells at or near Averill Park by the USGS between July 20 and September 10, 2002, and in 5 additional wells between September 17 and October 3, 2002. Measurements made in 13 other wells between July 19 and July 27, 2002, were made and furnished by Smith and Mahoney Engineers (written commun., 2002). Accordingly, the complete set of measurements in 2002 represented 145 wells. Most of these wells were domestic wells that were in regular use; therefore, arrangements were made with the residents to measure on dates when no one would be at home, at least during the day, and (or) when the residents could arrange to turn off power to the pump early in the day, at least 3 hours before the scheduled time of water-level measurement. Depth to water in each well was measured at 5- or 10-minute intervals for at least 20 minutes to verify whether or not the water level was static. Measurements in several wells of relatively low yield, and in a few wells in which water levels were rising rapidly, were continued for 1 to 6 hours to define the trajectory of recovery. Measurements in two wells were continued intermittently for 2 or 3 days, during which time the well remained idle, until a static water level was achieved. A water level in each well is listed in appendix B, accompanied by a code that represents the status of that water level and (or) conditions at the time of measurement.

Adjustments of Water-Level Measurements

Measurements were made with a chalked steel tape and two different electric tapes, all marked and read at 0.01-foot intervals. Measurements made with the electric tapes were adjusted to the values that would have been read with the steel tape, as calibrated from duplicate measurements in two wells.

The water level in each well at Averill Park, as in any locality in New York where numerous closely spaced domestic wells tap bedrock, is perpetually depressed below the level that would be observed under natural (nonpumping) conditions; the water level fluctuates slowly as pumps in nearby wells go on or off, in addition to the much larger fluctuations caused by pump operation in the well itself. Water-level measurements were scheduled and evaluated with the intent of identifying for each well a “static” water level that reflected the generalized effect of pumping in the neighborhood but that was not depressed by residual drawdown resulting from recent operation of the pump in the well being measured. Therefore, water levels that fell, or that rose and fell, during the interval of measurement were considered to be in dynamic equilibrium with other wells in the neighborhood and were accepted as effective static levels. Water levels that rose 0.01 foot or less over 10 minutes were also accepted as essentially static, and those that rose at greater rates were extrapolated to an estimated static level, if feasible, from the measurements available. Generally, the rate of rise decreased appreciably over time and could be extrapolated graphically or by means of the following equation, which assumes that the specific capacity (yield per foot of drawdown below the static level) does not change as the water level recovers.

$$\frac{R_e}{x+d} = \frac{R_l}{x} \qquad (1)$$

where

R_e = rise (in feet) over 5 (or 10) minutes early in the data observations,

R_l = rise (in feet) over 5 (or 10) minutes late in the data observations,

d = distance (in feet) between mean water levels in the two intervals selected, and

x = distance (in feet) from the mean water level in the later interval to the static water level (to be solved for).

All static water levels that were estimated by extrapolation are coded as such in appendix B. Neither method of extrapolation (graph or the above equation) produced plausible results where the rate of recovery was nearly constant with time or where measurements were made over periods of only 20 minutes, in which case appendix B merely gives the rate of recovery at the measured depth to water. The daily average water level in many wells and neighborhoods was probably a few feet lower than the static levels reported in appendix B because (1) the static levels in appendix B exclude intermittent drawdown caused by operation of the pump in the well measured, and (2) most measurements were made during afternoons, when many residents in the neighborhood were away from home, so the pumps in their wells were idle.

Next, the water-level measurements were adjusted as follows to a common date (August 15, 2002) so that the data used to construct a map of water-level altitudes would be as mutually consistent as feasible. Five wells were measured twice—once between July 24 and 28, and again between September 7 and October 5. Water levels declined seasonally during this time in all five wells by amounts that ranged from 0.22 to 2.33 feet. The median decline of about 0.01 foot per day for these five wells was used to adjust measurements in all wells to August 15, 2002. The use of a single median rate of decline was considered the best available method for adjustment in the absence of continuous records of water-level fluctuation at or near Averill Park. This method may have introduced some error, however, if the magnitude or timing of seasonal decline differed from one geologic terrane to another[2].

Finally, the altitude of the top of the casing (above the National Geodetic Vertical Datum of 1929) at each well in which depth to water had been measured was determined by differential leveling, within ± 0.05 foot. The basis and

[2] The timing of seasonal water-level fluctuations in bedrock may be a function of depth to the potentiometric surface, as evidenced by water-level measurements made in 12 wells on March 12–13 and July 19–26, 2002 (appendix B). Over these 4 months, water levels declined in 7 wells in which depth to water was 19 to 96 feet, and rose in 5 wells in which depth to water was 109 to 145 feet.

procedures for leveling are described in Appendix C. The depth to water in each well on August 15, 2002, was subtracted from the surveyed altitude of the measuring point to give the altitude of the water level, which is listed in appendix B along with the altitude of the top of the casing.

Measurements in 2005

Depth to water in 66 of the 145 wells that had been measured in 2002 was measured again from late July through mid-August 2005, using the same procedures that were used in 2002. These measurements were made to ascertain the extent to which water levels and recharge at Averill Park might be sensitive to changes in the magnitude of precipitation (inasmuch as years 2003–05 were substantially wetter than 1988 and 2001–02).

Water-Quality Data

The water-quality data collected for this investigation consist of (1) field measurements made during the investigation, (2) chemical analyses obtained from the files of the Rensselaer County Health Department and from well owners, and (3) experience with water quality as recalled by well owners or residents. Some of these data proved useful in interpreting paths of ground-water flow, the relation of well yield to depth, and the areal distribution of recharge.

Field Measurements

Specific conductance and hardness of water from nearly every well at Averill Park were measured at the time the owner and (or) occupants of each property were interviewed to obtain information on well construction and water usage; results are given in appendix A. The water was generally obtained from any convenient faucet, but where a water softener or other type of chemical water treatment was used, the water was obtained from an outside faucet or at the pressure tank.

Specific conductance was measured with a portable conductivity meter. Calibration of the meter was verified occasionally against several laboratory standard solutions and against water from a well whose specific conductance had been measured frequently in the past. (See appendix D.) Meter readings were temperature-compensated to yield specific conductance at 25°C. Water was placed for measurement in two cups that differed in sensitivity range; occasional disagreement usually indicated a need to clean corrosion from the wire terminals on one of the cups.

Hardness was measured with a Hach model 5B test kit and entailed titration with a solution of EDTA (ethylenediaminetetraacetic acid) of 0.035 normality. Each drop of titrant added before the sample changed color was equivalent to 1 grain per gallon (17.1 milligrams per liter) of hardness as calcium carbonate ($CaCO_3$). (When a partial color change was observed after some number of drops, and a complete change after one more drop, hardness was estimated as the intermediate 0.5 grain per gallon.) The hardness titration was repeated with a fresh sample at several wells; results invariably agreed within ± 1 grain per gallon. Whenever a fresh bottle of EDTA solution was first used, replicate titrations with the new and old solutions also agreed. Two qualifications may be pertinent to the accuracy of results from this method.

1. The test kit is designed for a hardness range of 0 to 30 grains per gallon (0 to 513 milligrams per liter). Most analyses at Averill Park were within that range, but a few ranged as high as 88 grains per gallon (1,500 milligrams per liter). The instructions do not indicate whether any systematic bias may be present above the recommended range.

2. Most samples had a strong, clear pink color after mixing with the initial reagent and eventually changed to a strong blue color after enough titrant was added. Some samples, however, started with a faint, cloudy pink color that eventually changed to nearly clear as titrant was added. The American Public Health Association (1995) states that indistinct end points in EDTA titrations can result from low pH (unlikely at Averill Park), absence of magnesium ion in the sample, or appreciable concentrations of various metals, but does not mention faint colors as a matter of concern.

No water samples were collected for laboratory verification of field measurements, but the field measurements of hardness were generally consistent with concurrent measurements of specific conductance and with laboratory analyses of samples collected from a few wells in previous years.

Chemical Analyses

The Rensselaer County Health Department collected water samples from many private wells for analysis by the New York State Health Department, or by a private laboratory, for many years, particularly during the 1970s and 1980s. Sampling frequency was greatly decreased after about 1990. Most samples were analyzed only for chloride, nitrate (as N), and bacteria, although a few samples were analyzed for several other constituents. The most recent chloride analysis available for each well is given in appendix A. These chloride analyses were used to appraise the areal distribution of chloride and the changes in concentration since the 1960s.

Several property owners whose water had been previously analyzed by private laboratories or water-treatment companies provided copies of the results for this study. These data, along with the few relatively complete analyses from the County Health Department, are compiled and evaluated in the section “Water quality in bedrock.”

Reported Experience of Residents

Each property owner or occupant was asked to describe water quality, particularly as to taste, odor, water treatment, sediment, and any changes in quality over time. Many of these opinions and experiences were helpful in appraising water quality and are noted in appendix A.

Ground-Water Levels and Flow Directions

The following section describes the water levels and the directions of ground-water flow at Averill Park in 2002. This section is followed by a brief summary of the history of ground-water development at Averill Park, a description of the patterns of change in water levels since the first comprehensive set of water-level measurements were made in 1988–89, and an analysis of the environmental factors that are inferred to have caused the observed declines in water level since 1988, which range from negligible to substantial.

Patterns of Ground-Water Flow in 2002

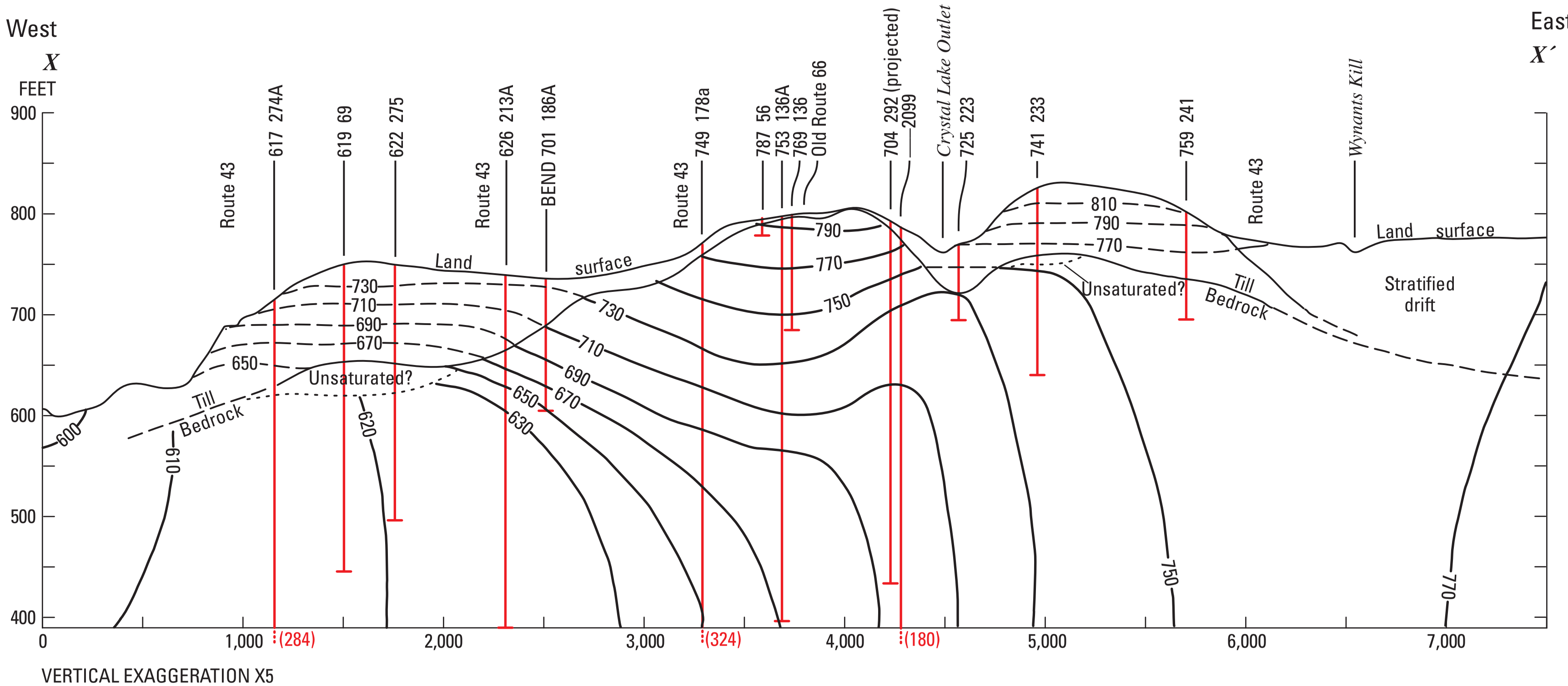
The altitudes of static water levels on August 15, 2002, in the 145 wells measured at Averill Park are depicted on plate 3. In theory, the horizontal component of ground-water flow should be perpendicular to the contours on plate 3, toward areas of lower water level (head). Within this area, ground water also has a vertical (downward) flow component because head generally decreases with increasing depth, as in most upland localities.

The contours on plate 3 depict two different sets of water levels. The first is represented by the green contours south and west of the center of Averill Park, which generally decline westward from an altitude of 700 feet to 610 feet, above NGVD29. This set of water levels includes a small, closed depression at an altitude of about 660 feet near Orient Avenue and seems to be nearly flat at an altitude of about 620 feet in a large area north of Route 43. Water levels in deep and shallow wells south and west of the center of Averill Park all closely match the water-level contours on plate 3. Downward gradients were detected at two locations but were small; water levels in deep wells 52A on Lake Avenue and 69A on Crowley Way were no more than 0.75 foot lower than those in shallower wells a few feet away. The absence of steep downward gradients within this area may be attributed to small recharge through thick overlying till or to relatively high bedrock permeability, in that most wells here were reported to yield more than 3 gallons per minute, whereas the yields obtained elsewhere are generally less.

The second set of water levels is represented by the black contours near the center of Averill Park and to the north and east, which range from 770 to 700 feet in altitude (nearly 100 feet higher than contours to the south and west) and generally decline westward and southward from a crest between Crystal Lake and Old Route 66. Strong downward gradients in bedrock generally prevail here; heads are commonly much deeper in deep wells than in shallow wells. For example, near the south end of Old Route 66, the static water level was 787.1 feet in altitude in a large-diameter well (56) that had been dug by hand to a depth of 20 feet entirely in bedrock, whereas the static water level was 767.5 feet in an adjacent drilled well (56A) that is 207 feet deep, and was 753.1 feet in a nearby drilled well (136A) that is 400 feet deep. Water-level contours on a map cannot readily depict such downward gradients. The contours near and northeast of the center of Averill Park approximate the average static heads in the upper 200 to 300 feet of bedrock; water levels in dug wells and in the shallowest drilled wells are even higher (closer to land surface). Water levels in some wells deeper than 300 feet are comparable to those in wells of lesser depth—an indication that water enters these deep wells largely through fractures in the upper part of the bedrock. In contrast, water levels in several deep wells near the center of Averill Park are comparable in altitude to water levels in wells to the south and west of the center, which suggests that head at depths of 300 to 500 feet near the center of Averill Park is in equilibrium with head in bedrock to the south and west. Therefore, water at depths less than 200 feet in bedrock near the center of Averill Park is inferred to flow southward and westward until it is depleted by the simultaneous downward flow, forming an umbrella-shaped mound of saturated shallow bedrock from which water is leaking downward at all points. This contrast in head with depth is illustrated by the two distinct sets of water-level contours on plate 3; in several localities, the green contours west and south of the center of Averill Park are extended beneath the black contours that represent head in the upper part of the bedrock to the east and north. The inferred distribution of head with depth also is shown in a vertical section through Averill Park (fig. 3).

The altitude of land surface near the center of Averill Park is similar to that in other parts of Averill Park; however, the bedrock surface (pl. 1) near the center is relatively high and is discontinuously mantled by less than 30 feet of till, whereas the bedrock surface in the region to the south and west is lower and mantled by 30 to 190 feet of till (fig. 2) in the form of drumlins. The high heads in many wells near the center of Averill Park are the result of water entering these wells from shallow bedrock, which apparently is saturated nearly to land surface. The heads near land surface in till to the south and west may be equally high (fig. 3), but the wells are cased through the till, so water can enter these wells only from bedrock below the bottom of the casing, commonly at depths of 100 feet or more where head is lower than at shallow depth. The persistence of high heads in shallow bedrock near the hamlet center, despite withdrawals from numerous wells, can be attributed to some combination of two factors.

1. Recharge to bedrock may be greater where the till overlying bedrock is discontinuous and thin, near the



EXPLANATION

—750— **Contour of equal head potential, in feet above National Geodetic Vertical Datum of 1929—Dashed in till because no measurements are available**

Well

617 274A — **Identification number** (274A); **Altitude of head measured, in feet** (617)

Bottom—altitude of bottom is given in parentheses if it is less than 390 feet above NGVD 29

Figure 3. Hypothesized distribution of head in August 2002 in a vertical plane along section X–X` through Averill Park, N.Y. (Location of section is shown on pl. 3.) The equipotential contours are drawn such that head along part or all of each well bore below the top of bedrock is equal to the measured head in that well. For well 178a, the measured head is matched by contoured head about 45 feet below top of bedrock because the hardness of water and the construction history in this deep well indicate that the water enters from fractures in the upper 132 feet of bedrock. Well 2099 is a commercial well that is pumped much of the time.

hamlet center, than where the recharge must penetrate 30 to 190 feet of till.

2. The water-transmitting capacity of bedrock in the area of high heads may be low enough that water simply cannot drain readily to greater depth. This condition cannot be attributed to subhorizontal layers of low water-transmitting capacity because the rock layers strike about north 15 degrees east and generally dip steeply to the east. Perhaps the steeply dipping shale layers at shallow depth may constitute a tightly folded syncline(s) underlain by more permeable strata that continue into the region of lower heads to the southeast, south, and west. Records of wells in the region of high heads do not support this hypothesis, however, in that the wells are reported neither to penetrate a different type of rock below some depth nor to obtain greater yield below some depth.

History of Ground-Water Development at Averill Park Since 1930

Most houses at Averill Park in the 1930s obtained water from a nearby dug well 10 to 20 feet deep and from a cistern in the basement that was fed by gutters on the roof. Some wells near the center of Averill Park, where the bedrock surface is generally close to land surface, were dug into bedrock. Because many of the dug wells failed to provide enough water in dry summers, fire-department tank trucks would go from house to house, filling wells upon request. This practice was successful because the poorly permeable till allowed little of the introduced water to seep out of these wells, just as it had allowed little native ground water to seep in.

Beginning in the 1930s and continuing through the 1960s, dug wells at Averill Park were gradually replaced by drilled wells, most of which were 80 to 200 feet deep. As of 1970, about 210 drilled wells served the residences within the study area, and about 10 more wells served businesses. At least 69 additional wells were drilled at new dwellings during the 1970s, 1980s, and 1990s, and at least 97 wells were either deepened or were replaced by deeper wells during these 30 years. Most well deepening was in response to frequent, brief losses of water pressure, but some well owners reported being suddenly and permanently out of water, and a few attributed water shortages to the recent drilling of another well(s) nearby. The numbers of wells finished in different depth intervals at Averill Park in 2002 are given in table 1.

Public sewers were laid along nearly all Averill Park streets in 1983 in response to many instances of surface discharge of effluent from inadequate septic systems. The sewer pipes were laid in trenches excavated in till or bedrock but were commonly backfilled in part with permeable sand, which in some localities may cause the trenches to function as French drains that lower the head at shallow depth in till or bedrock near the trenches.

Changes in Water Levels, 1988–2002 and 2002–2005

One of the generalizations on which the computation of recharge to bedrock in this report is based is that water levels in bedrock wells were not persistently rising or falling during the period of study; if so, recharge to bedrock would approximately equal discharge from bedrock. Water-level fluctuations at Averill Park have not been monitored over the years, but any net changes in water level since 1988 could be detected by repeated measurements of static water levels in many of the wells that had been measured in 1988. The 14-year period from 1988 through 2002 was expected to be long enough to reveal water-level responses to any changes in the rates of withdrawal or any imbalance between recharge and withdrawal, if antecedent precipitation and recharge for at least several months before mid-1988 and mid-1989 were reasonably similar to those before mid-2002. Net changes in static water levels at 45 sites from about 1988 through 2002 are plotted in figure 4. Measurements in 2002 were compared with 34 measurements in the same wells, 4 measurements in wells at adjacent houses, and 7 measurements made by owners or drillers, all in about 1988. Eight localities (A–H) were delineated; a generalized estimate of the average net change in each locality is given in figure 4. Boundaries between localities are approximate, and intermediate water-level declines near the boundaries are likely. The range in measured water-level changes, and the number of wells measured in each locality, are summarized in table 1.

Little or no net change in water level took place during the 14 years from 1988 to 2002 in locality A (fig. 4), in the center of Averill Park, where till is thin and discontinuous (fig. 2); a net rise averaging about 2 feet was recorded in six wells from June or July 1988 to August 2002, and a net decline averaging about 3 feet was recorded in four wells from late 1989 to August 2002. Estimated average net declines in localities B, C, and D (fig. 4) are less precise than elsewhere because only a few repeated measurements in these localities were available, and because some of the 1988 measurements were not made in the same season as the 2002 measurements, or were made by well owners who did not document the measurement conditions. Water-level changes in seven wells in area E varied widely. Net declines in all of these localities (A–E) are estimated to average from 0 to 5 feet, whereas net declines in localities F, G, and H averaged from 10 to 15 feet.

Net changes in water level in each of 65 wells from August 2002 to August 2005 are plotted in figure 5. Water levels generally rose in the central and eastern parts of Averill Park (localities A, B, C, F, and G), declined slightly to the north of Crystal Lake (locality D), and declined substantially to the west and southwest (localities E, H).

The observed water-level changes from about 1988 to 2002, and from 2002 to 2005, may be attributable to several factors, as explained in the following sections.

Table 1. Changes in depth to water, resident population, and well depth since 1970 and 1988 in several localities at Averill Park, N.Y.

[Locality boundaries are shown in fig 4. A dash (--) denotes data not available]

Locality	Estimated average decline in water level 1988–2002 (feet)	Range in water-level changes (feet)	Number of wells measured in 1987–91 and in 2002[a]	Resident population served by wells in these years		Number of dwellings in which population was counted	Additional dwellings in which population change is unknown
				1988	2002[b]		
A) Center of Averill Park (Lake Avenue to Eastern Union Tpk)	0	(+6.4 to -3.2)	8	200	180	52	11
B) East of Crystal Lake	-2	(-0.7 to -3.6)	3	19	22	7	1
C) Route 43 east of Bullis Drive	-2	(-1.0 to -6.3)	4	53	54	15	7
D) North side of Crystal Lake	-5	(-3.6 to -7.4)	5	13	18	10	1
E) Southern Burden Lake Road, Orient Avenue, Prospect Avenue	-4	(+2.9 to -8.6)	7[c]	108	108	28	7
F) Barzen Road and Route 43 nearby	-10	(-9 to -10.9)	4	58	59	18	1
G) Johnnycake Lane, Breezedale Drive	-13	(-9 to -17.2)	5	80	73	25	1
Morning Circle, south of Breezedale Drive	--	--	0	0	27	8	0
H) West side of Averill Park (Terrace Drive, Pine and Allen Avenues, Old Route 66)	-15	(-9 to -17.3)	9	154	151	57	5
Eastern Union Turnpike (south of Wynants Kill)	--	--	0	31	32	12	1
Total for Averill Park			**45**	**716**	**724**	**232**	**35**

	Number of domestic wells in bedrock					Number of domestic wells in 2002 within given depth interval (all values are in feet)			
	Existing in 1970	Deepened 1970–87[d]	New 1970–87	Deepened 1988–2002	New 1988–2002[e]	Less than 200	200–299	300–499	500 or greater
A) Center of Averill Park (Lake Avenue to Eastern Union Tpk)	62	17	4	15	3	25	15	20	8
B) East of Crystal Lake	3	1	4	0	1	1	2	4	1
C) Route 43 east of Bullis Drive	19	0	4	0	0	19	2	0	2
D) North side of Crystal Lake	7	3	3	1	1	4	1	5	1
E) Southern Burden Lake Road, Orient Avenue, Prospect Avenue	30	5	5	7	1	11	8	13	4
F) Barzen Road and Route 43 nearby	13	0	2	0	2	14	1	5	2
G) Johnnycake Lane, Breezedale Drive	19	3	7	5	0	7	8	10	0
Morning Circle, south of Breezedale Drive	0	0	0	0	9	0	4	5	0
H) West side of Averill Park (Terrace Drive, Pine and Allen Avenues, Old Route 66)	47	22	11	16	7	15	24	21	4
Eastern Union Turnpike (south of Wynants Kill)	10	0	4	2	1	8	3	4	0
Total for Averill Park	**210**	**51**	**44**	**46**	**25**	**104**	**68**	**87**	**22**

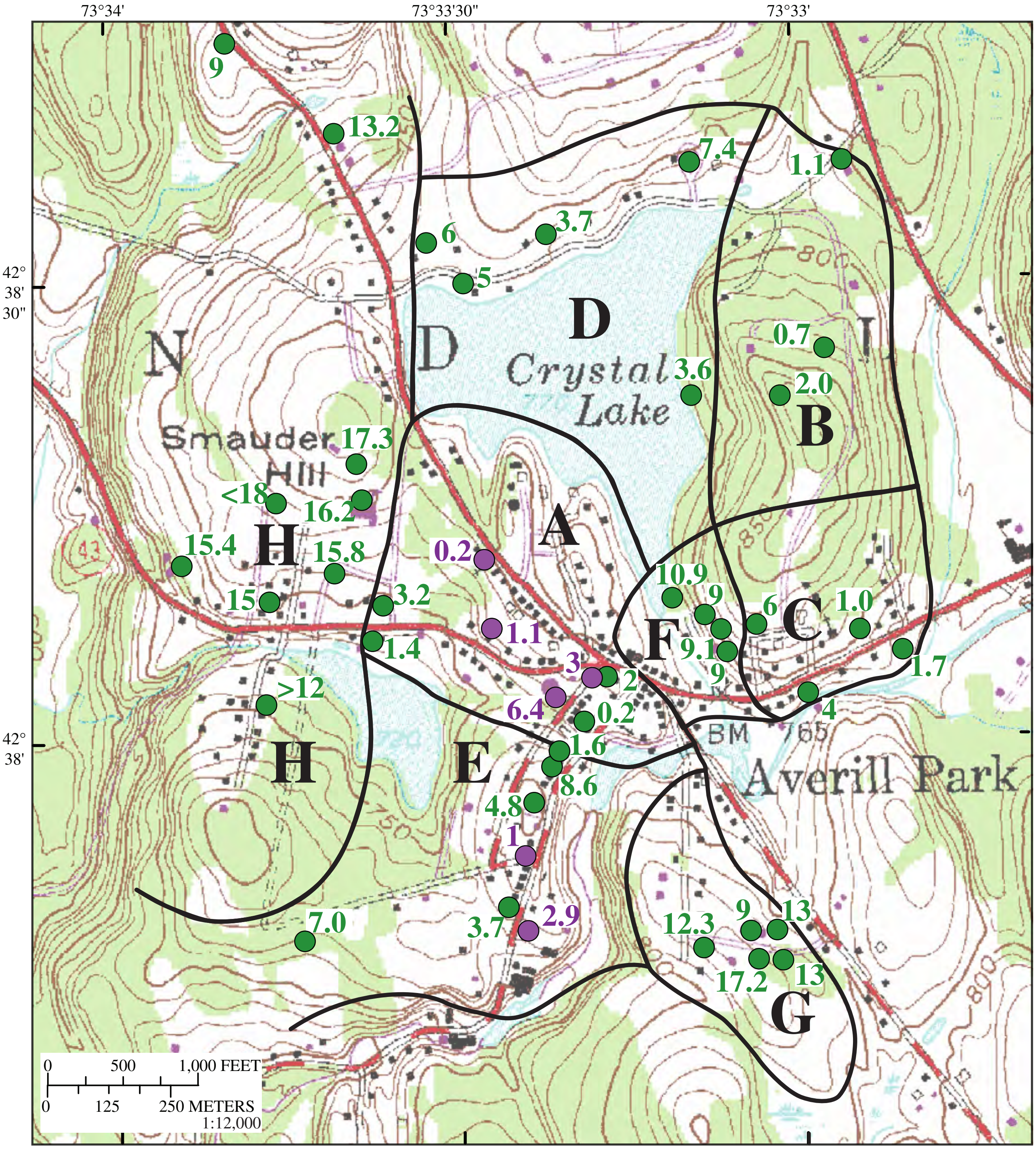
[a] Includes four wells where 2002 measurement was in a well on a lot adjacent to that where the 1987–91 measurement was made; also includes seven wells where 1987-91 measurement was made by driller, pump installer, or well owner.

[b] Resident population determined by interviews in 1999 from Route 43 south and Burden Lake Road west, in 2001 and 2002 for the remainder of the study area.

[c] This locality also includes two wells in which net declines are likely but not quantifiable because low recovery rates prevented determination of static water level.

[d] Includes new, deeper wells that replaced older wells.

[e] Includes a few wells that replaced dug wells.



Base from U.S. Geological Survey digital data, various dates, 1:24,000, Universal Transverse Mercator projection, NAD 83, Zone 18

EXPLANATION

0.2 ● Net water-level rise, in feet

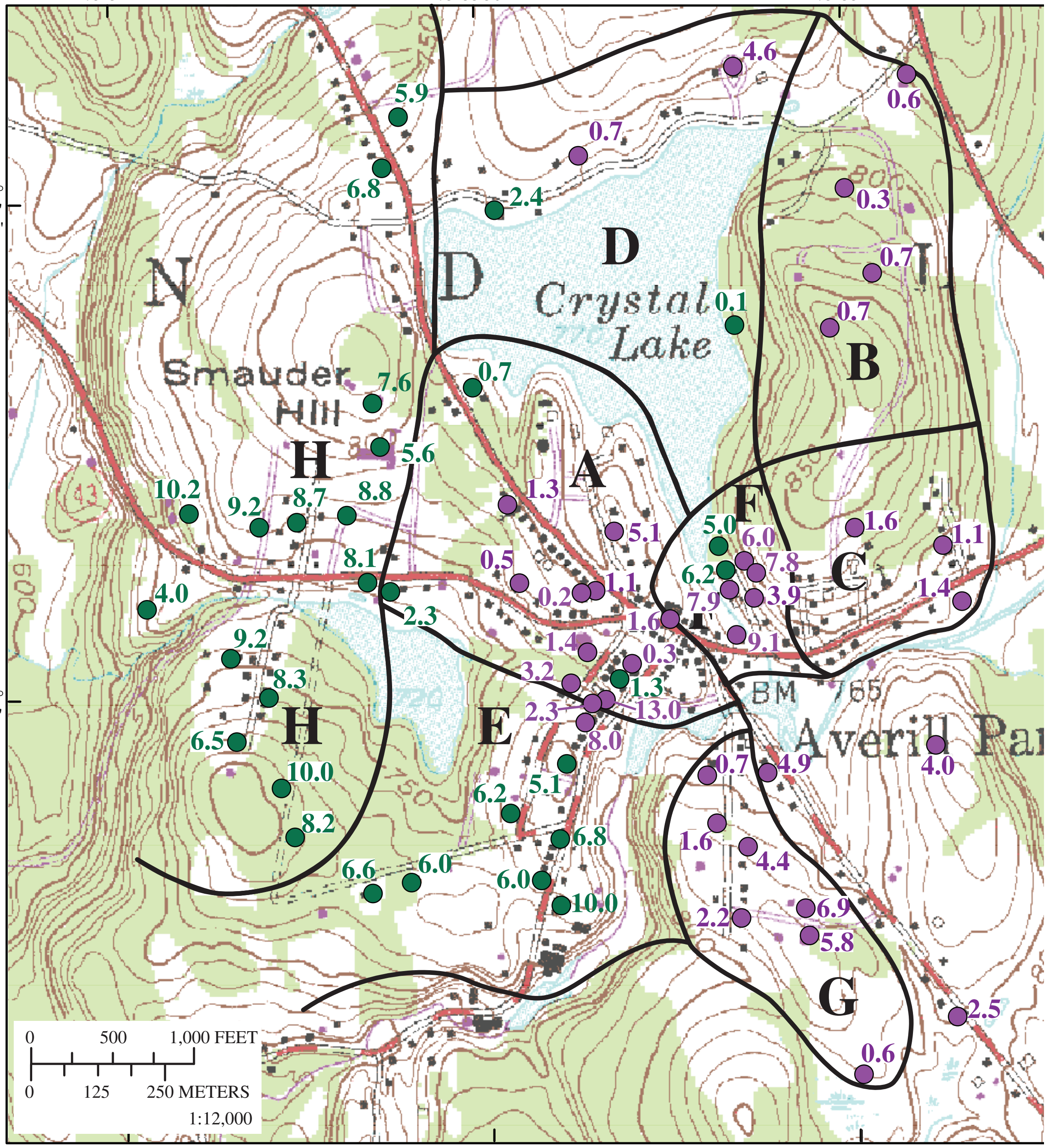
8.6 ● Net water-level decline, in feet

E — Boundary of locality designated by capital letter

Estimated average net change in water levels, within each designated locality, 1988± to 2002, in feet.

A	0	**C**	-2	**E**	-4	**G**	-13
B	-2	**D**	-5	**F**	-10	**H**	-15

Figure 4. Net change in static water levels in wells at Averill Park, Rensselaer County, N.Y., from 1988 to 2002. (General location is shown in inset map in fig. 1.)



Base from U.S. Geological Survey digital data, various dates, 1:24,000, Universal Transverse Mercator projection, NAD 83, Zone 18

EXPLANATION

Well, with change in depth to water between measurements in the summer of 2002, adjusted to August 15, 2002, and measurements in the summer of 2005, nearly all between July 30 and August 17

0.7 ● Net water-level rise, in feet

6.6 ● Net water-level decline, in feet

E — Boundary of locality designated by capital letter

Figure 5. Net change in static water levels in wells at Averill Park, Rensselaer County, N.Y., from 2002 to 2005. (General location is shown in inset map in fig. 1.)

Effect of Fluctuations in Precipitation and Recharge

Water levels throughout the northeastern United States typically show a net rise during winter and spring, and a net decline in summer and fall, chiefly in response to the regular annual cycle of evapotranspiration. Water levels also fluctuate in response to random variations in precipitation from month to month and from year to year, and these fluctuations can vary in magnitude from one rock type or geographic setting to another (Kontis and others, 2004; Frimpter, 1980; Socolow and others, 1994). No continuous records of water-level fluctuations in bedrock at locations affected solely by these natural processes during the study period were available from Averill Park or elsewhere in Rensselaer County; therefore, no attempt was made to quantify the magnitude or timing of water-level changes caused by fluctuations in precipitation or recharge. Nevertheless, the assumption that antecedent recharge in mid-2002 and 1988–89 were similar receives some support from three categories of hydrologic evidence. These three categories of evidence—estimated amounts of water available for recharge, net changes in water levels from 2002 to 2005, and trends in ground-water discharge to streams—are summarized below.

1. *Amount of water available for recharge during 1987–91 and 1999–2005.* Water available for recharge (Lyford and Cohen, 1988; Kontis and others, 2004) was computed month by month for the two periods during which water-level measurements used in this study had been made (1987–91 and 1999–2005) from records of precipitation and estimates of evapotranspiration, as follows:

- The mean annual rate of evapotranspiration of 20 inches for 1951–80 at Averill Park (Randall, 1996: Kontis and others, 2004) was distributed by months in proportion to the product of the percentage of annual daylight that occurs in that month (from ephemeris tables) and normal monthly mean temperature at Albany Airport, 15 miles west of Averill Park, by the method described by Olmsted and Hely (1962).
- Average evapotranspiration values thus computed for each month were subtracted from the actual precipitation values recorded during 1987–91 and 1999–2005 at station West Sand Lake 2S, about 5 miles southwest of Averill Park (National Weather Service, 1983–2005), to obtain the amount of water available for recharge month by month.
- If a month's estimated evapotranspiration exceeded the measured precipitation, the difference (soil-moisture deficit) was carried forward until offset by a subsequent surplus of water available for recharge.

The resulting monthly values are a reasonable estimate of actual recharge to surficial stratified drift. They are undoubtedly an overestimate of recharge to bedrock, however, because much of the surficial till at Averill Park probably becomes saturated to land surface for several months of each year, during which time most precipitation cannot infiltrate and becomes storm runoff (Kontis and others, 2004).

The depths to water that were measured on four to six dates during 1999–2005 in seven wells, all in central and southeastern parts of Averill Park, were ranked in order from shallowest to deepest and compared with cumulative totals of water available for recharge during the preceding 3, 4, 6, and 12 months, including the month of water-level measurement. Results for three of these wells are given in table 2. Depth to water in well 111 increased as the amount of water available for recharge during the preceding 3 or 4 months decreased, except for the May 2001 measurement. The same was true for three of four measurements in well 54. Therefore, the water-level fluctuations observed in these two wells may be largely a function of recharge over the previous few months—a plausible interpretation in that the surrounding till overburden is only a few feet thick and discontinuous. In contrast, the rank for depth to water in well 9, where bedrock is overlain by more than 100 feet of till, showed no correlation with the estimated amount of water available for recharge over the preceding 3 to 6 months but, in four of the five depth measurements, was inversely correlated with the amount of water available during the preceding 12 months (table 2). No correlation was evident between the rank order of depth to water and the amount of water available for recharge over any time period at the other four wells analyzed (10, 37, 145, 186).

These few records provide scant evidence of the magnitude and timing of water-level response to variations in the amount of water available for recharge. Nevertheless, water levels could be reasonably expected to be lower after a year or more of subnormal precipitation and subnormal amounts of water available for recharge than after a year or more in which these variables were well above normal. Fluctuations in the long-term amount of water available for recharge are illustrated in figure 6, which depicts, for each month of 1987–91 and 1999–2005, the total amount of water available for recharge during that month plus the preceding 11 months. Many of the water-level measurements listed in appendix B were made during June–August 1988, August–December 1989, and July–August 2002, and figure 6 indicates that, throughout each of these periods, the amount of water available for recharge during the preceding 12 months was about 20 inches (and had not exceeded this amount for many months prior to each of these periods). Therefore, figure 6 indicates that any net changes in water level between 1988–89 and 2002 are not primarily a function of differences in the cumulative amount of water available for recharge over the 12 months (or more) preceding the water-level measurements.

2. *Net changes in water levels from 2002 to 2005*. A net rise in water levels from August 2002 to August 2005 in bedrock wells throughout central and eastern Averill Park (fig. 5) can be attributed to greater precipitation and a greater amount of water available for recharge in 2003, 2004, and 2005 than in 2001 and 2002. The median net rise in this area was 1.6 feet. (A decline in water levels in southwestern

Table 2. Depth to water in three wells finished in bedrock at Averill Park, N.Y., on several dates in 1999-2005, and calculated amount of water available for recharge during antecedent time periods.

[Well locations shown on pl. 2. Measurements are listed in order of increasing depth to water]

Well number	Measured water level		Total amount of water available for recharge during indicated number of months, including and preceding month of measurement, in inches			
	Date	Depth below top of casing (feet)	3 months	4 months	6 months	12 months
111	Aug 17, 2000	18.04	8.67	11.79	19.09	37.90
	Mar 13, 2002	19.25	7.74	10.61	10.36	12.70
	Jul 25, 2002	21.56	6.04	8.50	13.22	19.18
	Jun 15,1999	22.87	1.32	4.74	11.93	5.80
	Aug 10, 2005	23.05	2.24	2.24	9.66	27.96
	May 17, 2001	23.54	5.96	8.40	14.96	26.80
54	Mar 12, 2002	23.61	7.74	10.61	10.36	12.70
	Aug 6, 2005	24.34	2.24	2.24	9.66	27.96
	Jul 25, 2002	25.44	6.04	8.50	13.22	19.18
	Jul 24, 2001	25.61	1.79	2.02	9.95	32.11
9	Aug 4, 2005	126.90	2.24	2.24	9.66	27.96
	Jan 12, 2000	127.79	7.19	10.16	15.55	22.00
	Jul 19, 2002	128.86	6.04	8.50	13.22	19.18
	Mar 12, 2002	129.71	7.74	10.61	10.36	12.70
	May 17, 2001	129.89	5.96	8.40	14.96	26.80

Averill Park can be attributed to withdrawals from several new wells, as discussed farther on.) The 12-month amount of water available for recharge was sustained at about 30 inches for nearly 3 years prior to the water-level measurements made in August 2005, a 50-percent increase over the 19.2 inches recorded from June through September 2002 (fig. 6). By contrast, the 12-month amount of water available for recharge in June–September 2002 was only 5 percent less than the amount available in June–September 1988. Therefore, one might expect the net water-level response to the slight difference in recharge from 1988 to 2002 to be much smaller than the response of 1.6 feet observed from 2002 to 2005.

3. *Ground-water discharge to streams.* Base flow (streamflow during dry intervals between storms) consists almost entirely of ground water that seeps into streams, and the rate of seepage is proportional to the water levels in the aquifers that border the stream system. Accordingly, similarity between base flows of an upland stream on two different dates implies that water levels in the adjacent till and bedrock on those dates were also similar. The nearest streamflow-gaging stations on upland streams that drain less than 50 square miles and were in operation from 1988 through 2002 are in the Schoharie Creek basin, about 48 miles southwest of Averill Park. Base flows in 1987–88 are compared with those in 2001–02 at one of these stations, Manor Kill at West Conesville, in figure 7. The flow of Manor Kill from October 2001 through January 2002 was the lowest of record, but flow returned to the normal range from February through early June of 2002 (fig. 7), as did the flow of larger streams in east-central New York. The flow of Manor Kill between storm peaks in June through September 1988 was similar to that in June through September 2002—generally well below the median flow but above the lowest flow of record. This similarity of base flows in the two summers implies that antecedent recharge from precipitation in 1988 was similar to that in 2002 in the Manor Kill watershed. That watershed is similar to Averill Park in consisting predominantly of till-covered bedrock uplands, but relief is greater, and glacial and alluvial gravel aquifers 1,500 feet wide border the main channel, so a somewhat different pattern of recharge and water-level response at Averill Park is possible.

The data in appendix B indicate that water levels in bedrock in areas of thin till at Averill Park have fluctuated as much as 4 to 6 feet over a year or two; much of this fluctuation may result from fluctuations in precipitation and evapotranspiration. The foregoing analysis indicates, however,

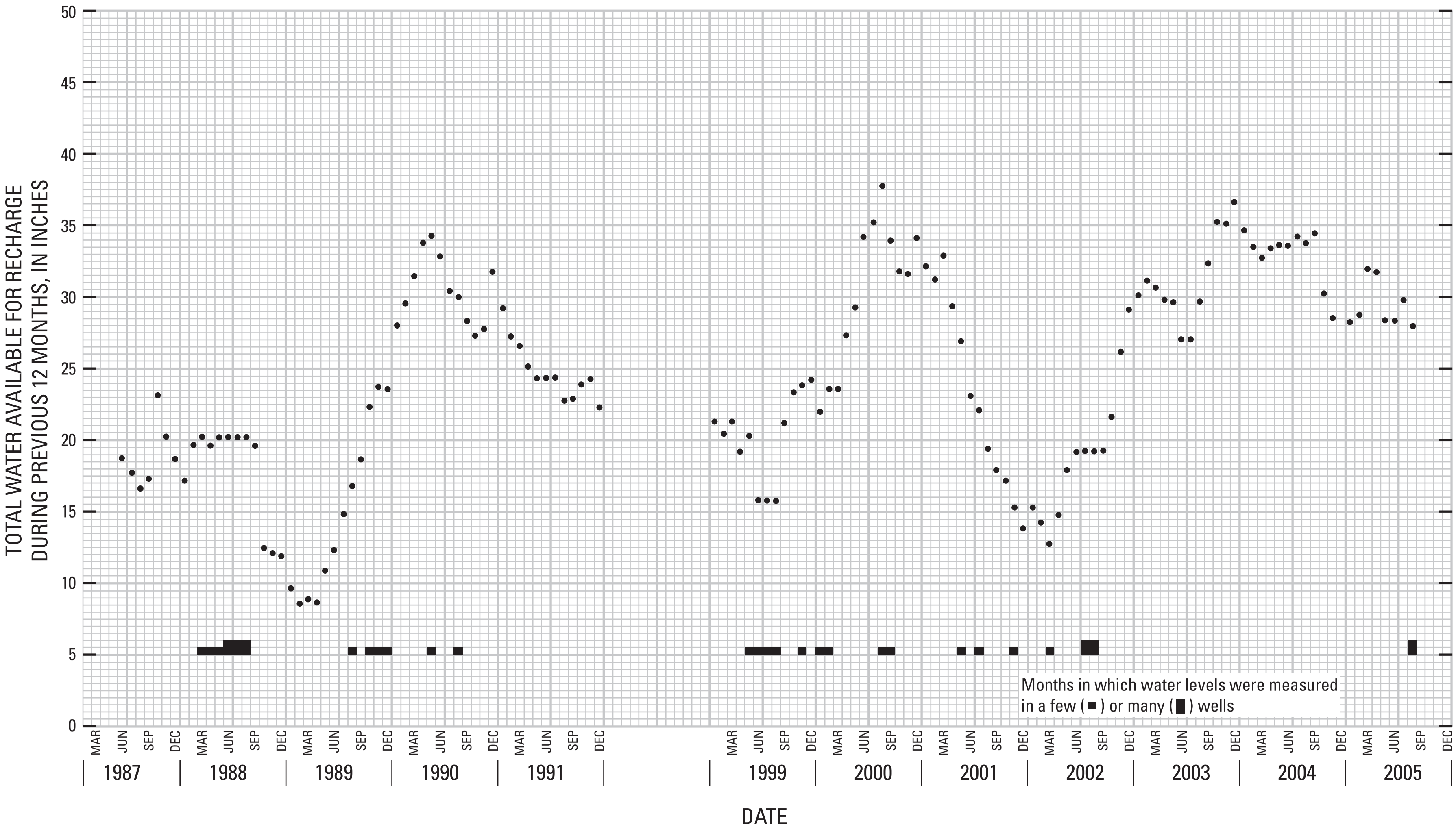


Figure 6. Amount of water available for recharge at Averill Park, N.Y., during 12-month periods ending in each month 1987–1991 and 1999–2005, as calculated from estimated evapotranspiration rate and recorded precipitation.

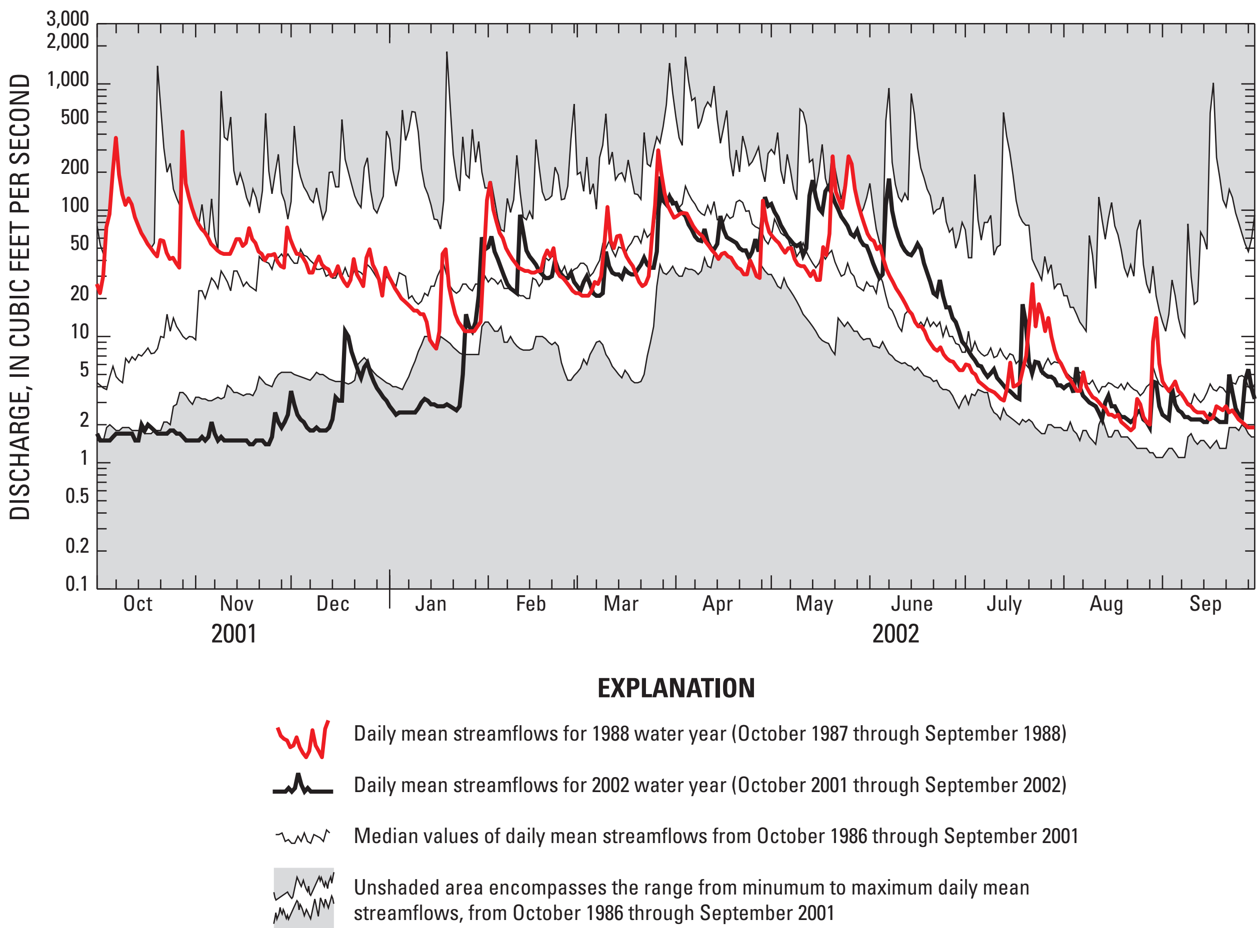


Figure 7. Hydrographs of daily mean streamflow in the Manor Kill at West Conesville, N.Y., 1987–88 and 2001–02. (Conesville is 48 miles southwest of Averill Park, in the Schoharie Creek basin.) Data from U.S. Geological Survey (1976–2005).

that any net water-level declines greater than 2 to 3 feet between 1988–89 and 2002 can probably be attributed to other factors, as discussed in the next three sections, because climatic conditions were similar prior to measurement of water levels in 1988–89 and 2002.

Water-Level Changes as a Function of Resident Population or Business Activity

Any substantial increase in the resident population or in water-using commercial activities, such as restaurants, would result in increased ground-water withdrawals and thereby lower water levels, at least locally. The resident population of Averill Park as a whole remained nearly constant from 1988 through 2002, as indicated by interviews at 232 houses and apartment buildings that disclosed 716 residents in 1988 and 724 residents in 1999–2002 (table 1). These totals do not include 35 dwellings for which the number of residents was not reported in 1988, or not in 2002; therefore, the population of Averill Park on both dates was probably about 15 percent greater than the totals reported here. The number of commercial properties did not increase appreciably from 1988 to 2002, although changes in the amount of water used by businesses are possible. Water-level declines that followed construction of new houses in two localities and increased business activity in a third locality are evaluated in the following paragraphs.

Locality G: Water levels in five wells along Breezedale Drive (locality G, fig. 4) declined 9 to 17 feet from about 1988 to 2002. Measurements in three of these wells in 2005 indicated substantial rises since 2002; nevertheless, net declines from about 1988 to 2005 ranged from 6 to 11 feet. These declines can be attributed to a new residential development of eight houses along Morning Circle, which extends southeast from Breezedale Drive; the wells here were drilled from 1990 through 1995, and the houses were occupied after about 1995. The resident population along Johnnycake

Lane and Breezedale Drive decreased slightly from 1988 through 2002, but with the new development included, locality G increased 20 percent in population from 1988 to 2002. The net declines in water level were probably smaller near the north end of this locality than near the new development, although no documentation is available.

Locality H: Water levels in eight wells widely spaced across the west side of Averill Park (locality H, fig. 4) declined 9 to 17 feet from 1988 to 2002. This substantial decline, which seems to have encompassed all of locality H, cannot be attributed to an increase in population, in that the number of residents in that locality remained nearly constant from 1988 to 2002 (table 1). Water-level declines before 1988 and after 2002, however, could be attributed to increased population.

A new development with nine houses was constructed in the late 1980s along Hickory Lane (a new road north of Gettle Road, about 600 feet west of Old Route 66). Wells were drilled here in 1987, and many houses were first occupied in about 1988. This new demand for water presumably lowered water levels near the north end of locality H, but whether most of the decline took place before or after water levels were measured in the summer of 1988 is uncertain. Construction of another new development began in 2002 in the triangular tract of land between Firemans Pond and Marcy and Prospect Avenues, which occupies the southern part of locality H and the western end of locality E; eight wells were drilled here from 1997 through 2002, but only two houses had been occupied, briefly, before the 2002 water-level measurements were completed. Therefore, withdrawals in this new development likely did not contribute to the observed decline in water levels. By 2005, however, 14 new houses had been built and occupied along Prospect and Marcy Avenues. All water levels measured in localities H and E declined from 2002 to 2005; median declines were 6.7 feet in locality E and 8.2 feet in locality H, and most of the largest declines in locality H were near and south of Route 43, close to the new development. These declines can be attributed at least in part to withdrawals from wells serving the 14 new houses.

Locality F: A decline in water levels in locality F from 1986–88 to 2002 seems to have resulted from increased commercial use of water. Water levels in four wells along Barzen Road in locality F declined 9 to 11 feet, and no declines of less than 9 feet were measured within this locality. The water level in 2002 in a well along Bullis Drive, just east of locality F, was about 6 feet lower than in the well at an adjacent home in May 1989. The resident population of locality F did not change from 1988 to 2002 (table 1), but two new wells were drilled in 1998 for a large restaurant (nos. 2098, 2099) to replace an inadequate well. These new, deeper wells have been pumped regularly since 1998. Another nearby restaurant (wells 7, 8) reportedly served increased numbers of customers after 2000. Increased commercial use at these businesses could at least partly explain the decline in water levels along Barzen Road. Water levels in five wells in locality F rose 4 to 9 feet from 2002 to 2005, but the three wells closest to well 2099 recorded declines of 4 and 6 feet and a rise of only 1.6 feet, which suggests a continuing response to persistently larger commercial withdrawals from 2002 to 2005.

In summary, water levels in most of Averill Park over the 14 years from 1988 to 2002 remained constant or declined only a few feet, which is consistent with the generally stable population. Declines of 9 to 17 feet in two localities (F, G) from 1988 to 2002, and in two other localities (E, H) from 2002 to 2005, can be largely attributed to localized increases in population or in commercial withdrawals. The decline from 1988 to 2002 along the western side of Averill Park cannot be similarly explained, however, and is discussed further in the next two sections.

Water-Level Declines as a Function of Withdrawals and Natural Discharge

Water levels in locality H seem to have declined substantially before the first comprehensive set of measurements were made in 1987–89. The potentiometric surface in locality H before the installation of bedrock wells probably sloped steeply westward toward the lowland west of Smauder Hill. No records of water levels when wells were first drilled into bedrock in this locality in the 1950s or earlier have been found, but unless the water levels were initially at least 50 feet above the bottoms of these wells, most drillers would presumably have drilled deeper to provide storage. Accordingly, the total water-level decline due to human activities at two wells along Old Route 66 that were dry, or nearly so, in 2002 probably exceeds 75 feet. A similar calculation for two wells along Allen Avenue suggests a total decline of at least 50 feet.

The inferred large decline in head in the northern part of locality H over the past 50 years, and the continuing large (15-foot) decline in head throughout locality H from 1988 through 2002, could be interpreted as normal aquifer response to increased withdrawals from wells—namely, a decrease in the westward gradient that would have existed in the 1930s, when all water in bedrock at Averill Park flowed westward to discharge naturally into the lowland west of locality H. The potentiometric surface in 2002 in locality H north of Route 43 is inferred to have been nearly level (pl. 3) and at nearly the same altitude as in the lowland to the west. Water levels measured in 19 wells along Old Route 66, and along Lake, Pine, and Allen Avenues and along Route 43 west of Lake Avenue, were all within 4 feet of an altitude of 620 feet. The lowland west of Smauder Hill is underlain largely by surficial sand and gravel (LaFleur, 1965); thus, the water table there is probably close to the altitude of swamps and streams shown on the topographic map—about 630 feet in the area north of Route 43 and about 610 feet in the area south of Route 43. Therefore, ground water north of Route 43 in locality H probably no longer flows westward to discharge into that lowland. South of Route 43, however, water levels remain higher in locality H than in the lowland and continue to slope steeply westward toward the lowland (pl. 3). If the water-level gradient had not reached equilibrium by 2002 and continued to decline at the same rate through 2005, this trend would explain 15 to 20 percent of the median water-level declines observed during these 3 years in localities H and E (8.2 and 6.7 feet). If the increase in recharge from precipitation during 2003–05 that caused a net rise in water levels in central and eastern Averill Park also occurred in localities H and E, the declines in water levels observed in these localities were probably a foot or so smaller than would have occurred if the dry conditions of 2001–02 had continued.

Water-Level Declines as Cause and Result of Well Deepening

A total of 47 bedrock wells had been drilled in locality H, on the west side of Averill Park, by 1970 (table 1). Nearly all of these wells were less than 200 feet deep. By 2002, 38 of those wells (81 percent) had been deepened, or replaced by deeper wells—a much higher percentage than in any other locality around Averill Park. Of the 65 wells inventoried in 2002, only 15 were less than 200 feet deep, and 25 were 300 to 722 feet deep (table 1). The long-term water-level declines described in the preceding section are an obvious proximate cause of the abundance of deepened wells in this locality. Several older, relatively shallow wells have reportedly been rendered useless by declining water levels, as indicated in the first table below. All have been replaced by deeper wells or by lake water.

The deepening of many wells in locality H and elsewhere around Averill Park is to some extent a cause of water-level decline, as well as a response to a previous decline. In humid regions such as the northeastern United States, head decreases with increasing depth beneath hills or uplands, and increases with increasing depth beneath major valleys or lowlands. This head distribution is the result of gravity, which causes precipitation on hills to infiltrate to the water table, where it then moves downward and laterally toward valleys, and finally upward into streams that drain those valleys (fig. 8; see also Toth, 1962; Kontis and others, 2004, fig. 5). Water levels in pairs of nearby shallow and deep wells document decreases in head with depth at four places in locality H, as indicated in the second table below.

The latter two well pairs are near the eastern margin of locality H and exemplify the large differences in head (pl. 3) between the shallow bedrock near the center of Averill Park and the much lower bedrock in locality H to the west (pl. 1), where bedrock is mantled by 60 to 190 feet of till. Head in bedrock at depths of 200 feet or more (fig. 3) may have been lower in 2002 than under natural (predevelopment) conditions as a result of withdrawals from deep wells, but head probably decreased with depth even under natural conditions (fig. 8).

Any well that is drilled to a depth of 300 to 600 feet at Averill Park is likely to intersect water-yielding fractures at multiple depths. If so, the water level in the well would be an average of the heads in the individual fractures, weighted in proportion to the water-transmitting capacity (hydraulic conductivity) of each fracture, and would be deeper than if the well had been drilled to a depth of only 200 feet. Water would

Well number (plate 2)	Street (figure 1, plate 2)	Depth below land surface (feet)		Owner's experience
		Bottom of well	Water level in 2002	
195	Old Rte 66	130.0	dry	Well failed abruptly in 1974
147	Old Rte 66	139.1	126.4	Yield only enough for drinking 1984-94
152	Old Rte 66	186 reported	not measured	Yield negligible after wells at adjacent homes were deepened 1979-85
69	Crowley Way	129.4	127.0	Yield inadequate 1998
309	Terrace Drive	110 reported	113.7*	Well failed 1996

*Depth to water level measured in nearby well 200 feet deep

Street (fig. 1, pl. 2)	Well numbers (pl. 2)	Well depth (feet below land surface)	Water- surface altitude (feet above NGVD29)	Date of water-level measurement
Crowley Way (off Allen Avenue)	69	129.4	619.26	August 15, 2002
	69A	300(?)	618.56	Do.
Lake Avenue	52	188	621.80	July 24, 2002
	52A	500	621.01	Do.
Route 43, near Lake Avenue	303	202	700.20	August 19, 2002
	213A	342	625.87	Do.
Old Route 66	247	139.1	676.36	August 7, 2002
	248a	400	620.92	July 22, 2002

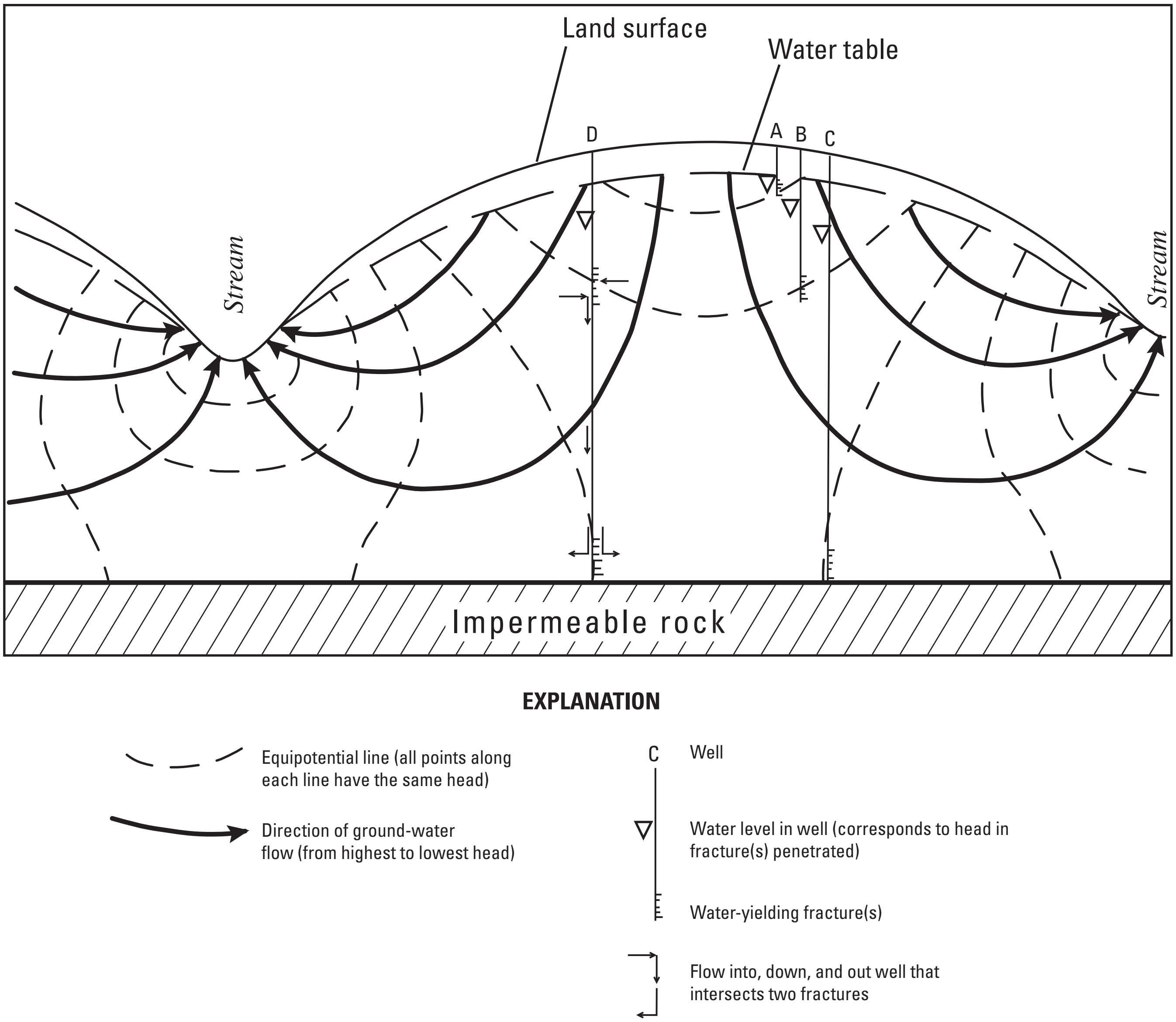


Figure 8. Vertical section through an idealized homogeneous aquifer showing typical ground-water flow paths in uplands and valleys. (Modified from Hubbert, 1940.) Wells A, B, and C each intersect one water-yielding fracture; head in each well is equal to the head represented by the equipotential line that intersects that fracture. Well D intersects two fractures; water flows into the well from the fracture with higher head and out of the well into the fracture with lower head.

drain into the well from shallow fractures and then flow down the well bore and out of the well through deep fractures. This process would lower the head in the shallow fractures and in any nearby well that tapped those same fractures—even if the number of wells in use, and the total volume of withdrawals, remained constant. Therefore, deepening wells could decrease the yield of individual wells that depend on shallow fractures without decreasing the total yield available from the bedrock aquifer.

The foregoing hypothesis, that drilling wells deep into bedrock in uplands can result in a decline in head in shallow bedrock by allowing downward flow along the boreholes (in addition to any decline that subsequently results from withdrawal of water), is supported by well and water-level records collected during this study from a tract of undeveloped land between Marcy Avenue, Prospect Avenue, and Firemans Pond. Two new wells were drilled here in 1999, and three more in 2002 (wells 2084–88, pl. 2); all were intended to serve individual houses, construction of which began in 2002. Water levels in five older wells along Prospect Avenue were measured in May 1999 and again in August 2002. The estimated amount of water available for recharge during the 12 months preceding the 2002 measurements was almost identical to that preceding the 1999 measurements (fig. 6). The two westernmost of the older wells, which are close to (and less deep than) the new wells, showed net water-level declines of 3.48 and 3.72 feet from 1999 to 2002 (table 3). In contrast, the two easternmost wells showed net water-level rises of 2.3 to 3.3 feet, and the middle well showed an intermediate net water-level change. A small net water-level rise from June or August 1999 to August 2002 also was observed in a few wells along Terrace Drive, west of Prospect Avenue (appendix B). This observed net water-level decline near five newly drilled deep wells that were not yet in use, over a period when water levels rose in more distant wells, could be plausibly explained by continuous downward flow along the new well bores, although it does not rule out other possible explanations, such as some unknown anomaly in the distribution of recharge or pumpage.

Downward flow undoubtedly takes place within many deep wells, but its magnitude is unknown. Downward head gradients in bedrock near the center of Averill Park are much steeper than in locality H, yet the bedrock remains saturated to within 10 to 15 feet of land surface in many places near the center (wells 56, 176, 177, 292, appendix A; pl. 2). Therefore, downward flow along boreholes seems to have only a small effect on head at shallow depth in bedrock.

The preceding discussion of water-level changes at Averill Park since 1988 can be summarized as follows. Water levels in bedrock wells fluctuate by a few feet in response to fluctuations in precipitation and evapotranspiration, and decline when and where an increase in resident population or commercial activity increases pumpage. Water levels in the upper part of the bedrock may have declined a few feet as a result of continuous small downward flows within deep wells. Small net declines in water levels from 1988–89 to 2002, averaging 0 to 5 feet, were measured in most localities in central and eastern Averill Park. Net declines averaging 15 feet that were measured in western Averill Park demonstrate that withdrawals from wells, plus some continued westward ground-water flow toward points of natural discharge, exceeded recharge to this locality. The magnitudes of net water-level declines from 1988–89 to 2002 were probably not affected substantially by natural fluctuations in precipitation because both sets of measurements were made after relatively dry periods.

Quality of Water in Bedrock

Chemical data collected during 1999–2001 indicated several pronounced contrasts in ground-water quality that affect the suitability of ground water for domestic or commercial use, and also provide clues as to the source and movement of ground water from which areal differences in well yields and recharge rates could be inferred.

Patterns of Chemical-Quality Distribution

Ground water in bedrock beneath Averill Park varies greatly in chemical character. Three principal types of water can be identified (fig. 9): (1) moderately hard, calcium bicarbonate water, which is found in the upper part of the

Table 3. Net change in water level from May 1999 to August 2002 in wells along Prospect Avenue at Averill Park, N.Y.

[All depths are in feet. Well locations are shown on pl. 2.]

	Well number	Well depth	Depth to Water		Net change
			May 1999	Aug 2002	
WEST	28	170	89.78	93.50	3.72 deeper
	27	152	100.55	104.03	3.48 deeper
↕	26	145	96.13	98.07	1.94 deeper
	29	295	125.14	121.85	3.29 higher
EAST	118	> 293	136.64	134.34	2.30 higher

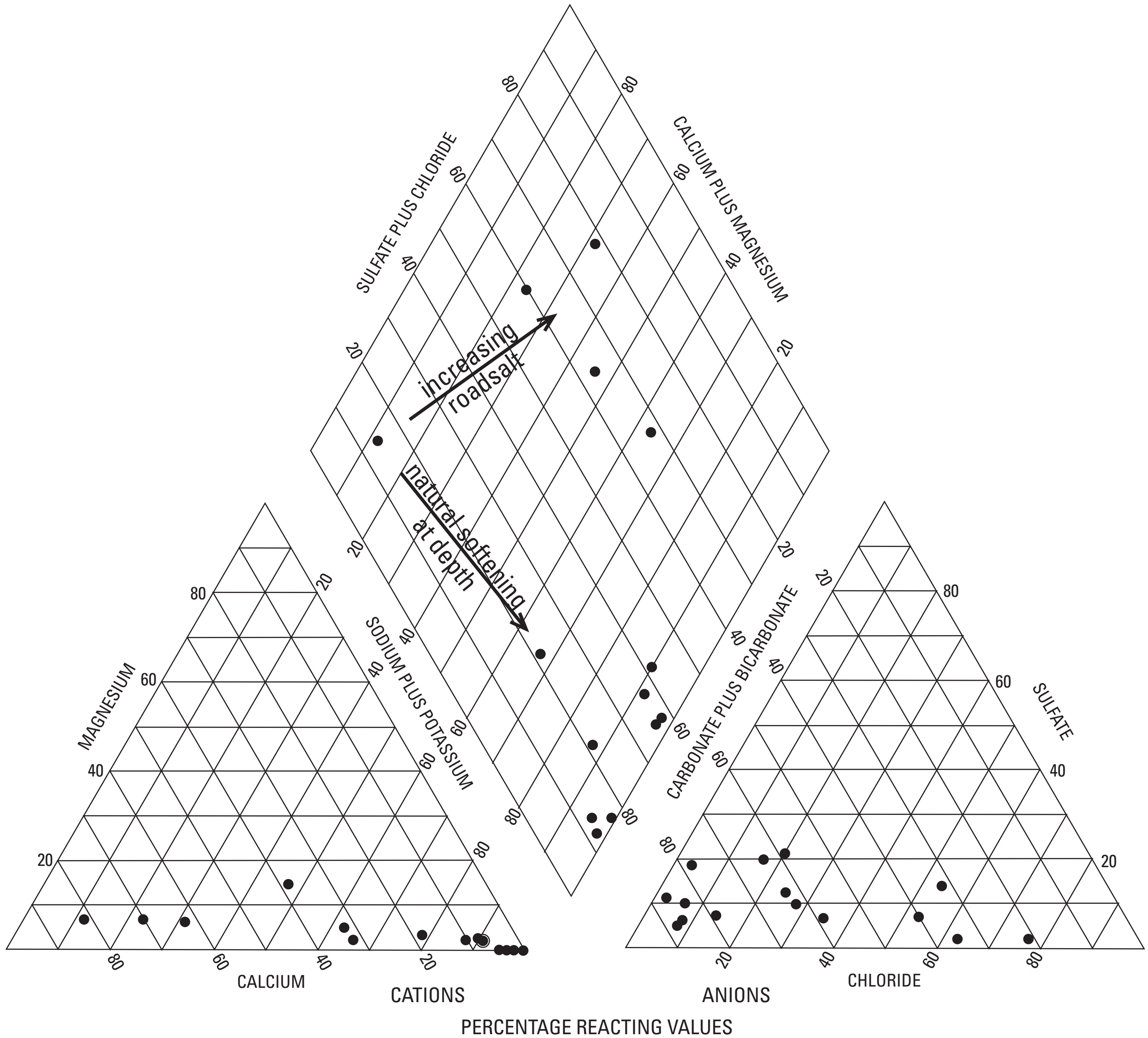


Figure 9. Distribution of major chemical constituents in water samples from 15 wells at Averill Park, N.Y.

bedrock, chiefly in areas of thick till overburden; (2) very soft, sodium-rich alkaline water, which is found at greater depth throughout the area; and (3) very hard, relatively mineralized chloride-rich water, which is found at shallow depths in areas of thin till overburden near major roads. The distribution and significance of these water types are discussed in the next three sections. Most of the analyses used to compile figure 9 were not complete (table 4). Therefore, for 13 wells the concentration of calcium plus magnesium was calculated from hardness (as analyzed or from field measurements in 2001), and the ratio of magnesium to calcium was estimated from results for other wells. For seven wells, one other constituent was estimated, generally by assuming that total anion milliequivalents equal total cation milliequivalents and subtracting measured cations from total anions (or vice versa).

Moderately Hard Water in Shallow Bedrock Beneath Thick Till

Bedrock is mantled by at least 30 feet of till in most localities surrounding the center of Averill Park. The maximum known till thickness is about 190 feet. Nearly all wells less than about 180 feet deep in these localities, and some deeper wells, had water hardness of 80 to 170 milligrams per liter and specific conductance of 300 to 550 microsiemens per centimeter (at 25˚C). Hardness in such wells along the western outskirts (Allen Avenue, Crowley Way, Route 43) was typically 100 to 240 milligrams per liter, and conductance was 600 to 660 microsiemens per centimeter. Chloride concentrations in these localities were typically 3 to 10 milligrams per liter but were as high as 40 to 55 milligrams per liter in a few wells.

The predominant dissolved constituents in this moderately hard water are calcium and bicarbonate ions, derived largely from dissolution of limestone fragments in the till. Hardness is caused chiefly by calcium, along with smaller amounts of magnesium. The alkalinity values in table 4 indicate that bicarbonate concentrations of 120 to 250 milligrams per liter are common near Averill Park (bicarbonate concentration = alkalinity concentration × 1.22). Hardness in water is not particularly objectionable for domestic uses until it exceeds about 100 milligrams per liter (Hem, 1985), and relatively few Averill Park property owners have chosen to soften this type of water. The heating of water decreases the solubility of carbon dioxide, which in turn can result in the deposition of calcium or magnesium carbonate (often referred to as “lime”) in water heaters, furnace coils, and hot-water pipes, and in the accumulation of sand-size calcium or magnesium carbonate crystals in washing-machine and faucet screens. Carbon dioxide also can evolve when water is subject to strong vacuum, such as on the suction side of a pump, or when ground water containing abundant carbon dioxide comes in contact with the atmosphere and equilibrates to the concentration of carbon dioxide therein.

Calcium or magnesium carbonate has precipitated within the plumbing system in unusually large amounts in several wells at Averill Park. For example, at well 115 copious amounts of sand-size carbonate crystals accumulated in a wound-string cartridge filter between the submersible pump and the pressure tank, carbonate precipitation caused the pump to fail after 7 years, and the furnace coil required acid treatment every 4 to 6 months to alleviate clogging. Carbonate crystals accumulated on filters installed after the pressure tank at wells 112 and 36. Carbonate precipitation forced replacement of the submersible pump at well 8 every 18 months from 1981 through 2000, clogged the furnace coil at well 143 despite several acid treatments, and formed an inch-thick coating on the submersible pump in well 2113 after 14 years of use. Water from well 2113 had a hardness of 137 milligrams per liter, but the other wells mentioned had water hardness of only 17 to 50 milligrams per liter (as measured at the pressure tank or a sink, presumably after some calcium carbonate had already precipitated). All but one of these five wells is deeper than 180 feet. Accordingly, the unusually abundant carbonate precipitation in these wells may result from the mixing of waters from two sources—water derived from shallow fractures that has a moderately high calcium concentration and high alkalinity, and water derived from deeper fractures that has somewhat higher alkalinity but a low calcium concentration (as discussed in the next section). Such a mixture could be supersaturated with respect to calcium carbonate (Drever, 1988, p. 63).

Soft Water in Deep Bedrock

Nearly all wells in several areas of thick till west and south of the center of Averill Park are more than 180 feet deep and yield soft water (0 to 50 milligrams per liter hardness). These areas include Orient Avenue and Burden Lake Road, more than 600 feet south of Route 43, also Marcy Avenue, Terrace Drive, Allen Avenue, Lake Avenue, and Old Route 66 north of Lake Avenue. A few older wells less than 180 feet deep in these localities yield water with greater hardness (65 to 155 milligrams per liter; wells 26, 27, 202, 2079, appendix A). Water from most wells near and east of the center of Averill Park, regardless of till thickness, is at least moderately hard, but some deep wells yield soft water. The soft water in all these localities is not characterized by consistently higher or lower chloride concentrations or specific conductance than the hard water from nearby wells. The few relatively complete chemical analyses of soft water from deep wells (table 4) are consistent, however, in reporting far more sodium than chloride, greater alkalinity than in shallow wells, and a pH generally between 8.0 and 9.6. Similar geochemical conditions prevail in the town of Poestenkill, 1 to 5 miles north of Averill Park, where water from 14 wells, some finished above bedrock, contained substantial calcium and magnesium concentrations (and therefore considerable hardness), but water from six wells contained far more sodium than calcium, and three others contained less than 5 milligrams

Table 4. Chemical analyses of ground-water samples collected from 21 wells at Averill Park, N.Y., 1978–2001.

[All values are in milligrams per liter except as noted. mg/L, milligrams per liter; --, no data, <, less than. Well status: N, newly drilled; I, in use. Source of analysis: N, New York State Department of Health; R, Rensselaer County Health Department.; P, private laboratory; W, water-treatment company. Abbreviations: µS/cm, microsiemens per centimeter at 25 degrees Celsius; $CaCO_3$, calcium carbonate. Well locations shown on pl. 2]

Well no.	Street (fig. 1)	Well depth (feet)	Date sampled	Well status	Turbidity (units)	pH (units)	Alkalinity	Hardness as $CaCO_3$	Sodium	Potassium	Calcium	Magnesium	Barium	Iron [a]	Manganese	Chloride	Sulfate	Nitrate (as N)	Fluoride	Total dissolved solids	Specific conductance (µS/cm)	Source of analysis
3A	N.Y. Route 43	245	3 Mar 99	I	--	7.4	194	692	140	1.6	244	17	7.7	<0.05	1.38	515	16	0.6	<0.2	1,220	--	P
37	Houston Way	400	13 Mar 87	N	35	9.6	184	2	97.5	--	--	--	<0.1	2.22	0.05	--	--	--	0.28	--	--	P
37	Houston Way	400	6 Mar 00	I	4.1	9.6	177	<2	--	--	--	--	--	0.12	0.01	11	20	<0.2	--	--	400	P
39a	Crystal Lake Rd.	155	28 Dec 01	I	0.1	7.7	157	64	59.5	--	--	--	--	0.10	0.20	5	36	<0.2	<0.2	--	360	P
79	Johnnycake Lane	190	19 May 93	I	--	7.4	138	--	--	--	--	--	--	0.05	--	--	--	--	--	397	--	R
131	N.Y.Route 43	190	2 Mar 78	I	43	6.9	160	191	207	1.7	156	36	--	9.70	0.80	195	10	0	--	--	1,000	W[b]
134B	Old Route 66	240	18 Nov 86	I	--	--	--	--	36.6	--	--	--	--	--	--	296	--	0.3	--	--	--	R
138a	N.Y. Route 43	400	24 Oct 84	I	--	--	--	--	74	--	--	--	--	--	--	368	--	0.3	--	--	--	R
138a	N.Y. Route 43	400	Oct 98	I	--	7.5	--	44	--	--	--	--	--	--	--	--	--	--	--	500	--	W
161	Johnnycake Lane	120	16 Jun 89	I	--	7.0	--	297	40.2	--	--	--	--	--	--	109	--	0.9	--	--	--	R
176A	N.Y. Route 43	443	10 Jul 98	I	6	8.8	--	48	195	--	--	--	--	0.09	0.00	--	--	1	--	243	--	W
183	N.Y. Route 43	95	19 Jan 87	I	--	--	--	--	--	--	--	--	--	0.18	0.04	530	--	1.8	--	--		R
190	Crystal Lake Rd.	--	18 Sep 01	I	0.6	8.2	148	23	--	--	--	--	--	0.06	0.04	18	15	<0.2	--	--	360	P
[c]	Crystal Lake Rd.	--	18 Sep 01	--	0.25	7.3	34	40	--	--	--	--	--	0.07	0.02	41	15	<0.2	--	--	230	P
204A	Old Route 66	340	10 Aug 98	I	--	9.4	226	9	116	--	--	--	--	<0.05	0.02	--	--	<0.2	--	--	--	P
221a	Beach Lane	265	7 Aug 00	I	8.3	8.0	104	37	--	--	--	--	--	0.29	0.05	43	12	<0.2	--	212	370	P

Table 4. Chemical analyses of ground-water samples collected from 21 wells at Averill Park, N.Y., 1978–2001.—Continued

[All values are in milligrams per liter except as noted. mg/L, milligrams per liter; --, no data, <, less than. Well status: N, newly drilled; I, in use. Source of analysis: N, New York State Department of Health; R, Rensselaer County Health Department.; P, private laboratory; W, water-treatment company. Abbreviations: µS/cm, microsiemens per centimeter at 25 degrees Celsius; $CaCO_3$, calcium carbonate. Well locations shown on pl. 2]

Well no.	Street (fig. 1)	Well depth (feet)	Date sampled	Well status	Turbidity (units)	pH (units)	Alkalinity	Hardness as $CaCO_3$	Sodium	Potassium	Calcium	Magnesium	Barium	Iron [a]	Manganese	Chloride	Sulfate	Nitrate (as N)	Fluoride	Total dissolved solids	Specific conductance (µS/cm)	Source of analysis
289A	Burden Lake Rd.	503	16 Sep 88	N	--	9.4	270	4	--	--	<2	--	<0.1	0.97	0.04	--	--	--	--	537	--	P
291a	Burden Lake Rd.	400	30 Jan 95	I	--	7.3	--	154	--	--	--	--	--	0.40	--	--	--	--	--	520	--	W
2060	Eastern Union Turnpike	380	7 Jul 97	N	4.5	7.5	--	280	15.3	--	--	--	--	0.32	0.40	5	34	<0.2	<0.2	332	--	P
2077a	Burden Lake Rd.	142	23 Mar 94	I	3.3	--	--	--	106	<0.5	3.5	<0.5	0.03	0.21	0.02	--	--	---	--	--	--	N
2081	Marcy Ave.	290	23 Oct 77	N	8	8.9	210	10	149	--	--	--	--	0.43	0.03	67	33	<0.2	0.22	447	720	P
2082	Marcy Ave.	210	27 Oct 97	N	15	8.8	183	26	115	--	--	--	--	1.05	0.04	51	34	<0.2	<0.2	340	560	P
2083	Prospect Ave.	350	30 Oct 97	N	16	8.0	198	28	128	--	--	--	--	0.42	0.05	38	60	<0.2	<0.2	403	620	P
2084	Prospect Ave.	170	19 May 99	N	0.4	8.0	195	38	--	--	--	--	--	<0.05	0.01	48	67	<0.2	--	--	670	P

[a] High iron values from wells with turbid water may reflect leaching of iron from suspended sediment as a result of acid used to preserve water sample.

[b] Alkalinity value converted from bicarbonate of 195 mg/L. This analysis is internally inconsistent: the sum of anions does not equal the sum of cations in milliequivalents per liter.

[c] Water from Crystal Lake, same house as well 190.

per liter of calcium but were not analyzed for sodium (LaFleur and Randall, 1995). Those nine wells ranged from 200 to 700 feet in depth; alkalinity generally exceeded 185 milligrams per liter as $CaCO_3$, and pH consistently exceeded 9.0.

The fact that some deep wells yield moderately hard water, whereas other equally deep wells nearby yield soft water, can be explained by differences in the depths at which the wells intersect water-yielding fractures. The wells that yield moderately hard water probably obtain that water from the upper part of the bedrock, either because these wells do not intersect fractures at greater depth, or because downward flow within the well bore recharges deeper fractures with water that entered the wells from the upper part of the bedrock. The fact that nearly all wells in several areas of thick till are deeper than 180 feet and yield soft water implies that local recharge through the thick till is small or is subject to rapid natural softening through cation exchange in the bedrock.

Water hardness at several properties was lower in 1999–2000 than reported earlier (table 5). The decrease in hardness in at least four wells coincided with an increase in well depth and, thus, could be attributed to a new source of soft water from deep fractures; the decreased hardness in the other wells might be attributed to water-level declines that dewatered shallow fractures that had yielded water previously. This interpretation is consistent with the observation that the static water levels in 2002 were below the bedrock surface at all but one of the 14 properties listed in table 5, but does not explain the apparent absence of hard water from modern recharge. An alternative hypothesis is that ground-water circulation in bedrock before wells were drilled around Averill Park may have taken place largely within about 180 feet of land surface, and that the capacity of bedrock in this zone of active circulation to soften water by cation exchange may have been depleted over the millennia through continual exposure to recharge that contained appreciable amounts of calcium and magnesium from the overlying till. In recent decades, deep wells may have penetrated a zone in which water circulation had previously been minimal and the ion-exchange capacity was undiminished. As soft water is withdrawn from this zone, any modern recharge that replaces it apparently is altered through the continued dissolution of carbonate minerals, a process that increases alkalinity and pH, and is softened through cation exchange. One implication of this hypothesis is that hardness should eventually increase as the ion-exchange capacity of the deep bedrock becomes depleted.

Very Hard, Mineralized Water near Highways Where Depth to Bedrock is Slight

Depth to bedrock near the center of Averill Park is slight (0 to 30 feet below land surface), and discontinuous outcrops of bedrock are common (pl. 1). Bedrock is equally close to land surface in a small area along Eastern Union Turnpike. The extent of these areas of shallow depth to bedrock is depicted in figure 2. Ground water in these areas is characterized by the following chemical characteristics:

- specific conductance is typically between 1,000 and 2,500 microsiemens per centimeter,
- hardness is typically between 250 and 425 milligrams per liter, but as high as 680 to 1,500 milligrams per liter in some wells,
- chloride concentrations have varied widely but exceeded 100 milligrams per liter in many wells, exceeded 500 milligrams per liter in a few wells, and increased from the 1960s to the 1980s or 1990s in most wells from which repeated samples were analyzed.
- sodium concentrations, available from only four scattered wells (table 4), are much lower than chloride concentrations.

This chemical signature is attributed to infiltration of salt-laden highway runoff in winter. Concentrations of chloride in winter runoff from streets and highways can reach 1,000 milligrams per liter or more (Kappel and others, 1986, fig. 6; Granato, 1996, table 3). Exchange of sodium ions in this saline water with calcium on the surfaces of soil particles or bedrock fractures greatly increases water hardness and depletes dissolved sodium relative to chloride. The restriction of this chemical signature to localities of shallow bedrock implies that, in areas of thick till, water that infiltrated since the start of intensive road-salt applications in the 1960s has not yet reached bedrock. Accordingly, the rate of recharge to bedrock must be slower in areas of thick till than in areas of thin, discontinuous till.

The distributions of specific conductance values and chloride concentrations are depicted in figures 10 and 11, respectively; these maps indicate that conductance values greater than 1,000 microsiemens per centimeter, and chloride concentrations greater than 100 milligrams per liter, are confined to the area of shallow depth to bedrock (0 to 30 feet, fig. 2). The spread of these contours farther to the south and west of Route 43 and Old Route 66 than to the north and east is consistent with the predominantly southward and westward directions of ground-water flow inferred from the water-level measurements (pl. 3).

Water in deep wells within the areas of shallow bedrock is generally characterized by lower specific conductance, hardness, and chloride concentrations than water in nearby shallow wells (but not as low as in deep wells in areas where till thickness exceeds 30 feet). This pattern can be attributed to the blending of salty recharge along streets in areas of shallow bedrock with the softer water that is typically found at depths below 180 feet throughout Averill Park and is presumed to have infiltrated far from streets, or before road salting became common.

Water that is very hard as a result of road salting contains an abundance of calcium with lesser concentrations of sodium and magnesium. Deposition of calcium and magnesium

Table 5. Evidence of decrease in water hardness at several properties at Averill Park, N.Y.

[µS/cm, microsiemens per centimeter at 25° Celsius; ft, feet; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate. A dash (--) denotes no data available]

Well number	Street (fig. 1)	Well depth (feet)	Specific conductance (µS/cm)	Hardness as $CaCO_3$ (mg/L)	Date sampled	Remarks
A. Decrease as a result of increased depth						
34	Johnnycake Lane	110?	700	265	9 Apr 01	Old well, small yield
34A	Johnnycake Lane	320	490	68	9 Oct 02	New well August 2002
203	Old Route 66 (north of Lake Avenue)	400	450	17	21 Jul 00	Water reported softer after well deepened from 147 ft in 1986
219	Beach Lane	143	280	120	24 Jul 02	Located 80 ft from well 220
220	Beach Lane	500	360	26	24 Jul 02	Located 80 ft from well 219
302	Johnnycake Lane	125	700	111	14 Apr 01	Old well, small yield
302A	Johnnycake Lane	380	470	43	11 Sep 02	New well May 2002
B. Apparent decrease over time in a well of constant depth						
28	Prospect Avenue	170	--	170	24 Nov 87	--
		--	680	77	24 Oct 99	--
57	Old Route 66 (south of Lake Avenue)	220	610	43	22 Jul 02	Hardness test 1964 after well was deepened; softener needed. Softener disconnected 1988, no difference in hardness noticed.
112	Burden Lake Road	250	1,040	17	11 Nov 99	Water tested 1986, "very high in lime," a "lime-removal device" (not a softener) installed, later replaced by filter to capture small carbonate crystals.
120	Burden Lake Road	390	750	0	31 Oct 99	Well was deepened from 219 ft in 1976, softener was installed before 1983, no longer used in 1999.
122	Orient Avenue	335	560	51	Nov 99	Softener installed 1985, discontinued 1993 due to mechanical problems.
148	Prospect Avenue	220?	560	17	4 Dec 99	1967–88, gritty sand ("lime"?) in washing-machine screen, so installed filter on water line. 1999, filter no longer in use, no sand in washer screen.
195	Old Route 66 (north of Lake Avenue)	200	480	68	16 Jun 02	Softener installed 1968 on old well 130 ft deep, primarily to remove iron; new well 1974, softener still in use in 2002.
248	Old Route 66 (north of Lake Avenue)	400	690	8	15 Jun 02	Softener installed sometime after 1972, still in use 2002.
277	Pine Avenue	220	730	34	2 Jun 02	Well deepened from 148 ft in 1970; new, deeper pump 1999. Water softer since 1999, has slight sulfur, no iron stains now.
313	Terrace Drive	560	670	0	21 Aug 99	Softener 1974 when well was drilled, removed 1986 when serviceman said not needed.

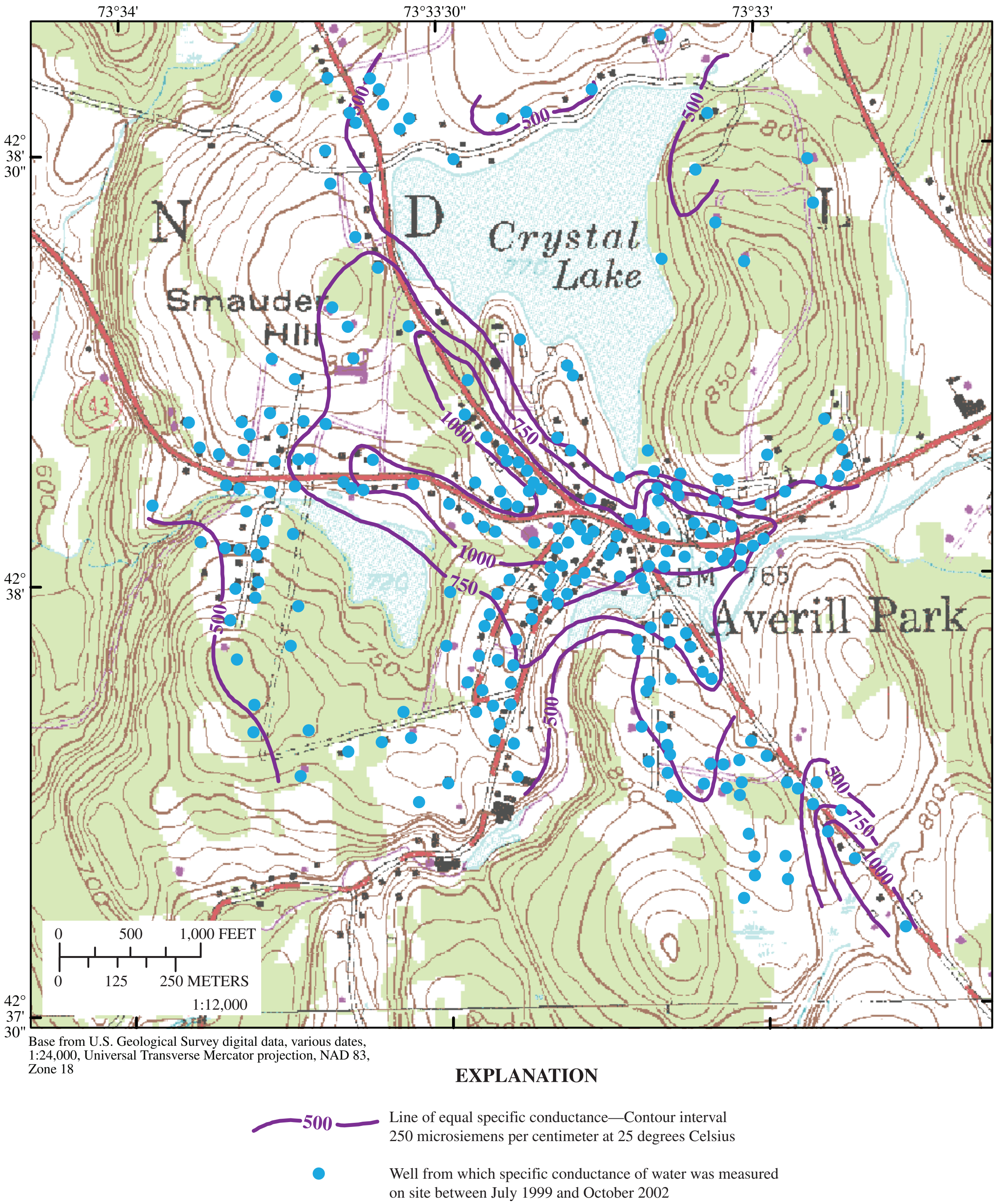
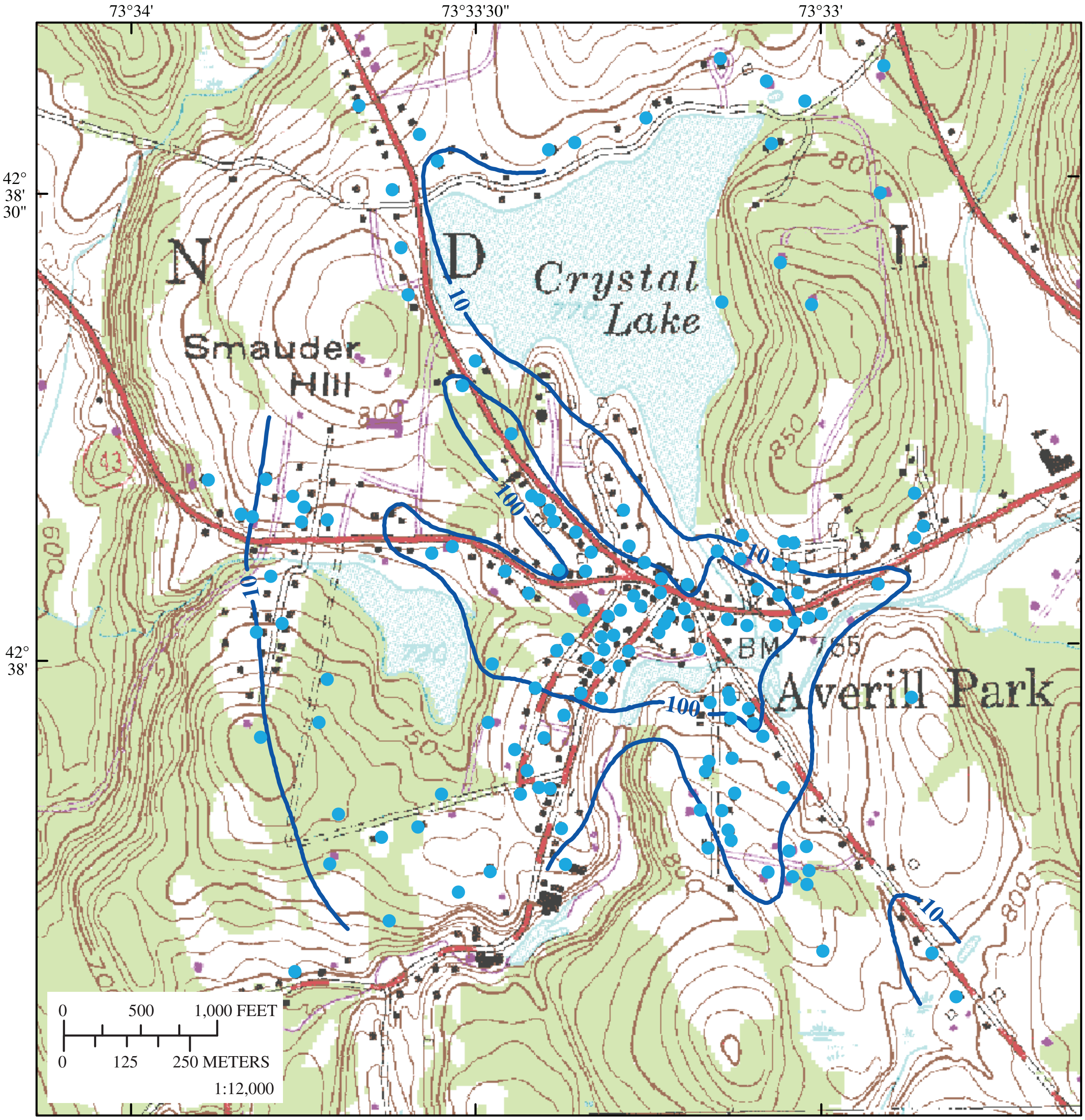


Figure 10. Specific conductance of water from wells at Averill Park, N.Y., as measured between July 1999 and October 2002.



Base from U.S. Geological Survey digital data, various dates, 1:24,000, Universal Transverse Mercator projection, NAD 83, Zone 18

EXPLANATION

100 — Line of equal chloride concentration—Contours at 10 and 100 milligrams per liter

● Well from which water sample has been analyzed for chloride—Dates of sampling vary, but 90 percent were between 1970 and 2001. For wells from which multiple analyses were available, the most recent was selected

Figure 11. Chloride concentrations in water from wells at Averill Park, N.Y., as measured between 1964 and 2001.

carbonates (“lime”) can occur when the water is heated or when the ambient pressure is decreased, but does not increase in proportion to hardness because bicarbonate is generally less abundant than chloride plus sulfate. Furthermore, many wells are equipped with softeners to remove hardness. Accordingly, deposition of carbonates is not widely reported to be a problem in homes with very hard water.

Three wells have relatively high hardness that seems unrelated to highway salting and might thereby provide clues as to the geochemical evolution of ground water. Their depths, sampling dates, specific conductance, and hardness are listed in the table below.

All three wells are at least 850 feet from major roads. Well 38 is in a sparsely populated locality; wells 2060 and 2112 are in undeveloped localities 600 feet or more from any other well. (Well 38 is only 200 feet from Crystal Lake Road, but road salting along that narrow residential street may be slight, till thickness exceeds 30 feet, and no other well produced water with a hardness greater than 150 milligrams per liter.) All three wells had been used much less than other wells at Averill Park prior to sampling. These circumstances suggest that the hardness of water from these wells might be representative of natural recharge to bedrock through thick till, whereas the hardness (50 to 240 milligrams per liter) of water from most wells that tap the upper part of bedrock in long-settled areas with thick till might reflect modification of local recharge by ion exchange, or by dilution with softer water from greater depth.

Localized Nuisance Conditions

Three other water-quality conditions that are not hazardous to human health but have caused inconvenience to several well owners at Averill Park are hydrogen sulfide, suspended clay or silt, and suspended or dissolved iron and manganese. These nuisance conditions are discussed in turn in the following sections.

Hydrogen Sulfide (“Sulfur Water”)

Hydrogen sulfide (H_2S) is a flammable gas that is highly soluble in water and gives water a distinctive “rotten-egg” odor that can be detected by most people at concentrations of only a few tenths of a milligram per liter (Hem, 1985, p. 117). Hydrogen sulfide can form through several bacterially mediated processes, including reduction of sulfate and, in the absence of oxygen, decomposition or anaerobic oxidation of organic matter (Chapelle, 1993).

About 30 percent of well owners at Averill Park acknowledge the presence of hydrogen sulfide in their well water but generally describe the condition as slight, temporary, or infrequent. The only locality in which most well owners report continuous strong sulfur odor and (or) have installed water-treatment equipment to remove sulfur is on Crystal Lake Road along the north shore of Crystal Lake (fig. 12). Most of the homeowners in this locality who did not report a problem with sulfur water use the lake rather than wells for their domestic supplies.

Well number	Date drilled	Depth (feet below land surface)	Casing length (feet)	Specific conductance (microsiemens per centimeter at 25°Celsius)	Hardness, as calcium carbonate, in milligrams per liter	Date sampled	Location and remarks
38	1967	150	45 (estimated)	910	427	August 8, 2002	Side of drumlin near east shore of Crystal Lake. House unoccupied for at least 1 year prior to substantial use on date sampled. Hardness measured by field kit.
2060	June 17, 1997	380	43.5	not measured	288	July 7, 1997	Hilltop east of Eastern Union Turnpike. Hardness measured by private laboratory.
2112	Mar 29, 2001	400	133	625	256	June 4, 2003	Hilltop (drumlin) west of Eastern Union Turnpike. House first occupied July 2002. Hardness measured by field kit.

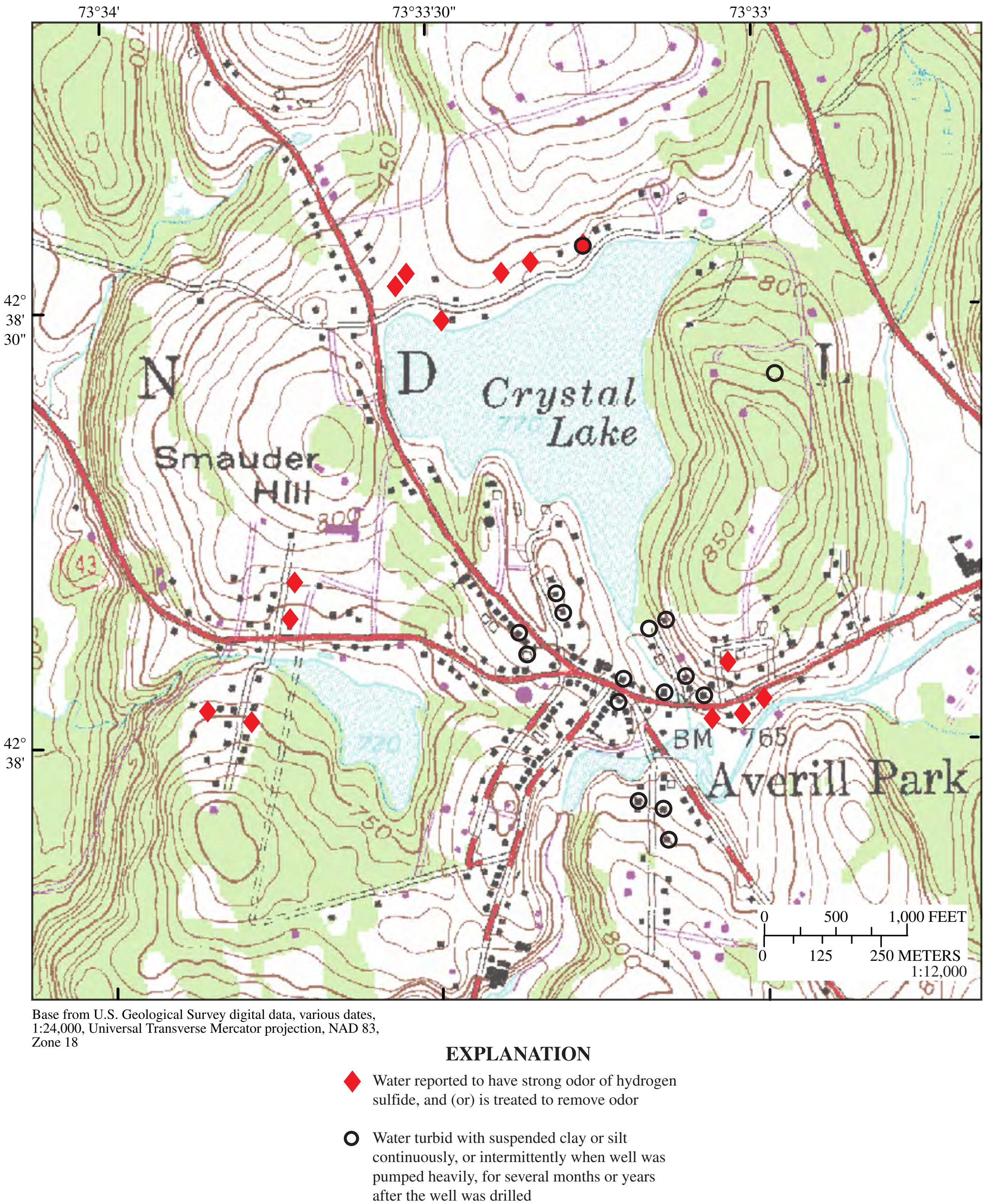


Figure 12. Distribution of wells at Averill Park, N.Y., whose water contains high concentrations of hydrogen sulfide or is turbid.

Suspended Clay or Silt

Several wells near and north of the center of Averill Park yielded water containing considerable suspended fine-grained sediment or turbidity for several years after the well was drilled, some at all times, and some only when heavily pumped. The distribution of wells that are, or were, affected by prolonged turbidity is shown in figure 12. Bedrock near Averill Park is generally described by well drillers as alternating red and gray shale. Most of the affected wells produced pink sediment derived from the red shale, but a great majority of the wells that penetrate red shale have never yielded turbid water, and a few wells have been reported to yield gray, silt-laden water. Apparently, a few rock layers consist of soft, weakly cemented shale that is easily eroded by flowing ground water. One owner reported that 60 feet of mud accumulated in his well in 3 months. The pumps in three other wells, all near Barzen Avenue, failed after a few weeks, months, or years and could not be pulled; whether the pumps simply became buried in mud, or whether chunks of rock along the well bore collapsed and lodged against the pumps, is unknown.

Iron and Manganese

The most widespread displeasing aspect of ground-water quality that occurs naturally in the northeastern United States is dissolved iron and manganese. These constituents can readily dissolve in water that lacks dissolved oxygen—a common characteristic of ground water that follows a long, deep flow path or that is exposed to organic matter near land surface in recharge areas or within the aquifer. Typically, iron- or manganese-bearing ground water is clear when pumped from the well or drawn from the faucet, but when it is exposed to oxygen in the air, the iron and manganese form insoluble oxides that stain plumbing fixtures and laundry and form a surface sheen on standing water.

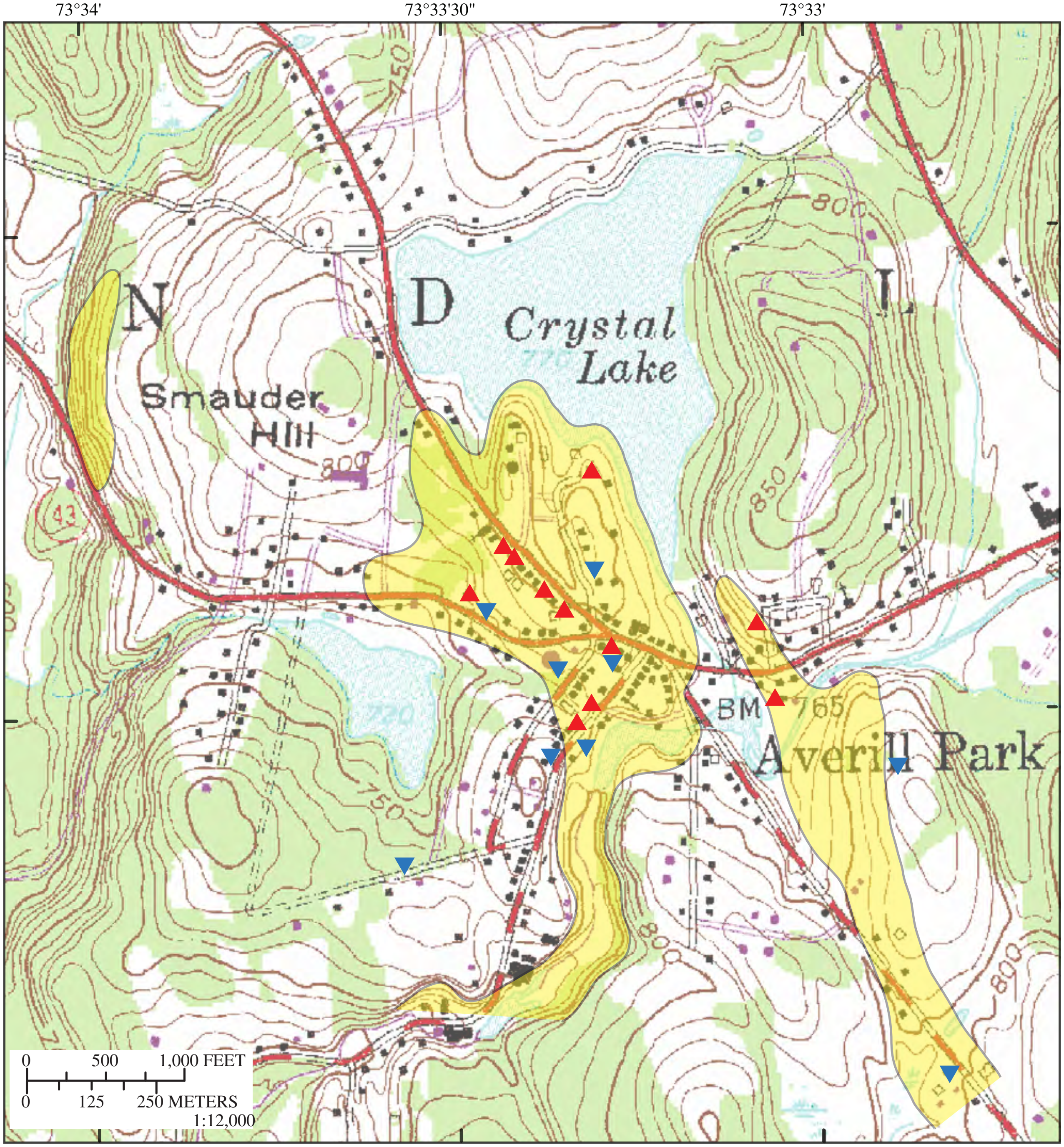
Severely troublesome concentrations of dissolved iron and manganese are not widespread at Averill Park. Some residents reported iron staining of toilets, and a few reported a brown color in water after adding bleach, generally in water that was moderately hard and derived from the upper part of the bedrock, but almost no one reported staining of laundry. Suspended fine particles of oxidized iron and manganese are present in the water at 11 homes, however. These 11 homes have wound-string sediment filters installed after the pressure tank to capture suspended sediment; the filters become heavily coated in a few months with a sludge that is extremely fine grained and black or dark brown (rather than the gray, gray-green, or red typical of the local bedrock). This sludge is particulate manganese and (or) iron oxide that precipitated inside the well, pump, or pressure tank. All of the 11 homes known to experience this condition (appendix A) are within the area of shallow depth to bedrock near the center of Averill Park (fig. 13), and well water at all but three of these homes had specific conductance values greater than 1,000 microsiemens per centimeter and (or) hardness values greater than 340 milligrams per liter. No residents reported staining of laundry before the filter was installed, however. Chemical analyses of well water from this area, and from the smaller area of shallow bedrock near Eastern Union Turnpike, indicated combined iron and manganese concentrations of 0.3 to at least 2 milligrams per liter in six of eight wells sampled. Those analyses were performed by private laboratories or water-treatment technicians, and may have included suspended particulate matter as well as dissolved iron or manganese. The suspended particulate manganese or iron in water is probably precipitated within the well or plumbing when oxygen-free water is mixed with oxygenated water from a different fracture system or is exposed to air in a pressure tank.

The foregoing sections have described the distribution and interaction of three principal types of ground-water quality in bedrock at Averill Park. Recharge in areas remote from major highways generates moderately hard water in the upper part of the bedrock. Shallow ground water near major highways in areas of thin overburden is much harder and more mineralized as a result of infiltration of salty winter runoff from the highways and subsequent cation exchange; furthermore, water from some wells in these areas contains abundant suspended particles of oxidized iron and manganese. Ground water that has penetrated to depths greater than about 180 feet is much softer than ground water at shallower depths nearby and is characterized by high alkalinity and high pH. Almost all wells in some localities of thick till yield soft water. About 30 percent of the wells at Averill Park produce hydrogen sulfide, generally intermittently and in only trace amounts. A few scattered wells have yielded persistently turbid water containing clay or silt derived from the disintegration of weak rock layers.

The relation of hardness to depth is used in the next section as a basis for interpreting the relation of well yield to well depth. The spatial distribution of water quality is cited farther on as evidence for inferred spatial differences in rates of recharge to bedrock.

Quantity of Water Obtainable from Bedrock

Bedrock aquifers are potential sources of water throughout Rensselaer County (Cushman, 1950), but the amounts of water available are limited by two constraints: well yield and aquifer yield. Well yield (the maximum rate at which water can be withdrawn from an individual well) is typically only a few gallons per minute and is chiefly a function of the water-transmitting properties of the bedrock, particularly the size and distribution of fractures through which all water movement takes place. Aquifer yield (the maximum rate at which water can be withdrawn from the bedrock aquifer through multiple wells in a given locality)



Base from U.S. Geological Survey digital data, various dates, 1:24,000, Universal Transverse Mercator projection, NAD 83, Zone 18

EXPLANATION

Depth to bedrock generally less than 30 feet

Well; filter accumulates black, very fine-grained sediment that is likely to be manganese and (or) iron precipitate

Well; water contained iron and manganese in concentrations greater than 0.3 milligrams per liter . Concentrations may represent suspended as well as dissolved iron and manganese. Some wells sampled when newly drilled

Figure 13. Distribution of wells at Averill Park, N.Y., that yield water containing abundant suspended or dissolved manganese and (or) iron.

can become a matter of concern where many wells are close to one another, as in large housing developments or in hamlets such as Averill Park. Aquifer yield is a function of the amount of water stored in the bedrock in the locality of interest, and the rate at which water enters (recharges) the bedrock, chiefly from infiltrating precipitation. Collective withdrawals from bedrock in excess of aquifer yield can result in lowered water levels and, thus, decreased well yield in that locality. This report is directed primarily to estimation of recharge rate and aquifer yield, but the following documentation of well yield at Averill Park may prove helpful in future studies that seek to explain differences among recharge rates estimated for several localities.

Well Yields

Yields reported for wells at Averill Park by well drillers ranged from 0.5 to 25 gallons per minute; most were near the low end of that range. Written records of the initial yield of many older wells were unavailable, but the owners' reported experiences enabled the yield of such wells to be deemed either adequate, or less than adequate, for domestic use. The following paragraphs summarize the geographic distribution of well yields within the study area.

Yields of wells near the center of Averill Park and north along Old Route 66 and Crystal Lake Road: Median reported yield was about 2.3 gallons per minute. Yields ranging from 0.5 to 3 gallons per minute were reported for 57 wells, and yields of 8 more wells were assumed to be in this range because they were deemed less than adequate, whereas 28 wells were reported to yield more than 3 gallons per minute. Of the 19 wells whose yields were unknown but adequate, at least 9 yields could have been less than 3 gallons per minute because enough water was stored in the casing to ensure that a yield of 0.5 to 3 gallons per minute would adequately supplya typical household[3].

Yields of wells west and southwest of the center of Averill Park: 42 of 74 wells in use in 2002 were reported to yield more than 3 gallons per minute when drilled. The yields of 21 other wells in this area were unknown but deemed adequate. Only six wells in this area were reported to have yields of 3 gallons per minute or less, and the yields of five others were less than adequate. Median reported yield was 6 gallons per minute.

Yields of wells east of the center of Averill Park, along and somewhat north of Route 43: Few well yields in this area were known, but nearly all wells were deemed adequate for domestic use. Of 34 wells, 30 were less than 270 feet deep, and 26 were less than 200 feet deep. Only three unknown well yields were deemed less than adequate.

Yields of wells elsewhere around Averill Park: Well yields and depths were less easily characterized because few written records were available and, perhaps, because the yields that were reported generally reflected conditions that prevailed when the wells were drilled, without any interference from wells drilled nearby more recently. Also, a well driller who believes that the yield and depth of a newly completed well are adequate to meet the customer's needs may report a yield larger than the actual measured yield to help the customer meet the demands of a lending institution; two examples of this were documented during this investigation.

In summary, most wells at Averill Park seem to be adequate for domestic use, but well yields less than 3 gallons per minute predominate near and north of the center, whereas yields greater than 3 gallons per minute predominate west and southwest of the center.

Possible Effect of Bedrock Lithology on Well Yield

Average yields of domestic wells can vary from one type of bedrock to another, as documented elsewhere in New York by Frimpter (1972) and Perlmutter (1959). For example, the bedrock fractures in which ground water is stored are typically longer and wider in hard, massive sandstone than in soft, easily deformed shale (Coates, 1971). The bedrock at Averill Park seems to be more permeable to the west and southwest (localities H and E, fig. 4) than elsewhere, as indicated by three factors—the greater frequency of wells with yields exceeding 3 gallons per minute, the greater uniformity in altitude of water levels among nearby wells of differing depths, and the consistency of large declines in water levels from 1988 to 2005 throughout these localities. Scattered outcrops in the areas of thin overburden (fig. 2), and brief drillers' logs of about 25 wells, provide some information on bedrock lithology at Averill Park but are insufficient to prove that a contrast in lithology coincides with the apparent contrast in permeability. Most drillers' logs report penetrating only alternating red and gray shale, although four wells along Terrace Drive and two wells east of Old Route 66 and Eastern Union Turnpike penetrate grit or hard sandstone interbedded with gray shale.

Possible Effect of Water-Level Declines on Well Yield

The water-level declines that have occurred in some localities, as described earlier, could adversely affect well yield by dewatering some shallow fractures that formerly contributed to well yield, and by decreasing the maximum potential drawdown in the well when it is pumped. Many studies in northeastern North America have concluded that

[3] For example, consider a deep well of 6-inch diameter that contains 200 feet of water (300 gallons) between the static water level and the pump. This stored water is ample to satisfy the average demand of a typical family, 220 gallons per day (55 gallons per day per person, as documented in appendix E). If well yield is only 0.5 gallon per minute at maximum drawdown, or 0.25 gallon per minute at median drawdown, daily inflow could easily average 367 gallons (0.25 gallon per minute multiplied by 1440 minutes per day), more than enough to replenish the storage required to supply the average daily demand.

the size and abundance of fractures typically decrease with depth below the bedrock surface (Randall and others, 1988; Morin and others, 2000). A study in New Hampshire reported that, although the yield of any given well might (or might not) increase as the well is deepened, the yield per foot of depth is likely to decrease with increasing depth (Moore and others, 2002, p. 29). LaFleur (1989) hypothesized that a water-level decline below the bedrock surface might cause a decrease in well yields that is large in proportion to the magnitude of the water-level decline because (1) the upper part of the bedrock, which is the most highly fractured and most permeable part, can no longer contribute water to wells, and (2) the hydraulic conductivity of the dewatered bedrock might be permanently diminished through subsequent compaction of thin fractures and (or) the growth of mineral oxides along those fractures. Water levels are below the bedrock surface in most of Averill Park, as shown in figure 14. The contours in figure 14 are based on (1) the depth to static water level and depth to bedrock at individual wells, and (2) superposition of water-level contours (pl. 3) on bedrock-surface contours (pl. 1). LaFleur's hypothesis that a potentiometric surface below the bedrock surface detracts from well yields seems plausible, but the 2002 data provide little support for a simple correlation of apparent dewatering with well yield, as discussed in appendix F.

Potential for Augmenting Well Yield by Deepening the Well

The yield of any well might be increased by drilling deeper. The probability of intersecting additional water-yielding fractures cannot be calculated directly from the well records at Averill Park, however, because those records generally do not include measurements of yields from successive depth increments that could be used to define a relation between yield and depth. The low yields of the deepest wells, typically less than 3 gallons per minute, merely indicate that fractures are poorly developed at any depth at these locations.

The relation of well yield to well depth at Averill Park was quantified through an analysis of records of all wells more than 200 feet deep for which yield and water-hardness measurements were available. The wells were classified into two yield categories—2 gallons per minute or less, and 2.2 to 10 gallons per minute. As explained in the earlier section "Patterns of chemical-quality distribution," wells less than about 180 feet deep typically yield moderately hard water, whereas many of the deeper wells yield soft water. Accordingly, wells with yields of 2.2 to 10 gallons per minute were further classified according to the following assumptions:

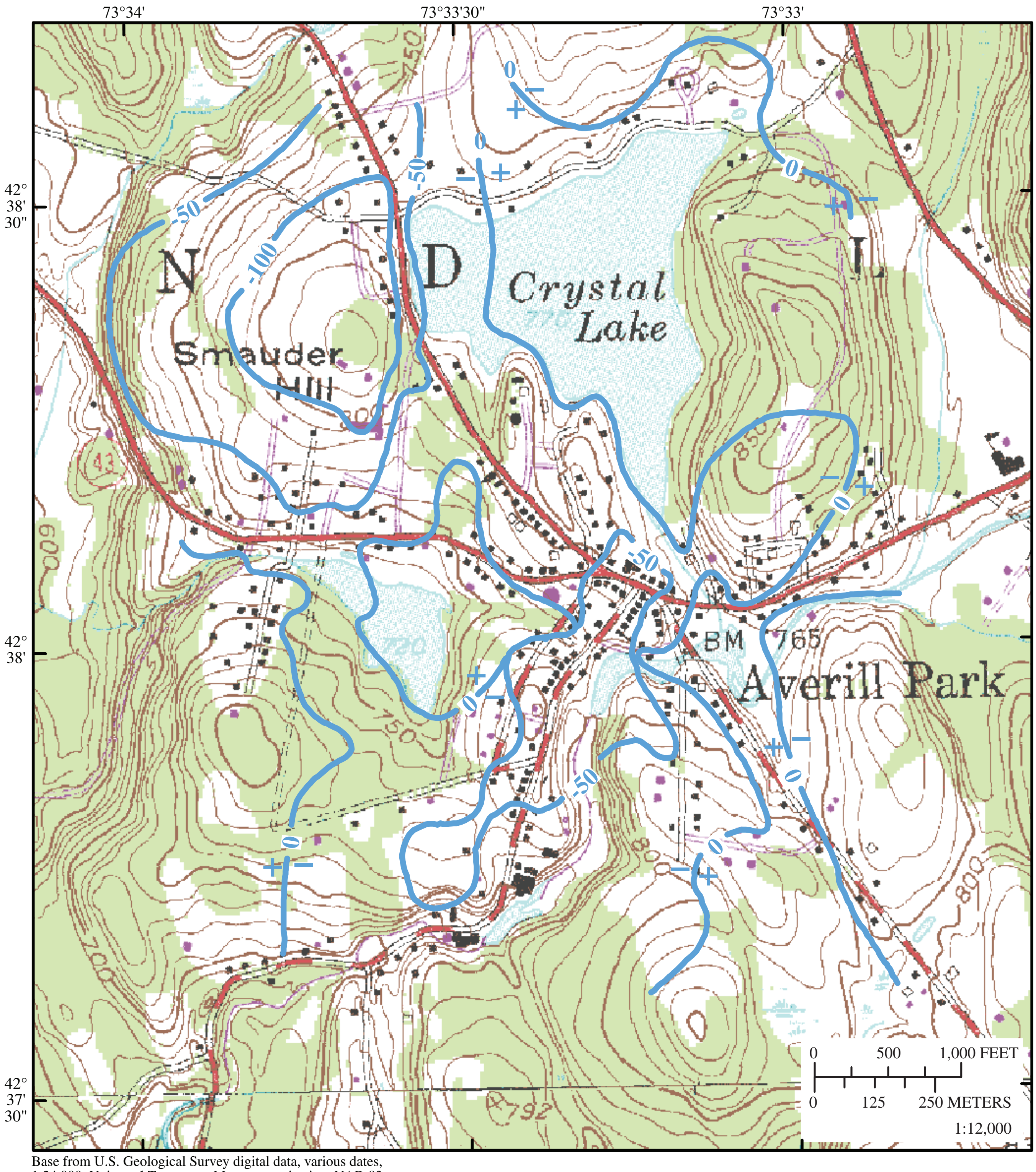
- Wells that yield water with hardness of at least 170 milligrams per liter obtain all their yield from fractures at depths less than 200 feet.
- Wells that yield water with a hardness of 50 milligrams per liter or less obtain all their yield from fractures deeper than 200 feet.
- The yield of wells with hardness between 50 and 170 milligrams per liter was assigned to deep and shallow fractures in proportion to the hardness.

The wells were also classified into three localities (fig. 15) as follows:

- The center of Averill Park, where two thirds of the wells have low yields, and water levels in most wells are above an altitude of 680 feet (pl. 3),
- A large area north, east, and southeast of the center, where water levels are also generally above an altitude of 680 feet; and
- An area west of the center, where water levels are generally below an altitude of 680 feet.

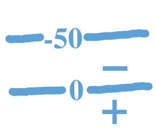
Results of the analysis are given in table 6. The percentages in the last column indicate that, if a well near, east, or north of the center of Averill Park were drilled to a depth of 200 feet without obtaining an adequate supply of water, or if an existing well nearly 200 feet deep were to fail because the water level declined below some fractures that formerly supplied that well, the liklihood of obtaining an additional 2.2 gallons per minute or more by deepening the well would be about 25 percent. A final depth of 350 to 400 feet (the median depths of wells analyzed) could be expected. West of the hamlet center, where water levels in wells are lower than near the center, the likelihood of obtaining an additional 2.2 gallons per minute or more by drilling beyond a depth of 200 feet is 51 percent, and a final depth of 320 feet could be expected. (Note that table 6 does not imply that if several wells west of the center were deepened from 200 to 320 feet in depth, 51 percent of those wells would gain an additional 2.2 gallons per minute or more. Indeed, table 6 actually implies that a majority of the wells deepened only to 320 feet would fail to gain 2.2 gallons per minute. If, however, some wells were drilled deeper than 320 feet in the hope of increasing their yield, and if the final array of wells had a median depth of 320 feet, then 51 percent of those wells would gain at least 2.2 gallons per minute.) The last row of table 6 indicates that only 34 percent of all the deep wells at Averill Park have obtained at least 2.2 gallons per minute from the lower part of the bedrock. A yield of 2.2 gallons per minute from a well 320 feet or more in depth would easily meet the needs of a typical home because water could be withdrawn from well-bore storage at 5 gallons per minute or more to meet short-term demands.

The computations in table 6 are not rigorously accurate and may under- or overestimate yields from deep bedrock. The main reason for inaccuracy is that a deep well that yields moderately hard water from shallow fractures was assumed to not also penetrate deep water-yielding fractures. Some of these wells might in fact intersect deep fractures, unrecognized



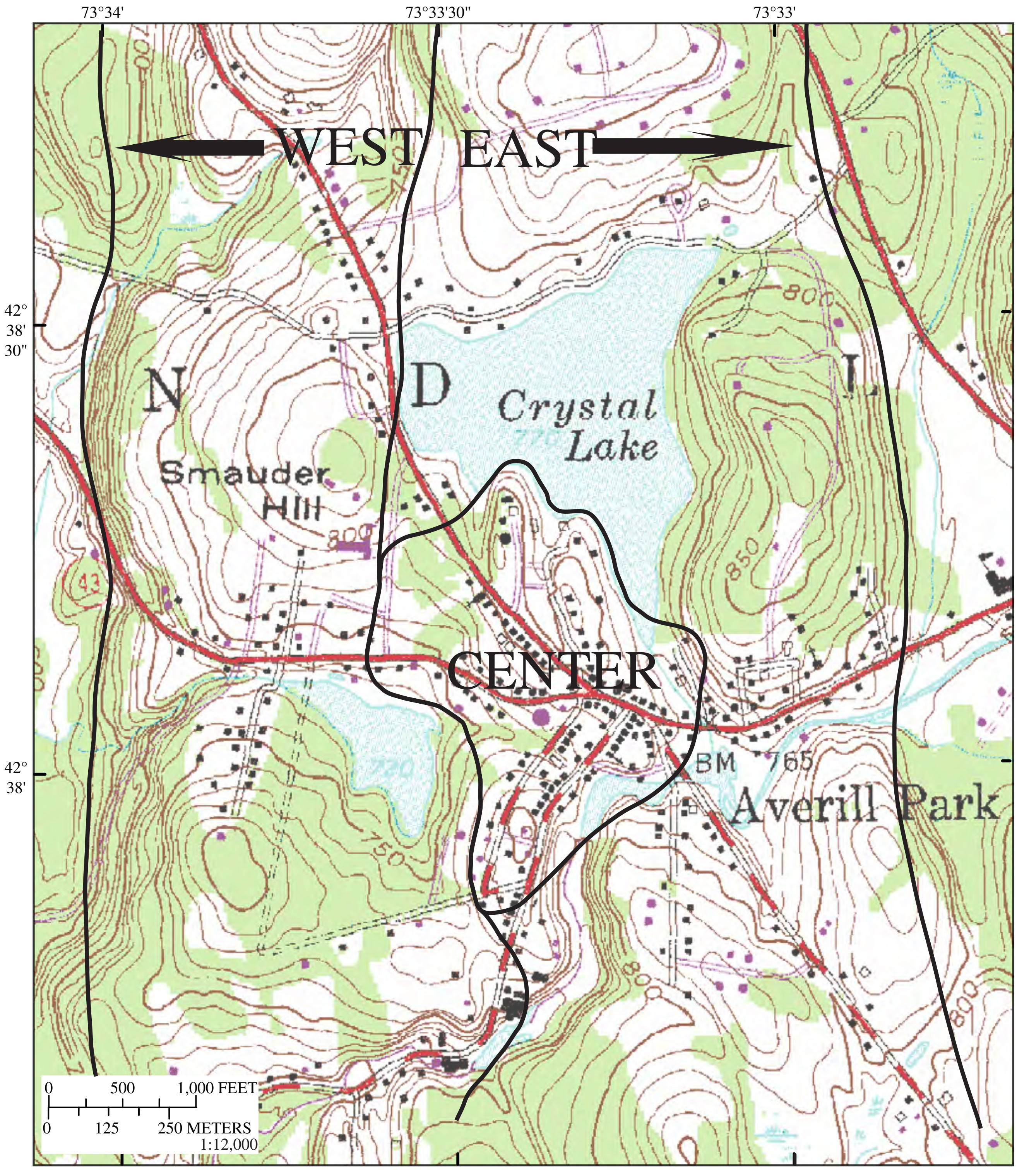
Base from U.S. Geological Survey digital data, various dates, 1:24,000, Universal Transverse Mercator projection, NAD 83, Zone 18

EXPLANATION



Contour lines showing position of water levels in wells above (+) or below (-) the bedrock surface. Juxtaposition or close proximity of contours in a few places reflects overlap of shallow and deep sets of water levels (plate 3)

Figure 14. Relation of water levels in 2002 to the bedrock surface at Averill Park, N.Y.



Base from U.S. Geological Survey digital data, various dates, 1:24,000, Universal Transverse Mercator projection, NAD 83, Zone 18

Figure 15. Boundaries of localities at Averill Park, N.Y., that were selected for analysis of well yield as a function of well depth.

Table 6. Well yield at Averill Park, N.Y., as a function of location, well depth, and depth at which water enters the well.

[Data set included all wells more than 200 feet deep for which driller's measurement of yield was known. gal/min, gallons per minute ; %, percent]

Locality (fig. 16)	Number of wells analyzed	Depth of wells analyzed		Number (and percentage) of wells yielding		
				0.5 to 2 gal/min	2.2 to 10 gal/min	
		Range (feet)	Median (feet)		Water is derived largely from upper part of bedrock [a] (hard water)	At least 2.2 gal/min is soft water derived from lower part of bedrock
Center of Averill Park	41	[b]220–740	400	25 (61%)	6 (15%)	10 (24%)
East or north of center	43	213–702	350	13 (30%)	19 (44%)	11 (26%)
West of center (area of low head)	43	218–722	320	9 (21%)	12 (28%)	22 (51%)
Totals (all of Averill Park)	**7**	**[b]213–740**		**47 (37%)**	**37 (29%)**	**43 (34%)**

[a] Generally bedrock within about 180 feet of land surface, but varies by location.

[b] One outlier, 1,000 feet deep.

because the shallow fractures that yield hard water generally have higher heads than deep fractures, as indicated by water levels in many pairs of nearby shallow and deep wells around Averill Park (appendix B and fig. 3). Therefore, once the water level in a well has recovered from prior pumping, hard water from the surrounding shallow fractures is likely to flow into and down the well bore, then out into the deep fractures, where heads are lower. The next time the well is pumped, this hard water in the deep fractures will be withdrawn along with hard water from the shallow fractures. The computations in table 6 therefore underestimate the yield from deep bedrock to the extent that this process occurs. A countervailing effect arises from the variation in depth to soft water, as evidenced by the presence of soft water in a few wells less than 200 feet deep, particularly north of Crystal Lake. The computations in table 6 overestimate the yield from deep bedrock to the extent that soft water occurs at depths less than 200 feet.

Despite some imprecision in table 6, the percentages in the last column indicate that deep bedrock in the area of low heads west of the center of Averill Park (fig. 15, pl. 3) is more productive than deep bedrock farther east. This contrast could reflect a difference in bedrock lithology, such as a greater abundance of lenses of graywacke west of the center of the hamlet than in the center, but the well logs currently available are inadequate to confirm or refute this explanation. Drilling below 200 feet anywhere around Averill Park is likely to increase well yield by only about 2.2 gallons per minute or less; however, a yield as small as 0.5 to 1 gallon per minute can meet typical domestic demand when supplemented by water stored within a deep well or auxiliary storage tank.

Recharge Rate as a Limit on Ground-Water Withdrawals from Bedrock

Pumping any well at Averill Park lowers the water level in the well and thus creates a water-level gradient that causes water in the surrounding bedrock to flow toward the well at a rate sufficient to equal the average rate of withdrawal. The small region in which water levels slope toward the well is termed the "cone of depression" of that well. The pumped water is eventually replenished through recharge—the infiltration and downward seepage of water that originated as precipitation. If several wells on adjacent lots together withdraw water at a rate that exceeds the local rate of recharge, the collective cone of depression will deepen and expand beyond those lots to the point at which it captures enough additional recharge from adjacent land to equal the average withdrawal rate. The installation of additional wells to supply new development on the adjacent land would inevitably result in greater water-level declines. Therefore, the rate of ground-water withdrawal (and thus the maximum sustainable population density) in an upland locality such as Averill Park is ultimately limited by the rate of recharge to the bedrock aquifer. The rate of recharge, in turn, depends on the infiltration capacity of the overlying till and the average rate of precipitation minus evapotranspiration

The average rate of recharge to the bedrock aquifer at Averill Park could be estimated if (1) a collective cone of depression for many wells could be delineated, and (2) the water levels in those wells were in a state of dynamic stability, such that fluctuations might occur from day to day, but the amount of water in the bedrock was not declining persistently and substantially over time. The sum of the withdrawals from those wells, each of which could be measured or estimated, would then be equal to the average local rate of recharge.

A map of water levels in wells at Averill Park in 1988 (LaFleur,1989, pl. 4) suggested that such a computation of recharge is indeed feasible here. The map was modified slightly (Randall, 2000) to depict topographic constraints on water levels beyond the map boundaries and to include a ground-water divide that encompassed three small cones of depression inferred by LaFleur near the center of Averill Park. The combined withdrawal within the area surrounded by that divide was roughly estimated as the number of wells multiplied by 200 gallons per day (on the assumption that each well served four persons who each used 50 gallons per day), and could be equated to recharge if the water levels could be shown to be stable. Accordingly, further data collection was undertaken, as described previously, to better document water levels in wells and water use by residents and businesses, and thereby permit a reasonably accurate estimate of recharge to bedrock in this locality. The two components of the estimation procedure (delineation of capture area and estimation of withdrawals) are described in the following sections.

Delineation of Capture Area

The contours of water levels in 2002 (pl. 3) encompass small cones of depression at the center of Averill Park and east of Orient Avenue that are bordered by ground-water divides to the north and west, and by hills to the south and southeast that are presumed to approximately coincide with ground-water divides. Control for the water-level contours is discussed in the earlier section "Measurements in 2002." A perimeter is drawn along all these divides on plate 3. Only one short reach of this perimeter, near the northeastern corner, does not fall on a ground-water divide. A divide was inferred to have existed in this locality under predevelopment conditions, beneath the drumlin east of Crystal Lake (LaFleur, 1989, pl. 5), but was not evident in 2002; instead, water levels in bedrock beneath the drumlin were inferred to be slightly lower than the water table in the sandy lowland around Sand Lake School, east of Victors Lane. The water-level gradient westward in the bedrock beneath the drumlin in 2002 was gentle, however, such that any flow across this reach of the perimeter was probably small enough to be ignored in the estimation of recharge rates.

Estimation of Ground-Water Withdrawals

Every building within the delineated capture area was visited, and inquiries were made as to the number of occupants in that building and their use of water. The occupants of most dwellings reported their use of water to be "normal," according to their needs and desires. Occupants of some dwellings, however, reported that their use of water was constrained by the modest yield of their well, or by restrictions at some rental properties on use of washing appliances, or by personal motivation to conserve the water resource shared by the community. Such constraints deserve consideration in any attempt to estimate residential water use by a particular community. Accordingly, each dwelling within the perimeter described above was assigned to one of four categories of water use and a ratio to "normal" use was assigned to each category; that ratio was then multiplied by the number of residents in that category to obtain an estimate of how many residents with "normal" water-use habits would use the same amount of water. This calculation is summarized in table 7 .

The magnitude of "normal" annual residential water use at Averill Park is unknown; therefore, an estimate of 55 gallons per day per capita was selected on the basis of a survey of water use at 206 homes similar to those in Averill Park but served by metered public water supplies in two

Table 7. Estimated domestic use of ground water in 2002 within the part of Averill Park, N.Y., that is encompassed by a ground-water divide, expressed in terms of an equivalent population that uses water normally.

[Location of divide shown on pl. 3]

(1) Use category [a]	(2) Number of residences	(3) Number of residents	(4) Estimated ratio for normal use	(5) Equivalent number of normal-use residents (column 3 x column 4)
N	127	403	1.0	403
C	21	59	0.9	53.1
R	26	109	0.7	76.3
Ex	3	12	0.4	4.8
Total	**177**	**583**		**537.2**

Average number of actual residents per dwelling unit (total for column 3 divided by total for column 2): 583 / 177 = **3.3**

Average number of equivalent residents who use water "normally" (total for columnn 5 divided by total for column 2): 537.2 / 177 = **3.0**

[a] N = Normal use, no concern about water availability, no effort to conserve water.

C = Concerned citizens: little or no use of water outdoors (for lawn, garden, car), avoid unnecessary use indoors; motivated by ethic of stewardship, concern for neighborhood water resource, or fear for one's own well.

R = Use restricted by low well yield; nearly all laundry done elsewhere, no use of water outdoors, showers and other personal use commonly limited; bottled water commonly used for drinking.

Ex = Extreme limit on well yield, less than 50 gallons per day total, or house frequently unoccupied.

nearby towns, as described in appendix E. Total residential water use (withdrawal) within the ground-water divide delineated around the center of Averill Park on plate 3 was then calculated as the per-capita water use of 55 gallons per day, multiplied by the 537.2 equivalent normal-use residents (table 7), to obtain a total of 29,546 gallons per day.

Water use at nonresidential properties was estimated by a variety of methods according to the information available. Water use by a restaurant was obtained from an engineering report that had been used to design the restaurant's water system, and was applied proportionately to a similar facility nearby. Water demand at several buildings was obtained from estimates of the average daily number of toilet flushes and other specific water uses, and (or) the average number of hours in which particular faucets were in use; these estimates were provided by the building's owner, manager, or custodian. The demand at one commercial building was available from a water meter that had been temporarily installed. The values for all nonresidential buildings were summed to obtain an estimated average use of 6,373 gallons per day.

Computations of Recharge to Bedrock and Population Density Supported by that Recharge

Total annual ground-water withdrawal within the ground-water capture area that encompasses the center of Averill Park (pl. 2) was estimated to average 35,919 gallons per day (29,546 gallons residential use plus 6,373 gallons nonresidential use); this total was divided by the number of square miles within this area (0.54 square mile as measured by planimeter) to obtain an average withdrawal of 66,500 gallons per day per square mile, or about 104 gallons per day per acre. This rate was taken as a reasonable estimate of average recharge from precipitation, inasmuch as water levels within most of this perimeter have changed little since 1988, as explained in the section "Changes in water levels, 1988–2002 and 2002–2005," and nearly all properties are served by sanitary sewers and, therefore, provide little or no return of wastewater to the ground-water system.

The estimated rate of recharge to bedrock, in gallons per day per acre, can be converted to an estimate of the average residential population per acre that could be supplied by that recharge in a locality where only residential buildings are present, as follows:

1. Calculate the number of residents that would use as much water as the estimated nonresidential usage at Averill Park in 2002. For this report, the estimated nonresidential water use (6,373 gallons per day) was divided by the assumed per-capita residential use (55 gallons per day) to obtain 115.9 "equivalent" residents—the number of residents that together would use as much water as the estimated nonresidential usage in 2002.

2. Add the number of "equivalent" residents computed in step 1 to the 537.2 normal-use residents calculated from the door-to-door survey at Averill Park. For this report, 115.9 "equivalent" residents from step 1 was added to 537.2 normal-use residents (from table 7) to obtain a total of 653.1 residents.

3. Divide the sum of residents obtained in step 2 by the area within the ground-water divide. For this report, 653.1 residents was divided by 0.54 square mile to obtain 1,209 residents per square mile, or 1.9 residents per acre.

Uncertainty in Estimate of Recharge

The chief potential sources of error in the foregoing estimate of recharge to bedrock from precipitation are as follows:

1. Imprecise estimates of water use. The foregoing calculations are spelled out in detail so that if a reader can obtain better estimates of normal residential use per capita, or of nonresidential uses, in this locality in 2002, such estimates could be substituted, and recharge recalculated.

2. Imprecise delineation of the ground-water divide around Averill Park. The southern reach of this perimeter was not constrained by water-level measurements in wells; its position was inferred from topography. The smallest and largest alternative positions that seemed plausible would have decreased the capture area by 5 percent or increased it by 15 percent, respectively.

3. Possible recharge from three sources other than infiltrating precipitation.

   - Seepage loss from the Wynants Kill where it crosses the study area. A detailed evaluation given in a later section, "The Wynants Kill as a possible source of recharge," concludes that seepage loss under low-flow conditions is negligible but could not rule out the possibility that seepage loss might increase during periods of moderate to high flow.

   - Recharge to bedrock from Crystal Lake. Water levels in bedrock near Crystal Lake are generally 10 feet or more below lake level, but till along most of the lakeshore ranges from 30 to 90 feet in thickness (fig. 2) and probably does not allow lake water to seep downward to bedrock any faster than precipitation infiltrates through thick till where no lake is present. In contrast, bedrock along 1,000 feet of the west shore of Crystal Lake, between the lake and Beach Lane, is close to land surface and may be in hydraulic contact with the lake, as indicated by heads close to lake level in a few wells. The water-level contours in this locality (pl. 3) depict ground-water flow to be nearly parallel to the shore, but a little recharge from the lake to bedrock is possible.

- Lateral flow across a short segment of the perimeter of the capture area. As pointed out earlier, a 3,000-foot reach of the northeastern perimeter of the capture area delineated on plate 3 is not a ground-water divide; rather, water levels in bedrock seem to rise eastward and merge with the water table beneath the valley floor around Sand Lake School (pl. 3). The gentle westward gradients within the bedrock, and the inferred presence of silt and clay within the valley fill (LaFleur and others, 1995; LaFleur, 1998), suggest that lateral flow across the perimeter in this area is probably small.

Each of the three potential sources of recharge described above, to the extent that they occur, would cause total recharge to exceed recharge from precipitation. Withdrawals from wells could still be equated to total recharge, but would represent an overestimate of recharge from precipitation. Furthermore, an underestimate of capture area seems more likely than an overestimate (item 2 above). Therefore, the recharge estimate of 104 gallons per day per acre from precipitation is more likely to be too large than too small.

Recharge Rate as a Function of Till Thickness

Several forms of evidence, considered together, indicate that the rate of recharge to bedrock is greater where till is thin and discontinuous than where it is continuously thicker than 30 feet. Near the center of Averill Park, where till is less than 30 feet thick (fig. 2), water-level contours form a pronounced mound (pl. 3), water levels showed no net change from 1998 to 2002 (table 1), and ground water contains elevated chloride concentrations and specific conductance values resulting from salt-laden winter highway runoff (figs. 10, 11). In contrast, beneath nearby drumlins, where till is much thicker than near the hamlet center, the water-level contours are not mounded, water levels declined slightly to substantially from 1988 to 2002, and chloride concentrations and specific conductance values show little or no effect of road salt. This contrast indicates that the average recharge rate of 104 gallons per day per acre calculated herein for Averill Park is an average of some unknown higher rate in the area of thin till near the center of Averill Park and some unknown lower rate in the nearby drumlin areas, where till thickness exceeds 30 feet. The apparent inverse relation between recharge rate and till thickness cannot be quantified here from data from a single cone of depression but could be quantified if recharge rates were calculated by similar methods in several localities that differ substantially in the extent of thick till relative to thin till.

The absence of mounding of water levels in bedrock beneath drumlins was clearly evidenced by measurements in 2002, but whether mounding occurred before ground-water development began is uncertain. LaFleur (1989, p.17) mentioned that the static water level in the first well drilled on the crest of one drumlin was reported to have “originally stood within 20 feet of the land surface.” Largely on the basis of this one homeowner’s statement, LaFleur sketched a map of the potentiometric surface “as it might have been before anyone lived in Averill Park” (LaFleur, 1989, p. 16, pl. 6) that depicts a substantial water-level mound in bedrock beneath each of several drumlins. Contrasting evidence was obtained at another drumlin during this study. A well drilled in 2001 for a new house on the crest of a 34-acre drumlin south of Averill Park (well 2112, pl. 2, appendix A) is at least 600 feet from any other well. The drumlin crest is 50 to 125 feet higher than the surrounding area, and bedrock was reached at a depth somewhat less than 133 feet. The static water level in 2003, 11 months after the house was first occupied, was 106 feet below land surface (appendix B). The record of this well indicates that either the water level in bedrock beneath this drumlin was not substantially mounded under predevelopment conditions, or any mound that did exist disappeared in response to 11 months of domestic withdrawals at one house. In either case, the rate of recharge to bedrock through the thick till in this drumlin is inferred to be small in relation to the water-transmitting capacity of the bedrock and (or) in relation to the calculated average recharge rate of 104 gallons per day at Averill Park

Contrast with Recharge in Other Upland Areas as Estimated from Streamflow Records

The recharge rate estimated in this report for Averill Park (104 gallons per day per acre or 1.4 inches per year) is much smaller than recharge rates that have been estimated from streamflow records for upland areas elsewhere in the northeastern United States. For example:

1. Several studies in Connecticut used graphical methods to distinguish the “base flow” (ground-water) component of streamflow from the storm-runoff component in selected streams for 1 or more years. These studies, summarized by Weaver (1987) and Kontis and others (2004, fig. 15), concluded that the average rate of ground-water recharge in till-mantled uplands equals 35 percent of mean annual streamflow. Mean annual streamflow over most of Connecticut ranges from 22 to 28 inches (Kontis and others, 2004, pl. 2). Therefore, annual recharge in the till-mantled uplands averages 8.7± 1 inches.

2. Posten (1984) developed and applied a different graphical method of base-flow separation to several years of streamflow records from two upland watersheds in northern New Jersey and calculated ground-water recharge under average conditions to be 10.3 inches (38 percent of average runoff) in the first watershed and 12.4 inches (46 percent of average runoff) in the second.

3. Flynn and Tasker (2004) applied a computer-generated method of base-flow separation to records of streamflow in New Hampshire. Their estimated ground-water recharge rates were 56 to 81 percent of mean annual streamflow in 13 watersheds in northern New Hampshire and higher percentages farther south.

Reconciling the estimates of ground-water recharge to bedrock in Averill Park with the higher recharge estimates obtained by base-flow-separation methods for upland watersheds elsewhere was beyond the scope of this report, but four factors may help explain the difference.

1. *Percentage of area overlain by thick till*: At Averill Park, till greater than 30 feet thick underlies about 70 percent of the 0.54 square mile on which the computation of average recharge was based. In the larger watersheds where others have calculated recharge from streamflow records, thick till probably underlies less than 70 percent of the uplands. For example, soils derived from till that is more than 5 or 6 feet thick above bedrock underlie 62 percent of the uplands in Rensselaer County, in which Averill Park is located, and only 40 percent of the uplands in adjacent Columbia County (Work, 1988; Chase, 1989). If so, till greater than 30 feet thick presumably underlies somewhat less than 62 percent and 40 percent of the uplands in these two counties. If recharge to bedrock is greater where till is thin and discontinuous than where it is greater than 30 feet thick, as inferred in this study, average recharge to bedrock in many upland watersheds seems likely to exceed average recharge to bedrock at Averill Park.

2. *Differing methods of computation*: Base flow estimated by stream-hydrograph separation is likely to include some ground water that discharges from shallow flow paths through till and does not recharge bedrock; therefore, recharge estimates obtained by that method are likely to be greater than the rate of recharge to bedrock estimated by methods used in this study.

3. *Till permeability*: Upland till in much of New England and New Jersey is derived from crystalline metamorphic bedrock and, thus, is likely to contain smaller percentages of clay and silt than the till derived from shale at Averill Park. Less clay and silt may result in greater permeability and, thus, greater recharge to bedrock.

4. *Differences in mean annual runoff*: Mean annual runoff, which equals the annual amount of water available for recharge (Lyford and Cohen, 1988), is substantially greater in Connecticut, northern New Jersey, and New Hampshire (18 to 40 inches) than at Averill Park (16.5 inches; Kontis and others, 2004, pl. 2). The amount of actual recharge in upland areas probably does not vary as widely as the amount of water available for recharge; nevertheless, the lesser amount of water available for recharge at Averill Park might result in somewhat less recharge here than in the other areas mentioned.

Probable Effect of Increased Withdrawals at Averill Park

Construction and use of new wells at Averill Park to serve new residential or commercial buildings, or to supply increased amounts of water to existing structures, would cause water levels in bedrock to decline, which in turn would diminish the maximum potential yields of existing wells. As water levels decline, the westward water-level gradient beneath the southwestern part of Averill Park would become less steep and thereby decrease the rate of ground-water flow away from Averill Park, and the ground-water divide that surrounds the center of Averill Park (pl. 3) would probably expand eastward, northward, and southward to capture sufficient additional recharge to compensate for the increased pumping.

Recharge to bedrock may increase after development takes place in some glaciated upland localities, but probably not at Averill Park. A ground-water flow model of a small New Hampshire upland watershed (Tiedeman and others, 1998) indicated that, under natural (nonpumping) conditions, about 40 percent of total ground-water recharge followed shallow flow paths through till overburden to streams and never entered bedrock. If that model were modified to specify an array of domestic wells that penetrated bedrock and were pumped sufficiently to lower the head in bedrock below the bedrock surface, simulated flowpaths would probably shift such that nearly 100 percent of recharge would reach bedrock. The clayey till at Averill Park is so poorly permeable, however, that it often becomes saturated to land surface, thereby forcing subsequent precipitation to run off to streams. Furthermore, head in bedrock at Averill Park is already below the bedrock surface in most places (fig. 14). Thus, additional ground-water withdrawals, and the resulting decline in water levels, would not appreciably increase the rate of recharge per acre through the till; instead, a larger and deeper cone of depression would result.

The Wynants Kill as a Possible Source of Recharge

The Wynants Kill, which flows southwestward through the part of Averill Park on which the recharge computation was based, was evaluated during this study as a possible source of induced infiltration to bedrock.

Induced infiltration is, in theory, a function of hydraulic conductivity of sediment beneath the stream channel and vertical head gradients, both of which vary along the Wynants Kill. The channel is incised in drumlin till nearly to bedrock in a reach that extends about 700 feet downstream from the Legion Hall (just west of well 2073, pl. 2). The next 1,200 feet of channel, as far as Johnnycake Lane, meanders across a small alluvial plain interpreted by LaFleur (1965) to be underlain by outwash. Downstream from Johnnycake Lane, the Wynants Kill occupies a gorge incised in bedrock. The first 800 feet of the gorge is floored by silty alluvium that was deposited in a pond behind a dam constructed in the 19th century to provide water power for mills. A small outlet structure in the dam was always open during 1999–2005. Water was ponded at the level of the spillway crest during periods of high flow. During periods of low flow, a narrow stream channel crossed the pond-bottom alluvium and exited through the outlet structure. Downstream from the dam, the Wynants Kill flows for about 2,300 feet to Olmstead Lane over gravelly alluvium a few feet thick that rests upon bedrock. This reach contains a permanent mill pond about 400 feet long adjacent to the former Faith Mills. Water levels in bedrock near the Wynants Kill (pl. 3) are 5 to 15 feet lower than the Wynants Kill channel upstream from Johnnycake Lane, and several tens of feet lower than that channel for some distance downstream from Johnnycake Lane.

The possibility of seepage from the Wynants Kill into bedrock was addressed by LaFleur (1989, p. 18), who reported a net loss of 0.65 cubic foot per second from the 5,000-foot reach of the Wynants Kill between the Legion Hall and Olmstead Lane. This net loss was derived as the difference between single current-meter measurements made at each site on April 11, 1986, and amounted to 4 percent of measured streamflow. The precision or uncertainty of current-meter measurements is a concern when differences of a few percent between measurements at two sites are to be taken as representing a net gain or loss in the intervening reach. An extensive literature survey (Pelletier, 1988) concluded that the uncertainty of individual measurements can be as low as 4 percent at the 95-percent confidence level if a variety of ambient conditions and measurement techniques are optimal, but that larger errors are commonly expected. Potential error was further investigated by Dysart and Rheaume (1999, p. 30–33), who applied rigorous procedures during an evaluation of water loss from a river in New Jersey to a municipal well field. They carefully selected and prepared measurement sites, made six replicate flow measurements at each site, and collected stage records sufficiently precise to allow adjustment for gradually declining stream stage during the several hours required to complete all measurements. Despite these efforts, the standard deviation of calculated loss was 0.46 cubic foot per second about a mean loss of 0.67 cubic foot per second (5 percent of streamflow). Results of the two studies cited suggest that errors in the single pair of streamflow measurements in the Wynants Kill in 1986 could have substantially exceeded the computed loss.

The possibility of seepage losses (aquifer recharge) from the Wynants Kill was evaluated from 10 sets of streamflow measurements made in August and September 2001, a period of low flow (92- to 98-percent flow duration[4], as estimated from graphs in LaFleur and others, 1995). This was an ideal time period in which to detect and quantify any seepage loss that might be taking place because the ratio of seepage loss to the flow of the Wynants Kill would be larger than during larger flows. Measurements were made at two sites 3,100 feet apart—one 70 feet downstream from the Johnnycake Lane bridge and the other 100 feet downstream from the bridge on Burden Lake Road near Olmstead Lane (fig. 1). Both measurement sites were on or adjacent to bedrock outcrops, and both were carefully straightened and smoothed to ensure straight, steady flow at velocities of 0.25 to 0.6 foot per second. The downstream site was measured about 45 minutes after the upstream site was measured, so as to approximately accommodate the travel time of any possible fluctuations in stage or flow. Stream stage was measured to the nearest 1 millimeter from a temporary reference point before and after each set of streamflow measurements; no fluctuations in stage were detected.

The 10 sets of measurements (table 8) indicate only small changes in streamflow over the study reach. The changes ranged from a gain of 0.05 cubic foot per second to a loss of 0.10 cubic foot per second (15 to 20 percent of streamflow). The mean result was a loss of 0.004 cubic foot per second (1.8 gallons per minute), and the median result was a gain of 0.005 cubic foot per second (2.2 gallons per minute). Results varied somewhat with time of day—five measurement pairs at about 9 a.m. showed a mean net gain of 0.022 cubic foot per second; two measurements at about noon showed a mean net change of zero; and three measurements at about 4 p.m. showed a mean net loss of 0.05 cubic foot per second. This pattern could be attributed to the diurnal cycle of riparian evapotranspiration, which can be large enough to convert a small net gain during overnight hours into a small net loss late on a summer afternoon; however, the number of measurement pairs was too small to lend statistical validity to this interpretation. The measurements do indicate, however, that the reach of the Wynants Kill downstream from Johnnycake Lane is insignificant as a source of recharge to the bedrock aquifer during periods of low flow. Whether some seepage loss might occur during periods of high flow, when stage and exposure area are increased, is unknown; the width of the Wynants Kill in the 800-foot reach downstream from Johnnycake Lane at high flow is approximately as shown on the topographic map, and water depth is about 10 feet near the dam; each of these is about 15 times the values typical of low flow.

Need for Additional Studies of Rates of Recharge to Bedrock

Residential and commercial developments in upland areas of New York that are beyond the reach of municipal water mains obtain water supplies from wells drilled into till-mantled bedrock. Future planning for development in such areas, and regulation of the density of development, would benefit from an accurate method for estimating the rate of recharge to bedrock.

The investigation described herein estimated recharge to bedrock in one upland locality by a method that has not been widely applied elsewhere. The resulting estimate of 1.4 inches per year is substantially lower than estimates of 8 to 12 inches of recharge in other upland areas that were derived by base-flow separation methods; the lower rate obtained at

[4] 92-percent flow duration is that daily mean flow that was exceeded on 92 percent of the days over a long period of record.

Table 8. Net change in flow of the Wynants Kill in a 3,500-foot reach at Averill Park, N.Y., August–September 2001.

[ft³/s, cubic feet per second. A dash (--) denotes no measurement or data. Street locations are shown in fig. 1]

Date (2001)	Site 70 feet downstream from Johnnycake Lane bridge			Site 100 feet downstream from Burden Lake Road bridge at Olmstead Lane		Net gain (+) or loss (-) (ft³/s)
	Time[a]	Reference point to water (centimeters)	Streamflow (ft³/s)	Time[a]	Streamflow (ft³/s)	
Aug. 22	1215	17.7	0.47	1310	0.49	+ 0.02
	1500	17.7	0.50	1540	0.46	- 0.04
	1640	17.7	0.49	1725	0.39	- 0.10
Aug .23	0845	18.0	0.41	0945	0.44	+ 0.03
	--	--	--	1055	0.43	+ 0.02
	1138	18.0	0.44	1220	0.42	- 0.02
Aug. 24	1930	17.9	--	--	--	--
Aug. 27	1930	18.2	--	--	--	--
Aug. 28	0828	18.4	0.35	0910	0.34	- 0.01
Aug. 30	1900	18.5	--	--	--	--
Aug. 31	0845	18.6	0.26	0935	0.28	+ 0.02
Sep. 3	1915	17.8	--	--	--	--
Sep. 7	1900	18.2	--	--	--	--
Sep. 8	0840	18.4	0.33	0925	0.38	+ 0.05
	1645	18.2	0.375	1725	0.365	- 0.01
					Sum	**- 0.04**
					Mean change over 10 measurements	**- 0.004**

[a] Eastern Daylight time at which streamflow measurement was completed or reference-point measurement was made.

Averill Park may result from differences in site hydrology and (or) in methods of analysis. Furthermore, the rate of recharge to bedrock from precipitation may vary widely from one locality to another, depending on several environmental factors, such as clay or silt content of the till (which in turn is a function of bedrock lithology), thickness of till, and average precipitation rate, which is generally a function of altitude. Therefore, selection of several well clusters (hamlets or housing subdivisions) that differ substantially in these or other environmental factors would provide a basis for comparision and assessment of the relative effect of each factor through procedures such as regression analysis, simultaneous equations, or graphical methods.

The method used in this study to estimate the rate of recharge to bedrock consists of (a) delineating the extent of the cone of depression around the selected cluster of wells through precise measurement of water-level altitudes in wells within and beyond the cone, (b) verifying that water levels are not changing substantially over time, and (c) estimating as accurately as feasible the average rate of withdrawal from each well within the cone of depression. Many of the specific procedures described in this report could be replicated in other studies, but modifications might be required in some circumstances. For example:

- Selection of a well cluster on a hilltop or group of hills, such as at Averill Park, simplifies delineation of the cone of depression. Recharge to a cluster that is low on a hillside is likely to be drawn from a large capture area upslope, which could be difficult to delineate. An alternative approach in this circumstance might be to calculate the water-transmitting properties of the bedrock by methods such as described in Randall and Klusman (2004) based on brief tests of wells in the cluster, followed by calculation of lateral flow into the cluster from the upslope bedrock.
- Discharge of wastewater to on-lot septic systems, which is typical of most upland residential clusters supplied by wells, could complicate estimation of recharge to bedrock from precipitation. Where the bedrock is mantled by thick till throughout the study locality, however, wastewater discharge may not substantially augment annual recharge to bedrock from precipitation.
- A continuous record of water-level fluctuation in a nearby unpumped well(s) that penetrates bedrock would help in evaluating the fluctuation and timing of recharge. Such a record was unavailable for this investigation.

Summary and Conclusions

The hamlet of Averill Park occupies an upland area in which shale bedrock is mantled by till that ranges in thickness from 0 to 190 feet. All residences and other buildings obtain water from drilled wells that penetrate bedrock. Water levels in the bedrock aquifer, which supplies the hamlet with water, have declined in response to increased withdrawals from new wells. Similar experiences in other upland localities have led to awareness that the rate of recharge to bedrock can be a significant constraint on the density of new development in uplands. The rate of recharge to bedrock at Averill Park was calculated from careful estimates of withdrawals from a reasonably well defined cone of depression. The data-collection and recharge-estimation procedures documented herein could be applied in other upland localities in support of community-planning studies.

Depths to static water level were measured in 2002 in 145 wells that penetrate bedrock, and top-of-casing altitudes were fixed by leveling. Water-level altitudes were contoured, and a 0.54-square-mile cone of depression was delineated within which ground-water discharge occurs solely as withdrawals from wells. Comparison with water-level measurements made in 45 of these 145 wells in 1988, under relatively dry conditions similar to those of 2002, revealed that net water-level declines over those 14 years had averaged from 0 to 5 feet in most neighborhoods. Interviews with building occupants in 1988 and 2002 indicated negligible change in resident population and nonresidential use within the cone of depression, except in two small neighborhoods where new homes or increased commercial activity resulted in localized water-level declines of 9 to 17 feet; these declines had largely stabilized by 2002. Water-level measurements made in 65 wells in 2005, after 3 years of sharply increased precipitation, revealed an average water-level rise of only 1.6 feet since 2002. Therefore, the cone of depression delineated in 2002 was deemed to be stable.

The per-capita withdrawal by residents whose use of water was not constrained by limitations in well yield or by voluntary conservation was estimated to average 55 gallons per day. This estimate was based on surveys of 206 homes similar to those in Averill Park that were served by metered public water supply in two nearby towns. Commercial/institutional use, as estimated by a variety of techniques, was 5 times smaller than the estimated residental use. Accordingly, recharge to bedrock from precipitation within the cone of depression was estimated to average 104 gallons per day per acre (1.4 inches per year)—enough to sustain 1.9 persons per acre if all use were residential. This result is subject to the following qualifications:

1. If new evidence were to indicate that the rate of daily per-capita residential water use in 2002 at Averill Park differed significantly from the 55 gallons per day estimated herein, the estimated rate of recharge per acre would change proportionately. The sustainable population density would change only slightly, however, because the resident population at Averill Park in 2002 was mostly counted, not estimated.
2. An evaluation of potential sources of error that might affect the estimation of recharge rate and sustainable population density, such as recharge from a nearby stream, lake, or gravel aquifer, suggests that both estimates are more likely to be too large rather than too small.
3. Vertical head gradients and the spatial distribution of ground-water quality suggest that recharge to bedrock is more rapid and abundant in localities where the bedrock is exposed or close to land surface (discontinuously mantled by till less than 30 feet thick) than in localities where the till is thicker and continuous. Therefore, the estimated recharge rate of 104 gallons per day per acre is an average of two unknown rates—a higher rate in the areas of discontinuous, thin till, which comprise 30 percent of the study area, and a lower rate in areas of thick till, which comprise 70 percent of the study area.

The average recharge rate of 104 gallons per day per acre could reasonably be applied to other upland localities that are similar to Averill Park in the following characteristics: thick till appears to be present in about two-thirds of the locality, bedrock is shale or slate, and average annual runoff is roughly 17 inches. Future studies of clusters of wells in localities that differ substantially from one another in these environmental characteristics could provide a basis for development of a regionalized method of estimating the rate of recharge to bedrock in any upland locality.

Acknowledgments

Several well drillers, particularly Paul Wehnau, provided records of drilled wells. William Embree, Angelo Kontis, Robert Martin, Bruce Perry, Edwina and David Randall, and William Welling assisted with leveling. Timothy Moot of Smith and Mahoney Engineers furnished water-level measurements made periodically in several wells as part of a concurrent study for the town of Sand Lake. Nearly every property owner and resident at Averill Park cooperated in providing information and in arranging for uninterrupted access to wells for water-level measurements when so requested. Robert G. LaFleur (Spectra Environmental Group), Thomas Mack and Kenneth Pearsall (U.S. Geological Survey), and Russell Urban-Mead (The Chazen Companies) provided technical review of the manuscript.

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[*] Reports whose citation is followed by this symbol were duplicated in small editions and distributed chiefly to town officials. Copies may or may not be available from the Sand Lake town clerk. Therefore, copies of all these reports were assembled, some bundled together within a cover labeled "Reports on water resources of the town of Sand Lake, N.Y. and vicinity by consultants, 1989–2008" and placed in the Sand Lake town library and in the library of the U.S. Geological Survey, 425 Jordan Road, Troy, N.Y. l2180–8349. Copies of the report by LaFleur and others (1995) in these libraries are accompanied by a compact disk containing well records compiled during the study, in dbf format.

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Appendix A. Records of Wells at Averill Park

Download Appendix A data table in three different formats (.csv, .txt, and .xls) here:

http://pubs.usgs.gov/sir/2008/5087/appendixa.htm

Definitions of column headings

Well # Well number. Serial numbers used to identify wells in this report. Letters following a number indicate successive wells on same property; lower-case letters indicate a deepening of the previous well, capital letters indicate a separate well. Numbers 1–320 were assigned by LaFleur (1989). Well locations are shown on plate 2, but successive wells on the same property are plotted and numbered only if far enough apart to be shown distinctively at map scale.

Date drill Date drilled (or deepened). Format is month/day/year; “1” denotes unknown month or day of drilling. Therefore, a date of 1/1/50 generally indicates that the well was drilled at some unknown date in or about 1950, and a date of 8/1/85 indicates that the well was drilled sometime in August 1985.

Depth Well depth below land surface, in feet.

Csd Depth of casing below land surface, in feet.

D S Source of well depth (and of casing depth, if known):
- D From driller’s bill or well-completion report, or from driller’s office records.
- M From memory of well owner or some other individual, not from a written record.
- R From written notes or report by owner, plumber, or some individual other than the well driller.
- U From measurement with steel tape 1999–2002 by U.S. Geological Survey.

Note: all wells listed are drilled wells of 6-inch diameter unless noted otherwise in Remarks column.

Yield Maximum well yield, in gallons per minute.

Y S Source of yield data:
- D From driller’s bill, well-completion report, or office records, generally measured with water level drawn down to bottom of well by bailing or air-lift pumping.
- M From memory of owner or some other individual; generally a recollection of the driller’s measurement upon well completion, but some represent results of more recent pumping.
- R From written notes or report by owner, plumber, or some individual other than the driller.
- U Based on specific capacity as determined during prolonged measurement of water-level recovery by U.S. Geological Survey in 1999–2002, extrapolated linearly to depth of pump. (This method used only for low-yield wells, and probably overestimates maximum yield because specific capacity can be expected to decrease as drawdown increases beyond the depth range of recovery data.)
- A Well yield not known but judged adequate from experience of residents.
- S Well yield not known but judged small from experience of residents.

Use Use of water from well:
- C Commercial (store, restaurant).
- D3 Domestic; number denotes the number of residents served on date of well inventory in 1999–2002.
- I Institutional (church, firehouse, hall).
- N Water not used (generally because well had been replaced or deepened prior to date of well inventory; also applied to wells for new houses not yet occupied as of the summer of 2002 and to a few test boreholes in which no well casing was installed).

Sp C Specific conductance, in microsiemens per centimeter at 25° Celsius, as measured on date of well inventory in 1999–2002 with a calibrated portable conductance meter (Electronic Switchgear Model MC-1 Mark V).

Hard Hardness, in milligrams per liter as $CaCO_3$, as measured on the date of well inventory in 1999–2002 by EDTA titration with a Hach model 5B field kit, which could generally be read to $\pm$ 8 milligrams per liter; the kit is designed for a hardness range of 0–30 grains per gallon (0–513 milligrams per liter). All tests represent water that was not softened, and at nearly all sites was free of any chemical treatment.

Cl Chloride concentration, in milligrams per liter, as reported in written records from a laboratory. Most samples were collected by, and analyzed for, the Rensselaer County Health Department.

Cl_date Date on which sample was collected for chloride analysis (month/day/year). If results of multiple analyses are on file for a particular well, results for the most recent sample are given here.

Qual Water-quality information, or problems reported by well owners:

- C Chemical analysis in table 4.
- S Sulfur odor (hydrogen sulfide), strong and persistent. (Occasional or slight sulfur odor not listed here.)
- Sx Water treatment to remove sulfur (generally chlorination followed by carbon filter).
- I Iron and(or) manganese, generally in suspended or particulate form, but at some sites dissolved in large concentrations. (Slight iron/manganese staining is not listed here. For wells equipped with softeners, current iron/manganese concentrations of untreated water are seldom obvious and are not listed here unless reportedly severe prior to installation of softener.)
- Ix Water treatment to remove iron (generally a cartridge-type sediment filter to remove suspended iron and manganese).
- L Abundant carbonate crystals trapped in sediment filter. (Many other well owners report modest amounts of "sand" (generally carbonate crystals) in screens on faucets or washing machines; this condition is not listed here, but is occasionally mentioned in Remarks column.)
  NOTE: Many wells are equipped with water softeners; this information is not reported in appendix A because hardness of untreated water is given in another column.
- T Persistent and(or) severe turbidity in water from well.
- Tx Cartridge filter, sand-bed filter, or alum treatment followed by filter, to remove turbidity.

Alt LS Altitude of land surface, in feet above NGVD29. Altitudes estimated from the topographic map (some modified on the basis of leveling to nearby sites) are reported as whole numbers. Altitudes determined by leveling to top of casing and measurement from top of casing to land surface are reported to the nearest tenth of a foot; for most of these wells, measurements of water level are tabulated in appendix B.

Alt R Altitude of bedrock surface, in feet above NGVD29, calculated from well log or estimated from casing depth.

USGS Serial numbers used to identify wells in U.S. Geological Survey National Water Information System electronic data base. In that data base located at http://waterdata.usgs.gov/nwis/si,each number is preceded by "Re" (to represent Rensselaer County, N.Y.) to form the site name (i.e. "Re3500" or "Re 2").

Remarks: This column includes well logs as reported by driller; numbers are in feet. Text following _ symbol is a continuation of remarks in the previous row. The following abbreviations are used: Cl, chloride. Diam, diameter. Dwl, depth to water level below land surface upon well completion, as reported by driller; numbers are in feet. PVC, polyvinylchloride. WL, depth to water, numbers are in feet. apts, apartments. avg, average. hrdpn, hardpan (till). ft, feet. gpm, gallons per minute. gpd, gallons per day. hr, hours. hydrofrac, hydrofractured. meas, measured. Rensselaer grit (or Renss. grit), hard greywacke or sandstone, of a type that predominates on Taborton Mountain (east of Averill Park). rept, reported. sh, shale. w/, with.

z	Street	Date drill	Depth	Csd	DS	Yield	YS	Use	SpC	Hard	Cl	Cl_date	Qual	AltLS	AltR
1	3039 NY Route 43		150	10	M			N						791	
1A	3039 NY Route 43	6/24/87	280	40	D	0.6	D	CD	1700	376				791	786
2	3041 NY Route 43	1/1/50	197	12	D	1.7	D	D5	1600	240	201	8/1/84		790	778
2A	3041 NY Route 43	7/11/88	312	40	D	0.67	U	D5						786.8	782
3	NY Route 43		219		U	1	M	N						789.9	
3A	NY Route 43	1/1/84	245		M	5	R	D8	1900	530	515	3/3/99	Cl	788.6	
4	1611 Burden LkRd	12/11/86	302	40	D	1	D	C	700	43				784.3	745
5	1613 Burden LkRd		200		M	0.5	M	D4	750	120				784	
6	1622 Burden LkRd	1/1/46	125		M		A	D2	1500	590				776	
7	3016 NY Route 43		250		M		A		1060	8				773	
8	3016 NY Route 43	11/3/81	380		D	3.5	D	C	1040	17			L	778	760
9	13 Breezedale Dr	6/8/87	320	122	D	2.5	D	D2	485	85				820.2	698
10	8 Breezedale Dr	1/1/57	170	115	R	7	R	D1	450	120	3	7/2/85		827.1	712
11	3 Breezedale Dr	4/1/86	320	102	D	1.5	D	D2	400	111	3	10/23/90		821	719
12	5 Breezedale Dr	9/4/85	400	119	D	1.5	D	D5	460	17	3	7/1/91		830	710
13	9 Johnnycake La		100		M		A	D4			24	10/20/64		782	
14	18 Johnnycake La	8/16/79	215	61	D	7	D	D3	590	136	35	7/27/82	Txl	810	749
15	12 Johnnycake La	7/18/69	145	34	D	6	D	D4	760	170	141	4/6/98		782.1	748
16	14 Johnnycake La	1/1/40	107	31	R		S	N						792	762
16A	14 Johnnycake La	8/31/98	320	41	D	2.2	D	D2	470	154			Tx	792	762
17	19 Johnnycake La		129		U		S	N			11	8/16/67		813.7	
17A	19 Johnnycake La	8/16/93	310	82	D	5	D	D2	700	154				813	731
18	6 Orient Ave		108	25	M		S	D4	1100	282	306	8/5/86		778	
19	12 Orient Ave	5/17/55	230	36	D	3.9	D	D2	980	26	94	10/11/77		775	739
20	1 Orient Ave	1/1/50	128	20	M		A	D2	1030	240	190	11/20/86		782	
21	8 Orient Ave	7/29/63	140	35	D	3	D	N			89	3/1/79		766.1	731
21A	8 Orient Ave	6/15/88	323	42	D	3	D	N						766	
21b	8 Orient Ave	3/11/97	600	42	D	1	R	D6	970	85				766	
22	16 Orient Ave		200		M			N			116	8/1/84		778	
22A	16 Orient Ave	1/1/85	350		M		S	D8	760	0				778.1	
23	28 Orient Ave	8/2/63	190	92	D	2	D	N			40	8/4/92		784	694
23A	28 Orient Ave	4/15/93	500	102	D	2	D	D6			58	4/3/96		782	682
24	18 Orient Ave	1/1/34	140	75	R		S	D5	510	154	96	5/31/88		786	711
25	17 Prospect Ave	12/20/72	162	60	D	7.2	D	D2	670	137			Ix	775	715
26	23 Prospect Ave		129	60	M			N			12	3/3/71		772	712
26A	23 Prospect Ave	1/1/70	145	60	M	5	M	D2	690	120	18	3/18/85		772.4	712
27	29 Prospect Ave	4/8/68	150	57	D	9	D	D3	820	128	8	1/20/69		773.6	717
28	25 Prospect Ave	5/25/73	170	83	D	10	D	D4	680	68	12	9/13/83		765.8	682
29	30 Orient Ave	12/9/64	158	84	D	5.3	D	N			40	11/26/84	T	783.7	700
29a	30 Orient Ave	6/1/92	295		D	9	M	D2	640	8				783.7	
30	14 East.Union Tpk	1/1/50	86		M		A	D3	790	325	83	2/28/85		787	
31	36 East.Union Tpk		300		M		A	D9	290	128			S	795	
32	52 East.Union Tpk	1/1/82	250?		M		A	D3	1000	420	42	6/24/84	IS	800.9	
33	60 East.Union Tpk							D4			28	9/12/86		795	
34	16 Johnnycake La	1/1/43	119		M		S	N	700	265				795	
34A	16 Johnnycake La	8/24/01	320	51	D	7	D	D5	490	68				795.8	750
35	62 Houston Way	4/23/70	250	130	D	7.3	D	D4	350	17	4	5/1/70		871.5	742
36	48 Houston Way	8/1/85	520	80	D	1	D	D2	270	34			LTx	833.2	753
37	64 Houston Way	4/1/86	400	60	D	2	D	D2	420	17	11	3/6/00	C	776.4	716
38	104 Crystal Lk Rd	1/1/67	150		M		A	N	910	427	18	1/12/83		790.2	
39	87 Crystal Lk Rd	1/1/55	155		D						2	7/11/66			
39a	87 Crystal Lk Rd		180		M	3	M	D3	360	85	5	12/28/01	C	805.8	
40	27 Crystal Lk Rd	8/12/85	400	110	D	1.5	D	D2	560	17	<2	12/23/85	Sx	791	681
49	Miller Hill Rd	1/1/65	150		M	5.2	M	N			14	1/1/72		802.3	
49A	Miller Hill Rd	6/1/88	300		M	7.8	M	D4							

Well#	USGS	Remarks
1	3500	Failed 1988
1A	3501	0-5 dirt, 5-280 soft red shale, some gray, water 150-58. WL meas 73.81 July 1987. 2 stores, 1 apt, often out of water.
2	3502	Used alternately with 2A; also cistern and occasionally buy truckloads of water.
2A	3503	0-5 ash&gravel fill, 5-12 broken red shale, 12-312 shale, red w/layers black, gray. Yield <0.5 gpm (driller).
3	3504	Supplied 2 buildings 1972-84, low-rate pump into storage tank.
3A	3505	Supplies 2 buildings.
4	3506	Supplies beauty parlor. Since 2002 also connected to 1 apartment..
5	3507	
6	3508	Hot-water coil in furnace plugged with lime in 1 year. Occasional sulfur odor.
7	3509	Supplies drinking water and ice cubes for inn/restaurant, all other uses from well #8.
8	3510	0-5 loam/gravel, 5-18 hardpan, 18-380 red shale w/seams Renss. grit. "Eggshell lime" forms in pump and pipes;
9	3511	0-119 hardpan, 119-320 red&gray shale. _pump replaced every 18 months. 500-gal storage tank.
10	3512	WL meas 1987-92, 1999-2002, on file.
11	3513	0-97 hardpan&boulders, 97-101 gray shale, 101-320 red&gray shale. Water heater plugged 1997. Dwl 90.
12	3514	
13	3515	Also dug well in front yard, not used.
14	3516	0-58 hardpan, 58-215 red&gray shale w/grit seams. Dwl 60. WL120 Nov 1992 (plumber)
15	3517	Gradual increase in chloride from 47 mg/L in 1969, 69 in 1979, 105 in 1989; total of 7 analyses.
16	3518	Enough water for 1 resident, not for 3.
16A	3519	0-30 hardpan&boulders, 30-320 red shale, a little gray, a little Rensselaer grit.
17	3520	
17A	3521	
18	3522	Cistern used for toilets, and laundry in wet seasons. Sodium 85 mg/L, chloride 402 Sept 1981
19	3523	Water tested hard in 1960's. Water dirty when well next door was drilled, later hydrofractured
20	3524	
21	3525	Dwl 20.
21A	3526	Dwl 40.
21b		Well hydrofractured March 1997
22	3527	
22A	3528	Typically out of water twice a week.
23	3529	0-10 overburden, 10-90 hardpan, 90-190 shale.
23A	3530	0-100 hardpan, 100-500 red&gray shale.
24	3531	WL 54 July 1974. Only 4gpd from well in 1999; use cistern, dug well, and buy truckloads of water.
25	3532	0-59 hardpan&boulders, 59-162 gray&red shale; 1gpm at 80, 5gpm at 132. Dwl 95.
26	3533	
26A	3534	
27	3535	0-57 hardpan&boulders, 58-150 shale.
28	3536	0-84 alternating layers hardpan and dry gravel, 84-170 red&gray shale. Hardness 170 mg/L 1987.
29	3537	Water often cloudy during heavy use 1984-92. Yield tested <1gpm 1992.
29a		Water black twice 1992-1999 during heavy use. Water much softer after deepening well.
30	3538	
31	3539	Intermittent strong sulfur odor since 1995.
32	3540	Sulfur odor was intermittent, but increased in 2002.
33	3541	Reverse osmosis unit on kitchen sink.
34	3542	Yield limited since 1990, very little June 2001, only 8 ft of water in well August 2001
34A	3543	0-46 hardpan&boulders, 46-320 red&gray shale & Renss. grit. Occasional sulfur odor.
35	3544	0-130 clay hardpan, 130-250 gray slate w/streaks red paint rock. Dwl 104.
36	3545	Intense red turbidity initially and when pumped hard; has gradually declined. Dwl 90
37	3546	0-55 hardpan, 55-400 red&gray shale
38	3547	Seasonal camp, little use 2001-2.
39	3548	
39a		
40	3549	Dwl 75.
49	3550	
49A	3551	

z	Street	Date drill	Depth	Csd	DS	Yield	YS	Use	SpC	Hard	Cl	Cl_date	Qual	AltLS	AltR
50	2 Houston Way	1/1/45	180		M		A	D1	540	135					
51	113 Crystal Lk Rd		360		D	2	D	D2			38	3/22/88		778.5	772
52	27 Lake Ave		188		U			N						786.1	
52A	27 Lake Ave	11/13/84	500	62	D	6	D	I	850	17				785.4	728
53	45 Lake Ave	1/1/63	182		M			N			6	6/10/64		812.2	
53a	45 Lake Ave	10/1/81	350		D	2	D	D2	670	8				812.2	
54	41 Old Route 66	4/25/83	138	38	D	8	D	N						786.7	757
54a	41 Old Route 66	7/1/93	300	38	D		A	I	4100	1500				786.7	757
55	13 Old Route 66		80		M	<3	M	D4	1850	795				800	
56	21 Old Route 66		19.7	0	U			N						799.2	798
56A	21 Old Route 66	1/1/67	207		U	10	M	D6	920	257			I	799.1	798
57	23 Old Route 66		120		M		S	N						800	
57a	23 Old Route 66	11/1/64	220		M	3	M	D6	610	43	115	12/9/81		800	
58	29 Old Route 66		95		D			N						800	
58a	29 Old Route 66	1/1/65	165		D	4.5	M	N			110	12/14/76		800	
58b	29 Old Route 66	4/1/86	187		D	11	D	D9	1180	445			Ix	800	
59	33 Old Route 66		160		D	2.7	M	N			57	7/23/74		800	
59a	33 Old Route 66	11/1/83	400		D	2	D	D7	1150	68	84	11/27/84	Ix	800	
60	26 Crowley Way	1/1/53	118		R	8?	M	N						733	
60a	26 Crowley Way	11/30/95	402		R		A	D1	620	154				733	
61	13 Allen Ave	10/6/62	137	105	D			N						759.2	654
61a	13 Allen Ave	10/14/87	343		D	8.5	D	D4	770	17				759.2	
62	Allen Ave		146		M			N			12	9/6/79		767	
62a	Allen Ave	6/6/80	232		D	9	D	D2	670	222	11	8/8/84		767	
63	15 Terrace Drive	3/7/80	122	98	D	4	D	D6	570	205				726	628
64	16 Terrace Drive	3/27/81	200	90	D	5	D	D3	550	170	16	3/6/96		721.3	633
65	4 Terrace Drive		125?		M			N						723.1	
65A	4 Terrace Drive	1/1/96	450?		M		A	D2	650	205				723.9	
66	12 Crowley Way		150	87	M		S	D5	630	240	5	2/27/73		741	654
66A	12 Crowley Way	4/5/04	540	92	D	0.5	M	D5						741	651
67	30 Allen Ave	9/28/64	165	90	D	8	D	N			7	3/12/68		785.7	696
67a	30 Allen Ave	12/19/88	322		D	6	D	D2	610	180				785.7	
68	12 Allen Ave		143	50	M			D3			11	11/3/78		755	
69	6 Crowley Way		129.4		U			N			9	11/14/84		746.3	
69A	6 Crowley Way	1/1/98	300?		M		A	D3	620	214				745.7	
70	34 Terrace Drive		180	150	M			D2			5	11/8/82		745	
71	21 Terrace Drive	1/1/55	121		R			N			38	10/5/84		732	
71A	21 Terrace Drive	2/25/97	300	95	D	6.5	D	D3	640	34				732	638
72	5 Cottage Street		115		M			N			15	9/6/85		739	
72a	5 Cottage Street	1/15/94	240	90	D	20	D	D4	560	111				739.1	649
73	Cottage Street	1/1/80	128.7	107	U	3.5	M	D2	505	137			Sx	737.9	631
74	55 Lake Ave		170		M		S	N			32	9/12/83		803.9	
74a	55 Lake Ave	1/1/95	475		M	5	M	D4	840	0				803.9	
75	47 Lake Ave	7/10/75	455	84	D	1.5	D	D2	790	8				823	740
76	1616 Burden LkRd	1/1/66	300?		M		A	D2	2500	975	230	2/5/81	I	775	
77	26 Johnnycake La	4/30/63	230	115	D	3	D	D3	450	111	6	6/2/87	Ix	822.8	708
78	24 Johnnycake La	1/1/74	240	100	M	6.5	M	D2	480	128	7	12/14/82		820.8	721
79	20 Johnnycake La	1/1/68	195	73?	M		A	D4	610	154	25	10/20/80	C	809.1	
80	15 Johnnycake La	1/1/65	200	60	M			D2	720	154	37	11/3/89		801.7	742
81	10 Breezedale Dr	1/1/57	206	117	M	4.5	M	D2	520	170				828	711
82	6 Johnnycake La		95		M		S	N						780	
82A	6 Johnnycake La	1/1/87	320	41	D	4.5	D	D4						780	745
83	11 Johnnycake La	1/1/50	100	55	M		A	D2	770	300	32	7/13/71		790	
84	14 Tin Can Alley	1/1/60	130	30	M	10	M	D1	1240	496				776.4	
85	8 Johnnycake La		130	40	M		A	D4	860	410	79	1/13/86		771.6	
86	23 Johnnycake La	7/1/56	198	122	D	10.5	D	D3	570	86	21	2/5/86		827	705

Well#	USGS	Remarks
50	3552	
51	3553	0-6 hardpan, 6-360 red&gray shale
52	3554	Diam. 8 inches
52A	3555	0-57 hardpan, 57-500 gray&red shale
53	3556	
53a		
54	3557	0-30 hardpan, 30-138 rock. Frequently out of water 1990-93.
54a		Reverse osmosis unit after softener for drinking water. Water supply adequate.
55	3558	Cistern in basement, used for laundry and showers. Pump replaced 1992, plugged with lime.
56	3559	Dug well, diameter several feet.
56A	3560	Shale at depth of about 1 foot on this property
57	3561	House also supplied by cistern prior to 1964
57a		Water hard in 1964 (tested with kit), installed softener; seemed softer in 1988, softener discontinued.
58	3562	
58a		
58b		
59	3563	
59a		
60	3564	Dug well & cistern until 1953, 12 residents then. In 1995, 4 residents, ran out of water often.
60a		
61	3565	
61a		137-343 red&gray shale & Rensselaer grit. Dwl 100. Hard crust on pump pipe Oct 2000.
62	3566	
62a		
63	3567	Owner thinks yield has dinimished since 1998. Also 2 dug wells, used for laundry and gardens
64	3568	0-55 hrdpn, 55-60 fine gray sand, stones, 60-88 hrdpn, 88-95 red shale, 95-200 Renss. grit, shale seams. Dwl 40.
65	3569	6-in PVC casing extension to above land surface.
65A	3570	
66	3571	In 2002, when filling washing machine must stop to let well recover. Replaced well 2004 when pump failed.
66A	3572	Well hydrofractured 4/7/2004.
67	3573	Dwl 132. WL deeper than 147 ft June 1988 (meas during study by R.G. LaFleur)
67a		
68	3574	Well deepened 1987, no information.
69	3575	WL meas 127.5 ft below land surface Aug 2002
69A	3576	
70	3577	
71	3578	WL 93 Feb 1997, yield inadequate.
71A	3579	0-94 hardpan, 94-300 shale, sandstone. Dwl 60.
72	3580	Pump failed Jan 1994, WL 106.
72a		112-180 Rensselaer grit, 180-185 red shale, 185-240 Rensselaer grit. 20gpm at 120, dwindled to 3gpm at 212,
73	3581	Well may have been deepened, no information. _20 gpm at 240
74	3582	
74a		Well hydrofractured, subsequent yield 8 gpm.
75	3583	0-80 red hardpan, 80-455 red&gray shale
76	3584	Carbon filter for drinking water.
77	3585	
78	3586	1998-2000, entrained gas and black gritty sediment if pumped 0.5 hour or more.
79	3587	Occasional gray silt until new pump in 1996. Chloride 8 mg/L in 1969, 17 in 1974.
80	3588	Abundant gray silt occasionally when pumped heavily.
81	3589	
82	3590	Often out of water 1982-87.
82A	3591	0-35 overburden, 35-320 rock.
83	3592	
84	3593	Lime plugs pump & intake pipe, must clean every 3 years. Shallow-well pump.
85	3594	Usage spaced out to avoid overstressing well. Lime buildup in faucets.
86	3595	

z	Street	Date drill	Depth	Csd	DS	Yield	YS	Use	SpC	Hard	Cl	Cl_date	Qual	AltLS	AltR
87	25 Johnnycake La	1/1/58	213		M	5.5	M	D3	480	86	20	9/8/88		827	
88	21 Johnnycake La		170	130	M			N			7	2/11/74		820	
88A	21 Johnnycake La	1/1/79	265		M	5.2	M	D5	560	128	16	5/27/86		820	
89	9 Tin Can Alley		175		M		A	D3					I	770	765
90	7 Breezedale Dr	1/1/55	213		M	5	M	N			4	6/28/65		831	
90A	7 Breezedale Dr	7/9/84	302	132	D	4.5	D	D3	440	120	9	4/18/85		830.3	700
91	11 Breezedale Dr	1/1/64	200		M		A	D2	550	170	41	5/15/92		833.2	
92	38 East.Union Tpk	1/1/54	84		M		A	D2	410	188				803	
93	4 Breezedale Dr	10/13/86	400	83	D	2	D	D5	500	26	15	12/24/86		812.4	729
94	35 Houston Way	9/1/70	245	50	D	6	D	D5	420	43	10			808.7	759
95	42 Houston Way	2/26/68	300	126	R	5.7	R	D3	440	85	2	4/1/68		840.7	715
97	17 Crystal Lk Rd		95		M			N							
97a	17 Crystal Lk Rd	9/1/79	320		D	1.8	D	D1	790	8	38	9/29/93	Sx	794.3	
98	9 Crystal Lake Rd	6/28/60	143		M	<1	M	N	210	34	5	6/28/65	S	781.8	
99	3 East.Union Tpk	1/1/83	110		M		S	D4	1600	720				772	
100	6 East.Union Tpk							C	960	565				772	
101	3021 NY Route 43	1/1/65	120		M		A	N			52	9/25/75		782	
101A	3021 NY Route 43	11/8/95	420	39	D	1.5	D	D2					T	782	747
102	2 Johnnycake La		100		M		A	N						783	
102A	2 Johnnycake La	10/28/88	400		D	2	D	D4						783	755
103	18 East.Union Tpk	1/1/62	146	45	D	5.3	D	D1			48	6/13/83		787	
104	20A East Union Tpk	3/1/50	138	58	D	6.3	D	N	760	255				786.5	729
104a	20A East Union Tpk	11/1/02	230		D	10	M	D5						786.5	
105	16 East Union Tpk		147		M		A	D1	870	265	105	8/22/85		782.7	
106	40 East Union Tpk		140		M	2.3	M	D2	440	205				802.4	
107	42 East Union Tpk	1/1/56	80	20	M	3	M	N						801	781
107A	42 East Union Tpk	8/13/02	230	40	D	5	D	D2	810	325				801	781
108	22-24 East Union Tpk	1/1/86	300		M		A	D8			61	5/19/87		790	
109	NY Route 43							C			81	9/25/79		790	
110	1621 Burden LkRd	2/28/78	350	39	D	1.3	D	D2	670	8	101	9/8/80		766	757
111	1623 Burden LkRd	1/1/85	360		M		A	D3	1220	393	148	5/1/90	Ix	774.7	
112	1630 Burden LkRd		250		M		S	D3	1040	17	108	6/11/86	L	807	
113	1626 Burden LkRd		26	0	U			C			24	7/20/64		805	
114	26 Orient Ave		240		M		A	D2	590	0				790	
115	1547 Burden LkRd	3/2/79	339	51	D	5	D	D5	800	43	41	1/21/93	L	775.6	727
116	1569 Burden LkRd		207	68	M			N						786	718
116A	1569 Burden LkRd	11/1/88	400	70	D	3	D	D3	675	8				786	721
117	1614 Burden LkRd	8/3/71	100	40	D	3	D	D3	2300	607	216	3/1/79		775	775
118	1581 Burden LkRd		22	0	U			N						791	
118A	1581 Burden LkRd		>293		U		A	D3	700	8				790.7	
119	20 Orient Ave		157		M		S	N			66	11/22/83		784	
119A	20 Orient Ave	5/13/94	460	91	D	2.5	D	D2	745	8				784.4	693
120	6 House Road		219		D			N							
120a	6 House Road	8/23/76	390		D	3.5	D	D2	750	0	83	10/10/89		806.9	
122	15 Orient Ave		158		U			N			76	7/31/79		773.6	
122A	15 Orient Ave	7/23/83	335	39	D	0.4	U	D2	560	51	100	2/13/85		774	752
123	3049 NY Route 43	1/1/53	350		M			N						787	
123A	3049 NY Route 43	3/1/74	485	42	D	1	D	D5C						787	
123B	3049 NY Route 43	12/24/83	740	40	D	1	D	D5C	1340	248				787	775
124	2989 NY Route 43		600		M		A	D3	1280	427	29	5/20/77		785	
125	3020 NY Route 43						S	D2	790	230				780	
125A	3020 NY Route 43	8/12/04	1020	140	D	1	D	N						782	652
126	3024 NY Route 43						A	D1	840	34	61	7/12/89		785	
127	3033 NY Route 43	1/1/53	215		M		S	N						791	
127A	3033 NY Route 43	1/1/88	400		M	1.1	U	D3	1260	197				791.5	
128	2981 NY Route 43	3/8/55	117	48	D	6.4	D	D3	540	180	42	8/22/85		781	733

Well#	USGS	Remarks
87	3596	
88	3597	
88A	3598	
89	3599	Cellar dug in shale.
90	3600	Diam 4 in.
90A	3601	0-130 hardpan&shale, 130-302 red&green shale. Dwl 40.
91	3602	Also supplied house next door for several months in 1984
92	3603	Replaced dug well.
93	3604	0-80 hardpan&boulders, 80-400 red&gray shale. Slight sulfur odor in hot water. Dwl 80
94	3605	0-50 hardpan, 50-245 bedrock
95	3606	0-126 clay; 4 gpm 126-244, 1.7 gpm 244-275. Dwl 75 ft
97	3607	
97a		Reverse osmosis unit for drinking water only. Use also for church office, 6 persons
98	3608	House supplied by lake water since 1988. WL 90.5 below land surface June 1991 (owner's records)
99	3609	Quality worse since 1988. Carbon filter in 1995 to extract gasoline.
100	3610	Mineralized taste. Filter for several years to extract gasoline, removed by 2001.
101	3611	Also old dug well about 30 ft deep
101A	3612	0-35hrdpn, 35-420red&gray sh, seams sandstone. Red clay persisted 1995-98(removed w/alum&filter);rare since.
102	3613	Well replaced because so much sand (lime?) in faucet filters; yield was adequate. _Dwl 60.
102A	3614	0-28 hardpan&boulders, 28-400 red&gray shale.
103	3615	
104	3616	Aug. 2002, out of water once a week, wait 6 hours. Pre-1996, filled pool & watered lawn, no problems.
104a		Reverse osmosis unit on kitchen faucet since pre-1996.
105	3617	
106	3618	Hot water pipes plugged with lime until softener installed years ago.
107	3619	In 2002, ran a faucet 45 minutes before water stopped flowing. WL 12 in 1983.
107A	3620	0-20 gravel, 20-230 red&gray shale
108	3621	
109	3622	
110	3623	0-9 red hardpan, 9-350 red&gray shale w/seams Rensselaer grit.
111	3624	Record is for well deepened 1985; no information on original well.
112	3625	
113	3626	Dug well, diameter several feet, supplies beauty parlor and real estate office. Often out of water 2001.
114	3627	Sulfur odor April-Nov 1997, not since.
115	3628	0-49 hrdpn, 49-100 graywacke, 100-260 gray sh, 260-339 red sh. Dwl 100. Lime plugs hot water pipes.
116	3629	This well had been deepened in 1960, no record of original depth.
116A	3630	0-65 hardpan, 65-400 red&gray shale. Dwl 122.
117	3631	0-100 red shale, water 85-100. Dwl 20.
118	3632	Dug well, diam 4.2 ft
118A	3633	This well may have been drilled or deepened in 1988.
119	3634	1988-94, out of water after each load of wash.
119A	3635	0-88 hardpan, 88-460 red&gray shale. Dwl 120. Occasional minor sulfur odor.
120	3636	
120a		
122	3637	
122A	3638	0-22 red hardpan, 22-335 red&gray shale. Dwl 50. Yield 1.3gpm driller
123	3639	Hydrofractured 1994. Not regularly used as of 2000. Wells 123,123A,123B <10 ft apart.
123A	3640	Hydrofractured 1994. Used occasionally when well 123B is overpumped because of a leak.
123B	3641	0-12 hrdpn, 12-740 red&gray shale. Hydrofrac 1994. Dwl 80. 2 stores, 3 apts; avg use 218 gpd(water meter)
124	3642	_Oct 2002, one store vacant.
125	3643	
125A	3877	0-130 red hrdpn, 130-1020 red shale. [Note: depth to bedrock inconsistent with records of many nearby wells.]
126	3644	Also dug well in cellar, valves allow either well to supply the house; pump inoperable 2002.
127	3645	Filter in 1980's to remove gasoline contamination.
127A	3646	
128	3647	

z	Street	Date drill	Depth	Csd	DS	Yield	YS	Use	SpC	Hard	Cl	Cl_date	Qual	AltLS	AltR
129	3005 NY Route 43		104		M		A	D1	1260	300	152	6/9/76		770	
130	2954 NY Route 43	12/10/91	175	40	D	6	D	D3		170				775.1	735
131	3055 NY Route 43	8/3/60	190	32	D	9	D	I	1220	410	269	4/20/89	C	775.2	745
132	67 Old Route 66	4/15/80	217		D	12	D	D			200	3/28/86		797	
133	76 Old Route 66	8/4/77	305	40	D	1.3	D	N			36	11/15/85		790.7	751
134	17 Old Route 66		100		M			N						800	
134a	17 Old Route 66	4/1/69	425		M	2	M	N	680	85			T	800	
134B	17 Old Route 66	1/1/75	240		M	5	M	D4	2350	940	296	11/18/86	TIxC	800	
135	NY Rt 43 & Old Rt 66		500		M			C						795	
136	11 Old Route 66		110		M		S	D3	1750	700	178	2/8/88	Ix	794.3	
136A	11 Old Route 66	9/1/95	400	40	D	2	D	D3	800	170			T	793.7	793
137	3066 NY Route 43		128		M		A	D2					Ix	760	
138	3075 NY Route 43	11/1/65	215	25	D	3.5	D	N			51	6/8/67		756	731
138a	3075 NY Route 43	12/1/84	400	25	D	2	D	D5		752	332	5/7/86	C	756	731
139	3089 NY Route 43		65	17	M			N						735	
139A	3089 NY Route 43	1/1/82	375		M		A	D3	1110	290	118	6/27/86		735	
140	3092 NY Route 43	1/1/45	187		M			N			20	10/11/66		743	
140A	3092 NY Route 43	8/16/89	502	40	D	3.5	D	D7	1140	359				742.9	722
141	3098 NY Route 43		150		M			N						745	
141A	3098 NY Route 43	1/1/90	210		M	7	M	D5						745	
142	1575 Burden LkRd		300		M		A	D6			14	6/4/82		790	
143	5 Victors Lane	1/1/68	158	50	D	8	D	D5	430	51	180	10/9/86		782.9	733
144	12 Barzen Road	1/1/58	86	32	M		A	D3	770	248	>60	8/24/71		777.5	745
145	20 Barzen Road	6/9/70	160	40	D	8	D	D4	410	51	7	5/10/72		800.6	774
146	13 Victors Lane	9/1/64	217	60	D	4	D	D2	320	120	2	12/19/66		803	743
147	9 Victors Lane	10/17/66	155	36	D	6	D	D2	310	110			S	788.3	754
148	19 Grand Way		150		M			D3	560	17	32	8/7/81		770	
149	25 Old Route 66		142		M			D4	1090	393	151	11/25/85		800	
150	2967 NY Route 43		80		M		A	D3			85	6/10/82		785	
151	2985 NY Route 43		150		M		A	D8	650	222	37	5/1/85	S	785	
152	105 Old Route 66	1/1/68	186		M		S	N			23	10/24/89		785	
153	4 Old Route 66	3/20/76	380		D	3	D	C			126	9/7/82		790.5	770
154	11 Pine Ave		190	44	M		A	D1	660	162	10	12/20/76		746	
155	17 Pine Ave	10/15/76	170	73	D	25	D	D1			22	12/20/76		749	675
156	2 Pine Ave		195	80	M	10	M	D2	780	145	28	5/19/86	S	742	
157	99 Crystal Lk Rd	8/26/77	294	50	D	5	D	D2		34	<5	12/19/77		778	730
159	NY Route 43		105		M		A	D5	2470	693	369	1/5/83		766.5	
160	25 Orient Ave		190		M		A	D2	610	8	26	8/10/81		795	
161	7 Johnnycake La		120		M		A	D2	640	290	109	6/16/89	C	779.3	
162	45 Terrace Drive	11/1/84	302		M		A	D4	600	17	9	1/7/85		802.7	
163	1 Crystal Lk Rd	10/1/87	360	61	D	5	D	D2	405	17			Sx	783	727
169	16 Crystal Lk Rd	1/1/46	185		R		A	D2	330	17			Sx	781.5	
171	Burden LkRd						A	D5			235	6/13/85		776	
173	22 Allen Ave	1/1/55	118		M			N						760.3	
173a	22 Allen Ave	1/1/76	290		D	9	D	D4	660	154				760.3	
174	3040 NY Route 43						A	D3		882	375			793	
175	3042 NY Route 43	12/20/45	118	19	D	1.7	D	N						786	781
175a	3042 NY Route 43	1/1/71	200	19	M	3.5	M	D5	410	137				786	
176	3048 NY Route 43	6/17/71	300	40	D	2.5	D	N			7	8/30/89		785.1	783
176A	3048 NY Route 43	10/3/91	443	42	D	5	D	D4	510	34			C	785.1	
177	3054 NY Route 43							D1	505	154				784	779
178	3060 NY Route 43	11/1/78	132	31	D	6	D	N					I	773.7	764
178a	3060 NY Route 43	1/1/95	450		M	3.5	M	D4	745	308				773.7	
179	3095 NY Route 43		50		M	3		D3		530	166	5/21/86		735	
180	3083 NY Route 43	1/1/79	100		M		A	D1						738	
181	3077 NY Route 43	1/1/42	66		M		A	D6	1380	615				750	

Well#	USGS	Remarks
129	3648	
130	3649	Dwl 8. Replaced older drilled well reported 78 ft deep
131	3650	0-28 gravel/red cobbly hardpan, 28-78 soft red shale, 78-190 red&green shale; bailed 2gpm w/well depth 160. Dwl 24.
132	3651	Well deepened 1980, original depth 147.
133	3652	Well unused since 1987 due to low yield; domestic water now obtained entirely from lake.
134	3653	
134a		Little or no additional yield after deepening. Used occasionally when newer well yields dirty water.
134B	3654	Water gray, gritty occasionally after prolonged pumping.
135	3655	
136	3656	In use alternately with well 136A
136A	3657	
137	3658	
138	3659	
138a		Dwl 23. Reverse osmosis unit in use. Dug well 12 ft deep below cellar floor, unused.
139	3660	
139A	3661	
140	3662	Softener backwashed each night in 1989, leaving inadequate water for occupants, so well replaced.
140A	3663	0-21 brown,red hardpan, 21-502 red&gray shale. Hydrofractured Aug 1989, subsequent yield 8 gpm.
141	3664	Inadequate yield June 1988, first time. Pump failed 1990, could not recover jet, so well replaced.
141A	3665	
142	3666	
143	3667	Tested 1992, very hard. Lime crystals in faucet screens 2002, furnace coil plugged. Cl 4 mg/L 4/1973,2/1985,9/1986
144	3668	This well also supplied house next door 1968-88; in 2001 it seems barely adequate for this house.
145	3669	0-27 boulders, 27-160 red&gray shale _WL 45.5 plumber 8/1996.
146	3670	Dug well rept. 17 ft deep, beneath garage floor; overflows each spring.
147	3671	0-35 hardpan, 1gpm at 75, 6gpm at 155. Sulfur odor since jet pump with broken pipe replaced by submergible 1998
148	3672	
149	3673	Well may have been deepened in about 1984, to 500 ft (?)
150	3674	House unoccupied, remodeled July-Aug 2002. WL meas 16.43 June 1988, rising.
151	3675	Sulfur odor only in upper 2 floors. Mineral deposits on coils in water heaters.
152	3676	Transitioned to use of lake water in 1980's as well became inadequate. Chloride 6 mg/L 10/17/68.
153	3677	0-21 clay, hardpan, 21-380 red shale. Supplied restaurant & 6 apts until 1998 (lake water used for toilets, etc).
154	3678	_Now seldom used.
155	3679	Dwl 90. WL meas. 112.28 Aug 1988
156	3680	Sulfur odor since 2001 only. Occasional periods of low water pressure.
157	3681	Rock at 48 ft
159	3682	Filter used through 2002 to remove gasoline leaked from adjacent filling station prior to 1989.
160	3683	pH test 8.5
161	3684	
162	3685	
163	3686	0-56 hardpan, 56-360 red&gray shale. Dwl 85. Formerly supplied by well #98
169	3687	Diam 10 inches. WL 80 below land surface Nov 1992 (owner's records)
171	3688	
173	3689	
173a		Dwl 105. Pump lowered July 2001.
174	3690	
175	3691	0-5 overburden, 5-118 rock. Dug well in cellar, WL 1 ft below cellar floor Aug 1999.
175a		
176	3692	0-2 overburden, 2-300 rock.
176A	3693	Bedrock exposed in cellar, 4 ft below grade. Dug well under porch, used to water gardens.
177	3694	Dug well in cellar, carved out of bedrock, not used, nearly full of water Sept 1999.
178	3695	Replaced dug well in cellar, excavated in shale. In 1995, yield <1 gpm (tested by plumber), water often dirty.
178a		
179	3696	
180	3697	
181	3698	

z	Street	Date drill	Depth	Csd	DS	Yield	YS	Use	SpC	Hard	Cl	Cl_date	Qual	AltLS	AltR
182	3071 NY Route 43		110		M	2.5	M	D4	1260	350				758	
183	3067 NY Route 43		95		M	0.15	U	D2	1500	462	530	1/15/87	C	760.4	
184	3063 NY Route 43		118		R		S	D2	975	360				762	
185	3101 NY Route 43		78		M	1.5	M							736	
185A	3101 NY Route 43	4/2/92	220	40	D	7.5	D	D						736	711
186	3105 NY Route 43	1/1/58	130		M	3.5	M	D2	1000	393				733.9	
187	32 East.Union Tpk		105		R			D2	350	137				792.8	
188	44 East.Union Tpk	5/23/86	300	31	D	2.5	D	D2	1180	487				802.6	793
190	11 Crystal Lk Rd						S	N		23	18	9/18/01	C		
190A	11 Crystal Lk Rd	7/18/02	400	86	D	5	D	D4						789.7	706
191	12 Gettle Road	1/1/50	200		M			N						785	
191a	12 Gettle Road	7/1/74	315		M	2	M	D3	640	8				785	
192	13 Gettle Road	1/1/28	220		M		A	D2	470				S	791	
192A	13 Gettle Road	9/5/05	540	42	D	1	D	D2						791	753
193	5 Gettle Road	1/1/85	196		M	4	M	D2	550	0				780	
194	6 Gettle Road	3/23/71	350	60	D	2.5	D	D2			1	7/15/74		782	744
195	135 Old Route 66		129.9		U			N						775.5	
195A	135 Old Route 66	2/20/74	200	60	D	7.5	D	D2	480	68				775.9	718
196	139 Old Route 66	1/1/38	150		M			N			3	4/1/66		777	
196A	139 Old Route 66	3/1/94					A	D2	630	17				777	
198	147 Old Route 66	1/1/50	140		D			N						763	
198a	147 Old Route 66	12/7/88	320		D	2	D	D2	480	0	<2	12/22/88		763	
202	140 Old Route 66	1/1/47	140		M	5	M	D4	380	68	6	6/30/82		777	
203	142 Old Route 66	1/1/45	147		D			N			10	11/27/81		769	
203a	142 Old Route 66	5/14/86	400		D	3	D	D1	450	17				769	
204	146 Old Route 66	1/1/37						N			2	2/13/62			
204A	146 Old Route 66	6/28/83	340	63	D	2.5	D	D4	515	17			C	759.6	700
208	168 Old Route 66	3/2/61	133	77	D	6.5	D	D						730	660
213	3109 NY Route 43	1/1/59	110		M			N						731	
213A	3109 NY Route 43	5/21/91	342	60	D	4	D	D4	850	34				731.5	672
214	7 Hickory Lane	2/1/87	380	61	D	1.5	D	D						732	677
215	5 Hickory Lane	1/20/87	320	61	D	2	D	D						718.1	660
219	38 Beach Lane		143		R		A	D2	280	120			Ix	792.5	
220	36 Beach Lane	9/1/94	500		M	5	M	D3	360	26			T	792.7	
221	12 Beach Lane	1/1/40	127		M			N						811	
221a	12 Beach Lane	1/1/60	265		M		A	D2	410	43	43	8/7/00	TC	811	
222	6 Old Route 66		408		M			N					T	797.7	
222a	6 Old Route 66	1/1/69	650		D	1	D	DC	460	34	29	1/19/70		797.7	
223	19 Barzen Road	1/1/53	75		M		A	D5	1120	308	>60	1/26/71		771.1	
224	23 Barzen Road	11/18/86	400	61	D	1.5	D	D4	450	17			T	776.7	716
225	27 Barzen Road	5/1/85	95		M		A	D2	290	77				779.9	
226	24 Barzen Road	1/1/30	128		D			N			3	3/2/88		789.4	
226a	24 Barzen Road	9/4/90	400		D	2.5	D	N					T	789.4	
226B	24 Barzen Road	6/22/93	400	72	D	2	D	D4	370	0			T	795	
227	16 Barzen Road	1/1/58						D1	530	77				795	
228	8 Barzen Road	3/1/88	502	40	D	6.7	D	D3					S	770.5	731
229	2992 NY Route 43		110		M		A	D3	520	145	165	6/23/80	SI	767.1	
230	2988 NY Route 43		34	0	M		A	N						769	
230A	2988 NY Route 43	6/7/00	702	40	D	4	D	N						769.5	735
230b	2988 NY Route 43	7/15/00	400	40	D			D2	920	239				769.5	735
231	5 Bullis Drive	1/1/41	100	15	M		A	D2	1160	333	>60	7/8/71		790	789
232	11 Bullis Drive	1/1/43	120		R		S	D3	830	230	72	10/27/97	Ix	817	
233	15 Bullis Drive		186		M		A	D4	370	51	3	4/30/85		825.5	
234	19 Bullis Drive		180		R		A	D3	390	77	5	7/8/86		834	
235	27 Bullis Drive	1/1/73	150		M	5	R	D3	380	103				823.3	
236	10 Bullis Drive	1/1/50	100		M		A	D3	600	180	7	3/19/87	Sx	823	

Well#	USGS	Remarks
182	3699	
183	3700	
184	3701	Ample water 1968-81. Out of water occasionally in 1980's, daily in late 1990's. WL 15 below cellar in 1977.
185	3702	WL 27 June 1983 rept by owner.
185A	3703	0-25 hardpan, 25-220 gray&black shale. Dwl 34.
186	3704	
187	3705	
188	3706	0-10 hardpan, 10-300 red&gray shale. Dug well used until 1986, still available.
190	3707	House supplied largely by lake water until 2002.
190A	3708	0-83 hardpan, 83-300 red shale w/seams gray, 300-400 gray shale; 1gpm from above 300, 4 gpm at 303
191	3709	Well went dry 1974
191a		
192	3710	Sulfur odor since about 1992. Softener since about 1995 to remove iron. No water often 2004-5, daily summer 2005.
192A	3876	0-38 hardpn & boulders, 38-540 gray shale & Renss. grit. Hydrofractured, little increase in yield. Replaces #192.
193	3711	Well deepened 1985, no information on original well
194	3712	Formerly used lake water
195	3713	Well dry July 24, 2002 (USGS measurement). Softener installed in 1968 to remove iron.
195A	3714	
196	3715	Well failed Feb 1994
196A	3716	
198	3717	
198a		140-320 gray shale, a litle red
202	3718	
203	3719	Chloride 3 mg/L 8/27/1967. Pump ran a lot in 1985, well dry after January 1986.
203a		Water softer after well deepened.
204	3720	Water harder than in replacement well
204A	3721	Dwl 120
208	3722	0-40 red clay hardpan, 40-65 soft wet clay, 65-70 gravel, 70-77 soft red&gray shale, 70-133 red&gray slate
213	3723	Also supplied next house east 1966-86.
213A	3724	
214	3725	0-55 hardpan, 55-380 gray shale
215	3726	0-58 hardpan & boulders, 58-320 Rensselaer grit, gray shale
219	3727	Pump replaced 1996, plugged with lime.
220	3728	House supplied by lake water and shallow drilled well prior to 1994.
221	3729	
221a		Well water turbid1960-80, used mostly lake water; well water clear since 1980 except if pumped hard.
222	3730	Original depth reported 219 ft; red cloudiness when deepened to 408.
222a		
223	3731	Used some lake water also 1953-65.
224	3732	Red cloudiness for several years, none since 1999. Dwl 15.
225	3733	Lake water used for lawn watering
226	3734	
226a		Dwl 55. Well caved in or filled with sediment in 1993, could not pull pump
226B	3735	4-inch PVC liner with saw-cut slots 20-400 ft. Dwl 50.
227	3736	Prior to 1970, hot water pipes would plug with lime
228	3737	Sediment filled bottom 100 ft in first few months of use.
229	3738	
230	3739	Dug well,diam 2.5ft. Pump occasionally broke suction in summer, must wait 2 hours. Replaced to help property sale.
230A	3740	0-35 hrdpn, 35-220 gray shale, 220-278 gray&red sh, 278-702 soft gray sh, weathered seams, graywacke 410-440.
230b		Well 230A caved in below 400 in July 2000; new pump set at 280. _Most yield below 500. Pump at 600.
231	3741	Softener since 1976, hardness tested every few years, has increased persistently.
232	3742	WL 60 Oct 2001, meas by owner.
233	3743	Diam 8 inches
234	3744	WL 83 May 1987, meas by plumber.
235	3745	
236	3746	

z	Street	Date drill	Depth	Csd	DS	Yield	YS	Use	SpC	Hard	Cl	Cl_date	Qual	AltLS	AltR
237	6 Bullis Drive		112		M		A	D4	1150	375	15	9/11/85	I	807	
239	2972 NY Route 43							D4	440	128				815	
240	2966 NY Route 43	10/1/52	<190	>20	R		A	D2I	680	145				815	
241	2956 NY Route 43	1/1/83	98	58?	M	12	M	D2	510	145				795.3	
242	2948 NY Route 43		89	41	M		A	D2	380	137	4	8/12/69		789	
244	2977 NY Route 43		102		M	10	M	D10	755	282			S	779.8	
245	21 Victors Lane	1/1/65	225		M	15	M	D5	340	86				817	
246	25 Victors Lane							D4		86				815	
247	91 Old Route 66	1/1/30	139		U			N			30	9/26/84		802.7	
247A	91 Old Route 66	12/7/94	500	63	D	1	D	D2	750	0				805	745
248	99 Old Route 66	1/1/72	240		D			N			7	9/19/72		805.9	
248a	99 Old Route 66	7/1/79	400		D	5	D	D2	690	8				805.9	
258	Old Route 66	1/1/80	400		M			D			3	12/31/86		722	
268	2999 NY Route 43	1/1/34	160		R		A	D8	1140	325	201	2/4/87	Sx	775	
269	10 Buy Way	1/1/47	116		R		A	D3	1180	436			Ix	777	
270	Crystal Lk Beach	1/1/52						C	295	110				784.5	
271	72 Old Route 66	12/14/87	120	39	D	6.5	D	D2	2200	700	293	7/8/88		790	
272	69 Old Route 66	8/17/90	200	41	D	6	D	D4	800	299				791	766
273	end Pine Ave	1/1/47	153		M	3	M	N						790	
273a	end Pine Ave	4/6/64	197		D	2.5	D	N						790	
273B	end Pine Ave		360		M	4	M	D2	700	34			S	790	
274	3164 NY Route 43	1/1/29	240		M			N						723	
274A	3164 NY Route 43	10/1/76	440	91	D	2.5		D4	570	103	7	5/17/77		723.8	632
275	4 Allen Ave	1/1/72	146		M			N						747	
275A	4 Allen Ave	5/20/02	250	90	D	10	D	D2						747.4	657
276	25 Pine Ave		125		D			N						752	
276a	25 Pine Ave	10/30/91	250		D		A	D2	730	162				752.1	
277	16 Pine Ave	1/1/52	148		M			N						763	
277a	16 Pine Ave	1/1/70	220		D	12	D	D2	730	34			Sx	763	
278	3110 NY Route 43	1/1/59	132	40	M	6	M	N						737	
278a	3110 NY Route 43	9/17/01	250		D	9	D	D1	820	60				737	
279	3106 NY Route 43		24	0	M			N						757	
279A	3106 NY Route 43	1/1/59	140		M			N						756.6	
279b	3106 NY Route 43	1/1/76	190		M		A	D1	750	68				756.6	
281	Beach & Old Rt 66		400		M			D			40	9/18/84		810	
282	8 Beach Lane		500		M	4/5	M	D4	820	120				807	
283	1635 Burden LkRd		197		D			N						787	
283A	1635 Burden LkRd	7/21/76	389		D	3	D	D8	1060	274	62	8/11/76		787	
284	Burden LkRd		155		U			N						783.3	
284A	Burden LkRd	10/1/98	1000	40	D	0.5	D	C						783	
285	4 Johnnycake La		280		M		A	D1			62	8/28/80			
286	1619 Burden LkRd		80		M			N			265	5/8/89		768	
286A	1619 Burden LkRd	8/4/94	400	41	D	2.5	D	D1	830	85			Ix	768.3	750
287	1617 Burden LkRd		197		M		S	D4	680	162	138	6/10/87		776	
289	1609 Burden LkRd		99		U						103	10/14/86		789	
289A	1609 Burden LkRd	7/13/88	503	48	D	1.5	D	D5	860	17	52	8/1/88	C	789.2	742
290	Burden LkRd	1/1/51						D1						798	
291	1608 Burden LkRd		132	20	D	0.3	D	N			190	7/30/85		777.1	757
291a	1608 Burden LkRd	6/1/90	400		D	1.9	U	D4	1000	120			C	777.1	
292	1638 Burden LkRd		14	0	M						96	12/23/86		784	
292A	1638 Burden LkRd	4/29/96	350	38	D	0.6	U	D3	1060	17	210	7/15/98		784.1	764
293	NY Route 43		>287		M			C	950	137				790	
294	3 Prospect Ave	1/1/73	218		R	3.5	R	D5	760	17	20	10/5/82		792	
295	39 Orient Ave	1/1/87					A	D1	700	0	32	11/9/90		785	
296	1589 Burden LkRd		196		R		A	D2	710	17				796.2	
298	2 Prospect Ave	1/1/68	179		M	3.5	M	D1	470	17	62	10/20/88		790	

Well#	USGS	Remarks
237	3747	
239	3748	
240	3749	Depth, casing estimated from recorded cost and prices. Well located at parsonage, also serves church.
241	3750	
242	3751	
244	3752	Also serves a lawyer's office.
245	3753	
246	3754	
247	3755	Well supplied drinking water until 1994, lake water used for other purposes.
247A	3756	0-60 hardpan, 60-500 red&gray shale. Dwl 70.
248	3757	
248a		240-400 red&green shale. Dwl 130.
258	3758	
268	3759	Sulfur odor noted only since about 1987.
269	3760	Owner recalls WL meas 13 in 1970, 27 in 1986. Well originally also supplied house next to east.
270	3761	Bedrock outcrop near well. Supplies one residence plus kitchen at beach pavilion.
271	3762	Reverse osmosis unit on kitchen tap to remove taste imparted by softener. Lake water for lawn watering.
272	3763	0-25 hardpan, 25-200 red&gray shale. Three 220-ft uncased holes in driveway for heat pump installation.
273	3764	1957-63, jet pump adusted several times, apparently to compensate for declining water level.
273a		Well failed in (1987, or later), no water.
273B	3765	
274	3766	
274A	3767	
275	3768	WL 106 June 2002, decided to drill new well.
275A	3769	0-60 hardpan, 60-90 clay, 90-250 shale
276	3770	Well failed in 1991, completely out of water.
276a		
277	3771	Yield declined after well drilled at house nearby.
277a		Since submergible pump replaced jet in 1999, water soft and light sulfur odor, no longer any iron.
278	3772	Hard water. Well failed Sept 2001, nearly dry, yield 0.25 gpm (reported by driller of well 278a).
278a		0-132 old well, 132-230 red&gray shale, 230-250 red shale. Dwl 72.
279	3773	
279A	3774	
279b		Also dug well, not used recently.
281	3775	
282	3776	
283	3777	
283A	3778	Drilled in dug well 9.4 ft deep. WL in dug well 8.17 Aug 9,2002 and 7.80 July 31,2005, below land surface.
284	3779	Well produced dirty water in 1998.
284A	3780	Telephone substation faces Orient Ave; wells in lot on Burden Lake Road.
285	3781	
286	3782	
286A	3783	0-18 gravel&hardpan, 18-400 red&gray shale & Rensselaer grit. Also carbon filter since 2001.
287	3784	
289	3785	Often out of water 1985-88.
289A	3786	
290	3787	
291	3788	Yield checked 1986 by driller, 0.3 gpm.
291a		Yield 1.5 gpm driller. Dwl 120.
292	3789	Dug well, diam several ft, is used for some toilets; also used for laundry 1987-2001.
292A	3790	0-20 hardpan, 20-350 red&gray shale. Yield 1 gpm driller. Water much softer than dug well.
293	3791	
294	3792	
295	3793	Also dug well, not used.
296	3794	WL 135 below casing, 139.4 below land surface Nov 1987 (records of pump installer)
298	3795	

z	Street	Date drill	Depth	Csd	DS	Yield	YS	Use	SpC	Hard	Cl	Cl_date	Qual	AltLS	AltR
299	1593 Burden LkRd	1/1/54	228		D	0.5	D	N						802	
299a	1593 Burden LkRd	10/8/96	500		D	1	D	D2	810	0				802	
300	11 Orient Ave		87		R		S	D2	825	265	148	9/2/86		765	
301	1563 Burden LkRd		155		D			N						779	
301a	1563 Burden LkRd	1/1/73	305		D		A	D7	740	0				779.2	
302	29 Johnnycake La		125		R		S	N	700	111				813	
302A	29 Johnnycake La	5/21/02	380	122	D	6	D	D4	470	43				813.4	697
303	3107 NY Route 43	1/18/86	202	60	D	10	D	D2	890	137				730.9	671
304	3125 NY Route 43		70		M			N						726.4	
304a	3125 NY Route 43	1/1/85	160		M		A	D3	710	196				726.4	
305	3147 NY Route 43	7/9/97	722	100	D	1	D	D5	660	51				726	626
306	3149 NY Route 43	1/1/58	150		M	3	M	D5	540	188				720	
307	3157 NY Route 43		138	>93	R		A	N						710.5	
307A	3157 NY Route 43	9/23/02	290	90	M	1.5	M	D2						709	619
308	25 Terrace Drive	1/2/80	330		D	10	D	D4	650	17	23	4/5/93	Sx	745	
309	Terrace Drive		100		M			N						774	
309A	Terrace Drive	10/1/96	200		M	4.5	M	D1	530	17				755.2	
310	39 Terrace Drive	1/1/48	170		D			N						762.7	
310a	39 Terrace Drive	9/25/98	320		D	4	D	D5	620	17				762.7	
311	50 Marcy Ave	1/1/59	218		M		A	D1	520	17				795	
312	46 Terrace Drive	11/1/71	167	167	M	2.5	M	D2	555	34				782.4	
313	42 Terrace Drive	10/1/74	560		M		A	D2	670	0				757.5	
314	15 Cottage Street	11/6/70	143		R			D2	325	171				730	
315	1560 Burden LkRd							N						770.9	
316	1554 Burden LkRd		425		R		A	D16	585	8	8	2/22/91		766	
317	1564 Burden LkRd	1/1/60	220	80	M		A	D5	875	17	11	8/16/67		779	700
318	1570 Burden LkRd		330		M		A	D4						783	
319	56 Marcy Ave	7/15/88	240	193	D	8.5	D	D2	600	17				789.1	599
320	22 Johnnycake La						S	N	470	111				821	
320A	22 Johnnycake La	9/24/02	400	94	D	1.7	D	D2						821	731
2060	East Union Tpk	6/17/97	380	43	D	6.5	D	N		288	5	7/7/97	C	826.9	795
2061	East Union Tpk		188	21	D			I						814.8	794
2062	2 Morning Circle	6/3/94	400	121	D	5.5	D	D2	380	137				832	715
2063	4 Morning Circle	1/5/90	390	99	D	3	D	D4	400	120	8	8/15/95		827	729
2064	6 Morning Circle	2/23/95	215	99	D	8	D	D3	400	136				818.5	719
2065	8 Morning Circle							D4	370	85					
2066	9 Morning Circle	6/7/94	400	101	D	3.5	D	D4						810.8	713
2067	7 Morning Circle	3/24/95	200	85	D	6.5	D								
2068	5 Morning Circle	6/6/94	400	90	D	3.5	D	D4	400	170				811.1	724
2069	3 Morning Circle	1/10/90	310	89	D	4	D	D3	420	170				814	726
2070	1 Morning Circle	7/10/95	205	80	D	7.5	D	N						815.3	735
2071	20 East.Union Tpk	6/20/95	400	61	D	2.5	D	D2	960	160				786.9	726
2072	13 Buy Way	7/16/96	170	38	D	6.5	D	D7	820	308				768	758
2073	NY Route 43	8/14/89	500	80	D	1	D	C						777.4	707
2076	Burden LkRd	9/20/88	320	51	D	7.5	D	D2			4	11/30/88		746	701
2077	1481 Burden LkRd	1/1/65	70		M	2.7	M	N			8	8/8/85		700.9	
2077a	1481 Burden LkRd	1/1/92	142		M	3.2	M	D4					TC	700.9	
2078	1504 Burden LkRd		60		U		A	D5						699.9	
2079	1545 Burden LkRd		135	58	M		S	D2	695	154	17	7/1/74		774	
2080	10 Marcy Ave	2/25/02	230	92	D	6	D	D3	640	197				725.3	633
2081	21 Marcy Ave	8/5/97	290	96	D	5	D	D2	590	17	67	10/23/97	C	755.8	660
2082	27 Marcy Ave	7/31/97	210	128	D	10	D	D4	560	26	51	10/27/97	C	774.7	647
2083	20 Prospect Ave	7/29/97	350	48	D	3.5	D		620	28	38	10/30/97	C	775.1	727
2084	55 Marcy Ave	1/1/99	170		R	8	R		670	38	48	5/19/99	C	777	689
2085	28 Prospect Ave	1/1/99	290		R	5	R							768.5	
2086	45 Marcy Ave	7/7/02	270	140	D	5	D							789.9	650

Well#	USGS	Remarks
299	3796	Yield checked 1996 by driller, 0.5 gpm.
299a		Dwl 120.
300	3797	
301	3798	
301a		
302	3799	Not out of water 1990-95; out at least twice yearly 1996-01. WL 85 Apr 2001. Dirty if pumped hard.
302A	3800	0-116 hardpan, 116-380 red&gray shale. Dwl 115.
303	3801	0-57 hardpan, boulders, 57-202 red&gray shale.
304	3802	Well failed suddenly in 1985, no water
304a		
305	3803	
306	3804	Also supplied next house east until 1997.
307	3805	Jet pump failed June 2002, plumber broke pipes, tried to install new pipes, failed, so new well drilled
307A	3806	
308	3807	
309	3808	Well went dry Sept 1996
309A	3809	
310	3810	Yield always modest, declined 1997-8.
310a		
311	3811	
312	3812	Many boulders, dynamited several times; bailed 2.5 gpm after last blast, owner elected to stop. Also dug well, unused.
313	3813	Pump repaired 1987, WL 90. Softener installed 1974, removed 1986 when water test showed it was not needed.
314	3814	Strong sulfur odor 1981-94, light and sporadic since.
315	3815	2 apt. buildings supplied 1975-92 by this well, supplied by well 316 before 1975 and since 1992
316	3816	Formerly owned by Faith Mills. 3-inch discharge pipe from former pump suggests large yield.
317	3817	Depth rept 184 in 1960; well may have been deepened.
318	3818	
319	3819	0-190 hardpan&boulders, 190-240 gray shale & Rensselaer grit. Sulfur odor occasionally since 2000.
320	3820	
320A	3821	0-90 hardpan, 90-400 red shale. Dwl 125 overnight.
2060	3822	0-32 till, 32-80 gray shale w/sandstone layers, 80-300 red&gray shale, w/quartz layers &water 175-200.
2061	3823	
2062	3824	0-117 hardpan&boulders, 117-400 red&gray slate. Dwl 90. House occupied since 1996.
2063	3825	0-98 hardpan&boulders, graywacke bldr 92-95, 98-140 green shale w/layers graywacke, 140-390 red&green shale.
2064	3826	0-99 hardpan&boulders, 99-215 rock. Dwl 68. House occupied since 1995.
2065	3827	
2066	3828	0-98 hardpan&boulders, 989-400 red&gray shale. Dwl 57.
2067	3829	0-85 hardpan&boulders, 85-200 rock.
2068	3830	0-87 hardpan&boulders, 87-400 red&gray shale
2069	3831	0-88 red hardpan&boulders, 88-120 green shale w/graywacke layers, 120-310 red&green shale. Dwl 60.
2070	3832	0-80 hardpan&boulders, 80-205 rock. Dwl 70. No house 2002.
2071	3833	
2072	3834	0-10 hardpan, 10-170 rock. Hot-water coil in furnace plugs, must be cleaned regularly.
2073	3835	0-70 overburden, 70-200 red shale w/quartz seams, 0.3gpm; 200-500 gray&red shale, 1gpm above 300.
2076	3836	_Hydrofractured.
2077	3837	
2077a		
2078	3838	
2079	3839	Lime plugged pipes until softener installed
2080	3840	0-60 hardpan, 60-92 sand, 92-230 red&gray shale.
2081	3841	0-96 hardpan & clay, 98-290 shale, mostly gray.
2082	3842	0-128 hardpan & clay, 130-210 shale.
2083	3843	0-50 hardpan, 50-350 gray shale. No house 2002.
2084	3844	House unoccupied 2002.
2085	3845	No house 2002.
2086	3846	0-10 clay, 10-140 hardpan, 140-270 shale. No house 2002.

z	Street	Date drill	Depth	Csd	DS	Yield	YS	Use	SpC	Hard	Cl	Cl_date	Qual	AltLS	AltR
2087	35 Marcy Ave	7/13/02	250	140	D	15	D							779.3	639
2088	34 Marcy Ave	7/1/02	270	160	D	6	D							789.5	630
2089	5 Allen Ave	6/1/02	290	90	M	6	M	D3	630	162			S	751	661
2090	3163 NY Route 43	5/18/01	250	84	D	6	D	D2	600	162				694.6	611
2091	18 Beach Lane	8/7/98	480	40	D	0.75	D	D2	560	180				809.8	809
2092	57 Crystal Lk Rd	10/1/96	501		M	1.5	M	D2	520	17	18	12/11/96	SxT		
2093	4 Houston Way	11/9/98	190	46	D	6	D	N						813.7	766
2094	6 Houston Way	3/29/95	280	40	D	1	D	N						807.3	767
2095	41 Houston Way	1/1/91	320		R		A	D4	590	154				820	
2096	7 Atlantic Ave	8/30/99	290	138	D	5	D	D						762.4	626
2097	14 Orient Ave	1/24/97	290	56	D	5	D	D2	735	17	150	11/13/97		754.1	698
2098	4 Old Route 66	1/13/98	600	41	D	1	D	C					T	792	774
2099	4 Old Route 66	9/22/98	600	38	D	1	D	C	510	68				780	758
2100	3010 NY Route 43	9/15/98	400	41	D	2	D	D1	2750	990				764.5	735
2101	Bullis Drive							D						845.3	
2102	5 Tin Can Alley	10/1/84	300	30	D	4	D	D4	660	240				767	
2104	16 Drumlough Rd	10/1/02	420	65	D	3	D							675	610
2105	11 Drumlough Rd	6/6/02	184	80	D	7	D								
2106	29 Drumlough Rd	6/5/02	564	140	D	2	D							690	550
2108	55 Mtn View Dr	10/9/02	540	102	D	5	D	D						830	733
2109	39 East.Union Tpk		350		M		A	D2	750	325			SI	810	
2110	43 East.Union Tpk	10/31/45	105	25	D	4.6	D	D1	560	230				816	793
2111	64 East.Union Tpk	1/1/41	170		M		A	D2	1270	425			I	802	797
2112	80 East.Union Tpk	3/29/01	400	133	D	5	D	D5	625	256				875	750
2113	2 Hickory Lane	1/1/89	380		M		A	D2	680	137					
2114	3019 NY Route 43	6/27/89	25		D			N						774.3	751
2115	3019 NY Route 43	9/13/89	30		D			N						772	742
2116	3049 NY Route 43	9/4/90	13		D			N						789.9	778
2117	3039 NY Route 43	9/5/90	12		D			N						793.1	782

Well#	USGS	Remarks
2087	3847	0-5 clay, 5-140 hardpan, 140-250 shale. House unoccupied 2002.
2088	3848	No house in 2002.
2089	3849	Sulfur odor developed several months after well placed in use June 2001
2090	3850	0-60 hardpan, 60-84 clay, 84-250 shale; 2gpm at 180, 2gpm 180-200, 2gpm below 200.
2091	3851	0-480 red&gray shale, seams Rensselaer grit. Well hydrofractured, subsequent yield 3 gpm.
2092	3852	1.2 gpm at 100, 0.3 gpm 100-320, none below. Hydrofractured 8gpm. Seasonal use only.
2093	3853	0-48 hardpan, 48-190 gray shale. Pumped 4.5 hr at 8gpm Nov 18,1988; WL declined from 53 to 77 ft
2094	3854	0-40 hardpan, 40-280 red&gray shale. Hydrofractured; pumped 5 hr at 3gpm, WL declined from 34 to 238 ft
2095	3855	
2096	3856	138-250 gray fine sandstone, minor gray shale, thin seams calcite (4 samples); water enters 210-230 (driller).
2097	3857	0-56 hardpan&boulders, 56-290 red&gray rock.
2098	3858	0-18 hrdpn, 18-600 red shale, little hard gray rock. Hydrofrac 1/15/98, yield 3 gpm. Yield declined when #2100 drilled.
2099	3859	0-22 hardpan, 22-600 red shale. Chief source of water for inn as of 2001-2; pumps into 1550-gal storage tank. Dwl 38.
2100	3860	0-30 hrdpn, 30-400 red&gray sh & Renss grit. Water clear at first, got dirty, pump at 380 buried in mud; redrilled to
2101	3861	Seasonal use only. PVC liner visible inside casing. _400, slotted 4-inch PVC liner installed
2102	3862	
2104	3863	0-65 clay hardpan, 65-420 shale.
2105	3864	0-80 clay&boulders, 80-184 red&green shale
2106	3865	0-140 hardpan&boulders, 140-200 red shale, 200-400 green shale, 400-564 red shale.
2108	3866	0-97 hardpan, 97-540 red&gray shale and Rensselaer grit
2109	3867	
2110	3868	Reverse osmosis unit on line to kitchen sink.
2111	3869	Taste worse since 1994. Bedrock near surface around the house
2112	3870	0-133 hardpan, shale, slate, 133-400 shale, slate. Well dynamited.
2113	3871	Sulfur odor 1989-92, treated 1992-2002; no odor 2002-03. Pump failed 2001, had chalky hard coating 1 inch thick
2114	3872	0-4 fill, 4-23 till, very compact, 23-25 weathered rock, 25.2 refusal. Test hole for gasoline spill study.
2115	3873	0-5 fill, 5-17 silty sandy clay &stones(till), 17-26 silty clay,thin layers fine sand &sandy gravel, 30 refusal.
2116	3874	0-3 fill, 3-12 till, 12-13 red slate. In a test hole east 50 ft, till 2-18 ft. Test holes for gasoline spill study
2117	3875	0-3 fill, 3-11 till, 11-12 red slate, foliation dips 45 degrees. Test hole for gasoline spill study.

Appendix B. Measured Water Levels in Wells, 1987–2005

Download Appendix B data table in three different formats (.csv, .txt, and .xls) here:

http://pubs.usgs.gov/sir/2008/5087/appendixb.htm

Definitions of column headings

Well number: Serial numbers are used to identify wells in this report. Letters following a number distinguish successive wells on the same property; the complete sequence of wells on each property is tabulated in appendix A. Well locations are shown on plate 2. Any numbers to the right of a decimal point are not part of the well number; they were added to force the computer program to keep multiple measurements in the same well in proper order.

Date measured (2002): Date, during the late summer of 2002, on which depth to water was measured in this well.

Status on date measured: Status of water level at the time of measurement is coded as follows:

- S Static; no change in water level over at least 20 minutes.
- D Dynamic equilibrium; water level was slowly falling, or rising and falling (presumably in response to nearby pumping) when measured.
- R Rising water level; number is feet of rise in 10 minutes. In most of these wells, the rise probably constitutes recovery from the last operation of the owner's pump several hours earlier, but temporarily rising water levels that reflect dynamic equilibrium with pumping in the neighborhood are also possible.
- ExS Static water level extrapolated from a series of measurements of rising water level, generally over periods of 1 to 4 hours.
- U Well unused—either abandoned, or a new well not yet in use.
- V Power to the pump known to be off, or no one home, for at least 6 hours prior to measurement.
- C Water level measured during this study but not in the summer of 2002; static water level adjusted to Aug 15, 2002, by correlation with other wells.

Other measurements

Date: Most measurements in 1988–91 made by students from Rensselaer Polytechnic Institute (R.G. LaFleur, written commun., 1999).

Most measurements in 1999–2002 made by USGS; some by Smith and Mahoney Engineers (Timothy Moot, written commun., 2002). All measurements in 2005 made by USGS.

Status: Same codes as previous status column.

Footnotes:

[a] After recovery period of 72 hours.

[b] Water level deeper than 147 feet.

[c] Water level rose at a constant rate from 1415 through 1530 hours; this rise may represent a dynamic equilibrium with withdrawals and recovery in the neighborhood.

[d] Water level rose from 113.13 feet at 1102 hours to 107.36 feet at 1306 hours; the rate of water-level recovery through this depth interval in 1988 was more rapid than the rate of recovery through the same interval on Oct. 12, 2002, which suggests that the static water level was several feet higher in 1988 than in 2002.

[e] After recovery period of 48 hours.

[f] Water level might have been as much as 0.5 feet deeper on August 15; the altitude given is the highest altitude possible.

[g] Altitude of top of casing was estimated from levels to the roadside nearby.

Appendix B. Measured water levels in wells.

Well number	Date measured (2002)	Status on date measured	Depth to water below top of casing (feet)		Altitude (feet) of		Other measurements		
			On date measured	Adjusted to Aug 15	Top of casing	Water level Aug 15	Date	Status	Depth to water below top of casing (feet)
2A		CD		75.80	787.81	712.01	7/20/1988	US	78.85
2A.1							2/13/2000	D a/	76.80
3	Aug 9	UR <0.01	59.07	59.13	789.90	730.77			
3A	Aug 11	ExS	71.22	71.18	788.59	717.41			
4	Sep 1	VD	85.18	85.01	785.44	700.43	12/12/1989	S	76.35
4.1							8/19/2005	ExS(?)	77.00
9	Jul 19	VS	128.86	129.13	821.66	692.53	6/19/1987	SU	108.94
9.1							5/10/1991	S	116.60
9.2							1/12/2000	R 0.02	127.79
9.3							5/17/2001	R 0.01	129.89
9.4							3/12/2002	R 0.02	129.71
9.5							8/4/2005	R 0.02	126.90
10	July 25	R 0.43	107.00				6/29/1988	S	97.73
10.1	Sep 7	R 0.02	109.39	109.16	828.32	719.16	7/12/1988	D	96.51
10.2							11/14/1989	S	94.13
10.3							8/9/1990	S?	100.60
10.4							8/20/1991	S?	97.80
10.5							6/8/1999	R 0.045	103.10
10.6							2/10/2000	R 0.03	101.66
10.7							8/17/2000	R 0.05	103.25
10.8							8/16/2005	VR 0.04	102.25
15	Aug 25	VS	68.50	68.40	783.00	714.60			
17	Aug 24	UD	102.66	102.57	810.94	708.37	11/1/2001	U	101.83
17.1							8/11/2005	US	98.17
21	Aug 21	US	20.68	20.62	766.96	746.34	7/31/2005	D	17.42
22A	July 26	ExS	111.75	111.95	780.28	668.33	7/14/1988	R 0.15	111.98
22A.1							6/1/1999	R 0.11	117.85
26A	Aug 17	VS	98.09	98.07	773.29	675.22	5/21/1999	?	96.13
26A.1							8/4/2005	VS	104.07
27	Sep 1	R 0.01	104.20	104.03	775.27	671.24	5/26/1999	S	100.55
28	Aug 21	R 0.01	93.56	93.50	762.77	669.27	11/14/1989	R 0.02	85.00
28.1							5/26/1999	S	89.78
28.2							2/4/2000	R 0.01	90.63
28.3							8/22/2000	R 0.01	90.74
28.4							8/12/2005	VS	100.11

Appendix B. Measured water levels in wells.

Well number	Date measured (2002)	Status on date measured	Depth to water below top of casing (feet)		Altitude (feet) of		Other measurements		
			On date measured	Adjusted to Aug 15	Top of casing	Water level Aug 15	Date	Status	Depth to water below top of casing (feet)
29a	Aug 16	R 0.01	121.86	121.85	784.25	662.40	5/27/1999	R 0.01	125.13
29a.1							8/3/2005	ExS	128.10
32	Aug 29	S	19.11	18.97	802.86	783.89	9/20/2005	S	16.52
34A	Aug 21	VS	92.36	92.30	798.34	706.04	8/24/2005	VR 0.02	91.64
35	Jul 26	ExS	116.24	116.44	872.82	756.38	8/2/1988	S	114.37
35.1							8/4/2005	VS	115.70
36	Sep 4	ExS	75.98	75.78	834.61	758.83	8/2/1988	S	77.76
36.1							10/25/1989	S	73.07
36.2							8/1/2005	VS	75.04
37	Jul 25	S	18.64	18.85	776.92	758.07	8/2/1988	S	15.23
37.1							5/17/2001	S	17.71
37.2							3/12/2002	S	17.78
37.3							8/16/2005	VS	18.95
38	Aug 26	VR 0.01	26.82	26.71	786.25	759.54			
39a	Jul 26	R 0.03	61.84	62.04	807.31	745.27	5/3/1988	?	54.63
39a.1							8/1/2005	VS	57.49
40	Jul 25	R 0.02?	87.41	87.62	792.50	704.88	3/7/1988	?	81.10
40.1							7/30/2005	VS	86.90
49	Aug 1	US	33.46	33.60	803.59	769.99	8/9/1990	S	35.11
49.1							8/1/2005	US	33.01
51						779.50	8/9/1990	S	13.81
52	Jul 24	US	154.27	154.49	776.07	621.58	4/23/1988	S	138.25
52.1	Sep 12	US	154.49	154.21			8/2/2005	US	159.96
52A	Jul 24	R 0.03	166.43	166.65	787.44	620.79			
53a	Jul 20	VR 0.02	190.39	190.65	812.56	621.91	11/2/1989	S	173.41
53a.1							8/3/2005	VS	198.20
54							6/29/1988	R 0.06	27.02
54.1							10/14/1989	R 0.20	24.04
54a	Jul 25	VS	25.44	25.65	787.53	761.88	7/24/2001	R 0.03	25.61
54a.1							3/12/2002	R 0.02	23.61
54a.3							8/6/2005	VR 0.015	24.34
56	Jul 31	V	12.51	12.66	799.73	787.07			
56A	Jul 31	VR <0.01	32.89	33.04	800.51	767.47			
61a	Jul 25	S	143.65	143.86	760.71	616.85	1/17/2000	S	141.63
61a.1							5/17/2001	D	143.40
61a.2							3/13/2002	R 0.04	146.11
61a.3							8/2/2005	VR 0.01	153.01
64	Aug 15	R 0.02	88.37	88.37	722.53	634.16			
65A	Aug 17	S	102.55	102.53	725.16	622.63			

Appendix B. Measured water levels in wells.

Well number	Date measured (2002)	Status on date measured	Depth to water below top of casing (feet)		Altitude (feet) of		Other measurements		
			On date measured	Adjusted to Aug 15	Top of casing	Water level Aug 15	Date	Status	Depth to water below top of casing (feet)
67a	Aug 15	S	166.30	166.30	786.86	620.56	6/21/1988	b/	
69	Aug 15	U f/	129.50	129.50	748.76	619.26			
69A	Aug 15	R 0.01	127.80	127.80	746.36	618.56			
73	Aug 16	R 0.02	99.90	99.89	738.84	638.95	8/23/1999	R 0.02	101.68
73.1							7/31/2005	D	109.05
74a	Sep 11	S	182.81	182.53	805.90	623.37			
77	Aug 24	VD	132.97	132.88	823.44	690.56			
78	Aug 23	US	130.37	130.29	822.67	692.38			
79	Aug 24	VD	122.36	122.27	810.31	688.04	8/11/2005	VS	120.70
80	Aug 21	S	98.75	98.69	802.02	703.33			
84	Aug 7	S	43.16	43.24	778.12	734.88			
85	Aug 22	R 0.035c/	44.40	44.33	773.34	729.01			
90A	Aug 27	VR 0.02	118.22	118.10	831.98	713.88	11/14/1989	S	100.87
90A.1							8/4/2005	VR 0.06	112.27
91	Aug 23	R 0.01	124.27	124.19	833.79	709.60			
93	Sep 5	ExS	95.05	94.84	813.96	719.12			
94	Sep 6	S	47.11	46.89	810.96	764.07			
95	Aug 1	S	84.66	84.80	842.13	757.33			
97a	Jul 25	ExS	95.82	96.03	795.79	699.76	5/17/2001	R 0.02	95.10
97a.1							3/12/2002	R 0.02	94.21
98	Jul 31	US	90.79	90.94	776.32	685.38			
104	Sep 1	VR 0.01	49.74	49.57	782.83	733.26			
105	Aug 28	VR 0.015	50.20	50.07	783.69	733.62	7/30/2005	VS	45.16
106	Aug 28	R 0.015	50.06	49.93	803.75	753.82			
111	Jul 25	VS	21.56	21.77	775.81	754.04	7/14/1988	S	24.11
111.1							11/14/1989	S	18.87
111.2							8/9/1990	S?	18.80
111.3							6/15/1999	R 0.01	22.87
111.4							8/17/2000	S	18.04
111.5							5/17/2001	R 0.03	23.54
111.6							3/13/2002	S	19.25
111.7							8/10/2005	S	23.05
115	Sep 10	R 0.015	108.96	108.70	776.63	667.93	6/7/1999	R 0.01	111.93
115.1							5/17/2001	S	108.98
115.2							3/13/2002	S	109.51
118A	Jul 26	S	134.14	134.34	791.80	657.46	5/29/1999	R 0.035	136.64
118A.1							9/3/2000	R 0.035	137.76
118A.2							3/12/2002	R 0.03	134.40
118A.3							8/9/2005	VS	141.09

Appendix B. Measured water levels in wells.

Well number	Date measured (2002)	Status on date measured	Depth to water below top of casing (feet)		Altitude (feet) of		Other measurements		
			On date measured	Adjusted to Aug 15	Top of casing	Water level Aug 15	Date	Status	Depth to water below top of casing (feet)
119A	Aug 21	VR 0.01	120.55	120.49	786.68	666.19			
120a	Aug 14	R 0.03?	149.36	149.37	808.02	658.65	8/9/1990	S	144.45
120a.1							6/7/1999	R 0.02	151.74
120a.2							2/7/2000	R 0.02	150.29
120a.3							8/5/2005	VS	154.42
122	Aug 14	US	65.21	65.22	774.33	709.11	5/6/1991	U	63.65
122.1	Oct 13	US	64.56	64.07	774.33		8/17/2000	US	64.41
122.2							8/8/2005	US	62.90
122A	Oct12	ExS	100.25	99.67	774.50	674.83	8/3/1988	d/	
127A	Oct3	ExS	69.68	69.19	793.43	724.24			
130	Aug30	R0.005	13.12	12.97	776.55	763.58			
131	Jul28	VS	28.88	29.06	777.34	748.28	6/22/1988	?	35.25
131.1	Oct5	VS	29.50	28.99			5/29/1999	ExS	30.88
131.2							2/12/2000	R0.01	32.69
131.3							8/19/2000	R0.01	30.10
131.4							7/30/2005	VS	27.65
133	Jul24	US	67.92	68.14	792.10	723.96	8/10/2005	US	68.87
133.1	Sep13	US	69.51	69.22					
136	Jul22	VF	20.42	20.66	789.40	768.74	8/1/2005	VS	19.60
136A	Jul20	VR0.02	41.52	41.78	794.85	753.07	8/6/2005	VR0.01	41.54
140A	Jul26	D	43.24	43.44	744.38	700.94	8/22/1989	UD	40.04
143	Aug30	D	23.59	23.44	783.91	760.47			
144	Sep11	ExS	50.06	49.80	778.97	729.17	8/4/2005	D	45.92
145	Jul25	D	74.31	74.52	802.13	727.61	6/28/1988	S	65.43
145.1							1/20/2000	R0.05	68.41
145.2							3/12/2002	R0.16	72.11
145.3							8/15/2005	VD	66.70
147	Jul26	ExS	29.05	29.25	789.32	760.07	9/14/2000	D	29.05
147.1							3/12/2002	R0.03	27.56
147.2							8/19/2005	R0.01	28.16
153	Aug18	D	68.22	68.19	791.97	723.78	8/10/2005	US	66.59
155							8/1/1988	R0.04	112.28
159	Aug19	D	29.70	29.66	766.65	736.99			
161	Aug24	S	24.05	23.96	780.57	756.61			
162	Sep4	R0.025	161.18	160.98	803.87	642.89	6/1/1999	R0.03	163.28
169	Jul22	R0.01g/	80.00	80.24	776.60	696.36	8/12/2005	S	82.59
173a	Aug15	D	151.01	151.01	762.43	611.42			
176	Jul27	US	22.16	22.35	785.58	763.23	11/23/1999	D	24.02
176.1							8/17/2000	S	19.66

Appendix B. Measured water levels in wells.

Well number	Date measured (2002)	Status on date measured	Depth to water below top of casing (feet)		Altitude (feet) of		Other measurements		
			On date measured	Adjusted to Aug 15	Top of casing	Water level Aug 15	Date	Status	Depth to water below top of casing (feet)
178						727.62	6/29/1988	S	26.00
178a	Jul29	ExS	24.88	25.05	774.49	749.44	6/7/1999	R0.09	27.88
178a.1							8/3/2005	VD	24.51
183	Aug22	ExS	18.63	18.56	760.60	742.04			
186	Aug14	R0.02	34.36	34.37	735.50	701.13	6/22/1988	R0.01	32.94
186.1							6/4/1999	R0.02	33.02
186.2							2/4/2000	S	36.00
186.3							8/17/2000	R0.01	32.18
186.4							8/3/2005	R0.03	36.71
187	Aug25	D	47.61	47.51	794.55	747.04			
188	Aug26	R0.01	21.52	21.41	804.53	783.12			
190A	Jul20	US	104.31	104.57	791.20	686.63			
195A	Jul31	R<0.01	156.77	156.92	777.64	620.72	8/25/2005	VS	163.73
202						767.56	9/26/2007	DV	94.94
204A	Jul25	S	138.16	138.37	760.86	622.49	6/22/1988	S	125.22
204A.1							9/14/2000	S	135.65
204A.2							3/13/2002	S	138.52
204A.3							8/13/2005	VS	144.22
213A	Aug19	S	108.05	108.01	733.88	625.87	8/7/2005	R0.01	116.06
215		C		81.00	718.74	637.74	5/17/2001	R0.06	82.35
219	Jul27	ExS	18.93	19.12	789.05	769.93			
220	Jul25	R0.015	26.96	27.17	795.08	767.91			
222a	Aug4	R0.16	86.67	86.78	799.11	712.33			
223	Sep5	ExS	47.48	47.27	771.90	724.63	8/12/2005	?	39.41
224	Sep5	ExS	34.85	34.64	779.03	744.39	8/12/2005	ExS	40.83
225	Sep10	R0.01	36.24	35.98	780.94	744.96	6/28/1988	ExS	25.06
225.1							8/7/2005	VS	40.93
226a	Sep5	UD	64.56	64.35	770.93	726.58	8/7/2005	UD	58.35
228						771.99	6/28/1988	S	34.04
229	Sep6	R0.01	10.34	10.12	767.30	757.18			
230b	Aug23	ExS	35.48	35.40	770.49	735.09			
233	Sep25	D	79.96	79.55	820.25	740.70			
235	Sep4	D	83.37	83.17	824.84	741.67			
241	Aug22	R0.02	37.58	37.51	796.83	759.32	6/28/1988	ExS	36.49
244	Aug18	R	41.38	41.35	781.80	740.45	6/29/1988	D	37.29
247	Aug7	US	126.38	126.46	802.74	676.28			
248a	Jul22	R0.02	186.39	186.63	807.31	620.68			
258	Jul25	S	71.74	71.95			6/22/1988	S	63.06
258.1							3/13/2002	S	70.91

Appendix B. Measured water levels in wells.

Well number	Date measured (2002)	Status on date measured	Depth to water below top of casing (feet)		Altitude (feet) of		Other measurements		
			On date measured	Adjusted to Aug 15	Top of casing	Water level Aug 15	Date	Status	Depth to water below top of casing (feet)
270	Jul24	R	18.41	18.62	786.97	768.35			
274A	Aug18	ExS	109.70	109.67	726.48	616.81	6/21/1988	S	94.30
274A.1							8/2/2005	ExS	119.90
275A	Jun5	U	126.20		748.39				
275A.1	Jul26	US	125.66	125.86	748.39	622.53			
275A.2	Aug25	U	126.27	126.17	748.39	622.22			
275A.3	Sep12	U	126.15	125.87	748.39	622.52			
276a	Aug15	D	131.24	131.24	752.77	621.53	8/2/2005	US	139.98
279	Aug9	U	3.11	3.17			8/3/2005	U	1.80
279A	Aug9	S	133.32	133.40	757.91	624.51	10/24/1989	S	117.60
279A.1							8/3/2005	VS	142.19
284	Aug9	UD	67.28	67.34	784.51	717.17	8/17/2000	US	56.52
284.1	Aug15	US	64.90	64.90	784.51	719.61			
284.2							8/9/2005	US	64.65
286A	Aug9	VS	65.10	65.16	769.21	704.05	8/10/2005	VS	52.18
289A		C		123.45	790.55	667.10	7/20/1988	R0.88	123.68
289A.1							2/7/2000	ExS	124.45
291a	Sep7	ExS	72.58	72.35	778.30	705.95			
292A	Aug3	VDe/	81.55	81.67	785.23	703.56			
301a	Aug24	R0.01	117.76	117.67	780.60	662.93	7/28/1988	R0.18	114.10
301a.1							8/15/2005	VD	123.63
302A	Sep11	S	116.30	116.03	815.20	699.17			
303	Aug19	S	32.03	31.99	732.23	700.24			
304a	Aug15	S	103.34	103.34	727.62	624.28			
307	Aug17	U	94.77	94.75	710.95	616.20			
307A					710.05				
309A	Aug16	R0.02	116.13	116.12	757.49	641.37	6/1/1999	R0.10	117.49
309A.1							8/17/2000	D	116.80
309A.2							8/1/2005	D	124.45
310a						763.68	6/1/1999	D	123.57
312	Aug15	S	144.68	144.68	783.44	638.76	5/28/1999	D	145.46
312.1							8/2/2005	VD	151.14
313	Aug30	VS	119.68	119.53	759.84	640.31	8/23/1999	D	119.73
315	Aug24	UR0.01	113.68	113.59	772.80	659.21	7/28/1988	UD	116.46
315.1							11/9/1999	UD	116.51
315.2							8/17/2000	UD	117.37
315.3							8/15/2005	UD	123.59
319	Aug20	R0.01	145.52	145.47	791.11	645.64			
2060	Aug30	US	47.72	47.57	828.17	780.60	6/24/1997	US	41.66

Appendix B. Measured water levels in wells.

Well number	Date measured (2002)	Status on date measured	Depth to water below top of casing (feet): On date measured	Depth to water below top of casing (feet): Adjusted to Aug 15	Altitude (feet) of: Top of casing	Altitude (feet) of: Water level Aug 15	Other measurements: Date	Other measurements: Status	Other measurements: Depth to water below top of casing (feet)
2060.1	Nov14	US	43.01				7/30/2005	US	43.56
2061	Sep25	VR0.015	35.11	34.70	816.13	781.43			
2064	Aug29	D	84.59	84.45	819.73	735.28			
2066	Aug29	D	75.48	75.34	811.80	736.46	8/19/2005	VD	74.78
2068	Sep2	VD	73.59	73.41	812.71	739.30			
2070	Aug30	UD	73.32	73.17	816.07	742.90	11/4/2001	U	71.70
2071	Aug28	VS	69.93	69.80	788.40	718.60			
2073	Sep8	D	19.53	19.29	779.04	759.75	8/22/1989	US	17.57
2073.1							7/31/2005	S	17.94
2077a		C		44.96	701.26	656.30	7/6/1999	VS	47.91
2078		C		8.50	701.29	692.79			
2080	Sep1	S	88.54	88.37	725.52	637.15			
2081	Aug27	VS	105.66	105.54	756.57	651.03			
2082					776.34				
2083		C	89.49	89.49	766.49	677.00	5/21/1999	U	88.50
2084	Aug4	US	107.46	107.57	777.76	670.19			
2085					769.45				
2086	Jul 29	US	121.98	122.15	791.24	669.09	8/11/2005	D	130.31
2087	Aug 4	US	121.46	121.57	780.24	658.67			
2088	Aug 4	UD	143.98	144.09	790.61	646.52	8/10/2005	R 0.01	154.07
2090	Aug 19	R 0.01	74.94	74.90	695.35	620.45	8/16/2005	R 0.015	78.88
2091	Sep 13	ExS	44.19	43.90	811.46	767.56	8/24/2005	VD	38.80
2093	Jul 26	US	56.61	56.81	814.44	757.63			
2094	Jul 26	US	33.60	33.80	808.76	774.96	8/11/2005	US	33.51
2096					763.20		8/30/1999	UD	126.84
2097		C		39.88	755.25	715.37	11/11/1999	R 0.01	40.89
2100	Aug 23	S	41.50	41.43	766.51	725.08	8/24/2005	S	32.33
2101	Sep 4	US	106.19	105.99	847.17	741.18	8/12/2005	S	104.39
2112		C				775.00	6/12/2003	VS	101.66

Appendix C. Procedures by which Measured Water Levels in Wells Were Converted to a Common Datum

Differential leveling procedures were used to ascertain the altitude of the top of the casing at each well in which depth to water was measured in 2002, thereby providing a common datum for calculation of water-level altitudes (pl. 3 and appendix B). All altitude values in this report represent vertical distance above the National Geodetic Vertical Datum of 1929 (NGVD29).

All level lines can be traced back to the following benchmarks: (1) a stone monument along Marcy Avenue with an altitude given as 727.83 feet on a map by ABD Engineers (Andress, 1997), and (2) a concrete slab in front of Sand Lake School on New York Route 43 (900 feet east of Victors Lane, fig. 1) with an altitude given as 774.67 feet NGVD by Tallamy Contractors (Federal Emergency Management Agency, 1979). Both of these engineering reports referenced benchmark altitudes to "USGS datum" without identification of the USGS benchmark source(s). Level lines from these two benchmarks were joined near the intersection of Barzen Road and New York Route 43, with an error of closure of 0.12 foot. Another level line originating at the Marcy Avenue monument was run to a third benchmark set by Tallamy Contractors on an unused dam on the Wynants Kill (east of well 120 along Burden Lake Road, pl. 2), also with an error of closure of 0.12 foot. An error of 0.12 foot was deemed small enough that the surveyed altitudes of top of casing at all wells could be treated as a single data set without adjustment.

All level lines were extended by means of a double-rodding method. The altitude of the measuring point on the top of each well casing was taken as the average of the results from two parallel sets of level lines, which seldom differed by more than 0.015 foot. Six long loops were closed where one level line joined another; errors of closure were 0.005, 0.005, 0.015, 0.03, 0.035, and 0.04 foot. The errors of closure indicate that the surveyed altitudes of measuring points are accurate within at least 0.1 foot, and probably within 0.05 foot in most instances, relative to the datum defined by the benchmarks set by the two engineering firms cited.

The altitude of land surface at each well was measured to the nearest 0.1 foot from the surveyed measuring point. This value was then compared to the altitude estimated to the nearest 1.0 foot by interpolation between 10-foot contours on the topographic map (Averill Park 7.5-minute USGS topographic quadrangle, 1980 edition). Altitudes estimated from the topographic map ranged from 7.8 feet higher to 10.1 feet lower than surveyed altitudes (except for one site at which some excavation apparently took place after preparation of the topographic map). The departures of estimated altitudes from surveyed altitudes probably result chiefly from errors in preparing the topographic map, in plotting well locations on the map, and in interpolating altitudes between map contours. One might expect such departures to be randomly distributed about a median departure of zero, and indeed, they were distributed about a median of zero in two areas on the fringes of Averill Park, near Crystal Lake Road and Houston Way and near southern Johnnycake Lane and Eastern Union Turnpike. Over the entire study area; however, land-surface altitudes estimated from the topographic map were lower than surveyed altitudes at 78 percent of the wells surveyed. The median underestimate was 4.7 feet in areas west of Lake Avenue and Firemans Pond, and 2.7 feet near or east of the center of Averill Park.

Appendix D. Calibration of conductivity meter.

[Meter was Electronic Switchgear Model MC-1 Mark V; scales used were temperature-compensated to yield specific conductance in microsiemens at 25 degrees Celsius. Repeated measurements at residence were intended as a convenient check on meter consistency. Most measurements for this report were made from August 1999 through July 2002; all are tabulated in appendix A. Double dash (--) means that this parameter was not measured]

Date	Specific conductance of untreated well water from residence at 35 Taborton Rd, Sand Lake, N.Y.		Comparison with specific conductance of laboratory standard solutions			Remarks
	0.1-K cell (reading x 100)	1.0-K cell (reading x 1000)	Standard	0.1-K cell (reading x 100)	1.0-K cell (reading x 1000)	
July 4, 1995	325	--	--	--	--	Meter 296628
Aug. 9, 1995	330	--	--	--	--	Meter 296628.
Feb 4, 1999	330	--	--	--	--	Meter 296628.
Sep 29, 1999	--	330	--	--	--	Meter 296628. Test balance = 970
Nov 5, 2000	310	--	--	--	--	Meter 314860, used for all subsequent readings.Test balance = 1000.
Nov 25, 2000	140	320	--	--	--	Test balance = 1000.
Dec 3, 2000	--	--	499	360	489	Readings erratic with 0.1 K cell, as well as commonly less than 1.0 K cell and less than standards. Decided to use results from 1.0K cell only, from October-November 2000.
	--	--	743	460	730	
	--	--	989	975	930	
Dec 5, 2000	--	--	499 743	487 720	475 700	Results after sanding wires at connections from cells to meter.
	--	--	989	900	965	
	--	--	1780	1750 ±	1730	
Apr 14, 2001	300	330	--	--	--	
Oct 25, 2001	--	--	500 993 1780	500 980 1750	490 970 1750	New battery installed.0.1 K cell would not replicate 1.0 K cell in this test (nor in the field, recently) until connection plug was repeatedly twisted in meter socket.
Nov 20, 2001	--	310	--	--	--	Tested after replacing 1.0 K cell connecting wire, following a malfunction in the field today.
Dec 5, 2001	315	470	--	--	--	1.0 K cell malfunctioned in the field today; test confirmed that it is reading incorrectly.
Dec 5, 2001	--	315	--	--	--	Tested after replacing connecting wire, again.
Mar 12, 2002	320	325	--	--	--	--
Aug 7, 2002	300	300	--	--	--	--
July 27.2003	380	380	--	--	--	--
May 4, 2004	345	345	--	--	--	--
Jun 24, 2005	335	335	--	--	--	--

Appendix E. Estimation of Annual Average Per-Capita Water Use

The section entitled “Recharge rate as a limit on ground-water withdrawals from bedrock,” describes how the rate of ground-water withdrawal from wells was calculated largely as the known residential population multiplied by an estimate of average daily per-capita water use. That estimate (55 gallons per day) was derived by the method described below.

Several localities served by municipal water systems in two neighboring towns—North Greenbush and East Greenbush (fig. 1)—were selected for a survey of water use. These localities are about 8 miles from Averill Park and only a few hundred feet lower in altitude. Like Averill Park, these localities are characterized largely by one- and two-story single-family homes that were built 30 to 60 years earlier. All homes are fairly close to small commercial districts on nearby streets, and a few homes have been divided into two or three apartments.

The municipal water department for each locality furnished a printout that showed metered water consumption at each property served by the municipal water system during two successive 6-month periods in 2004–2005. Door-to-door inquiries ascertained the number of residents in each house during those periods, noted the month in which any change occurred, and found that nearly all residents did their own laundry at home. Several homes in each locality had swimming pools that were filled or topped off from the municipal water supply, and a few others had hot tubs, fish ponds, or (at one home) a midwinter ice rink; the amount of water consumed by each of these facilities was estimated, generally from the dimensions of the water body and the owner’s estimate of the depth of water added, and was subtracted from the metered water consumption before water use per person was calculated. Little effort was made to include every home in each locality; if no one answered the door on one or two Saturday or evening visits, that home was ignored. Three homes in North Greenbush were excluded because water consumption for one or both 6-month periods was 2 to 10 times the maximum per-capita use at other homes, probably because of a known (in one home) or suspected long-term water leak in a toilet. Two homes in East Greenbush were excluded because the owners were in residence there only about 6 months each year. Slightly more than 100 homes were included in each town survey.

East Greenbush

Most water meters in East Greenbush were read by drive-by remote-sensing equipment. Some meters could be read only in increments of 100 cubic feet, others in increments of 1 cubic foot. The exact dates of all meter readings were furnished; all were in mid-April 2004, early to mid-October 2004, and mid-April 2005, although the dates varied slightly from one locality to another. Most homes in several localities had originally been served by private on-lot wells but switched to municipal water supply after it became available in 1966; by 2004, only a few homes had not connected to the municipal water system, or had connected but retained private wells to supply outdoor faucets. All homes in one locality were originally served by a community water system supplied by a well within the locality; that system was taken over by the town water department in 1995, and use of the local supply well was discontinued.

North Greenbush

Water meters in North Greenbush recorded consumption in increments of 1,000 gallons and were read by drive-by remote-sensing equipment at the end of February and in late August varied slightly from one street to another, but approximate dates of March 3, 2004 (or slightly earlier), August 27, 2004, and February 23, 2005, were available from water-department records. Municipal water supply was extended in 1997 to the localities studied. Nearly all homes were originally served by private on-lot wells; in 2005, about 20 percent were still served only by these wells, and 43 percent of those served by the municipal system retained use of private wells for occasional outdoor uses (such as watering plants and lawns, washing cars, or filling pools) and, in a few homes, for drinking water. Therefore, the water-use habits of most current residents may have been affected by their past experience of relying on a well for water supply.

East Greenbush and North Greenbush Combined

The final data set included 206 residences—102 in East Greenbush and 104 in North Greenbush. In each town, the average number of persons per residence was 3.0, nearly the same as at Averill Park, and use per day per capita during the spring and summer averaged 7 percent higher than during the fall and winter. Annual average per-capita use ranged widely—from less than 20 to more than 110 gallons per day. Mean and median values of annual average use per capita in North Greenbush were 52.9 and 52.1 gallons per day, respectively, and in East Greenbush, 58.9 and 61.2 gallons per day. Among the factors that might account for the differences in rate of water use are the uncertainty as to the exact dates of meter readings in North Greenbush, the availability of well water for outside use at 43 percent of the homes in North Greenbush, and possible socioeconomic and age differences that were beyond the scope of this investigation.

The distribution of per-capita daily use values in the East Greenbush and North Greenbush data sets was somewhat erratic and bimodal (lower curves, fig. E–1), whereas that of the combined data set (upper curve, fig. E–1) was smooth and fairly close to a normal distribution, although somewhat skewed. Mean per-capita use in the combined data set was 55.4 gallons per day, and median per-capita use was 54.4 gallons per day. Accordingly, an average withdrawal of 55 gallons per day per capita was applied in estimating ground-water recharge at Averill Park.

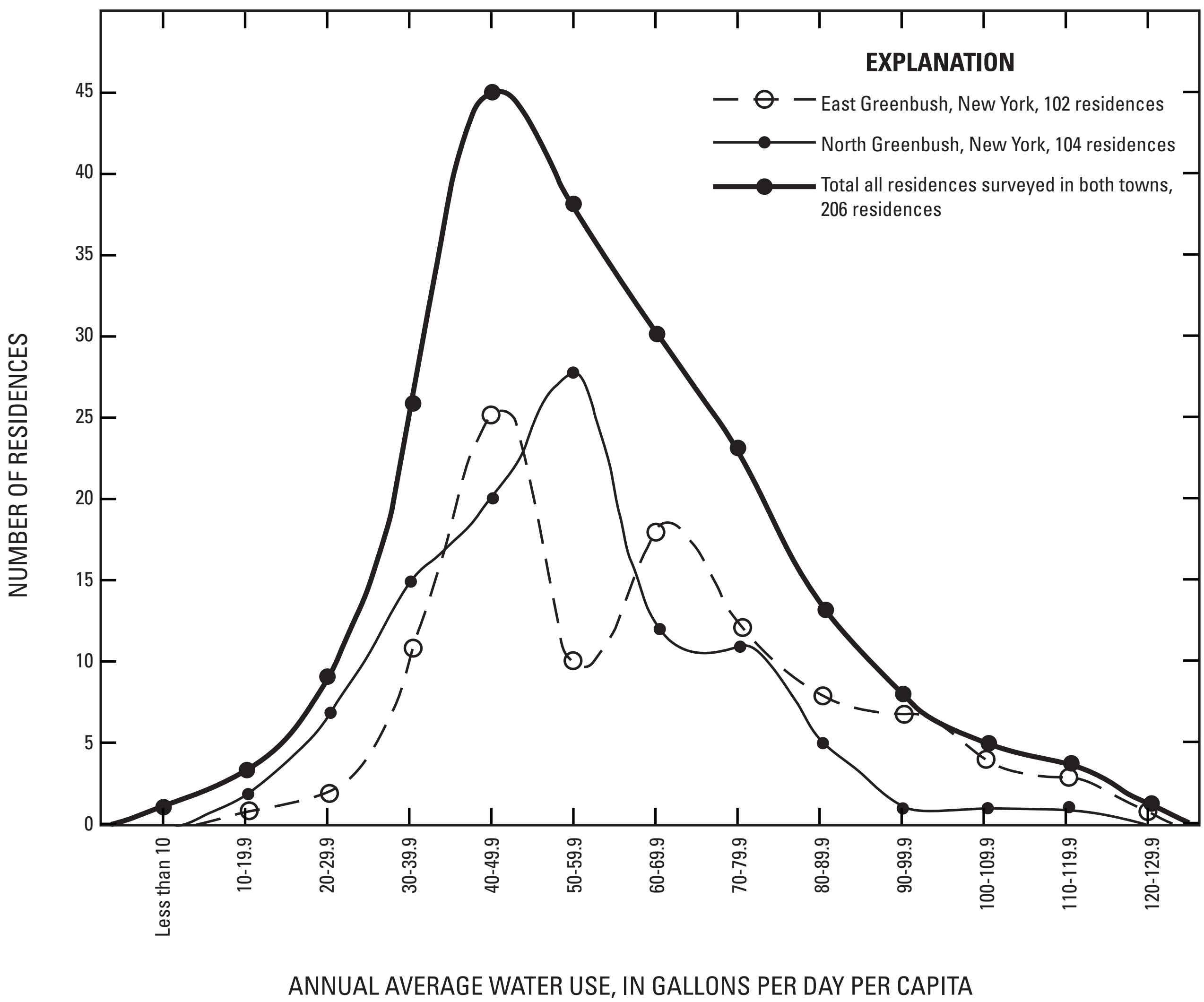

Figure E–1. Frequency distribution of average daily per-capita water use among 2006 residences surveyed in East Greenbush and North Greenbush, N.Y.

Appendix F. Effect of a Decline in Water Levels Below the Bedrock Surface on Well Yield

LaFleur (1989) coined the term "freeboard" to describe the distance that separates the water level in bedrock from the bedrock surface. "Positive freeboard" denotes a water level above the top of bedrock, whereas "negative freeboard" denotes a water level below the bedrock surface. The distribution of freeboard (fig. 14) was mapped on the basis of known depths to the static water level and known depths to bedrock at individual wells, and on superposition of bedrock-surface contours (pl. 1) on water-level contours (pl. 3). The water level is below the bedrock surface in most localities around Averill Park.

LaFleur's hypothesis that a decline in water levels that dewatered the upper part of the bedrock would significantly decrease well yield seems plausible, but the 2002 data provide little support for a simple correlation of apparent dewatering of bedrock with well yield. For example, freeboard is commonly negative near and north of the center of Averill Park, where a majority of wells yield less than 3 gallons per minute, but the areas of strongly negative freeboard do not closely coincide with the areas where many wells yield less than 3 gallons per minute. Most wells west of the center yield more than 3 gallons per minute, but freeboard varies: wells along Marcy Avenue and Terrace Drive generally have positive freeboard, whereas wells along and north of Route 43 have consistently negative freeboard (-20 to -70 feet). The area east of the center of Averill Park, along Bullis Drive and the east side of Barzen Avenue, has negative freeboard, but well performance here seems similar to that along Route 43 and Victors Lane where freeboard is positive. Variations in freeboard among individual wells in other localities seem generally to not correlate with variations in well performance. One reason for the lack of correlation is that part of the bedrock above the water level in drilled wells is probably saturated even in areas of negative freeboard. This interpretation is supported by observed water levels only 6 to 12 feet below land surface in large-diameter dug wells excavated into bedrock at three locations near the center of Averill Park in which the water level in drilled wells was 20 to 30 feet below land surface. Furthermore, the sides of the well bore were wet for at least several feet above the water level in few wells with deep static water levels, presumably as a result of seepage from fractures in saturated bedrock. Thus, freeboard is apparently not a predominant control on well yields, although yields in any given locality are likely to decrease if freeboard becomes more negative.

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An Estimate Based on Pumpage within a Defined Cone of Depression