GROUND-WATER LEVELS AND DIRECTIONS OF FLOW IN GEAUGA COUNTY, OHIO, SEPTEMBER 1994, AND CHANGES IN GROUND-WATER LEVELS, 1986-94

By Martha L. Jagucki and Lori L. Lesney

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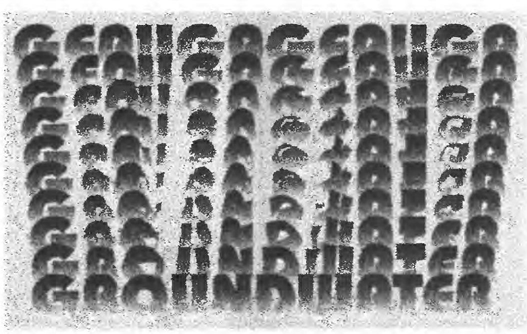

Prepared in cooperation with the
GEAUGA COUNTY PLANNING COMMISSION

Columbus, Ohio
1995

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch (in)	25.4	millimeter
inch per year (in/yr)	25.4	millimeter per year
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
foot per mile (ft/mi)	0.1894	meter per kilometer
square mile (mi^2)	2.590	square kilometer
gallon per day (gal/d)	3.785	liter per day
million gallons per day (Mgal/d)	3,785	cubic meter per day

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Ground-Water Levels and Directions of Flow in Geauga County, Ohio, September 1994, and Changes in Ground-Water Levels, 1986-94

By Martha L. Jagucki and Lori L. Lesney

ABSTRACT

This report presents the results of a study by the U.S. Geological Survey, in cooperation with the Geauga County Planning Commission and Board of County Commissioners, to determine directions of ground-water flow and to assess differences from 1986 to 1994 in ground-water levels in the glacial deposits and Pottsville Formation, Cuyahoga Group, and the Berea Sandstone. Water levels were measured in 219 wells in Geauga County, Ohio, in September 1994. Water levels measured in January and February 1986 in 88 of the 219 wells were used for comparison.

Water-level maps constructed from measurements made in September 1994 show that ground-water levels in the Pottsville Formation and the glacial deposits generally correspond to the land-surface configuration and that ground water flows from the uplands to adjacent streams and buried valleys. Ground-water flow in the Cuyahoga Group is generally downward from the Pottsville Formation to the Berea Sandstone. Directions of ground-water flow in the Berea Sandstone are toward outcrop areas at the north and east edges of Geauga County and toward subcrops beneath buried glacial valley deposits in Chardon, Chester, Munson, and Russell Townships and along the west edge of the county.

A comparison of water level measurements in 1986 and 1994 indicates that water levels declined in 70 percent of the measured wells and increased in 30 percent. The change in water levels from 1986 to 1994 ranged from an increase of 13.58 feet to a decrease of 29.25 feet. Thirty percent of all water-level changes were less than 1 foot in magnitude. In nearly 80 percent of the wells, water-level changes were within the range of plus or minus 5 feet. Among the wells for which two or more historical measurements were available, the 1994 water levels in 54 percent were outside the range of water-levels observed in previous studies (only 24 percent were greater than 1 foot outside of the previously-observed range). Water-level declines of greater than 10 feet were primarily in the Cuyahoga Group and Berea Sandstone.

Some factors considered in the analysis of the differences in water levels in 1986 and 1994 were changes in water use, population, and the amount of available recharge. Water level differences could not be correlated to population changes between the 1980 and 1990 censuses. A decrease in the available recharge from 1986 to 1994 may be part of the cause for the decrease in water levels observed in two-thirds of the wells in and adjacent to Geauga County. Effects of withdrawal rates due to population increase on water levels, if present, are overshadowed by the effects of annual variations in precipitation.

INTRODUCTION

In Geauga County, Ohio, 95 percent of county residents use ground water as their source of drinking water (unpublished data on file at the U.S. Geological Survey, Columbus, Ohio). The county experienced a 29-percent growth in population between the 1970 and

1990 censuses, and its population is expected to increase by another 20 percent from 1990 through 2005 (Northeast Ohio Coordinating Agency, 1983). Problems associated with this rate of growth include increased ground-water withdrawals, which may affect the availability of ground-water supplies and ground-water quality.

The U.S. Geological Survey (USGS) measured ground-water levels in Geauga County in 1978, 1980, and 1986 as part of previous studies (Nichols, 1980; Eberts and others, 1990) that examined ground-water flow and quality. Eberts and others (1990) constructed a regional, steady-state, ground-water-flow model by use of the 1986 data to simulate changes in water levels in the county that would be caused by increased ground-water withdrawals. According to the results of the simulations, 4 ft of drawdown could occur in western parts of the county by 1995 and 8 ft of total drawdown could occur in these areas by 2005 if the population grew according to rates and distributions forecasted by the Northeast Ohio Area Coordinating Agency (1983). Because ground-water levels had not been systematically measured in Geauga County since 1986, the USGS, in cooperation with the Geauga County Planning Commission and Board of County Commissioners, assessed water levels in the county in 1994 and compared these water levels to past data collected by the USGS in 1978, 1980, and 1986 to determine the location and magnitude of ground-water declines. This information can be used by city planners as they manage the continuing population growth and their ground-water resources.

Purpose and Scope

This report presents the results of a study done from July 1994 through September 1995 to determine ground-water levels in the aquifers of Geauga County and to compare them with previous ground-water levels measured by the USGS. Water-level data were collected in September 1994 from aquifers in the glacial deposits, the Pottsville Formation, the Cuyahoga Group, and the Berea Sandstone. Water-level maps and generalized flow directions in the aquifers are presented, as well as a map showing long-term (1986-94) water-level changes. Factors considered in the evaluation of water-level differences in 1986 and 1994 include changes in water use, population, and amount of available recharge.

Description of Study Area

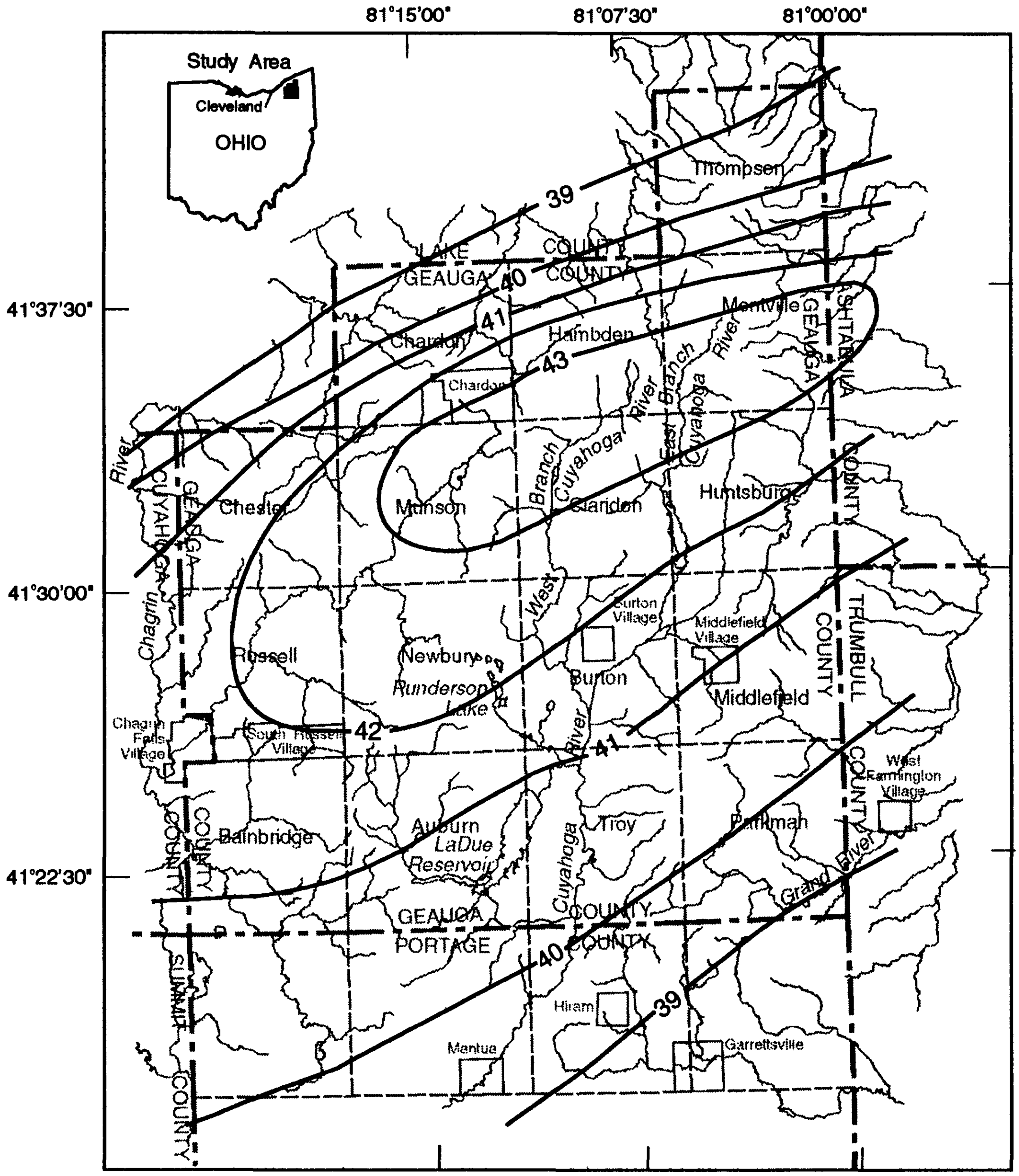
Climate and Topographic Setting

Geauga County is in northeastern Ohio, immediately east of Cleveland (fig. 1), and is approximately 409 mi^2 in area. Geauga County has a humid temperate climate. Average annual precipitation during 1931-80 ranged from 39 to 43 in/yr (Harstine, 1991) throughout the county (fig. 1). Much of the precipitation is snowfall. Chardon, Hambden, Montville, Huntsburg, Claridon, and Munson Townships received an average annual snowfall of more than 100 in/yr during 1931-80—the highest snowfall rate in the State (Harstine, 1991).

The region is hilly; land-surface altitudes range from about 860 to about 1,360 ft above sea level. Geauga County is in the glaciated Allegheny Plateau section of the Appalachian Plateaus Physiographic Province (Fenneman, 1938). The county is drained by the Cuyahoga, Chagrin, and Grand Rivers. The headwaters of all three rivers are within the county. Gain-loss studies done in 1980 indicated that these rivers and their major tributaries are gaining streams; therefore, they are discharge locations for ground water (unpublished data on file at the U.S. Geological Survey, Columbus, Ohio). Rural residential property and urban land compose about 30 percent of the county; most of this type of land use is concentrated in western Geauga County. About 40 percent of the county is forest land, and the remaining 30 percent is agricultural land (unpublished data on file in the National Resources Inventory database, U.S. Department of Agriculture, National Resources Conservation Service, Columbus, Ohio).

Hydrogeologic Setting

A detailed description of the geology of Geauga County is given by Eberts and others (1990). Stratigraphy of the geologic units underlying the county is summarized in table 1, along with the water-bearing properties of the units. The oldest units that crop out in the study area are pre-Berea sedimentary rocks (stratigraphically, oldest to youngest, the Chagrin Shale, the Cleveland Member of the Ohio Shale, and the Bedford Shale). These units crop out along the sides and bottoms of valleys, but in some places are completely covered by glacial deposits that have buried preglacial valleys. The pre-Berea units are not widely used for



Base Digitized from U.S. Geological Survey Ashtabula, Cuyahoga, Geauga, Lake, Portage, and Trumbull, 1:250,000; compiled by Ohio Geological Survey

Data from L.J. Harstine, (1991)

0 2 4 6 8 MILES

0 2 4 6 8 KILOMETERS

EXPLANATION

—42— LINE OF EQUAL AVERAGE ANNUAL PRECIPITATION--Interval 1 inch

Figure 1. Average annual precipitation in Geauga County, 1931-80.

Table 1. Summary of rock units and associated water-bearing properties in Geauga County, Ohio

[From Eberts and others, 1990. Abbreviations: >, greater than]

System	Geologic unit	Approximate maximum thickness (feet)	Character of deposits	Water-bearing properties
Quaternary (Pleistocene)	Glacial deposits	400	Clay, silt, sand, and gravel; deposited by ice and meltwater.	Locally productive aquifer.
Pennsylvanian	Pottsville Formation	200	Sandstone; contains local channels of conglomerate.	Productive aquifer; most extensively developed aquifer in Geauga County.
Mississippian	Cuyahoga Group	250	Shales and sandstones; interbedded; fine-grained.	Leaky confining unit on a regional scale; poorly productive aquifer on a local scale.
Mississippian	Berea Sandstone	70	Quartz sandstone; relatively well sorted.	Productive aquifer; yields more water at shallow depth than where it is deeply buried.
Mississippian and Devonian	Pre-Berea sedimentary rocks	>500	Shales	Poorly permeable; does not meet demands of domestic use.

domestic water supply. Overlying the Bedford Shale is the Berea Sandstone. The Berea Sandstone, which underlies much of Geauga County, has not been developed extensively as an aquifer throughout most of the county because it is too deeply buried to be developed economically; however, the Berea Sandstone is used for water supply near areas where it crops out along the northern, eastern, and western edges of the county. Overlying the Berea Sandstone is the Cuyahoga Group, consisting of interbedded, shallow marine shales and sandstones. The Cuyahoga Group is widely exposed, particularly in the eastern part of the county. Even though the unit is poorly productive, it is commonly used for domestic water supply where more permeable, shallower deposits are lacking. The most extensively developed aquifer in the county is the Pottsville Formation, which, in areas where it has not been removed by erosion, overlies the Cuyahoga Group. The Pottsville Formation is most extensive in the southern part of the county; it consists of sandstone, conglomerate, and some shale. Most of the bedrock in Geauga County is covered by unconsolidated glacial deposits. Glacial deposits are widely used for domestic water supply where they contain significant amounts of sand and gravel. Most productive of the glacial deposits are the buried glacial valleys that were filled with a mixture of clay, silt, sand, and gravel by glacial meltwater.

Population

A total of 81,129 people lived in Geauga County in 1990 (U.S. Bureau of the Census, 1991), compared to 74,474 county residents in 1980 (U.S. Bureau of the Census, 1983). This represents an 8.9 percent growth in population (an increase of 6,655 people) during the decade, most of which was in Bainbridge and Auburn Townships (table 2). Only in the townships of Chester and Montville did population decrease between the 1980 and 1990 censuses. During this time, the average population density of the county increased from 180.8 to 196.9 people per square mile, an average increase of 16.1 people per square mile.

Overall, the county population grew 5.4 percent (4,052 people) less between the 1980 and 1990 censuses than had been predicted by the Northeast Ohio Area Coordinating Agency (1983). (The most growth had been expected in Chester Township, where population actually decreased.) Growth in the county has slowed since the decade between 1970 and 1980, when the county population expanded by 11,497 people, a growth rate of 18 percent.

Water Use

Geauga County was ranked 50th (out of 88 counties) in total water use in Ohio in 1990 (unpublished data on file at the U.S. Geological Survey, Columbus, Ohio). Although water use in Geauga County is less than 10 Mgal/d the counties to the west, north, and east use 100 to 3,000 Mgal/d. These counties (Cuyahoga, Summit, Lake, Ashtabula, and Trumbull), however, rely predominantly on surface water, whereas Geauga County relies mostly on ground water. Summit and Portage Counties used more ground water than Geauga County in 1990—20.5 and 11.0 Mgal/d, respectively compared to Geauga's 7.9 Mgal/d (unpublished data on file at the U.S. Geological Survey, Columbus, Ohio). Water use in Geauga County for 1975, 1980, 1985, and 1990 is summarized in table 3 by category of use. Total water use in the county has increased with time. Fluctuations within a single category of use in table 3 may be the result of water-conservation, fluctuation in population, upgrades in equipment, and (or) changes in data compilation methods.

Approximately 22 percent of the water used in Geauga County in 1990 was consumed by evapotranspiration, incorporated into products or crops, or ingested by humans and animals. Public wastewater from the villages of Geauga County is discharged to streams; however, because most of the county is rural, at least 48 percent of the water used in Geauga County is returned to the ground-water system by way of septic systems (unpublished data on file at the U.S. Geological Survey, Columbus, Ohio).

Acknowledgments

The authors express thanks to the Geauga County Planning Commission for their assistance and to personnel of the Ohio Department of Natural Resources for making available their well log files. The authors also thank the many property owners who allowed access to their wells.

Table 2. Actual and predicted population growth by township, 1980 and 1990, Geauga County, Ohio

[1980 and 1990 population data from U.S. Bureau of the Census (1983, 1991); predicted population data from Northeast Ohio Area Coordinating Agency (1983)]

Township	1980 population (actual)	1990 population (actual)	Population difference (1990-1980)[a]	Predicted population in 1990	Difference between actual and predicted population[b]
Auburn	2,351	3,298	947	2,939	359
Bainbridge	8,207	9,694	1,487	10,185	-491
Burton	4,180	[c]4,187	7	4,588	-401
Chardon	7,971	[d]8,483	512	8,911	-428
Chester	11,212	11,049	-163	13,362	-2,313
Claridon	2,812	[e]3,016	204	3,043	-27
Hambden	2,934	3,311	377	3,225	86
Huntsburg	2,201	2,642	441	2,524	118
Middlefield	5,569	[f]6,009	440	5,985	24
Montville	1,722	1,682	-40	2,036	-354
Munson	5,222	5,775	553	5,724	51
Newbury	5,337	5,611	274	5,914	-303
Parkman	2,638	3,083	445	3,000	83
Russell	8,300	[g]9,167	867	9,259	-92
Thompson	2,083	2,219	136	2,426	-207
Troy	1,735	1,903	168	2,061	-158
Total	**74,474**	**81,129**	**6,655**	**85,182**	**-4,053**

[a]Positive value indicates population growth from 1980 to 1990; negative value indicates population decline.
[b]Positive value indicates actual population in 1990 exceeded predicted value; negative value indicates actual population in 1990 was less than predicted.
[c]1,349 people (32 percent of the township population) live in Burton Village.
[d]4,446 people (52 percent of the township population) live in Chardon Village.
[e]360 people (12 percent of the township population) live in Aquilla Village.
[f]1,898 people (32 percent of the township population) live in Middlefield Village.
[g]151 people (1.6 percent of the township population) live in Huntington Valley Village; 3,402 people (37 percent of the township population) live in South Russell Village.

METHODS OF INVESTIGATION

Water-Level Measurement

Water levels in a total of 219 wells were measured for this study during the week of September 6-9, 1994 (plate 1). Of these 219 wells, 37 were completed in glacial outwash, 95 in the Pottsville Formation, 56 in the Cuyahoga Group, and 31 in Berea Sandstone. The number of wells measured in each formation is approximately representative of the number of wells in the county that are completed in each aquifer. The goal of the program was to collect evenly spaced and hydrologically representative data where possible. However, because torque arresters in some of the deep Berea Sandstone and Cuyahoga Group wells made measurement of targeted wells impossible, data in these formations may be somewhat underrepresented.

Table 3. Water use in Geauga County, Ohio, 1975, 1980, 1985, and 1990

[Data sources: 1975, Hathaway and Eberle (1981); 1980, Eberle and McClure (1984); 1985 and 1990, unpublished data on file at the Columbus, Ohio, office of the U.S. Geological Survey. Grand total equals total ground water plus surface water usage. All values given in million gallons per day. Abbreviations: --, data not available]

	1975		1980		1985		1990	
Usage category	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water
Public[a]	1.6	0.0	1.9	0.0	1.7	0.0	1.2	0.0
Rural[b]	2.7	.4	2.9	.4	4.8	.1	4.9	.3
Irrigation[c]	.1	.3	--	--	.0	.0	.0	.1
Industrial[d]	.5	.0	.1	1.5	.0	.0	1.6	.0
Power	.0	.0	.0	.0	.0	.0	.0	.0
Commercial[e]	--	--	--	--	1.2	.0	.2	.1
Total	**4.9**	**.7**	**4.9**	**1.9**	**7.7**	**.1**	**7.9**	**.5**
Grand total	**5.6**		**6.8**		**7.8**		**8.4**	

[a]Public supply refers to a water utility that served at least 25 people or had a minimum of 15 service connections for the years 1980, 1985, and 1990. In 1975, public suppliers were identified as those who served 50 people or more. Public supply usage was estimated from permits on file at the Ohio Environmental Protection Agency (for years 1975, 1980, and 1985) and from registration forms on file at the Ohio Department of Natural Resources (for year 1990).

[b]Rural usage includes both domestic and livestock water-use estimates. Domestic usage was estimated as the rural population (calculated as the total population minus the number of people served by public suppliers) multiplied by 50 gallons per day per person (for years 1975 and 1980) or 75 gallons per day per person (for years 1985 and 1990). Livestock usage was estimated by multiplying the number of animals in an area (U.S. Department of Agriculture, 1989; U.S. Bureau of the Census, 1989) by water-use coefficients for each animal (obtained from U.S. Environmental Protection Agency (1973) for years 1975, 1980, and 1985 and from the U.S. Department of Agriculture (1975) for year 1990).

[c]Irrigation usage was estimated based on inventories of number of acres irrigated and coefficients (in inches of water per acre) for the years 1975, 1980, 1985, and 1990 (Black, 1983; Brown, 1989) and reported water-use values from registration forms on file at the Ohio Department of Natural Resources (for year 1990).

[d]Industrial usage was estimated using the Ohio Environmental Protection Agency wastewater discharge permits in 1975 and 1985, and an Ohio Department of Natural Resources industrial survey in 1980. For year 1990, usage was estimated as the number of employees (U.S. Bureau of the Census, 1990) multiplied by coefficients for each industry type (Planning and Management Consultants, Ltd., 1987).

[e]Commercial usage (restaurants, retail shops, office buildings, and so forth) for 1985 and 1990 was estimated from permits and registration forms on file at the Ohio Environmental Protection Agency and the Ohio Department of Natural Resources, respectively.

Thirteen of the 219 wells were in adjacent counties so that water levels could be interpolated to the edges of Geauga County.

Wells selected for measurement had to be documented in an available driller's log, completed in a single geologic formation, judged to be of sound construction, and accessible. Permission of property owners was obtained before measurements in private wells were made. The water levels were measured by use of either an electric tape or a chalked steel tape. Measurements of depth to water were accurate within $\pm$ 0.01 ft. Depth of water below land surface was converted to water-table altitude by subtracting water-level depth from land-surface altitude as depicted on 7.5-minute topographic maps (contour interval, 10 ft). Absolute elevations are considered to be accurate within $\pm$ 5 ft. The electric and (or) steel tape was disinfected with bleach after each measurement to prevent the possible transfer of bacteria between wells.

Determination of Water-Level Changes

Of the 219 wells measured in 1994, 96 were measured in one of the previous USGS studies in Geauga County (Nichols, 1980; Eberts and others, 1990). All 125 wells measured in the 1986 study were targeted, but only 88 of these wells were accessible in 1994. Those 88 wells that were measured in January or February 1986 and again in September 1994 were used for water-level-difference comparisons. Water-level differences are considered to be accurate within measurement error (± 0.01 ft) because depth to water in each well in 1994 was measured from the same reference point on the well casing that was used in the previous studies.

GROUND-WATER LEVELS AND DIRECTIONS OF FLOW IN 1994

Well location, formation of completion, land-surface altitude, and water-level data for the 219 wells measured in September 1994 are summarized in table 4 (back of report). Ground-water-level maps were constructed and are included in this report as plates 2-4. Water levels in the Pottsville Formation and the glacial deposits are shown in plate 2. The Pottsville Formation is the surficial aquifer where the glacial deposits are either absent or unsaturated. The glacial deposits compose the surficial aquifer in the valleys where the Pottsville Formation has been eroded. Because of the general absence of confining layers at the contact between the glacial deposits and the Pottsville Formation and the similarity of water levels in paired wells completed in the two units (see GE-64 and GE-91, table 4), the glacial deposits and the Pottsville Formation are considered to be hydrologically connected and have been contoured as one hydrostratigraphic unit. Generally, the water-level surface in the surficial aquifer is a reflection of land surface in Geauga County. Ground water in the surficial aquifer flows from recharge areas associated with ground-water highs to topographically low discharge areas. As shown in plate 2, ground water generally flows from the uplands toward adjacent streams and buried valleys. Primary areas of ground-water discharge include the Cuyahoga River, Chagrin River, Grand River, and their larger tributary streams.

Ground-water levels in the Cuyahoga Group for September 1994 are shown in plate 3. The data are generally limited to the outcrop areas of the Cuyahoga Group along the northern, eastern, and western boundaries of the study area. Ground-water levels were not contoured in the Cuyahoga Group because the predominant direction of ground-water flow in the unit is vertically downward from the Pottsville Formation to the Berea Sandstone (Eberts and others, 1990).

A potentiometric-surface map was constructed from water levels measured in the Berea Sandstone in September 1994 (plate 4). Because few wells were available to measure where the aquifer is deeply buried, water-level data are generally limited to outcrop areas of the Berea Sandstone along the northern, eastern, and western boundaries of Geauga County. Ground water within the Berea Sandstone flows radially away from Hambden and Claridon Townships. Flow is not parallel to the structure of the Berea Sandstone, which dips to the south at approximately 10 to 20 ft/mi. The ground-water high in Hambden and Claridon Townships indicates a recharge area that is at the same latitude as the most concentrated area of precipitation in the county (fig. 1); however, the recharge area is oriented generally north-south, whereas the precipitation trend is more east-west. Instead, the recharge area may be associated with the deeply incised valley of the West Branch of the Cuyahoga River. Along this valley and to the south, beneath Punderson Lake and La Due Reservoir, lie 100 to 200 ft of glacial deposits filling a valley incised into the Cuyahoga Shale, leaving only 15 ft of shale between the saturated glacial deposits and the top of the Berea Sandstone (Eberts and others, 1990, plates 1 and 2). Although the surficial aquifer is thought to discharge to the West Branch of the Cuyahoga River and its downstream reservoirs, perhaps a deeper component of flow within the buried valley deposits and the Cuyahoga Shale moves downward as recharge to the Berea Sandstone. Recharge to the Berea Sandstone is not evident beneath other, less deeply incised stream valleys. Valleys that have been eroded completely through the Berea Sandstone are discharge areas for the Berea aquifer to adjacent buried glacial valley deposits such as are found in Chardon, Chester, Munson, and Russell Townships and along the western edge of the county. Ground water also discharges at outcrop areas along the northern and eastern edges of the county.

CHANGES IN GROUND-WATER LEVELS, 1986-94

Differences in water levels in 1986 and 1994 are shown in plate 5 and summarized in table 5 (back of report). Of the 88 sets of water-level differences, 62 (70 percent) were declines, and 26 (30 percent) were increases. Thirty percent of all water-level changes were less than 1 foot in magnitude. The change in water levels from 1986 to 1994 ranged from an increase of 13.58 ft to a decrease of 29.25 ft. These water-level-difference data represent only two points in time. The data likely do not represent a steady linear decline or increase in water level from 1986 to 1994 because ground-water levels fluctuate seasonally and annually in response to changes in available recharge with time, as is illustrated by a hydrograph of well SU-7 in Summit County (fig. 2a)[1].

To evaluate the significance of differences in water levels in 1986 and 1994 relative to observed seasonal and annual fluctuations in water level, USGS investigators compared the 1994 water levels to historically observed minimum and maximum depth to water at each well, as summarized in table 5. A graphical example of the comparison of 1994 data to historical water levels is shown for well GE-157 (fig. 2c). Among the 74 wells for which two or more historical measurements had been made, water levels in 40 (54 percent) were outside of the range of water levels observed in previous studies; however, water levels in only 18 (24 percent) were more than 1 ft outside the previously observed range. This comparative test was more meaningful at wells in which numerous historical measurements had been made over a time span of several years because the full extent of the long-term water-level fluctuations (such as are shown in fig. 2a) was more apparent at these wells, than at wells where only five historical measurements had been made (fig. 2c). In general, the fewer historical observations of water level at a well, the greater the likelihood that 1994 water levels exceeded the previously observed minimum and maximum range.

[1]Because no long-term water-level data are available for Geauga County that are unaffected by well-field pumping, a well located approximately 14 mi southwest of Geauga County, in Summit County, is used for illustration of seasonal and annual fluctuations in water level. Actual water levels and fluctuations in water levels in similar aquifers in Geauga County may be different, owing in part to pronounced spatial variability in precipitation rates in this part of the State.

Differences in water levels in 1986 and 1994 are listed in table 6 by magnitude of difference and by aquifer. In nearly 80 percent of all wells measured both years, water-level differences were within ±5 ft. Water levels in 76 percent of wells (42 of 55) in the surficial aquifer (the Pottsville Formation and the glacial deposits) decreased from 1986 to 1994. Nearly all the wells (6 out of 7) where water levels decreased more than 10 ft from 1986 to 1994 are completed in either the Cuyahoga Group or the Berea Sandstone. Because these units can be poorly productive in some areas, wells completed in the Cuyahoga Group or the Berea Sandstone are commonly constructed to provide water storage in the well bore to meet water-supply demands. Water levels in such wells vary greatly with pumping of the wells, and recovery rates can be slow. Although water-level measurements known to be affected by recent pumping were discarded during the 1986 and the 1994 studies, some of the large water-level differences observed in the Cuyahoga and Berea aquifers may be the result of measurement of nonstatic water levels during 1986 and (or) 1994.

Factors considered in the analysis of the differences in water levels in 1986 and 1994 include changes in water use, population, and precipitation. According to the data in table 3, ground-water use in Geauga County increased by 200,000 gal/d during 1985-90. Population of Geauga County also increased. Population growth between the 1980 and 1990 censuses was greatest in Bainbridge Township. Its population grew from 8,207 to 9,694—an increase of 1,487 people. At all five wells in the surficial aquifer in Bainbridge Township, water levels decreased from 1986 to 1994. The next largest population growth was in Auburn Township, which increased by 947 people, from 2,351 to 3,298. Likewise in Auburn Township, water levels in the surficial aquifer decreased at all four wells from 1986 to 1994. In townships where growth was small, (such as Montville, Thompson, and Troy), however, all water levels measured in the surficial aquifer also decreased from 1986 to 1994. In fact, measured water levels in the Pottsville and the glacial deposits in 10 of the 16 townships in Geauga County decreased from 1986 to 1994. The average water-level change for all measured wells in each of the 16 townships was calculated and compared graphically to the population change in that township but no relation between the two was noted. Statistical analysis by use of Spearman's rho rank correlation test showed a weak correlation ($r = 0.39$) between average water-level change and population, and this tentative correlation

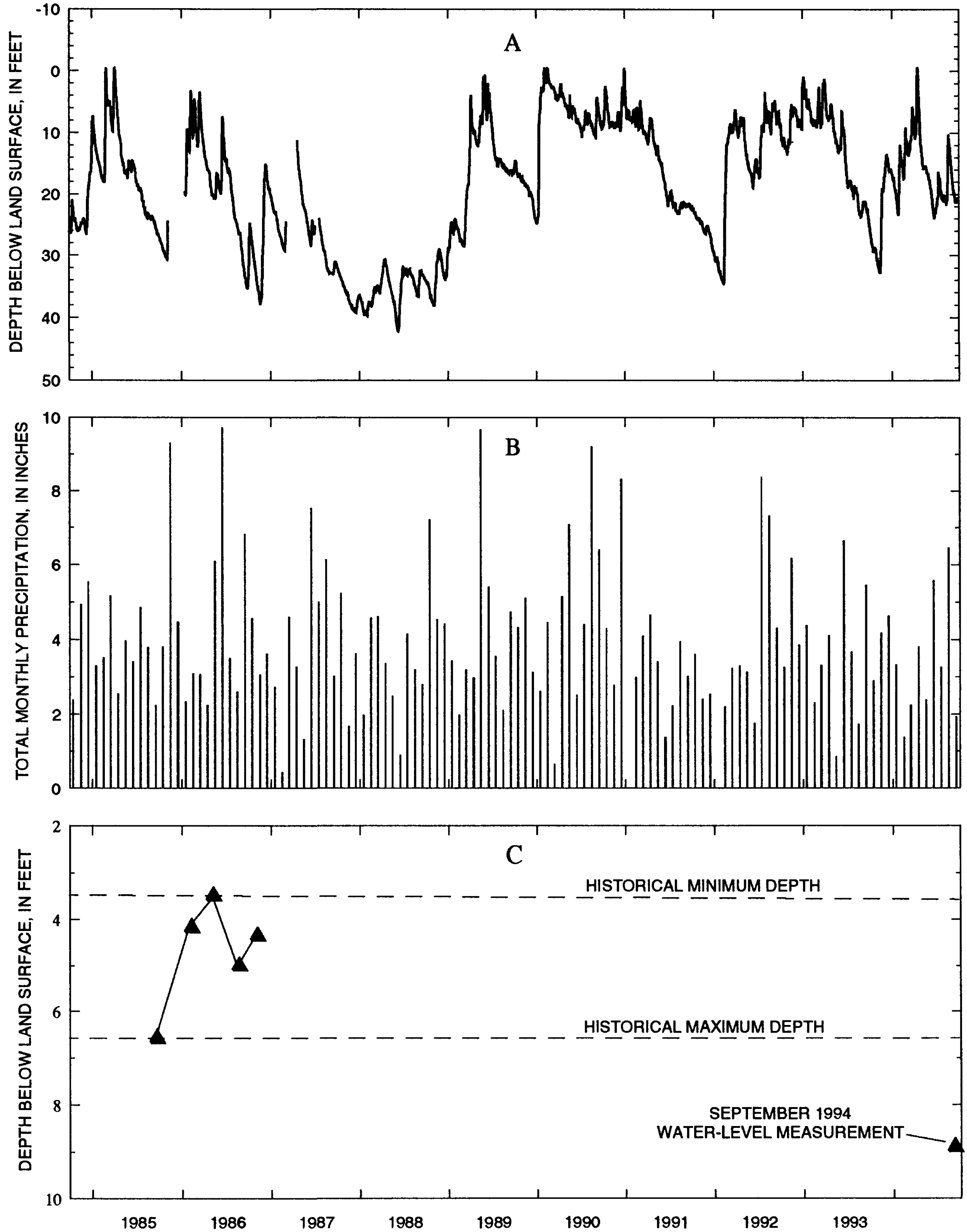


Figure 2. Comparison of (A) hydrograph of well SU-7 in Summit County, (B) precipitation in Chardon, and (C) water levels in well GE-157 in Geauga County, Ohio, 1984-94.

Table 6. Difference in1986 and 1994 water levels, by aquifer, in Geauga County, Ohio

[Measurements were made in January or February of 1986 and in September 1994. Negative difference represents a decrease in elevation of potentiometric surface between 1986 and 1994. Positive difference represents an increase in elevation of potentiometric surface from 1986 to 1994]

Water-level difference (feet)	Number of wells in each aquifer				
	Outwash	Pottsville Formation	Cuyahoga Group	Berea Sandstone	All aquifers
≥ 10.00	0	1	1	0	2
5.00 to 9.99	0	1	1	0	2
1.00 to 4.99	3	1	3	1	8
0.00 to 0.99	3	4	2	5	14
-0.01 to -0.99	1	8	3	0	12
-1.00 to -4.99	5	21	3	6	35
-5.00 to -9.99	2	4	1	1	8
≤ -10.00	1	0	2	4	7

was positive, unlike what would be expected if a negative change (water-level decline) was associated with an increased population.

Precipitation is the source of virtually all ground water in Geauga County. The water-level maps (plates 2 and 4) indicate that there is no major inflow of ground water to the county from surrounding areas. Moreover, the fact that streams within the county are gaining (unpublished data on file at the U.S. Geological Survey, Columbus, Ohio) indicates that infiltration of surface water is not a significant source of recharge to ground water. Therefore, changes in precipitation amounts from year to year will affect the amount of water that is available to recharge the ground-water system. For the 12-month period before water levels were measured in 1986 (January 1985-December 1985), the total precipitation at the weather station in Chardon was 50.30 in., whereas in the 12 months before the most recent measurement in September 1994 (September 1993-August 1994), total precipitation measured 45.59 in. (National Oceanic and Atmospheric Administration, 1985, 1993, 1994), about 10 percent less than in 1986. The December 1985 "Monthly Water Inventory Report for Ohio" (Harstine and Cashell, 1985) noted that precipitation throughout the northeastern part of Ohio was above average for 1985, owing primarily to a record snowfall in November 1985. The report also noted that groundwater levels in long-term observation wells[2] throughout the state rose significantly in response to recharge from the excessive precipitation in November 1985 and were above monthly mean levels in December 1985.

The decrease in water levels in two-thirds of all wells measured in 1986 and 1994 may be due to variations in precipitation prior to each of these measurements. Rainfall was ample in the 12 months prior to the 1986 measurement, and a major recharge event occurred in November 1985, 2 months before water levels were measured. Thus, a decrease in the available recharge from 1986 to 1994 may be part of the cause for the decrease in water levels observed in two-thirds of the wells in and adjacent to Geauga County. Effects of withdrawal rates due to population increase on water levels, if present, are overshadowed by the effects of annual variations in precipitation.

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[2] None of the long-term observation wells referenced in the "Monthly Water Inventory Report for Ohio" are in Geauga County.

SUMMARY AND CONCLUSIONS

In Geauga County, Ohio, 95 percent of county residents use ground water for their drinking water. The growth in population since the 1970's has prompted concern for the availability of ground-water supplies. Water-level maps constructed from measurements made in September 1994 show that ground-water levels in the Pottsville Formation and the glacial deposits generally correspond to the land-surface configuration and that ground water flows from the uplands to adjacent streams and buried valleys. Ground-water flow in the Cuyahoga Group is generally downward from the Pottsville Formation to the Berea Sandstone. Directions of ground-water flow in the Berea Sandstone are toward outcrop areas at the north and east edges of Geauga County and toward subcrops beneath buried glacial valley deposits in Chardon, Chester, Munson, and Russell Townships and along the western edge of the county.

A comparison of water-level measurements in 1986 and 1994 indicates that water levels declined in 70 percent of the measured wells and increased in 30 percent. The change in water levels from 1986 to 1994 ranged from an increase of 13.58 ft to a decrease of 29.25 ft. In nearly 80 percent of the wells, the range of water level differences was ±5 feet. Among the wells for which two or more historical measurements were available, the 1994 water levels in 54 percent were outside the range of water levels observed in previous studies. Water-level declines of greater than 10 ft were primarily in the Cuyahoga Group and Berea Sandstone.

Some factors considered in the analysis of the differences in water levels in 1986 and 1994 were changes in water use, population, and the amount of available recharge. Water levels declined in all townships regardless of the population change, an indication that the decline in water levels cannot be attributed to population growth. Rather, a decrease in available recharge from 1986 to 1994 is likely the predominant cause of the overall decline in water levels.

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Table 4. Location, formation of completion, and water-level altitudes for wells used in the 1994 synoptic water-level survey, Geauga County, Ohio

Prefix on well number indicates county in which well is located: AB, Ashtabula County; GE, Geauga County; L, Lake County; PO, Portage County; T, Trumbull County. Datum for altitudes is mean sea level. Altitude of land surface was determined from topographic maps and is accurate within ± 5 feet. Water-level altitude determined by subtracting depth to ground water (measurement error is ± 0.01 feet) from land-surface elevation; therefore, error on water-level altitude measurements is ± 5 feet. All water-level measurements have been rounded off to the nearest foot for this table. A water-level altitude preceded by ">" indicates that the well was flowing (water-level elevation is greater than land-surface elevation). Abbreviation: Fm., Formation

Well number	Latitude (degrees)	Longitude (degrees)	Township	Aquifer	Altitude of land surface (feet)	Water-level altitude (feet) Sept. 1994
GE-22	41°23′31″	81°12′30″	Auburn	Pottsville Fm.	1,160	1,146
GE-23	41°23′09″	81°20′24″	Bainbridge	Pottsville Fm.	1,160	1,141
GE-29	41°24′49″	81°23′27″	Bainbridge	Berea Sandstone	955	917
GE-36	41°24′39″	81°18′30″	Bainbridge	Pottsville Fm.	1,260	1,189
GE-39	41°25′14″	81°20′22″	Bainbridge	Pottsville Fm.	1,200	1,160
GE-42	41°29′01″	81°04′53″	Middlefield	Glacial deposits	1,105	1,056
GE-48	41°32′02″	81°01′57″	Huntsburg	Cuyahoga Group	1,090	1,085
GE-60	41°20′51″	81°16′57″	Auburn	Pottsville Fm.	1,200	1,140
GE-64	41°27′49″	81°14′52″	Newbury	Pottsville Fm.	1,235	1,205
GE-67	41°25′22″	81°09′28″	Troy	Cuyahoga Group	1,100	1,098
GE-69	41°31′51″	81°12′58″	Munson	Pottsville Fm.	1,260	1,232
GE-72	41°34′33″	81°07′55″	Hambden	Pottsville Fm.	1,220	1,201
GE-73	41°36′29″	81°08′28″	Hambden	Pottsville Fm.	1,300	1,252
GE-76	41°31′38″	81°15′20″	Munson	Glacial deposits	1,170	1,147

Table 4. Location, formation of completion, and water-level altitudes for wells used in the 1994 synoptic water-level survey, Geauga County, Ohio—Continued

Well number	Latitude (degrees)	Longitude (degrees)	Township	Aquifer	Altitude of land surface (feet)	Water-level altitude (feet) Sept. 1994
GE-77	41°30′28″	81°22′10″	Chester	Cuyahoga Group	1,140	1,098
GE-83	41°26′27″	81°07′54″	Burton	Pottsville Fm.	1,220	1,188
GE-89	41°27′49″	81°17′15″	Newbury	Pottsville Fm.	1,270	1,190
GE-91	41°27′48″	81°14′39″	Newbury	Glacial deposits	1,250	1,206
GE-92	41°27′13″	81°12′32″	Newbury	Glacial deposits	1,170	1,136
GE-101	41°37′57″	81°12′23″	Chardon	Glacial deposits	990	966
GE-102	41°34′50″	81°17′30″	Chardon	Berea Sandstone	1,025	980
GE-103	41°37′55″	81°10′12″	Hambden	Berea Sandstone	1,160	1,070
GE-104	41°36′06″	81°10′21″	Hambden	Berea Sandstone	1,215	1,119
GE-105	41°35′44″	81°06′05″	Hambden	Cuyahoga Group	1,220	1,180
GE-106	41°34′56″	81°04′16″	Montville	Cuyahoga Group	1,255	1,220
GE-107	41°32′49″	81°17′32″	Munson	Glacial deposits	1,045	985
GE-108	41°31′06″	81°17′19″	Munson	Glacial deposits	1,120	1,075
GE-109	41°30′02″	81°13′02″	Munson	Pottsville Fm.	1,280	1,204
GE-110	41°30′49″	81°08′39″	Claridon	Pottsville Fm.	1,280	1,240
GE-112	41°32′07″	81°04′44″	Huntsburg	Pottsville Fm.	1,265	1,218
GE-113	41°36′33″	81°05′18″	Montville	Cuyahoga Group	1,250	1,227
GE-114	41°29′01″	81°07′02″	Burton	Pottsville Fm.	1,265	1,222
GE-115	41°27′37″	81°06′33″	Burton	Pottsville Fm.	1,170	1,145
GE-116	41°29′26″	81°14′43″	Newbury	Glacial deposits	1,180	1,137
GE-117	41°26′00″	81°14′48″	Newbury	Pottsville Fm.	1,205	1,187
GE-119	41°26′58″	81°04′12″	Middlefield	Pottsville Fm.	1,185	1,172
GE-121	41°27′46″	81°20′20″	Russell	Berea Sandstone	1,085	1,015
GE-122	41°24′10″	81°22′39″	Bainbridge	Berea Sandstone	1,010	948
GE-123	41°26′33″	81°16′44″	Newbury	Berea Sandstone	1,160	1,063
GE-124	41°30′16″	81°15′25″	Munson	Berea Sandstone	1,130	1,106
GE-125	41°31′00″	81°10′55″	Claridon	Berea Sandstone	1,235	1,154
GE-126	41°22′12″	81°02′53″	Parkman	Berea Sandstone	1,070	949
GE-130	41°36′23″	81°10′10″	Hambden	Berea Sandstone	1,215	1,124
GE-135	41°29′59″	81°03′07″	Middlefield	Glacial deposits	1,110	1,098

Table 4. Location, formation of completion, and water-level altitudes for wells used in the 1994 synoptic water-level survey, Geauga County, Ohio—Continued

Well number	Latitude (degrees)	Longitude (degrees)	Township	Aquifer	Altitude of land surface (feet)	Water-level altitude (feet) Sept. 1994
GE-136	41°28′41″	81°02′32″	Middlefield	Cuyahoga Group	1,130	1,111
GE-137	41°33′18″	81°00′43″	Huntsburg	Cuyahoga Group	1,100	1,092
GE-137A	41°33′48″	81°00′43″	Huntsburg	Berea Sandstone	1,100	1,035
GE-138	41°21′59″	81°10′41″	Troy	Pottsville Fm.	1,180	1,134
GE-139	41°21′38″	81°07′20″	Troy	Pottsville Fm.	1,170	1,134
GE-141	41°22′24″	81°08′43″	Troy	Glacial deposits	1,120	1,111
GE-144	41°22′11″	81°18′34″	Bainbridge	Pottsville Fm.	1,160	1,120
GE-145	41°37′29″	81°02′47″	Montville	Cuyahoga Group	1,210	1,165
GE-147	41°28′45″	81°03′01″	Middlefield	Cuyahoga Group	1,120	1,106
GE-150	41°31′55″	81°21′49″	Chester	Pottsville Fm.	1,220	1,194
GE-151	41°23′19″	81°13′50″	Auburn	Pottsville Fm.	1,270	1,185
GE-153	41°34′15″	81°16′09″	Chardon	Glacial deposits	1,275	1,210
GE-157	41°36′28″	81°16′18″	Hambden	Glacial deposits	1,185	1,176
GE-159	41°24′20″	81°10′21″	Troy	Berea Sandstone	1,140	1,100
GE-160	41°25′20″	81°08′45″	Troy	Cuyahoga Group	1,135	1,114
GE-161	41°23′04″	81°10′23″	Troy	Pottsville Fm.	1,180	1,157
GE-163	41°24′15″	81°03′35″	Parkman	Pottsville Fm.	1,180	1,165
GE-165	41°23′19″	81°16′30″	Auburn	Glacial deposits	1,165	1,154
GE-166	41°24′54″	81°16′24″	Auburn	Pottsville Fm.	1,260	1,203
GE-169	41°26′28″	81°12′28″	Newbury	Cuyahoga Group	1,115	1,116
GE-170	41°23′11″	81°21′30″	Bainbridge	Cuyahoga Group	1,110	1,062
GE-171	41°25′11″	81°22′59″	Bainbridge	Cuyahoga Group	985	931
GE-173	41°21′42″	81°21′23″	Bainbridge	Pottsville Fm.	1,095	1,088
GE-176	41°35′21″	81°14′31″	Chardon	Pottsville Fm.	1,310	1,261
GE-177	41°34′08″	81°08′30″	Claridon	Glacial deposits	1,190	1,171
GE-178	41°31′38″	81°08′42″	Claridon	Pottsville Fm.	1,310	1,254
GE-180	41°31′14″	81°20′16″	Chester	Pottsville Fm.	1,210	1,180
GE-181	41°31′18″	81°19′36″	Chester	Pottsville Fm.	1,230	1,220
GE-183	41°24′29″	81°04′51″	Parkman	Pottsville Fm.	1,220	1,178
GE-185	41°36′30″	81°14′50″	Chardon	Cuyahoga Group	1,260	1,237

Table 4. Location, formation of completion, and water-level altitudes for wells used in the 1994 synoptic water-level survey, Geauga County, Ohio—Continued

Well number	Latitude (degrees)	Longitude (degrees)	Township	Aquifer	Altitude of land surface (feet)	Water-level altitude (feet) Sept. 1994
GE-186	41°36′47″	81°16′18″	Chardon	Cuyahoga Group	1,150	1,107
GE-193	41°35′06″	81°16′18″	Chardon	Pottsville Fm.	1,300	1,248
GE-195	41°35′13″	81°11′07″	Hambden	Glacial deposits	1,130	1,115
GE-196	41°38′08″	81°03′47″	Montville	Pottsville Fm.	1,300	1,232
GE-197	41°39′57″	81°01′18″	Thompson	Berea Sandstone	1,135	1,088
GE-198	41°40′58″	81°01′00″	Thompson	Berea Sandstone	1,070	1,054
GE-199	41°41′06″	81°04′14″	Thompson	Pottsville Fm.	1,255	1,239
GE-202	41°36′07″	81°03′25″	Montville	Pottsville Fm.	1,245	1,215
GE-204	41°32′56″	81°04′58″	Huntsburg	Pottsville Fm.	1,230	1,219
GE-220	41°24′51″	81°13′47″	Auburn	Pottsville Fm.	1,220	1,209
GE-221	41°24′29″	81°13′42″	Auburn	Pottsville Fm.	1,230	1,190
GE-222	41°24′38″	81°15′00″	Auburn	Pottsville Fm.	1,220	1,200
GE-223	41°21′22″	81°15′36″	Auburn	Pottsville Fm.	1,210	1,145
GE-224	41°20′55″	81°13′44″	Auburn	Pottsville Fm.	1,155	1,133
GE-225	41°20′54″	81°21′32″	Bainbridge	Glacial deposits	1,040	0,985
GE-227	41°21′42″	81°2243″	Bainbridge	Glacial deposits	1,020	0,969
GE-228	41°24′08″	81°22′15″	Bainbridge	Cuyahoga Group	1,060	1,057
GE-229	41°23′13″	81°18′15″	Bainbridge	Pottsville Fm.	1,155	1,141
GE-230	41°25′58″	81°07′36″	Burton	Pottsville Fm.	1,195	1,170
GE-231	41°29′48″	81°07′06″	Burton	Pottsville Fm.	1,315	1,255
GE-232	41°28′18″	81°08′04″	Burton	Pottsville Fm.	1,245	1,197
GE-233	41°26′13″	81°11′34″	Burton	Glacial deposits	1,130	1,102
GE-234	41°29′48″	81°09′00″	Burton	Pottsville Fm.	1,170	1,157
GE-235	41°27′33″	81°09′46″	Burton	Glacial deposits	1,105	1,092
GE-236	41°27′24″	81°11′09″	Burton	Glacial deposits	1,155	1,140
GE-237	41°25′41″	81°09′50″	Burton	Pottsville Fm.	1,135	1,086
GE-238	41°28′28″	81°10′35″	Burton	Pottsville Fm.	1,175	1,149
GE-239	41°37′23″	81°13′40″	Chardon	Cuyahoga Group	1,130	1,083
GE-240	41°35′43″	81°17′39″	Chardon	Glacial deposits	885	878
GE-241	41°34′26″	81°15′03″	Chardon	Pottsville Fm.	1,285	1,248

Table 4. Location, formation of completion, and water-level altitudes for wells used in the 1994 synoptic water-level survey, Geauga County, Ohio—Continued

Well number	Latitude (degrees)	Longitude (degrees)	Township	Aquifer	Altitude of land surface (feet)	Water-level altitude (feet) Sept. 1994
GE-242	41°36′30″	81°14′49″	Chardon	Cuyahoga Group	1,175	1,106
GE-243	41°35′57″	81°11′54″	Chardon	Glacial deposits	1,130	1,073
GE-244	41°35′59″	81°14′31″	Chardon	Cuyahoga Group	1,278	1,246
GE-245	41°35′29″	81°16′39″	Chardon	Cuyahoga Group	1,190	1,145
GE-246	41°37′55″	81°13′44″	Chardon	Glacial deposits	1,125	1,086
GE-247	41°30′26″	81°18′41″	Chester	Glacial deposits	1,080	1,049
GE-248	41°33′52″	81°19′58″	Chester	Berea Sandstone	1,070	1,020
GE-249	41°31′25″	81°21′47″	Chester	Cuyahoga Group	1,125	1,033
GE-250	41°32′11″	81°20′54″	Chester	Pottsville Fm.	1,240	1,198
GE-251	41°32′38″	81°19′15″	Chester	Berea Sandstone	1,082	1,015
GE-252	41°30′26″	81°21′15″	Chester	Cuyahoga Group	1,100	1,028
GE-253	41°32′15″	81°23′12″	Chester	Berea Sandstone	1,072	1,005
GE-255	41°33′57″	81°21′48″	Chester	Berea Sandstone	1,075	1,022
GE-256	41°30′53″	81°18′10″	Chester	Glacial deposits	1,130	1,041
GE-257	41°32′58″	81°09′21″	Claridon	Pottsville Fm.	1,215	1.204
GE-258	41°32′34″	81°06′35″	Claridon	Cuyahoga Group	1,185	1,161
GE-259	41°31′20″	81°09′48″	Claridon	Pottsville Fm.	1,225	1,201
GE-260	41°31′30″	81°10′08″	Claridon	Cuyahoga Group	1,138	>1,138
GE-261	41°31′02″	81°07′31″	Claridon	Pottsville Fm.	1,265	1,247
GE-262	41°36′34″	81°10′35″	Hambden	Cuyahoga Group	1,200	1,163
GE-263	41°37′42″	81°10′56″	Hambden	Berea Sandstone	1,142	1,059
GE-264	41°37′08″	81°06′06″	Hambden	Berea Sandstone	1,205	1,170
GE-265	41°35′22″	81°10′49″	Hambden	Glacial deposits	1,180	1,098
GE-266	41°37′44″	81°10′56″	Hambden	Berea Sandstone	1,140	1,061
GE-267	41°37′46″	81°07′45″	Hambden	Cuyahoga Group	1,260	1,224
GE-268	41°38′14″	81°08′58″	Hambden	Pottsville Fm.	1,160	1,068
GE-269	41°34′58″	81°07′59″	Hambden	Cuyahoga Group	1,275	1,230
GE-270	41°34′53″	81°06′05″	Hambden	Glacial deposits	1,197	1,197
GE-271	41°36′58″	81°06′06″	Hambden	Cuyahoga Group	1,198	1,123
GE-272	41°34′52″	81°09′29″	Hambden	Glacial deposits	1,275	>1,275

Table 4. Location, formation of completion, and water-level altitudes for wells used in the 1994 synoptic water-level survey, Geauga County, Ohio—Continued

Well number	Latitude (degrees)	Longitude (degrees)	Township	Aquifer	Altitude of land surface (feet)	Water-level altitude (feet) Sept. 1994
GE-273	41°32′25″	81°04′16″	Huntsburg	Pottsville Fm.	1,255	1,216
GE-274	41°30′31″	81°05′04″	Huntsburg	Cuyahoga Group	1,175	1,169
GE-275	41°30′40″	81°05′14″	Huntsburg	Pottsville Fm.	1,180	1,170
GE-276	41°33′47″	81°03′09″	Huntsburg	Pottsville Fm.	1,235	1,198
GE-277	41°33′08″	81°05′16″	Huntsburg	Pottsville Fm.	1,195	1,190
GE-278	41°30′46″	81°00′14″	Huntsburg	Cuyahoga Group	1,105	1,076
GE-279	41°31′18″	81°02′36″	Huntsburg	Cuyahoga Group	1,115	1,102
GE-280	41°31′27″	81°02′59″	Huntsburg	Cuyahoga Group	1,145	1,110
GE-281	41°33′46″	81°01′36″	Huntsburg	Cuyahoga Group	1,105	1,101
GE-282	41°33′03″	81°01′59″	Huntsburg	Cuyahoga Group	1,110	1,101
GE-283	41°29′36″	81°03′12″	Middlefield	Cuyahoga Group	1,135	1,091
GE-284	41°26′45″	81°03′12″	Middlefield	Pottsville Fm.	1,230	1,181
GE-286	41°29′36″	81°02′31″	Middlefield	Glacial deposits	1,110	1,086
GE-287	41°26′19″	81°03′34″	Middlefield	Pottsville Fm.	1,165	1,137
GE-288	41°28′31″	81°00′14″	Middlefield	Cuyahoga Group	1,161	1,120
GE-289	41°26′31″	81°03′12″	Middlefield	Cuyahoga Group	1,120	1,110
GE-290	41°27′27″	81°01′56″	Middlefield	Cuyahoga Group	1,150	1,121
GE-291	41°27′09″	81°03′08″	Middlefield	Cuyahoga Group	1,185	1,165
GE-292	41°29′38″	81°05′13″	Middlefield	Pottsville Fm.	1,235	1,198
GE-293	41°25′36″	81°04′12″	Middlefield	Pottsville Fm.	1,170	1,169
GE-294	41°34′46″	81°03′18″	Montville	Pottsville Fm.	1,280	1,202
GE-295	41°38′28″	81°03′59″	Montville	Pottsville Fm.	1,283	1,224
GE-296	41°35′44″	81°04′07″	Montville	Pottsville Fm.	1,265	1,229
GE-297	41°35′02″	81°04′13″	Montville	Cuyahoga Group	1,255	1,228
GE-298	41°38′18″	81°00′49″	Montville	Cuyahoga Group	1,133	1,063
GE-299	41°37′08″	81°03′32″	Montville	Pottsville Fm.	1,275	1,223
GE-300	41°36′30″	81°00′48″	Montville	Cuyahoga Group	1,130	1,079
GE-303	41°33′50″	81°16′35″	Munson	Cuyahoga Group	1,230	1,168
GE-304	41°32′46″	81°17′40″	Munson	Glacial deposits	1,035	995
GE-305	41°30′26″	81°11′24″	Munson	Pottsville Fm.	1,310	1,222

Table 4. Location, formation of completion, and water-level altitudes for wells used in the 1994 synoptic water-level survey, Geauga County, Ohio—Continued

Well number	Latitude (degrees)	Longitude (degrees)	Township	Aquifer	Altitude of land surface (feet)	Water-level altitude (feet) Sept. 1994
GE-306	41°33′55″	81°15′21″	Munson	Berea Sandstone	1,230	1,063
GE-307	41°30′18″	81°14′45″	Munson	Cuyahoga Group	1,303	1,198
GE-308	41°33′15″	81°13′42″	Munson	Cuyahoga Group	1,165	1,143
GE-309	41°26′56″	81°14′45″	Newbury	Pottsville Fm.	1,225	1,198
GE-310	41°25′57″	81°15′41″	Newbury	Glacial deposits	1,190	1,184
GE-311	41°29′26″	81°16′33″	Newbury	Pottsville Fm.	1,190	1,161
GE-312	41°29′34″	81°16′32″	Newbury	Cuyahoga Group	1,175	1,163
GE-313	41°29′45″	81°11′36″	Newbury	Pottsville Fm.	1,310	1,251
GE-314	41°26′19″	81°17′06″	Newbury	Pottsville Fm.	1,180	1,156
GE-315	41°28′05″	81°11′36″	Newbury	Cuyahoga Group	1,230	1,163
GE-316	41°21′26″	81°03′40″	Parkman	Pottsville Fm.	1,090	1,076
GE-317	41°24′35″	81°03′22″	Parkman	Pottsville Fm.	1,205	1,177
GE-318	41°23′04″	81°04′52″	Parkman	Pottsville Fm.	1,170	1,144
GE-319	41°22′44″	81°02′20″	Parkman	Cuyahoga Group	1,060	1,021
GE-320	41°25′00″	81°05′04″	Parkman	Pottsville Fm.	1,270	1,200
GE-321	41°23′18″	81°00′32″	Parkman	Glacial deposits	925	895
GE-322	41°20′56″	81°09′41″	Troy	Pottsville Fm.	1,095	1,094
GE-323	41°21′03″	81°06′43″	Troy	Pottsville Fm.	1,110	1,096
GE-324	41°22′27″	81°06′28″	Troy	Pottsville Fm.	1,245	1,214
GE-325	41°24′25″	81°07′03″	Troy	Pottsville Fm.	1,220	1,182
GE-326	41°23′42″	81°07′37″	Troy	Pottsville Fm.	1,200	1,170
GE-327	41°20′53″	81°07′23″	Troy	Glacial deposits	1,115	1,096
GE-328	41°22′41″	81°10′17″	Troy	Pottsville Fm.	1,170	1,142
GE-329	41°21′26″	81°11′11″	Troy	Pottsville Fm.	1,162	1,117
GE-330	41°25′14″	81°08′39″	Troy	Pottsville Fm.	1,140	1,134
GE-331	41°25′48″	81°19′54″	Russell	Pottsville Fm.	1,225	1,163
GE-332	41°25′58″	81°18′42″	Russell	Pottsville Fm.	1,180	1,146
GE-333	41°26′08″	81°18′40″	Russell	Pottsville Fm.	1,195	1,161
GE-334	41°26′18″	81°18′43″	Russell	Pottsville Fm.	1,185	1,155
GE-335	41°26′17″	81°18′41″	Russell	Pottsville Fm.	1,190	1,160

Table 4. Location, formation of completion, and water-level altitudes for wells used in the 1994 synoptic water-level survey, Geauga County, Ohio—Continued

Well number	Latitude (degrees)	Longitude (degrees)	Township	Aquifer	Altitude of land surface (feet)	Water-level altitude (feet) Sept. 1994
GE-336	41°28′21″	81°20′31″	Russell	Glacial deposits	1,042	1,037
GE-337	41°28′06″	81°19′47″	Russell	Cuyahoga Group	1,125	1,061
GE-338	41°27′43″	81°19′57″	Russell	Berea Sandstone	1,078	1,019
GE-339	41°27′45″	81°21′53″	Russell	Glacial deposits	1,075	1,012
GE-340	41°40′50″	81°02′28″	Thompson	Cuyahoga Group	1,290	1,244
GE-341	41°41′21″	81°03′08″	Thompson	Cuyahoga Group	1,267	1,257
GE-342	41°40′59″	81°05′55″	Thompson	Berea Sandstone	1,080	1,054
GE-343	41°39′57″	81°05′21″	Thompson	Berea Sandstone	1,145	1,072
GE-344	41°40′02″	81°00′53″	Thompson	Berea Sandstone	1,097	1,076
GE-345	41°38′50″	81°05′15″	Thompson	Cuyahoga Group	1,190	1,176
GE-346	41°38′29″	81°04′49″	Thompson	Glacial deposits	1,230	1,227
GE-347	41°40′34″	81°02′14″	Thompson	Cuyahoga Group	1,225	1,996
AB-126	41°36′46″	80°59′31″	Hartsgrove	Berea Sandstone	1,080	1,066
AB-127	41°39′44″	80°59′26″	Trumbull	Berea Sandstone	1,060	1,047
L-86	41°40′08″	81°06′44″	Leroy	Berea Sandstone	1,080	1,055
L-88	41°38′41″	81°08′50″	Leroy	Glacial deposits	1,145	1,069
PO-8	41°19′39″	81°03′00″	Nelson	Pottsville Fm.	1,130	1,100
PO-9	41°18′40″	81°05′41″	Nelson	Cuyahoga Group	1,050	1,029
PO-10	41°18′58″	81°05′40″	Nelson	Pottsville Fm.	1,100	1,072
PO-11	41°17′13″	81°08′23″	Hiram	Pottsville Fm.	1,100	1,055
PO-12	41°17′43″	81°09′41″	Hiram	Pottsville Fm.	1,310	1,268
PO-13	41°19′58″	81°08′15″	Hiram	Cuyahoga Group	1,100	1,087
PO-14	41°19′15″	81°13′19″	Mantua	Pottsville Fm.	1,210	1,197
PO-15	41°18′39″	81°16′56″	Mantua	Pottsville Fm.	1,170	1,135
T-6	41°23′33″	80°58′24″	Farmington	Berea Sandstone	885	869

Table 5. Historic and current water-levels for wells measured during the 1986 and 1994 synoptic water-level surveys, Geauga County, Ohio

[Prefix on well number indicates county in which well is located: AB, Ashtabula County; GE, Geauga County; L, Lake County; PO, Portage County; T, Trumbull County. Error on water-level measurements is ± 0.01 feet. A water-level measurement preceded by "+" indicates that the well was flowing (waterlevel elevation is greater than land-surface elevation). Abbreviations: "--" indicates no data was collected; NA, not applicable]

			Water level (feet below land surface)				
Well number	Period of record for historical measurements	Number of historical measurements	Maximum historical depth-to-water and date	Minimum historical depth-to-water and date	Jan.-Feb. 1986	Sept. 1994	Water-level difference (feet) 1986-1994[a]
GE-22	1978-1985	6	14.34 (11-12-80)	12.36 (10-19-78)	--	13.60	--
GE-23	1978-1986	10	13.46 (11-3-86)	10.46 (04-26-78)	12.37	19.01	- 6.64
GE-29	1978-1986	26	41.33 (08-28-85)	39.04 (05-07-86)	39.79	38.08	1.71
GE-36	1978-1986	10	72.23 (08-27-85)	63.47 (05-04-78)	66.27	70.91	- 4.64
GE-39	1978-1986	11	41.45 (08-18-86)	35.63 (05-09-78)	38.48	40.40	- 1.92
GE-42	1978-1986	10	48.33 (08-19-86)	37.01 (05-08-86)	39.63	48.99	- 9.36
GE-48	1978-1986	22	5.84 (03-03-80)	4.58 (09-17-80)	--	4.60	--
GE-60	1978-1986	10	61.35 (11-06-80)	58.23 (05-24-78)	59.44	60.21	- .77
GE-64	1978-1986	8	30.58 (01-30-86, 11-06-86)	25.88 (06-14-78)	30.58	29.60	.98
GE-67	1978-1986	6	2.63 (10-19-78)	.64 (04-09-80)	--	2.44	--
GE-69	1978-1986	10	28.58 (08-08-85)	19.60 (06-15-78)	28.39	27.83	.56
GE-72	1978-1986	10	15.05 (08-06-85)	9.15 (04-11-80)	9.46	14.48	- 5.02
GE-73	1978-1986	7	47.77 (04-15-86)	43.49 (06-15-78)	--	47.53	--
GE-76	1978-1986	25	24.50 (05-09-86, 08-21-86)	21.19 (06-15-78)	23.85	23.27	.58

Table 5. Historic and current water-levels for wells measured during the 1986 and 1994 synoptic water-level surveys, Geauga County, Ohio—Continued

Well number	Period of record for historical measurements	Number of historical measurements	Water level (feet below land surface): Maximum historical depth-to-water and date	Water level (feet below land surface): Minimum historical depth-to-water and date	Water level (feet below land surface): Jan.-Feb. 1986	Water level (feet below land surface): Sept. 1994	Water-level difference (feet) 1986-1994[a]
GE-77	1978-1986	8	41.45 (08-07-85)	34.68 (04-22-86)	40.47	41.69	- 1.22
GE-83	1978-1986	10	33.95 (11-12-80)	27.59 (08-14-85)	31.11	32.31	- 1.20
GE-89	1978-1986	9	85.84 (11-06-86)	81.48 (10-19-78)	85.22	80.40	4.82
GE-91	1978-1986	9	44.70 (01-30-86)	40.10 (10-19-78)	44.70	43.68	1.02
GE-92	1978-1986	6	34.53 (10-20-78)	33.34 (04-10-80)	--	34.06	--
GE-101	1980-1986	6	25.08 (08-21-86)	21.49 (01-29-86)	21.49	24.26	- 2.77
GE-102	1980-1986	4	51.28 (05-07-80)	39.84 (08-27-85)	--	44.93	--
GE-103	1980-1986	7	87.00 (08-21-86)	79.44 (05-07-80)	81.54	89.83	- 8.29
GE-104	1980-1986	7	97.00 (02-07-86)	90.83 (05-07-80)	97.00	96.34	.66
GE-105	1980-1986	7	44.10 (08-06-85)	25.28 (08-21-86)	25.98	39.82	-13.84
GE-106	1980-1986	7	36.10 (11-05-86)	30.84 (05-07-80)	34.58	35.21	- .63
GE-107	1980-1986	7	62.20 (02-13-86)	58.78 (05-09-86)	62.20	59.68	2.52
GE-108	1980-1986	7	50.42 (08-07-85)	48.86 (05-08-80)	49.16	45.12	4.04
GE-109	1980-1986	7	76.09 (11-06-86)	72.85 (11-07-80)	75.10	75.75	- .65
GE-110	1980-1985	3	39.41 (08-08-85)	36.76 (05-08-80)	--	39.93	--
GE-112	1980-1986	7	46.75 (11-04-86)	43.86 (05-05-80)	45.83	47.33	- 1.50
GE-113	1980-1986	8	28.60 (11-05-86)	18.68 (05-08-80)	22.73	22.77	- .04

Table 5. Historic and current water-levels for wells measured during the 1986 and 1994 synoptic water-level surveys, Geauga County, Ohio—Continued

			Water level (feet below land surface)				
Well number	Period of record for historical measurements	Number of historical measurements	Maximum historical depth-to-water and date	Minimum historical depth-to-water and date	Jan.-Feb. 1986	Sept. 1994	Water-level difference (feet) 1986-1994[a]
GE-114	1980-1986	7	52.05 (08-08-85)	39.94 (05-09-80)	42.73	43.49	- .76
GE-115	1980-1986	7	25.38 (02-06-86)	23.10 (05-09-80)	25.38	24.69	.69
GE-116	1980-1986	7	42.87 (08-14-85)	41.83 (05-09-80)	42.56	42.64	- .08
GE-117	1980-1986	6	17.70 (08-14-85)	15.33 (05-09-80)	16.41	17.71	- 1.30
GE-119	1980-1986	7	11.73 (11-04-86)	7.96 (08-20-80)	9.76	12.94	- 3.18
GE-121	1980-1986	7	73.41 (08-13-85)	68.82 (11-06-86)	70.53	70.29	.24
GE-122	1980-1986	7	62.26 (08-18-86)	59.22 (06-17-80)	61.22	62.43	- 1.21
GE-123	1980-1986	6	100.67 (08-14-85)	87.13 (11-06-86)	--	97.27	--
GE-124	1980-1986	7	27.24 (08-21-86)	22.73 (05-09-86)	24.36	24.23	.13
GE-125	1980-1986	8	88.41 (08-21-86)	68.51 (05-09-86)	70.01	80.68	-10.67
GE-126	1980-1986	7	118.86 (08-18-86)	90.10 (08-15-85)	96.78	120.54	-23.56
GE-130	1980-1986	7	89.78 (02-07-86)	83.74 (11-14-80)	89.78	91.25	- 1.47
GE-135	1985-1986	5	15.20 (08-08-85)	10.11 (05-08-86)	12.93	12.47	.46
GE-136	1985-1986	5	17.12 (08-08-85)	13.31 (05-08-86)	14.39	19.12	- 4.73
GE-137	1985-1986	5	20.88 (08-08-85)	12.17 (02-06-86)	12.17	8.38	3.79
GE-137A	1985-1986	5	60.80 (11-04-86)	35.20 (08-08-85)	36.00	65.25	-29.25
GE-138	1985-1986	5	46.50 (11-03-86)	44.75 (02-05-86)	44.75	45.84	- 1.09

Table 5. Historic and current water-levels for wells measured during the 1986 and 1994 synoptic water-level surveys, Geauga County, Ohio—Continued

Well number	Period of record for historical measurements	Number of historical measurements	Water level (feet below land surface)				Water-level difference (feet) 1986-1994[a]
			Maximum historical depth-to-water and date	Minimum historical depth-to-water and date	Jan.-Feb. 1986	Sept. 1994	
GE-139	1985-1986	5	35.74 (08-15-85)	35.21 (05-07-86)	35.23	36.02	- .79
GE-141	1985-1986	5	9.78 (08-15-85)	7.13 (02-05-86)	7.13	9.48	- 2.35
GE-144	1985-1986	5	38.72 (11-03-86)	36.88 (08-28-85)	38.24	39.53	- 1.29
GE-145	1985-1986	5	49.88 (08-19-86)	41.21 (09-18-85)	49.41	44.99	4.42
GE-147	1985-1986	5	2.28 (11-04-86)	1.26 (04-30-86)	1.74	13.91	-12.17
GE-150	1986	4	25.71 (08-22-86)	25.12 (05-09-86)	25.34	25.81	- .47
GE-151	1985-1986	5	83.74 (09-19-85)	82.28 (02-04-86)	82.28	84.65	- 2.37
GE-153	1985-1986	5	66.61 (05-09-86)	62.30 (08-21-86)	64.81	64.60	.21
GE-157	1985-1986	5	6.59 (09-19-85)	3.50 (05-08-86)	4.19	8.91	- 4.72
GE-159	1986	4	20.80 (11-03-86)	15.42 (02-05-86)	15.42	40.11	-24.69
GE-160	1986	2	34.90 (02-05-86)	9.39 (05-07-86)	34.90	21.32	13.58
GE-161	1986	4	23.84 (11-03-86)	21.48 (02-05-86)	21.48	23.38	- 1.90
GE-163	1986	4	14.50 (08-18-86)	8.17 (02-05-86)	8.17	15.36	- 7.19
GE-165	1986	4	9.28 (11-03-86)	8.24 (02-04-86)	8.24	10.95	- 2.71
GE-166	1986	4	53.43 (11-03-86)	50.92 (02-04-86)	50.92	56.52	- 5.60
GE-169	1986	4	+ .83 (08-20-86)	+ .95 (11-06-86)	+ .93	+ 1.00	.07
GE-170	1986	4	50.00 (08-18-86)	47.35 (11-03-86)	47.54	47.83	- .29

Table 5. Historic and current water-levels for wells measured during the 1986 and 1994 synoptic water-level surveys, Geauga County, Ohio—Continued

Well number	Period of record for historical measurements	Number of historical measurements	Water level (feet below land surface)				Water-level difference (feet) 1986-1994[a]
			Maximum historical depth-to-water and date	Minimum historical depth-to-water and date	Jan.-Feb. 1986	Sept. 1994	
GE-171	1986	4	55.39 (08-18-86)	53.93 (11-03-86)	54.55	54.05	.50
GE-173	1986	3	6.14 (11-03-86)	4.94 (02-04-86)	4.94	6.96	- 2.02
GE-176	1986	4	48.46 (08-21-86)	45.34 (02-13-86)	45.34	48.88	- 3.54
GE-177	1986	4	19.69 (08-21-86)	6.92 (05-09-86)	7.18	18.90	-11.72
GE-178	1986	4	55.43 (11-04-86)	54.85 (02-06-86)	54.85	55.79	- .94
GE-180	1986	5	31.48 (11-06-86)	30.65 (04-23-86)	30.88	30.36	.52
GE-181	1986	4	9.65 (08-20-86)	5.63 (01-29-86)	5.63	10.09	- 4.46
GE-183	1986	4	41.06 (11-04-86)	39.86 (02-05-86)	39.86	42.08	- 2.22
GE-185	1986	4	39.25 (08-21-86)	28.80 (05-08-86)	29.57	23.09	6.48
GE-186	1986	4	46.25 (08-21-86)	37.41 (01-29-86)	37.41	43.16	- 5.75
GE-193	1986	4	53.03 (11-05-86)	49.14 (01-30-86)	49.14	52.06	- 2.92
GE-195	1986	4	14.85 (08-21-86)	13.03 (05-08-86)	13.16	15.36	- 2.20
GE-196	1986	4	67.12 (08-19-86)	66.62 (02-10-86)	66.62	68.23	- 1.61
GE-197	1986	4	62.53 (08-19-86)	45.24 (02-11-86)	45.24	47.23	- 1.99
GE-198	1986	4	15.60 (11-05-86)	13.89 (05-08-86)	14.00	15.67	- 1.67
GE-199	1986	4	15.89 (11-05-86)	12.14 (02-11-86)	12.14	15.95	- 3.81
GE-202	1986	4	28.84 (08-19-86)	27.60 (02-10-86)	27.60	30.30	- 2.70

Table 5. Historic and current water-levels for wells measured during the 1986 and 1994 synoptic water-level surveys, Geauga County, Ohio—Continued

Well number	Period of record for historical measurements	Number of historical measurements	Water level (feet below land surface)				Water-level difference (feet) 1986-1994[a]
			Maximum historical depth-to-water and date	Minimum historical depth-to-water and date	Jan.-Feb. 1986	Sept. 1994	
GE-204	1986	4	10.45 (05-08-86)	9.81 (02-06-86)	9.81	11.04	- 1.23
AB-126	1986	1	NA	NA	14.59	14.37	.22
AB-127	1986	1	NA	NA	10.26	12.67	- 2.41
L-86	1986	1	NA	NA	23.36	24.65	- 1.29
L-88	1986	1	NA	NA	69.35	75.70	- 6.35
PO-8	1986	1	NA	NA	36.40	30.50	5.90
PO-9	1986	1	NA	NA	19.86	21.30	- 1.44
PO-10	1986	1	NA	NA	26.91	27.85	- .94
PO-11	1986	1	NA	NA	56.12	45.30	10.82
PO-12	1986	1	NA	NA	41.40	41.76	- .36
PO-13	1986	1	NA	NA	14.07	12.89	1.18
PO-14	1986	1	NA	NA	9.20	13.34	- 4.14
PO-15	1986	1	NA	NA	32.95	35.07	- 2.12
T-6	1986	1	NA	NA	16.80	15.91	.89

[a]A negative value indicates that the water level decreased between January/February 1986 and September 1994. A positive value indicates that water level has increased.

Notes:

Notes: