# Geohydrology and Water Quality of the Unconsolidated Deposits in Erie County, Pennsylvania

by Theodore F. Buckwalter, Curtis L. Schreffler, and Richard E. Gleichsner

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## CONVERSION FACTORS AND VERTICAL DATUM

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| inch (in.) | 25.4 | millimeter foot |
| foot (ft) | 0.3048 | meter |
| mile (mi) | 1.609 | kilometer |
| | Area | |
| acre | 4,047 | square kilometer |
| square foot ($ft^2$) | 0.0929 | square meter |
| square mile ($mi^2$) | 2.590 | square kilometer |
| square foot per day ($ft^2$/d) | 0.09290 | square meter per day |
| | Flow | |
| cubic foot per second ($ft^3$/s) | 0.02832 | cubic meter per second |
| gallon per day (gal/d) | 3.785 | liter per day |
| gallon per minute (gal/min) | 0.06308 | liter per second |
| million gallons per day (Mgal/d) | 0.04381 | cubic meter per second |
| | Volume | |
| gallon (gal) | 3.785 | liter |
| | 3,785 | milliliter |
| | Temperature | |
| degree Fahrenheit (°F) | °C = 5/9 (°F – 32) | degree Celsius (°C) |
| | Specific capacity | |
| gallon per minute per foot [(gal/min)/ft] | 0.2070 | liter per second per meter |
| | Hydraulic conductivity | |
| foot per day (ft/d) | 0.3048 | meter per day |
| cubic foot per second per square mile | 0.01093 | cubic meter per second per square kilometer |
| | Transmissivity | |
| square foot per day ($ft^2$/d) | 0.09290 | square meter per day |

Abbreviated water-quality units used in report:

mg/L milligram per liter

µS/cm microsiemens per centimeter at 25 degrees Celsius

µg/L microgram per liter

Degree Celsius (°C) may be converted to degree Fahrenheit (°F) by using the following equation:

$$°F = 9/5\,(°C) + 32.$$

Degree Fahrenheit (°F) may be converted to degree Celsius (°C) by using the following equation:

$$°C = 5/9\,(°F - 32).$$

**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.

# Geohydrology and Water Quality of the Unconsolidated Deposits in Erie County, Pennsylvania

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## Abstract

Water in unconsolidated deposits is used for the water supplies of homes, farms, municipalities, and industries in Erie County. The unconsolidated deposits cover most of the bedrock of Erie County. Thickness of the unconsolidated deposits ranged from 60 to 400 feet at 30 sites surveyed by seismic refraction and reflection methods. Water wells, mostly in the unconsolidated deposits, provide adequate domestic supplies. Wells in fractured bedrock can generally provide small domestic supplies; however, droughts can affect some of the domestic water wells. Ground-water withdrawals accounted for 10 million gallons per day of the water used in Erie County in 1984.

Mean annual precipitation ranged from 42 to 47 inches per year in Erie County from 1961 through 1990; the southeastern region of the county generally receives more precipitation than the lake shore region to the north. Overland runoff to three segments of the French Creek watershed in the upland area ranged from about 13 to 19 in. per year and base flow ranged from 14 to about 18 in. per year from 1975 to 1992. Evapotranspiration ranged from about 13 to 16 in. per year for those segments.

Beach and outwash deposits generally provide the largest supplies of water to wells in Erie County. A median specific capacity of 17 (gal/min)/ft (gallons per minute per foot) of drawdown was determined from records of nondomestic wells in beach deposits and 9 (gal/min)/ft of drawdown in outwash. Mean specific capacity for wells in till deposits was 1.5 (gal/min)/ft. The range in yield and specific capacity, however, was great for the unconsolidated deposits and high yielding outwash deposits are sometimes difficult to locate beneath till and valley-fill deposits.

Hydraulic conductivities from three aquifer tests of outwash deposits (sand and gravel) at separate sites ranged from 110 to 2,030 ft/d (feet per day). Hydraulic conductivities from another aquifer test of sand and silt in the water table at Presque Isle ranged from 120 to 215 ft/d. Transmissivities from a third aquifer test of beach sand and gravel ranged from 235 to 262 feet squared per day.

Laboratory analyses of stream samples collected during base flows in 1987 and 1988 indicate that concentrations of arsenic, barium, cadmium, chromium, fluoride, lead, mercury, and selenium did not exceed the maximum contaminant levels (MCL's) established for drinking water by the U.S. Environmental Protection Agency (USEPA). Concentrations of two nontoxic elements, iron and manganese, exceeded USEPA secondary maximum contaminant levels (SMCL's) in samples from selected stream sites. Manganese concentrations exceeded the SMCL of 0.05 milligrams per liter at 19 of 30 stream sites sampled in the Upland Plateau Section of Erie County. Twenty-one wells were sampled for inorganic constituents and selected pesticides. Some samples from three of the wells exceeded the MCL for nitrate. Total arsenic concentrations above the MCL of 50 micrograms per liter were documented intermittently in three water wells in North East Township.

Water from six of seven tile drains sampled in agricultural fields contained detectable concentrations of herbicides. These samples document the transport of the herbicides from the shallow ground-water system to local streams. Herbicide concentrations were at or more than minimum reporting levels for atrazine, cyanazine, prometone, and simazine. Atrazine concentrations in all seven samples from tile drains did not exceed the USEPA MCL of 3.0 micrograms per liter.

## INTRODUCTION

Although the City of Erie and some adjacent areas use water from Lake Erie, ground water from the unconsolidated deposits is used extensively for homes, farms, municipalities, and industry in Erie County. Droughts have resulted in rationing of ground-water supplies, particularly from those water wells that produce small yields.

Federal, State, and local officials, as well as citizens of Erie County, became concerned about the water resources of the county during the early 1980's when ground-water contamination was reported at several locations. In 1984, public officials and citizens formed the Erie County Water Resources Commission to improve the knowledge of the quality and quantity of the water resources of Erie County and to determine how these resources could best be used to promote the sound, economic and environmental well being of the county. At the request of the Erie County Water Resources Commission, the USGS, in cooperation with the Erie County Department of Health (ECDH), initiated a study in 1984 to improve the existing data base of information on ground-water quality and quantity in Erie County.

### Purpose and Scope

The geohydrology and water quality of the unconsolidated deposits of Erie County, Pa., are described in this report. Water-use data were compiled, water budgets were calculated, and ground-water availability was assessed. Ground-water contamination of specific sites was summarized from a literature search. Water wells were inventoried, line of sections were surveyed, test holes were drilled, and aquifer properties were determined by time-drawdown test. Water samples were collected from wells, tile drains, and base flows of streams. The water samples were analyzed for major ions and selected contaminants.

### Well-Numbering System

The well-numbering system used in this report consists of a county-abbreviation prefix followed by a sequentially-assigned number. The prefix Er denotes a well in Erie County.

### Acknowledgments

The authors thank the many individuals who provided assistance and information for this study. Special thanks are given to the members of the Erie County Water Resources Commission for their involvement and guidance during this study.

The authors gratefully acknowledge the cooperation of individuals who permitted access to their property and wells for the collection of data. The Pennsylvania Department of Environmental Resources (PaDER) Bureau of State Parks, Pennsylvania State University, and D. Hill are gratefully acknowledged for access to their property for the purpose of installing observation wells. Special thanks are given to Michael Burch and Moody and Associates, Inc. for providing hydrogeologic data on Erie County.

## DESCRIPTION OF STUDY AREA

### Physiography and Drainage

Three physiographic divisions are recognized in Erie County (fig. 1): lake plain, escarpment slope, and upland plateau (Tomikel and Shepps, 1967). The northern border of the lake plain is at the elevation of Lake Erie (mean lake elevation 571 ft) and extends inland to an elevation of about 800 ft. The escarpment slope separates the nearly flat lake plain from the upland plateau, which is characterized by broad valleys with flat bottoms and relatively steep walls. The transition from lake plain to escarpment slope in western Erie County is gradual with gentle changes in elevation and mixed surface features in both divisions. Thus, the escarpment slope in Erie County exhibits some lake-plain features. The maximum elevation of the escarpment slope is about 1,000 ft. The highest elevation of the upland plateau is slightly above 1,900 ft in southeastern Erie County.

The drainage divide between the St. Lawrence River Basin and the Mississippi River Basin crosses Erie County. Streams tributary to Lake Erie are part of the St. Lawrence River drainage system. Many of these streams have cut deeply into bedrock. The French Creek-Allegheny River system that includes many south-flowing streams are headwaters of the Ohio River and subsequently the Mississippi River. These streams flow mostly on glacial or alluvial deposits.

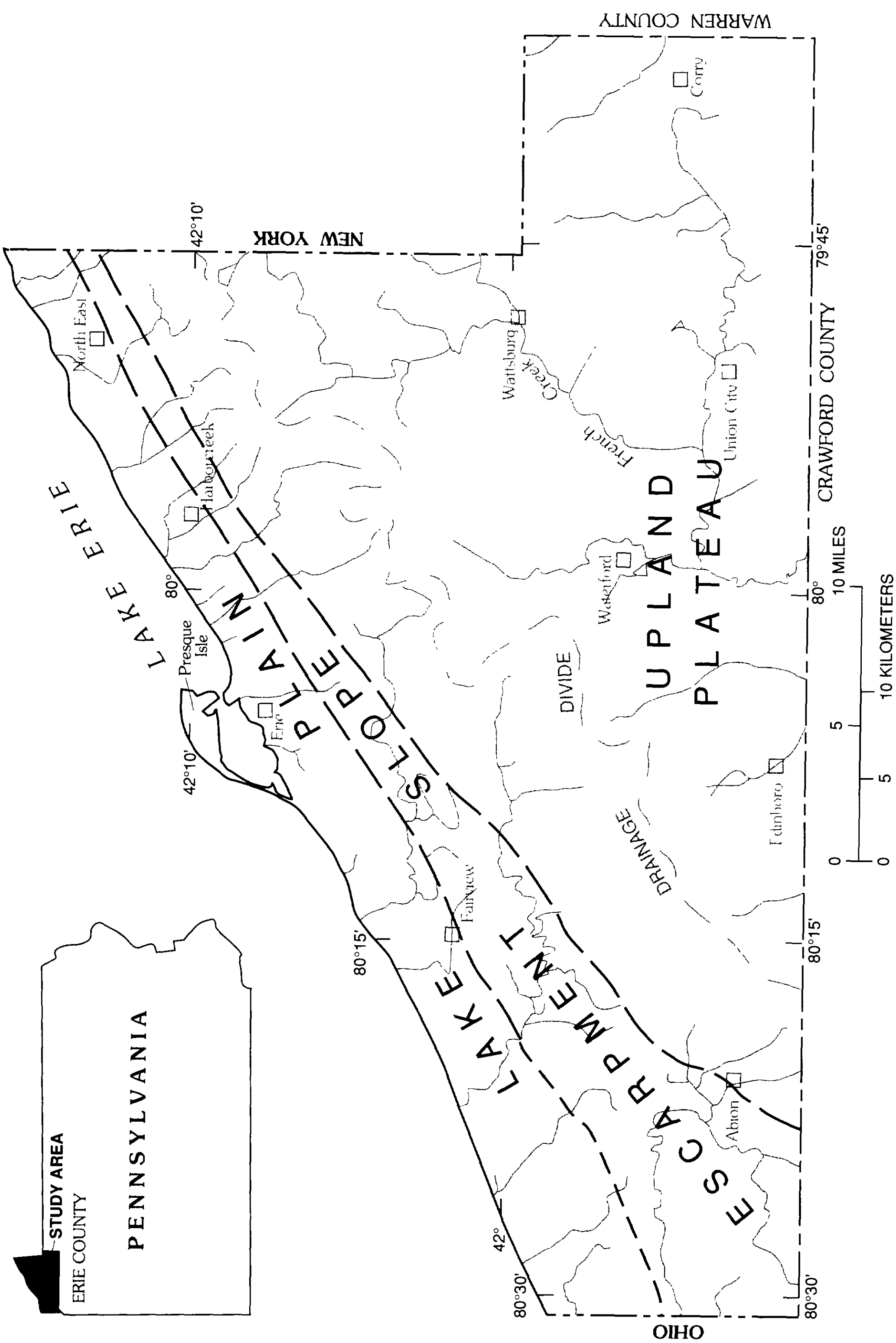


**Figure 1.** Physiographic divisions of Erie County, Pennsylvania.

## Population and Water Use

The population of Erie County in 1990 was 275,600—a 1.5-percent loss compared to the population in 1980 (U.S. Department of Commerce, 1982, 1992). The population of the City of Erie (fig. 2) declined from 119,100 in 1980 to 108,700 in 1990. Millcreek Township, which is adjacent to the City of Erie, increased in population during the period 1980 to 1990 by 5.1 percent (U.S. Department of Commerce, 1982, 1992). A general trend for the period was for residents of the City of Erie to move to outlying townships. The gradual movement of population from the city resulted in an increased demand for ground water in many localities for private residential and public-supply use. Figure 2 shows population shifts for Erie County from 1980–90. Population gains or losses for boroughs were combined with the population gains or losses of the respective townships containing the boroughs.

Total water withdrawal in Erie County in 1984 was about 400 Mgal/d (Gast, 1990). Ground-water withdrawals accounted for 10 Mgal/d and surface-water withdrawals accounted for 390 Mgal/d (Gast, 1990). Most of the ground-water withdrawals are from unconsolidated deposits (Richards and others, 1987, p. 4). The following is a breakdown of total withdrawal by water-use category for 1984 (Gast, 1990):

| | |
|---|---|
| Thermoelectric power | 300 Mgal/d |
| Public water supply | 49 Mgal/d |
| Industrial/mining | 45 Mgal/d |
| Domestic/commercial | 3 Mgal/d |
| Agriculture | 3 Mgal/d |

Estimates of water withdrawals for 1990–93 are presented in table 1 for community or commercial water-supply systems exceeding an average pumpage of 10,000 gal/d. The total pumpage from ground water by these supply systems is 5.6 Mgal/d. The 39.7 Mgal/d of water pumped from Lake Erie by the City of Erie is the largest withdrawal for public supply. The City of Erie also supplies some adjacent areas with water. Ground water is used for water supply in the remainder of Erie County with the exceptions of North East Borough and Union City, which use surface water (table 1).

Residential water usage on a per capita basis varies extensively. Outdoor consumption varies seasonally including water used for lawn watering, swimming pools, and car washing. Statistics compiled for Pennsylvania on per capita water use indicate that individuals with a public water supply average 110 gal/d; those with rural supplies (domestic wells and springs) average 50 gal/d per person (Ernst and Young, Inc., 1990, p. 57). Thus the approximately 57,000 people that obtain their water from domestic wells use about 2.8 Mgal/d. Agricultural use from ground water is estimated to be 1.3 Mgal/d. Estimates of future population and projected water use for Erie County are given in the "Erie County Water Supply and Distribution Plan" (Erie County Metropolitan Planning Commission and Erie Metropolitan Planning Department, 1976) and the "Comprehensive Water Quality Management Plan" (Engineering-Science, Inc., 1976).

## Previous Studies

### General

The availability and quality of ground water in Erie County were described by Richards and others (1987). Data are given on the depths, yields, and quality of water from more than 1,700 wells. In addition, maps showing bedrock geology and thickness of unconsolidated deposits are provided. Mangan and others (1952) discussed surface-water and ground-water resources of the Lake Erie shore region.

Other reports that include data on or evaluation of the ground-water resources of Erie County are Leggette (1936) and Engineering-Science, Inc. (1976). The geology and ground-water resources of western Crawford County, bordering much of Erie County on the south, are described by Schiner and Gallaher (1979). An estimate of the altitude of the base of the fresh ground-water system at a study area in western Crawford County is provided by Buckwalter and Squillace (1995). Adjacent to Erie County in Chautauqua County, N.Y., Frimpter (1974) mapped ground-water availability in unconsolidated aquifers and noted that several aquifers in the unconsolidated deposits support high-yield wells.

### Ground-Water Contamination of Specific Sites

Ground-water contamination in Erie County has resulted from many activities including the disposal of municipal and industrial wastes, leaking underground storage tanks, spills, and oil and gas development (Pennsylvania Department of Environmental Resources, 1988). A summary table of 44 sites in Erie County with documented or potential ground-water contamination is given in the Commonwealth of Pennsylvania 1988 Water Quality Assessment (Pennsylvania Department of Environmental

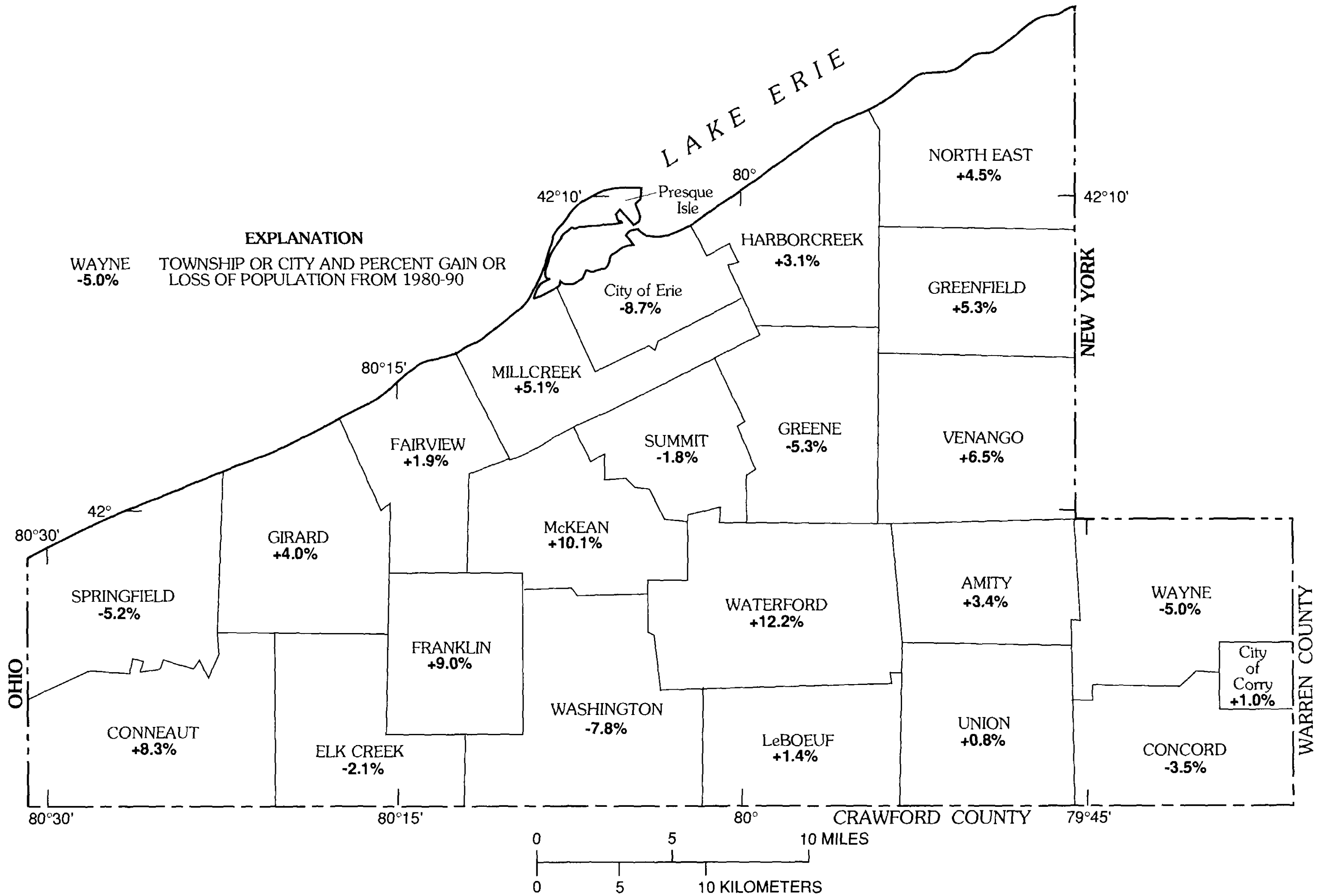


**Figure 2.** Townships and major cities of Erie County, Pennsylvania, with percent change in population from 1980–90.

**Table 1.** Estimated water use by community and commercial water supplies in Erie County, Pennsylvania, 1990–93

[From Erie County Department of Health, written commun., 1995]

| Water supplier | Location of water supplier | Pumpage estimate (gallons per day)[1] | Water source |
|---|---|---|---|
| | Surface water | | |
| Country Side Mobile Home Park | McKean Township | 34,000 | Pond |
| City of Erie | Erie | 39,734,000 | Lake Erie |
| North East Borough | North East | 2,268,000 | 3 reservoirs and 4 springs |
| Union City Municipal Water Authority | Union City | 460,000 | Reservoir on Bentley Run |
| | Ground water | | |
| Albion, Borough of Best Western Inn | Albion Borough | 221,000 | 3 wells |
| | McKean Township | 11,000 | 2 wells |
| Corry Municipal Authority | City of Corry | 1,451,000 | 6 wells |
| Country Gardens Trailer Court | Girard Township | 16,000 | 3 wells |
| Crystal Court Mobile Home Park | Millcreek Township | 24,000 | 3 wells |
| Days Inn | Summit Township | 18,000 | 1 well |
| Edinboro Water Authority | Edinboro Borough | 725,000 | 2 wells |
| Erie County Geriatric Center | Girard Township | 71,000 | 5 wells |
| Fairview Borough Water Dept. | Fairview Borough | 121,000 | 5 wells |
| General McLane High School | Washington Township | 30,000 | 1 well |
| Girard Borough Water Dept. | Girard Borough | 320,000 | 4 wells |
| Gladstone Heights Water Assoc. | Millcreek Township | 16,000 | 3 wells |
| Green Shingle Restaurant and Truck Stop | McKean Township | 12,000 | 2 wells |
| Idyll Whyle Village Inc. | McKean Township | 18,000 | 1 well |
| Imperial Point South Mobile Home Park | Washington Township | 14,000 | 1 well |
| Imperial Point Water Service Co. | Girard Township | 90,000 | 2 wells |
| Lake City Borough Municipal Water Supply | Lake City Borough | 350,000 | 3 wells |
| Lakeshore Water Association | Millcreek Township | 104,000 | 2 wells |
| Manchester Heights Water Association | Fairview Township | 6,700 | 1 well |
| Millcreek Township Water Authority | Millcreek Township | 1,700,000 | 2 wells |
| Millfair Heights Association Water System | Millcreek Township | 28,000 | 2 wells |
| Palmer Shore Water Association | Fairview Township | 11,000 | 1 well |
| Popps Mobile Home Park | Summit Township | 12,000 | 5 wells |
| Ridgeville Water Company | Millcreek Township | 13,000 | 3 wells |
| Shenandoah Home Owners | Millcreek Township | 14,000 | 2 wells |
| Valasion Mobile Home Park | Fairview Township | 18,000 | 1 well |
| Waterford Municipal Authority | Waterford Borough | 198,000 | 2 wells |
| Woodhaven Mobile Home Park | Greene Township | 22,000 | 5 wells |

[1]This table is restricted to water suppliers providing a daily average of greater than 10,000 gallons per day. Pumpage estimates are for 1990 or 1993. Some small private water suppliers are not presently required to report ground-water pumpage. For these suppliers, average daily sewage-treatment-plant flows originating from well water were used as estimates of ground-water pumpage.

Resources, 1988). The table lists the location of sites by township, estimates of acreage contaminated (when available), and programs underway or proposed to correct the ground-water problem.

Potential discharge of contaminated ground water to Presque Isle Bay is described by Potomac-Hudson Engineering, Inc. (1991). Ground-water investigations are described in that report for 10 sites within about 2 mi of Presque Isle Bay. Environmental studies dealing with ground-water contamination are ongoing at many sites in the county by various parties including the ECDH, PaDER, Pennsylvania Department of Transportation, USEPA, and consulting firms.

USEPA investigation reports for 115 sites in Erie County were screened for ground-water contamination. The sites were included in the 1989 USEPA listing of old and new hazardous-waste sites. This screening process found nine sites with clearly documented ground-water contamination (table 2)(fig. 3). The total area affected is undetermined, but probably small and limited to local flow systems. If the contaminants are discharging to small streams, or if they have moved through outwash or fractured bedrock for a long time period, however, they could have moved considerable distances, even though the area affected might still be considered small. Concentrations of one or more chemical contaminants exceeded some USEPA limit at each of the sites.

The USEPA 1989 listing generally does not include ground-water contamination from leaks in underground-storage tanks such as gasoline or diesel fuel tanks. Leaking underground-storage tanks and piping failures are significant sources of ground-water contamination in Pennsylvania (Pennsylvania Department of Environmental Resources, 1990, p. 56–57). No published reports are available summarizing the past and present status of the extent and severity of ground-water contamination from leaking underground storage tanks in Erie County. Laboratory analyses and other information concerning selected sites in Erie County are available at the Meadville Regional office of PaDER.

## GEOLOGIC SETTING

### Bedrock

Sedimentary rocks ranging in age from Late Devonian to Early Mississippian crop out in Erie County. Unconsolidated surficial deposits overlie most of the bedrock. Bedrock outcrops become progressively younger toward the south. The regional dip of the bedrock units generally is toward the south at about 15 to 20 ft/mi (Richards and others, 1987).

Seismic-refraction data were collected in 1987 and seismic-reflection data were collected in 1988. These data were interpreted and geologic sections showing the bedrock surface were drawn (Appendix 1). The depth to bedrock and corresponding thickness of unconsolidated deposits were estimated to range from 60 to 400 ft at 30 locations in Erie County (fig. 4). The latitudes and longitudes of the end points of the lines of section and the depth to bedrock are listed in table 3.

Four test wells were installed at selected seismic-survey locations to determine lithology of unconsolidated deposits and confirm depths to bedrock at survey sites. A tabulation of depths to bedrock calculated from seismic-reflection techniques and determined from drilling is given in table 4. The depths to bedrock determined by drilling are more reliable than estimates of depth to bedrock from seismic-reflection data.

## HYDROLOGIC SETTING

### Hydrologic Cycle

The Earth's water-circulation system is called the hydrologic cycle. The cycle is a dynamic process in which water is transported from the oceans to the atmosphere and, by various pathways, back to the oceans. In the natural cycle, precipitation on the land surface may infiltrate downward to the zone of aeration, evaporate or transpire back to the atmosphere, or flow over the land surface as direct runoff (fig. 5). Some precipitation percolates to the water table (the upper surface of the zone of saturation) and recharges the ground-water reservoir. Water in the hydrologic cycle flows at various rates, depending on whether it is in the form of water vapor, surface water, or ground water.

### Precipitation

Annual precipitation is unevenly distributed in Erie County. The southeastern region of the county generally receives more precipitation than the lake shore region to the north. Data from three long-term precipitation stations in the county show this anomaly (table 5). Two stations in the southeastern region at Corry and Union City show 30-year mean annual precipitation greater than that at the other station located in the lake shore region at the Erie airport (fig. 6) (table 5). During the 3-year period of this study, annual

**Table 2.** Hazardous-waste sites in Erie County, Pennsylvania, with ground-water contamination documented by site investigations for the U.S. Environmental Protection Agency

[Sites are shown in figure 3]

| Site number | 7–1/2-minute quadrangle | City, borough, or township | Latitude | Longitude | Ground-water contaminants | Source of data |
|---|---|---|---|---|---|---|
| 1 | Edinboro South | Edinboro | 41°52'23" | 80°07'57" | Various organics | Ryan (1988) |
| 2 | Columbus | City of Corry | 41°55'00" | 79°36'54" | Various organics; various inorganics including chromium | McCarthy (1988) |
| 3 | Swanville | Millcreek Township | 42°05'45" | 80°08'30" | Various inorganics including arsenic, barium, and lead | Chamberlain (1988) |
| 4 | Albion | Girard Township | 41°58'40" | 80°21'05" | Various organics; various inorganics including arsenic and lead | Lasky (1984) |
| 5 | Swanville | Millcreek Township | 42°05'30" | 80°09'12" | Various organics | Chambers (1985) |
| 6 | Wattsburg | Venango Township | 42°02'03" | 79°50'05" | Various inorganics including lead | Heffron (1988) |
| 7 | Waterford | Waterford Township | 41°58'12" | 79°59'33" | Various organics; various inorganics including arsenic and lead | Pennsylvania Department of Environmental Resources (1986) |
| 8 | Edinboro North | Washington Township | 41°52'51" | 80°09'33" | Various organics | Patarcity (1988) |
| 9 | Erie South | City of Erie | 42°06'28" | 80°06'29" | Various organics | Gorman (1986) |

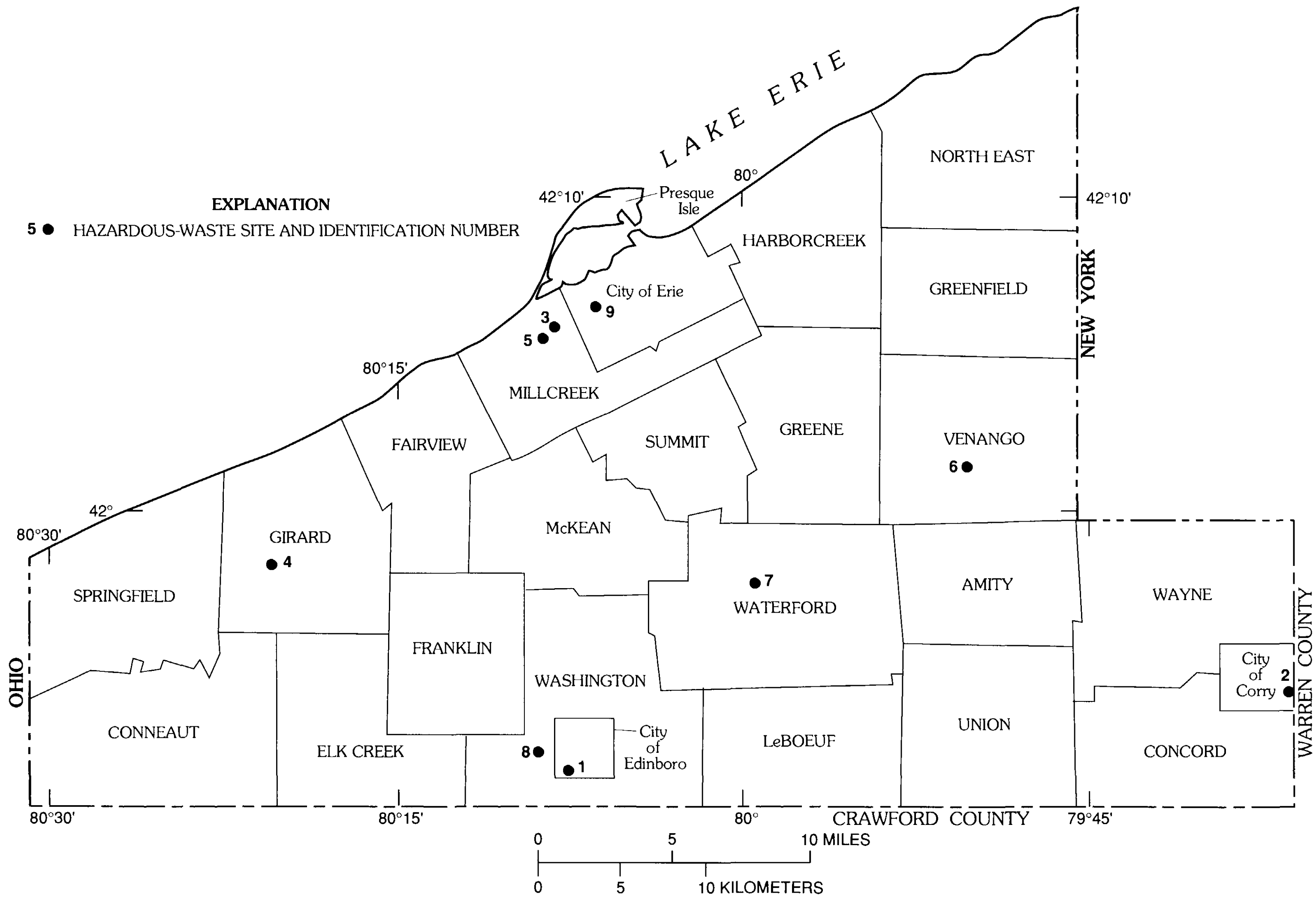


**Figure 3.** Selected hazardous-waste sites with ground-water contamination in Erie County, Pennsylvania. (Site locations are listed in table 2.)

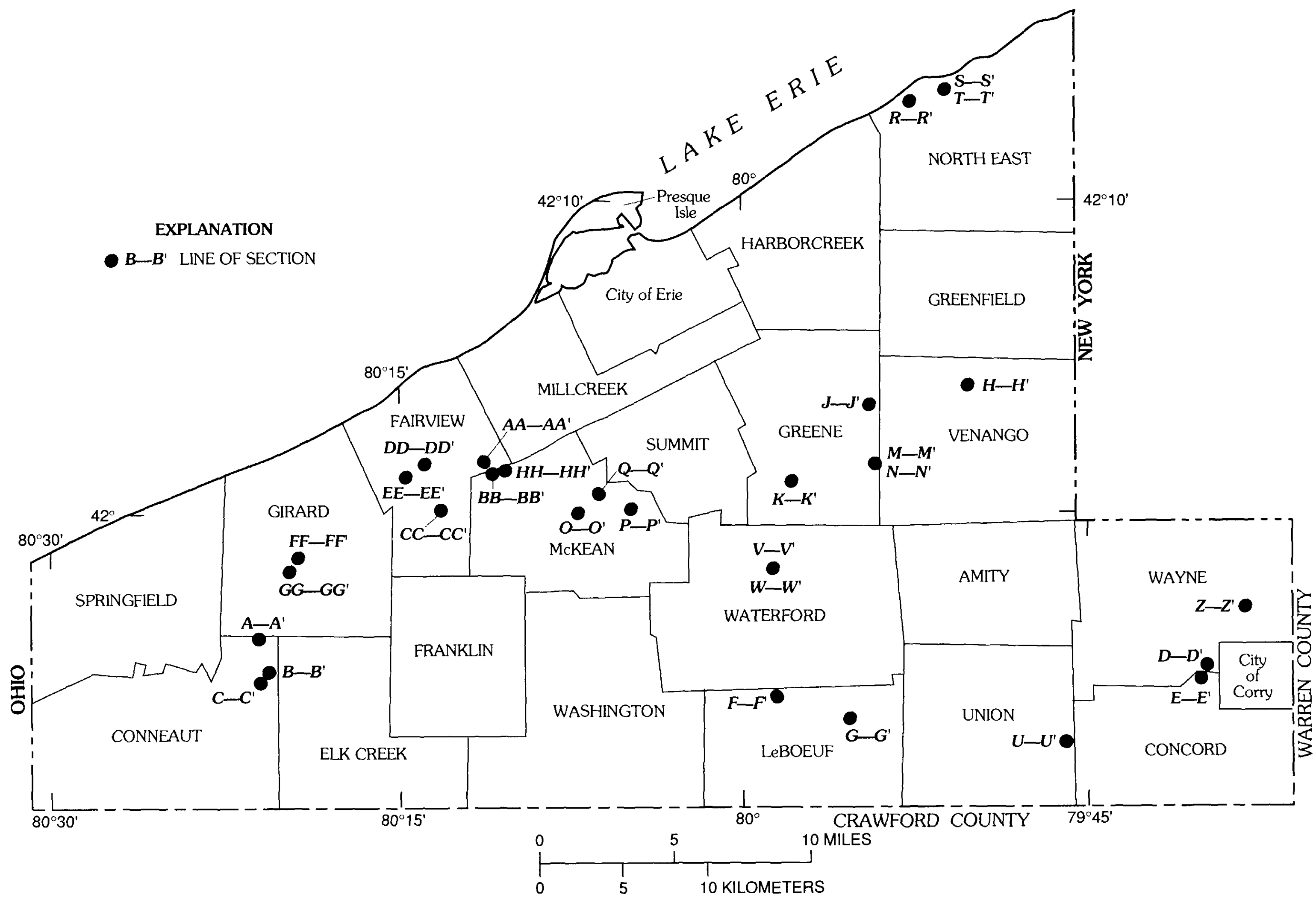


**Figure 4.** Locations of lines of section in Erie County, Pennsylvania. (See table 3 for endpoint latitudes, longitudes, and bedrock depths).

**Table 3.** Latitude and longitude of end points and average depth to bedrock of lines of section in Erie County, Pennsylvania

[Locations of lines of section shown in figure 4, °, degree; ', minute; ", second]

| Line of section | Township | Latitude | Longitude | Average depth of bedrock (feet) |
|---|---|---|---|---|
| E-E' | Concord | 41°55'24" | 79°40'48" | 400 |
| | | 41°55'03" | 79°40'33" | |
| A-A' | Conneaut | 41°56'41" | 80°22'06" | 150 |
| | | 41°55'40" | 80°21'41" | |
| B-B' | Conneaut | 41°55'32" | 80°21'37" | 250 |
| | | 41°54'48" | 80°21'11" | |
| C-C' | Conneaut | 41°54'38" | 80°21'12" | 250 |
| | | 41°54'44" | 80°22'16" | |
| AA-AA' | Fairview | 42°01'44" | 80°12'03" | 126 |
| | | 42°01'44" | 80°11'56" | |
| CC-CC' | Fairview | 42°00'18" | 80°13'43" | 116 |
| | | 42°00'21" | 80°13'38" | |
| DD-DD' | Fairview | 42°01'40" | 80°14'34" | 55 |
| | | 42°01'42" | 80°14'28" | |
| EE-EE' | Fairview | 42°01'14" | 80°15'23" | 78 |
| | | 42°01'15" | 80°15'15" | |
| FF-FF' | Girard | 41°58'41" | 80°20'09" | 198 |
| | | 42°58'37" | 80°19'55" | |
| GG-GG' | Girard | 41°58'13" | 80°20'47" | 173 |
| | | 41°58'13" | 80°20'32" | |
| J-J' | Greene | 42°03'45" | 79°54'45" | 200 |
| | | 42°03'33" | 79°54'45" | |
| K-K' | Greene | 42°01'12" | 79°58'18" | 148 |
| | | 42°01'10" | 79°58'06" | |
| M-M' | Greene | 42°01'55" | 79°54'33" | 150 |
| | | 42°01'43" | 79°54'30" | |
| N-N' | Greene | 42°01'42" | 79°54'34" | 140 |
| | | 42°01'42" | 79°54'19" | |
| F-F' | LeBoeuf | 41°54'34" | 79°59'11" | 200 |
| | | 41°54'34" | 79°58'22" | |
| G-G' | LeBoeuf | 41°54'01" | 79°55'17" | 100 |
| | | 41°53'40" | 79°55'18" | |
| O-O' | McKean | 42°00'19" | 80°07'38" | 60 |
| | | 42°00'13" | 80°07'38" | |
| P-P' | McKean | 42°00'24" | 80°05'22" | 150 |
| | | 42°00'15" | 80°05'26" | |
| Q-Q' | McKean | 42°00'54" | 80°06'55" | 180 |
| | | 42°00'44" | 80°06'46" | |
| BB-BB' | McKean | 42°01'26" | 80°11'48" | 126 |
| | | 42°01'29" | 80°11'39" | |
| HH-HH' | McKean | 42°01'27" | 80°11'18" | 135 |
| | | 42°01'28" | 80°11'11" | |

**Table 3.** Latitude and longitude of end points and average depth to bedrock of lines of section in Erie County, Pennsylvania--Continued

| Line of section | Township | Latitude | Longitude | Average depth of bedrock (feet) |
|---|---|---|---|---|
| R-R' | North East | 42°13'27" | 79°52'54" | 120 |
| | | 42°13'05" | 79°52'55" | |
| S-S' | North East | 42°13'51" | 79°51'26" | 120 |
| | | 42°13'30" | 80°51'27" | |
| T-T' | North East | 42°13'41" | 80°51'20" | 120 |
| | | 42°13'40" | 79°51'36" | |
| U-U' | Union | 41°53'29" | 79°46'29" | 60 |
| | | 41°53'13" | 79°46'05" | |
| H-H' | Venango | 42°04'18" | 79°51'00" | 150 |
| | | 42°04'17" | 79°50'06" | |
| V-V' | Waterford | 41°58'26" | 79°59'26" | 180 |
| | | 41°58'31" | 79°58'42" | |
| W-W' | Waterford | 41°58'28" | 79°59'02" | 230 |
| | | 41°58'14" | 79°58'02" | |
| D-D' | Wayne | 41°55'48" | 79°40'12" | 400 |
| | | 41°55'32" | 79°40'13" | |
| Z-Z' | Wayne | 41°57'35" | 79°38'31" | 130 |
| | | 41°57'28" | 79°38'31" | |

**Table 4.** Estimated depths to bedrock from seismic-reflection data and well drilling in Erie County, Pennsylvania

[>, greater than]

| Line of section | Estimated depth to bedrock from interpretation of seismic-reflection data (feet) | Estimated depth to bedrock at line of section interpreted from either drillers logs of nearby water wells or test well drilled on line of section (feet) | Remarks |
|---|---|---|---|
| BB-BB' | 126 | 132 | Test well Er-8545 drilled on line of section BB-BB' |
| CC-CC' | 116 | 108 | Test well Er-9563 drilled on line of section CC-CC' |
| DD-DD' | 55 | >52 | Test well Er-9562 drilled on line of section DD-DD' to a depth of 52 feet but did not reach bedrock. |
| GG-GG' | 173 | >144 | Test well Er-10525 drilled on line of section GG-GG' to a depth of 144 feet but did not reach bedrock. |
| HH-HH' | 135 | 110 | Depth to bedrock of 110 feet estimated from bedrock depths reported from four water wells within 1,200 feet of line of section. |

precipitation was similar to the long-term normal with 1988 having slightly less precipitation and 1987 having slightly more precipitation. Annual precipitation at the airport was always lower than at the other two stations.

**Table 5.** Annual precipitation at three sites in Erie County, Pennsylvania

[Sites are shown in figure 6]

| Site | Precipitation, in inches[1] | | | 30-year mean annual precipitation, (1961–90)[2] |
|---|---|---|---|---|
| | 1987 | 1988 | 1989 | |
| Erie airport | 44.86 | 38.87 | 41.88 | 41.53 |
| Corry | 46.40 | 40.82 | 49.83 | 47.39 |
| Union City | 49.76 | 42.41 | 44.31 | 45.02 |

[1]U.S. Department of Commerce (1987–89).

[2]U.S. Department of Commerce (1992).

Two major factors responsible for greater precipitation in the southeastern region are lake effect snow storms and summertime thunderstorms. In winter months, the prevailing westerly and northwesterly winds blow a majority of the subsequent lake effect snow storms to the southeast. In summer months, the lake water cools the air and retards localized thunderstorm growth. However, the air is heated as it moves inland, and thunderstorms form more frequently and with greater intensity (Forbes, 1990).

## Streamflow

Streamflow records have been collected in Erie County by the USGS as part of a cooperative, systematic monitoring program (fig. 6). Current data are published annually by the USGS in "Water Resources Data for Pennsylvania, Volume 3: Ohio River and St. Lawrence River Basins." Streamflow records for 1986–91 (Lescinsky and others, 1986–91) were collected at four continuous-record sites and at three partial-record sites (table 6). The partial-record sites are crest-stage gages that record only peak-stream stage.

Figure 7 is an example of a hydrograph of stream discharge for the West Branch French Creek near Lowville for 1987–89 (fig. 7). Seasonal trends are evident with minimum flows during the summer and fall.

Low-flow frequency characteristics provide information useful for planning utilization of streamflow for water supply and dilution of industrial waste or sewage effluents. The most common low-flow frequency characteristic is the 7-day, 10-year low flow ($Q_{7\text{-}10}$). The $Q_{7\text{-}10}$ is a statistical estimate of the lowest 7-consecutive-day mean flow that can be expected once every 10 years. Calculations and estimates of $Q_{7\text{-}10}$ for selected stream sites in Erie County are given in table 7. Because of discharges and withdrawals, and differences in precipitation, evapotranspiration, geology, land use, soils, and basin size and slope, $Q_{7\text{-}10}$ varies among streams. For streams in Erie County, $Q_{7\text{-}10}$ ranges from 0 to 0.09 $(ft^3/s)/mi^2$ for unregulated streams. Regulation can substantially increase the $Q_{7\text{-}10}$. For example, for French Creek near Union City (03021520), the regulated $Q_{7\text{-}10}$ is almost three times the unregulated $Q_{7\text{-}10}$.

$Q_{7\text{-}10}$ can be estimated for ungaged (or gaged) sites with the appropriate regression model (Flippo, 1982). For example, the $Q_{7\text{-}10}$ for West Branch French Creek near Lowville (03021410) with a drainage area of 52.3 $mi^2$ is 1.3 $ft^3/s$ or 0.025 $(ft^3/s)/mi^2$. This estimate is only about one-half of the calculated value for 1976–92 of 2.72 $ft^3/s$. This may be partly because the regression model is based on a much longer period of time than 17 years.

## Water Budgets

A water budget is an estimate of water entering and leaving a basin plus or minus changes in storage for a given time period. For a basin where ground-water divides and surface-water divides coincide, water enters as precipitation and leaves as streamflow, evapotranspiration (ET), and diversions, such as ground-water pumpage. Water budgets for selected streams in Erie County were calculated from streamflow and precipitation data. For a basin where ground-water divides and surface-water divides do not coincide, water also enters and (or) leaves a basin as ground-water underflow. Water also is taken into or released from ground-water and soil-moisture storage.

Because the water budgets in this report begin and end in winter when soil moisture is usually at field capacity, the change in soil moisture is, for practical purposes, equal to zero, and a soil-moisture term is not included in the following water-budget equation. A simple annual water budget for basins where ground-water and surface-water divides coincide can be expressed as:

$$P = SF + \Delta GWS + \Delta SWS + ET, \qquad (1)$$

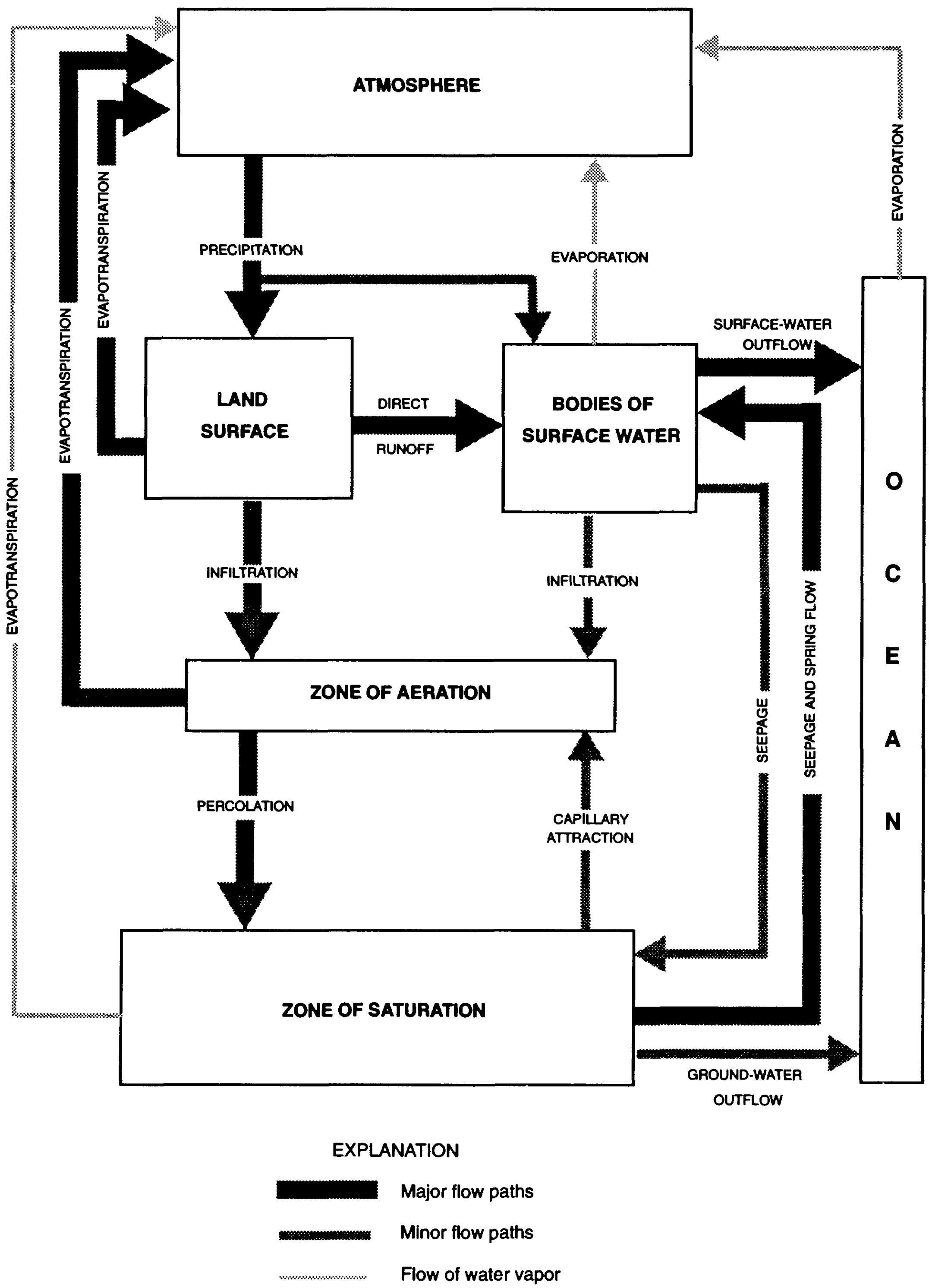


**Figure 5.** Flow diagram of the hydrologic cycle under natural conditions in Erie County, Pennsylvania. (Modified from Franke and McClymonds, 1972, fig. 13).

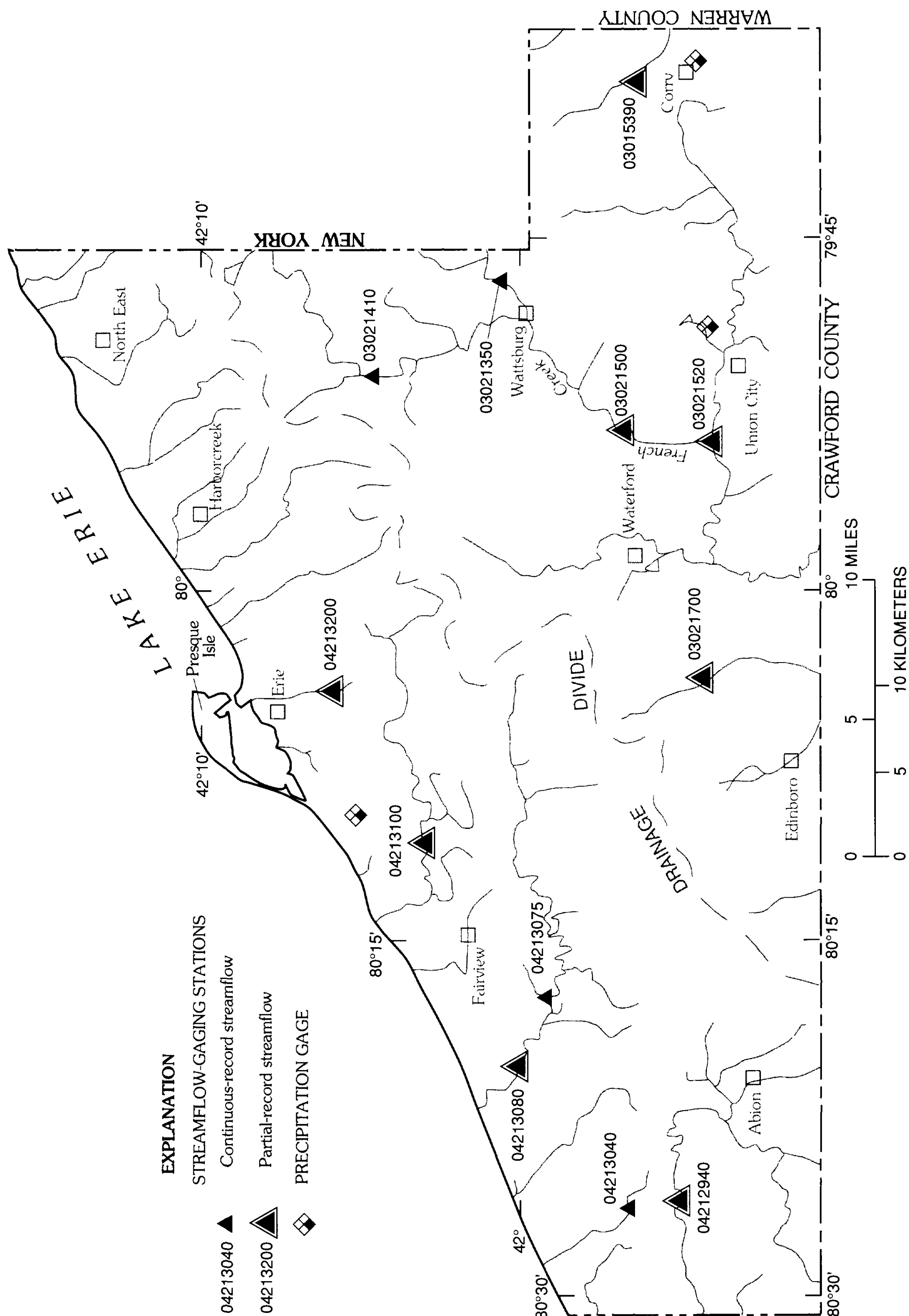


**Figure 6.** Streamflow-gaging stations and precipitation stations, Erie County, Pennsylvania.

**Table 6.** Continuous-record streamflow-gaging stations in Erie County, Pennsylvania

[Locations of stations are shown in figure 6]

| Station number | Station name | Drainage area (square miles) | Period of record | Remarks |
|---|---|---|---|---|
| 03021350 | French Creek near Wattsburg, Pa. | 92.0 | 1974 to current year | |
| 03021410 | West Branch French Creek near Lowville, Pa. | 52.3 | 1974 to current year | |
| 03021500 | French Creek at Carters Corners | 208 | 1909–71 | |
| 03021520 | French Creek near Union City, Pa. | 221 | 1971–91 | |
| 03021700 | Little Conneauttee Creek near McKean, Pa. | 3.60 | 1960–78 | |
| 04213040 | Raccoon Creek near West Springfield, Pa. | 2.53 | 1962 to current year | Partial-record, crest-stage site, 1962–68 Continuous-record site since October 1968 |
| 04213075 | Brandy Run near Girard, Pa. | 4.45 | 1986 to current year | |

**Table 7.** Seven-day, 10-year low flow for streams in Erie County, Pennsylvania

[Locations of stations are shown in figure 6; $mi^2$, square miles; $ft^3/s$, cubic feet per second; $(ft^3/s)/mi^2$, cubic feet per second per square mile]

| Station number | Station name | Drainage area ($mi^2$) | 7-day, 10-year low flow | | Source |
|---|---|---|---|---|---|
| | | | $ft^3/s$ | $(ft^3/s) / mi^2$ | |
| 03015390 | Hare Creek at Corry, Pa. | 17.4 | 0.7 | 0.04 | Estimated by Page and Shaw (1977, p. 328) |
| 03021350 | French Creek near Wattsburg, Pa. | 92.0 | 5.95 | .065 | Calculated for 1976–92 |
| 03021410 | West Branch French Creek near Lowville, Pa. | 52.3 | 2.72 | .051 | Calculated for 1976–92 |
| | | | 1.3 | .025 | Estimated by method of Flippo (1982) |
| 03021520 | French Creek near Union City, Pa. | 211 | 9.6 | .045 | Calculated for 1911–72 |
| | | 221 | [1] 26.7 | [1] .121 | Calculated for 1976–91 |
| 03021700 | Little Conneauttee Creek near McKean, Pa. | 3.60 | .00 | .000 | Calculated for 1960–72 |
| 04212940 | Conneaut Creek at Cherry Hill, Pa. | 149 | 2.1 | .014 | Estimated by Page and Shaw (1977, p. 345) |
| 04213040 | Raccoon Creek near West Springfield, Pa. | 2.53 | .00 | .000 | Calculated for 1976–92 |
| 04213080 | Elk Creek at North Girard, Pa. | 96.7 | 1.8 | .019 | Estimated by Page and Shaw (1977, p. 347) |
| 04213100 | Walnut Creek at Weis Library, Pa. | 26.9 | 0.9 | .03 | Estimated by Page and Shaw (1977, p. 347) |
| 04213200 | Mill Creek at Erie, Pa. | 9.16 | 0.8 | .09 | Estimated by Page and Shaw (1977, p. 347) |

[1]Flow regulated by Union City Reservoir since October 1971.

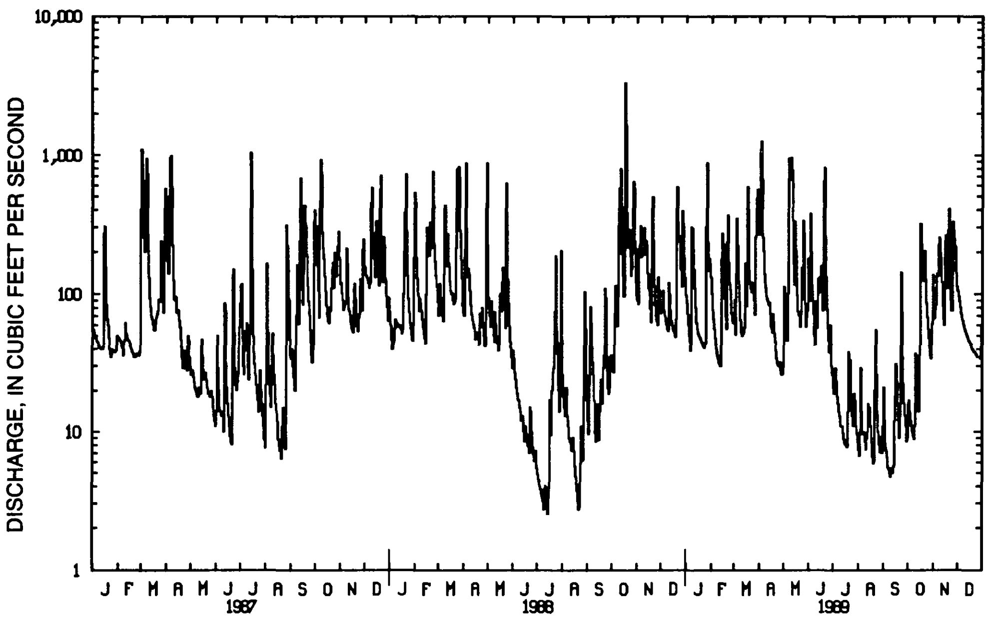


**Figure 7.** Mean daily discharge of West Branch French Creek near Lowville, Pennsylvania, calendar years 1987–89.

where:

$P$ is precipitation;
$SF$ is streamflow;
$DGWS$ is change in ground-water storage;
$DSWS$ is change in surface-water storage; and
$ET$ is evapotranspiration.

All terms in the water-budget equation can be measured or estimated with the existing data network except ET, and equation 1 can be solved for ET as the unknown.

Continuous streamflow data can be separated into base flow (BF) and overland runoff (OR) components by use of a computer program of Sloto (1991). Table 8 gives base-flow data for four streams in Erie County for 1975–92. The local minimum hydrograph-separation technique of Sloto was used.

Median base flows ranged from 42 to 46 percent of streamflow at three of the streamflow-gaging stations with little or no regulation but was 58 percent of streamflow for the other—French Creek near Union City, Pa.—which is regulated by the Union City Reservoir. Regulation has substantially increased the storage of surface water and thus the apparent base flow of French Creek. For 1961–70, prior to regulation, base flow was 49 percent of streamflow at Carters Corners (station 03021500), 4.6 mi upstream from the streamflow-gaging station near Union City, Pa.

Change in ground-water storage ($\Delta GWS$) is generally negligible in Erie County over long time periods. Thus, if streamflow is separated into its components, equation 1 can be rewritten as:

$$P = BF + OR + DSWS + ET. \quad (2)$$

The mean of the precipitation at the National Oceanic and Atmospheric Administration (NOAA) rain gages at Corry and Union City was used with streamflow separation and surface-water storage data to prepare a water budget for French Creek Basin upstream of the gage near Union City (03021500) for the 1961–90 calendar years. The mean change in surface-water storage from 1961–90 was 0.1 in. per year. Thus, equation 2 becomes:

$$P = BF + OR + DSWS + ET, \quad (3)$$

$$46.2\ in. = 17.1\ in. + 13.8\ in. + 0.1\ in. + 15.2\ in. \quad (4)$$

Because data for 1961–71 were used, BF is lower and OR is higher than it would be for a water budget that is based only on post-regulation data.

Table 9 presents water budgets for 1975–92 for gaged areas in Erie County. For this table, equation 2 has been rewritten to eliminate the change in surface-water storage term ($\Delta SWS$), which is negligible for this period, and to add a term for ground-water flow out of the basin (underflow (U)). Underflow out of the Raccoon Creek Basin probably is at least 16 in.; on the basis of ET estimates in the area much of this underflow is through sands and gravels under the channel of Raccoon Creek at the site of the gage. Base flow to three segments of the French Creek watershed ranged from about 14 to 18 in. per year and evapotranspiration ranged from about 13 to 16 in. per year from 1975 to 1992. Overland runoff for those segments ranged from about 13 to 19 in. per year.

# GEOHYDROLOGY

## Ground-Water Flow

In unconsolidated deposits such as sand and gravel, ground water is present in intergranular openings. The water available for withdrawal by wells is located below the top of the saturated zone or water table. In the bedrock of Erie County, ground water available to wells for water supply generally is present in fractures formed after the rock was consolidated. Wider fractures and well-interconnected horizontal and vertical or near vertical fractures greatly improve the yield of bedrock wells. Recharge to bedrock fractures may be enhanced if the rocks are overlain by saturated, permeable unconsolidated deposits receiving infiltration from precipitation. Recharge to a fractured bedrock formation is greater where the formation is overlain by permeable sand and gravel than where it is overlain by clay-rich deposits with low permeability.

Ground-water movement can be categorized into two general flow systems—a shallow, local aquifer system with active flow and a deeper, regional aquifer system with flow that is almost stagnant relative to the circulation of ground water in the shallow system. Generalized paths of ground-water movement typical of the glaciated plateau are shown in figure 8. The direction of shallow ground-water flow is influenced by the composition and structure of the subsurface materials but generally is in the direction of the slope of the topography. The water table is shown intercepting the upland streams in figure 8. Water tables, however, can fluctuate and periodically may be below the stream bottom especially during droughts. During these periods, ground water moves out of the upland valleys and draws as subsurface flow along the valley floors. Actual movement may differ considerably in places because of the complexity of geologic controls and human activities such as pumping of wells. About 95 percent of the ground-water circulation occurs in the

**Table 8.** Annual base-flow summary for selected streams in Erie County, Pennsylvania

[The local minimum hydrograph separation technique (Sloto, 1991) was used to compute base flow; --, no data]

| Calendar year | French Creek near Wattsburg, Pa. (03021350) | | West Branch French Creek near Lowville, Pa. (03021410) | | French Creek near Union City, Pa. (03021520) | | Raccoon Creek near West Springfield, Pa. (0421304[illegible]) | |
|---|---|---|---|---|---|---|---|---|
| | Annual base flow (inches) | Base flow as a percentage of streamflow | Annual base flow (inches) | Base flow as a percentage of streamflow | Annual base flow (inches) | Base flow as a percentage of streamflow | Annual base flow (inches) | Base flow as a percentage of streamflow |
| 1975 | 15.48 | 42.99 | 14.11 | 42.26 | 16.81 | 51.87 | 7.17 | 33.12 |
| 1976 | 15.97 | 44.46 | 17.15 | 50.67 | 21.02 | 64.22 | 7.78 | 48.28 |
| 1977 | 19.13 | 44.79 | 17.84 | 40.72 | 26.96 | 67.19 | 11.57 | 44.10 |
| 1978 | 12.12 | 50.89 | 13.04 | 42.14 | 14.51 | 58.45 | 4.82 | 43.90 |
| 1979 | 17.30 | 42.39 | 16.10 | 45.63 | 22.27 | 59.20 | 6.51 | 39.57 |
| 1980 | 13.78 | 44.90 | 11.85 | 42.43 | 17.77 | 56.23 | 5.16 | 42.21 |
| 1981 | 14.50 | 43.51 | 12.74 | 35.65 | 15.74 | 45.82 | 5.03 | 34.12 |
| 1982 | 15.47 | 41.80 | 15.44 | 38.98 | 17.55 | 56.89 | 8.67 | 50.36 |
| 1983 | 12.52 | 46.05 | 11.47 | 42.40 | 17.76 | 59.55 | 8.14 | 48.28 |
| 1984 | 16.11 | 43.65 | 14.76 | 44.54 | 18.56 | 52.70 | 10.99 | 53.76 |
| 1985 | 15.63 | 49.31 | 15.70 | 46.92 | 23.03 | 67.14 | 9.98 | 45.29 |
| 1986 | 13.40 | 33.36 | 13.04 | 29.92 | 17.96 | 45.30 | 6.00 | 30.69 |
| 1987 | 12.47 | 45.62 | 13.25 | 43.67 | 16.75 | 57.20 | 6.14 | 47.38 |
| 1988 | 12.87 | 45.53 | 14.38 | 42.99 | 16.83 | 58.72 | 5.77 | 55.12 |
| 1989 | 13.04 | 48.40 | 13.88 | 48.69 | 15.76 | 56.95 | 9.74 | 57.16 |
| 1990 | 16.55 | 41.05 | 16.34 | 37.61 | 26.90 | 65.33 | 12.01 | 40.21 |
| 1991 | 9.61 | 48.38 | 9.60 | 42.76 | -- | -- | 5.42 | 49.61 |
| 1992 | 16.20 | 47.24 | 15.26 | 38.92 | -- | -- | 7.99 | 57.86 |
| Median | 14.99 | 44.85 | 14.25 | 42.42 | 17.76 | 57.82 | 7.48 | 46.34 |

[1] Regulated by the Union City Reservoir. "Base" flows reflect temporary storage and release of surface water as well as ground-water discharge to the creek.

**Table 9.** Water budgets for principal drainage basins in Erie County, Pennsylvania, 1975–92

| Drainage basin | Precipitation (P) (inches) | | Base flow (BF) (inches) | | Overland runoff (OR) (inches) | | Evapotranspiration (ET) and underflow (U) (inches) |
|---|---|---|---|---|---|---|---|
| French Creek upstream from Wattsburg, Pa. | [1]47.0 | = | 15.0 | + | 18.4 | + | 13.6 |
| West Branch French Creek | [1]47.0 | = | 14.2 | + | 19.3 | + | 13.5 |
| French Creek upstream from Union City, Pa. | [1]47.0 | = | 17.8 | + | 13.0 | + | 16.2 |
| Raccoon Creek | [2]44.4 | = | 7.5 | + | 8.7 | + | 28.2 |

[1] Mean of National Oceanic and Atmospheric Administration rain gages at Corry and Union City Filtration Plant.

[2] National Oceanic and Atmospheric Administration rain gage at Erie.

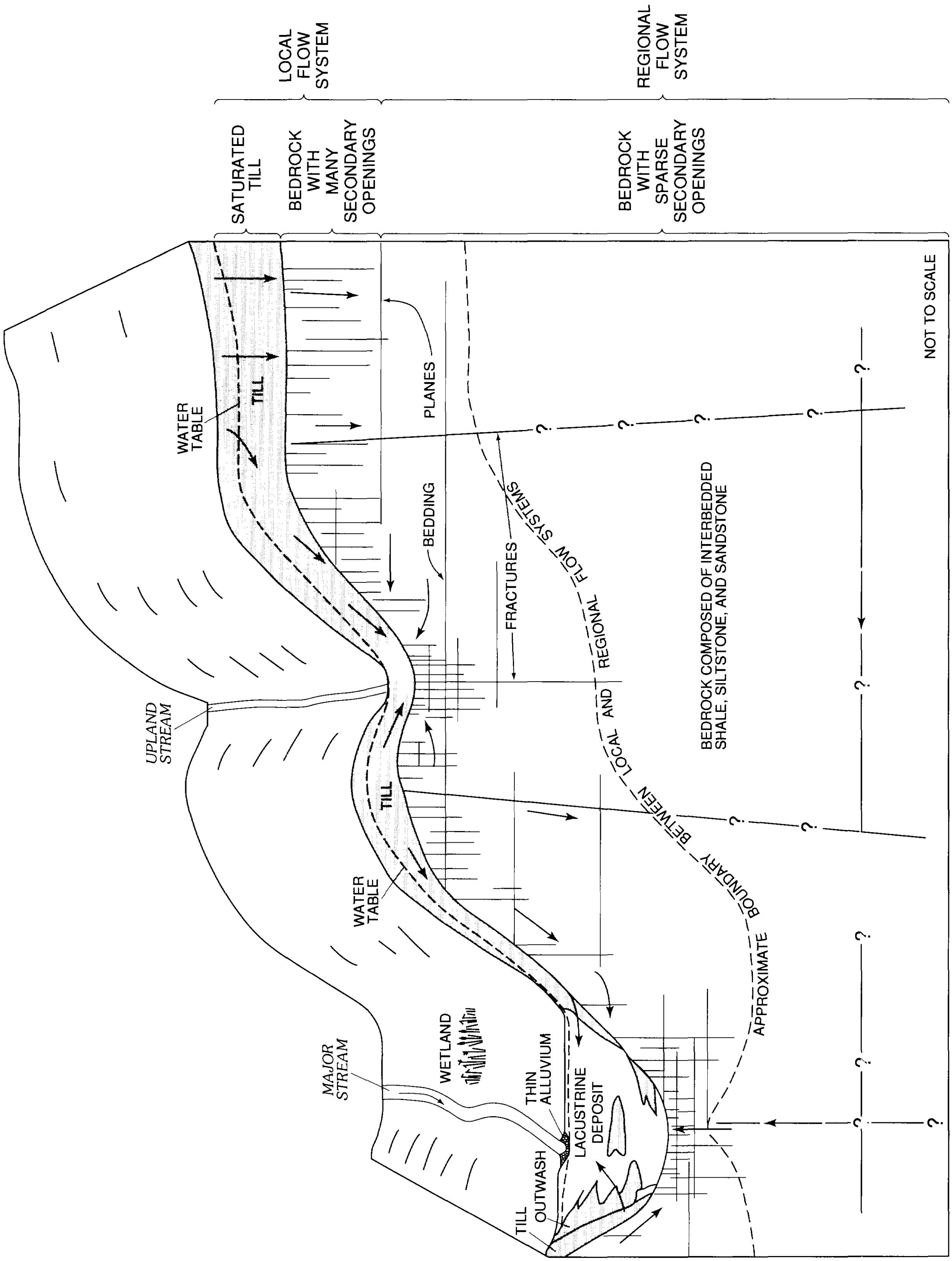


**Figure 8.** Schematic diagram of ground-water flow in Upland Plateau, Erie County, Pennsylvania.

local aquifer system (D.R. Williams, U.S. Geological Survey, written commun, 1995).

Permeability generally decreases with depth in the bedrock because the density of open fractures diminishes with depth. This is caused by the weight of the rocks, which increase overburden pressures. The depth of the active local flow system is variable, and the transition to the regional flow system is difficult to delineate. Data that would accurately define the transition are generally lacking below about 200 ft. The variable thickness of saturated unconsolidated deposits overlying bedrock also precludes any concise statements about the exact depth of the saturated portion of the local flow system. However, in most places, the bottom of the local flow system would roughly parallel the bedrock surface and would be expected to be about 150 to 175 ft beneath the bedrock surface.

The base of the regional aquifer system is generally unknown. Few water wells penetrate the deeper parts of the regional system because of drilling costs, the high probability of finding mineralized water unfit for human consumption, and the lack of success of previous deep test wells.

### Recent Alluvium

Alluvium is deposited by flowing water in stream channels and on adjacent flood plains and is composed of well to poorly defined layers of clay, silt, sand, gravel, and some boulders. Individual layers generally are not continuous for more than a few feet. Sorting is variable and grain shapes are subangular to well rounded. Distribution of recent stream alluvium is shown on figure 9 for that part of Erie County that drains to Lake Erie. In the part of the county that drains to French Creek, recent alluvium is a small percentage of the total area mapped and is not differentiated from other unconsolidated deposits. Surficial mapping by Shepps and others (1959) at the scale of 1:125,000 shows many small deposits of alluvium in valleys of the French Creek watershed.

### Pleistocene Deposits

In this report, the Pleistocene deposits of Erie County are classified into three major groups: (1) unsorted, unstratified deposits (till), (2) sorted, stratified deposits (mostly outwash), and (3) beach deposits (generally, sorted sand and gravel). Figure 9 shows the areal extent of till and beach or outwash deposits, undifferentiated.

#### Till

Thomas and others (1987, p. 8) speculate ice advanced up to eight times into northwestern Pennsylvania during the Pleistocene Epoch. During each advance, rock and sediments were picked up locally in northwestern Pennsylvania and from places to the northeast. Rock debris and sediment were deposited after being carried along by the ice for varying distances. Till is rock debris and sediment that was deposited by glacial ice without being sorted by water. The pile or ridge of material that was built up around the edge of a glacier is called the end moraine. Ground moraine is a blanket of till left stranded over the landscape with the final melting of a glacier.

Till in Erie County consists of unconsolidated, nonsorted or poorly sorted, nonlayered or vaguely layered deposits of clay, silt, sand, gravel, and boulders. Till deposits are common throughout most of the county and have been mapped and described lithologically by Shepps and others (1959) and White and others (1969). Tills in Erie County have recently been classified (Sevon, 1989) as either silty glacial diamict or sandy glacial diamict. Thin soils generally develop on these diamicts (Sevon, 1989) or tills.

In some areas, till may be composed of an upper layer of deposits from the most recent glacial-ice advance and a lower layer of deposits from an earlier advance. Till in upland areas almost always overlies bedrock and commonly is less than 50-ft thick. Till in valley settings can be interbedded with outwash.

#### Outwash

Deposits of clay, silt, sand, gravel, and boulders that were sorted by standing or running water from a melting glacier are termed outwash. These materials were removed or washed out from a glacier by meltwater streams and deposited in front of or beyond the end moraines. The coarser material was generally deposited nearer to the ice.

As the ice advanced southward in Erie County, uplands were eroded and valleys scoured out. When the ice sheets melted, torrential streams formed, eroding land forms and redepositing sediments downstream. Streams coursed through drainageways and even formed new drainageways when blocked by ice dams. Large lakes were formed in some valleys behind ice dams. Some ice dams were topped or broken, and torrents from many of those lakes cut channels across upland drainage divides.

Outwash deposits ranged from fine-grained lake sediments called lacustrine deposits to coarse-grained sands and gravels called kames, kame terraces, kame

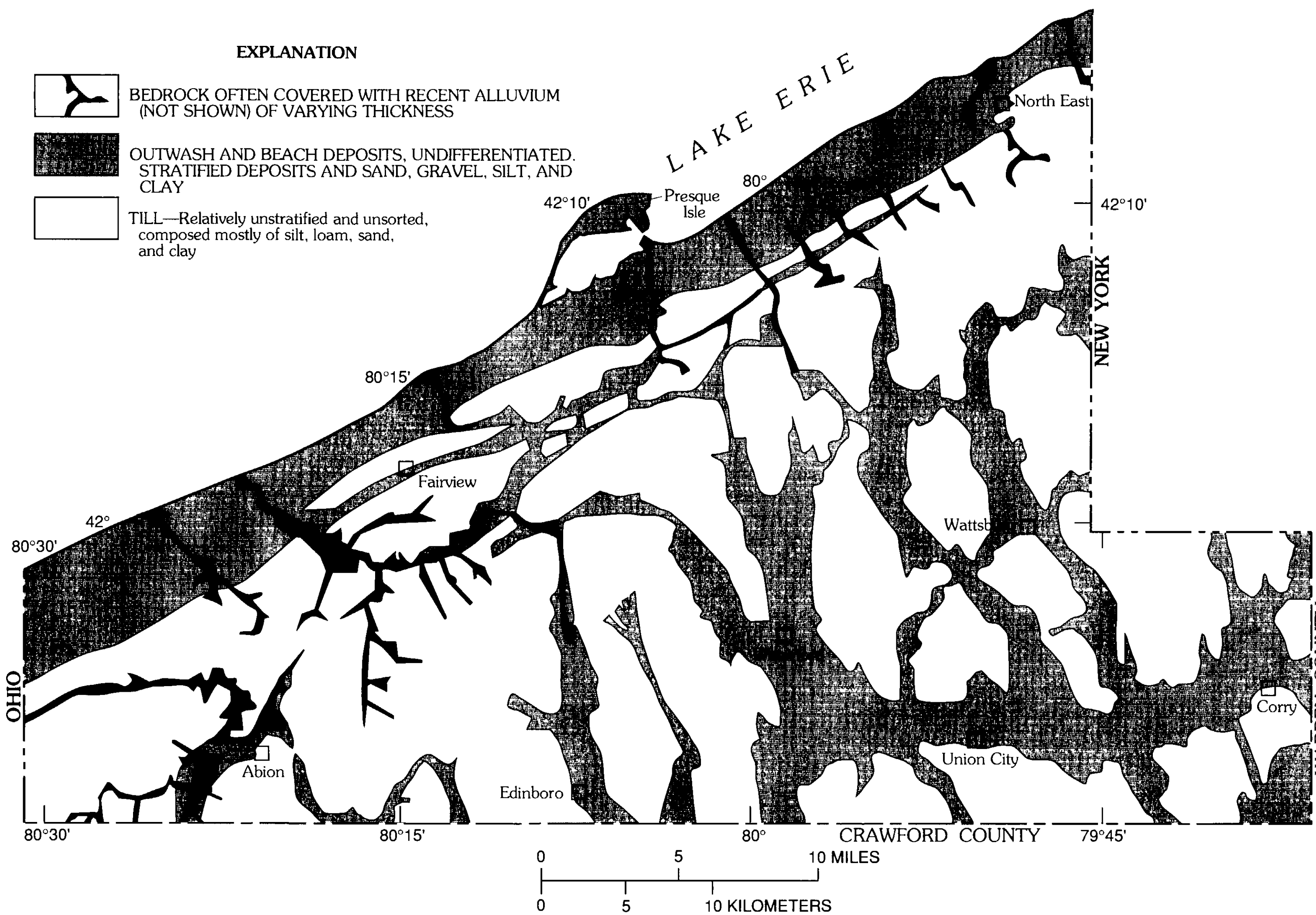


**Figure 9.** Unconsolidated deposits of Erie County, Pennsylvania. [Geology modified from Richards and others (1987, fig. 11) and Shepps and others (1959, pl. 1)].

moraines, and valley trains. Schiner and Gallaher (1979, p. 6–7) note that in western Crawford County, Pa., valley outwash consists mostly of great thicknesses of lake deposits—mostly clay, silt, and fine sand with a small percentage of coarse sand and gravel. In the buried valleys of the plateau province of Erie County, lake deposits are common but have not been mapped as separate entities.

Detailed mapping of the many types of glacial deposits as a function of depth in the buried valleys of the plateau in Erie County has not been done to date and is hampered mostly by a lack of descriptive data. Sand and gravel outwash in some buried valleys could provide high sustained well yields.

#### Beach Deposits

Beach ridges are low, generally continuous mounds of sand, gravel, and shingle that were heaped up by wave and current action on a shoreline. Remnants of ancient beach ridges from four major proglacial lakes have been mapped on the lake plain of Erie County (Schooler, 1974). These beach ridges roughly parallel the present shoreline of Lake Erie and generally vary in composition vertically and laterally. Beach deposits have been quarried extensively for sand and gravel in Erie County. On the flat lake plain between the beach ridges and Lake Erie, lacustrine sediments, predominantly silt and sand, were deposited.

### Fractured Bedrock

Data generally are lacking concerning the existence of vertical or near vertical fractures in Erie County. Such fractures could extend below the bottom of the shallow ground-water flow system and could convey ground water deeper in the system. Deep vertical fractures are queried in figure 8 because of this uncertainty. When zones of vertical fractures are interconnected with horizontal fractures, yields of ground water to wells can be substantial. Not all fractures, however, convey water and fractures that do not yield water are commonly penetrated when drilling wells. High yields have been documented in many areas outside of Erie County, particularly in carbonate rocks (Siddiqui and Parizek, 1971). In Erie County, however, vertical-fracture zones are generally difficult to locate because of thick glacial and lake deposits. Also, fractures in shales tend to close with depth because of the plasticity of the shale (O'Neil and Anderson, 1984).

Many processes affect the degree of fracturing in shallow bedrock including stress-relief fracturing, paleoweathering, and erosion. Stress relief, the removal of compressional stress on underlying rocks by erosion of overlying rocks, results in predictable fracture patterns of bedrock in valleys in the Appalachian Plateaus Physiographic Province (Wyrick and Borchers, 1981). The bedrock fractures are generally horizontal under valley floors and are generally vertical along valley walls. Stress-relief fracturing of bedrock occurs in Erie County, but data are generally lacking concerning the depth, frequency, and degree of interconnection of fractures in valleys and valley walls. Some documentation of the extent of stress-relief fracturing is reported by Ferguson (1974) at Union City Reservoir (fig. 6).

Rocks weathered prior to or during the Wisconsin glacial stage are said to be paleoweathered; this bedrock may be fractured at shallow depths. Bedrock erosion by glacial ice and meltwater may have partially or completely removed preglacial weathered bedrock. Glacial material deposited on the bedrock after removal of the weathered rock zone generally restricts bedrock weathering because the glacial material acts as a protective covering (Kirkaldie, 1991, p. 208). In figure 8, the depth of fractures in the top of the bedrock is shown as nonexistent to very shallow in some areas and deeper in others to reflect the variable nature of paleoweathering and bedrock erosion by meltwater and ice. The thickness of the different bedrock units removed by glaciation is not known.

Taylor (1988) discusses probable modifications to the hydrogeologic system by glaciation in the Chemung River Basin in northcentral Pennsylvania and southcentral New York. Similar modifications probably took place in Erie County. In the Chemung River Basin, as much as 50 to more than 100 ft of rock may have been removed from valleys by glaciation with considerably less material removed from valley walls and hilltops. Taylor (1988) concludes that low-permeability bedrock aquifers in some valleys are partially the result of the scouring and removal of fractured and weathered intervals. These processes discussed by Taylor (1988) also are mentioned by Williams (1991) in a ground-water study of the Marsh Creek Valley in Tioga County in northcentral Pennsylvania. Williams (1991, p. 5) states that the bedrock was deeply eroded by glacial ice, and the more fractured rock was removed; consequently, the bedrock underlying the stratified drift is relatively impermeable.

Weathered bedrock that does remain after glaciation is fractured, and the interconnected fractures can contribute significantly to secondary permeability of the shallow bedrock. Kirkaldie (1991, p. 203–204) defined three weathering zones of bedrock in his study of the depth of bedrock fracturing beneath glacial materials. In the upper zone, the bedrock is highly weathered, highly fractured, and well oxidized; rock core is generally in gravel-sized pieces (0.25 to 3 in.). In the next lower zone, the bedrock is moderately weathered, moderately fractured, and partially oxidized. In the deepest zone, bedrock is slightly weathered or unweathered with little or no observable oxidation. Examination of a series of adjacent bedrock core borings is one method to identify the depth of highly weathered (highly fractured) bedrock. Highly-weathered fractures and fractured rocks can, however, also be filled with or embedded in clay or other fine-grained sediments and thus be closed—not permeable in some places. Description of core in the geologic literature is not common for Erie County. However, in adjacent Crawford County where core from 17 holes were studied, the depth of highly weathered rock ranged from 0 to at least 31.5 ft; the average depth was 14 ft (Kirkaldie, 1991, p. 207).

## Water-Level Fluctuations

Water levels were continuously recorded at selected wells to observe aquifer response to recharge and discharge. Water levels in wells may be evaluated with respect to short-term (daily) fluctuations or long-term (monthly, seasonal, yearly) trends.

Seasonal cycles are evident in many well hydrographs. Water levels generally start to decline in March or April and continue to decline until late fall. Even though precipitation is greater during the summer than during the winter, less precipitation reaches the water table during the summer and fall because large amounts of water are evaporated from the soil and transpired by vegetation. Rain and snow melt recharge the aquifers during the winter and early spring, and water levels generally rise during this period. Water levels in the winter are dependent to some degree on not only precipitation but on whether or not soils are frozen. Frozen soils have a tendency to reduce ground-water infiltration and increase runoff. Ground-water levels may be above normal during mild winters when infiltration is not reduced by frozen soils.

Shallow water-table wells commonly respond quickly to precipitation. Water levels of semiconfined or confined aquifers generally respond to precipitation slowly, and water-level changes in response to wet seasons or drought may be delayed. At selected wells in confined, unconsolidated aquifers, water-level fluctuations were closely correlated to barometric-pressure changes. An increase in barometric pressure causes a decline in water levels. The barometric efficiency of an aquifer is defined as the ratio of incremental water-level changes to incremental barometric-pressure changes.

Two water-level hydrographs are shown in figure 10. Well Er-82 has an estimated yield of less than 1.0 gal/min; the well is completed in fractured shale that underlies about 55 ft of relatively impermeable till. Occasionally, such as periods in April and May 1989, the water level responded to precipitation faster than compared to most other months. Seasonal trends, described previously, are apparent. Well Er-3021 taps sand and gravel at a depth of about 41 ft and yields an estimated 6 gal/min. The aquifer is probably semiconfined. The seasonal fluctuations in well Er-3021 are similar but more subdued than those in the bedrock well Er-82. Several test wells were drilled at Presque Isle State Park to investigate ground-water quality and examine water-level fluctuations. In addition, data were compiled from a Lake Erie stage recorder operated by the U.S. Department of Commerce near the wells. Figure 11 shows the ground-water level (well Er-7506), precipitation, and lake stage for August 20 to September 20, 1989. Well Er-7506 is completed in a shallow water-table aquifer, which is composed mostly of silt and fine- to medium-grained sand. The distance from well Er-7506 to the water on the shoreline of Lake Erie varies as a function of lake stage but is about 150 ft. The rapid response of the water-table aquifer to precipitation is evident.

The water level in well Er-7506 also appears at times to respond to changing lake stage. The lake stage fluctuates because of a combination of many factors including wind, seiches, precipitation, tides, evaporation, and rates of inflow and outflow. The lake-stage recorder is in the narrow shipping channel connecting Presque Isle Bay to Lake Erie. The channel stage may not accurately reflect the exact lake stage at the shoreline. Differences of at least several tenths of a foot are suspected at times between the channel lake stage and the shoreline.

## Ground-Water Availability

The availability of ground-water resources may be estimated by a variety of methods including aquifer tests, ground-water models, geophysical surveys, and statistical analyses of data from water wells, test wells, and some oil and gas well records. Sufficient ground water for domestic use generally is available from properly constructed water wells throughout most of Erie County. However, some wells may yield inadequate supplies during drought periods. Reported well yields and specific capacities are commonly used to estimate ground-water availability because other more reliable information from aquifer tests are unavailable.

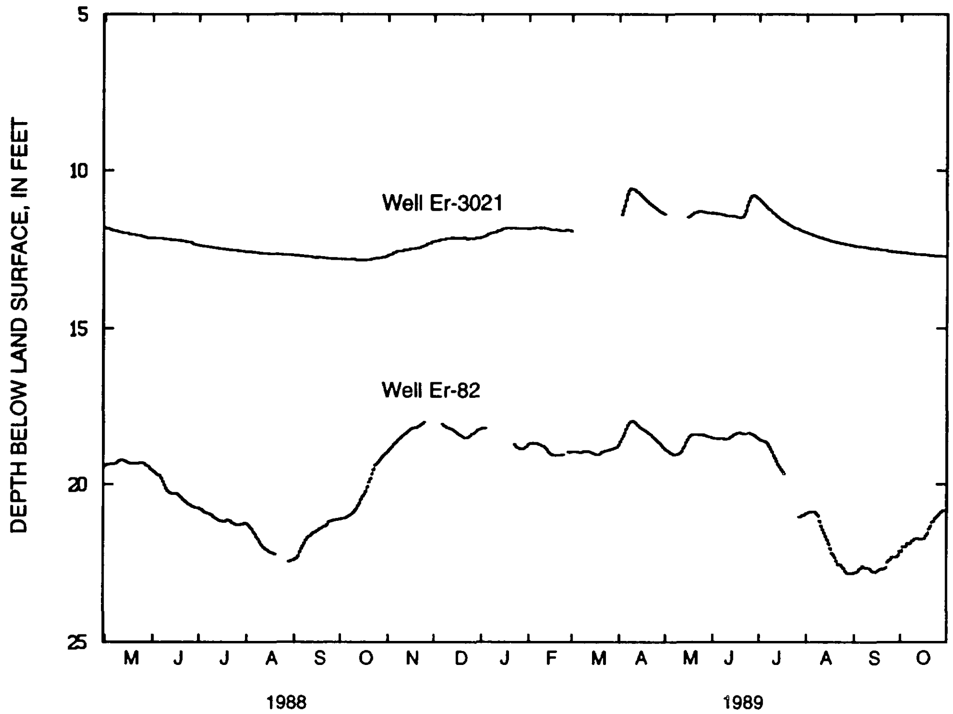


**Figure 10.** Maximum daily depth to water in two wells in Erie County, Pennsylvania.

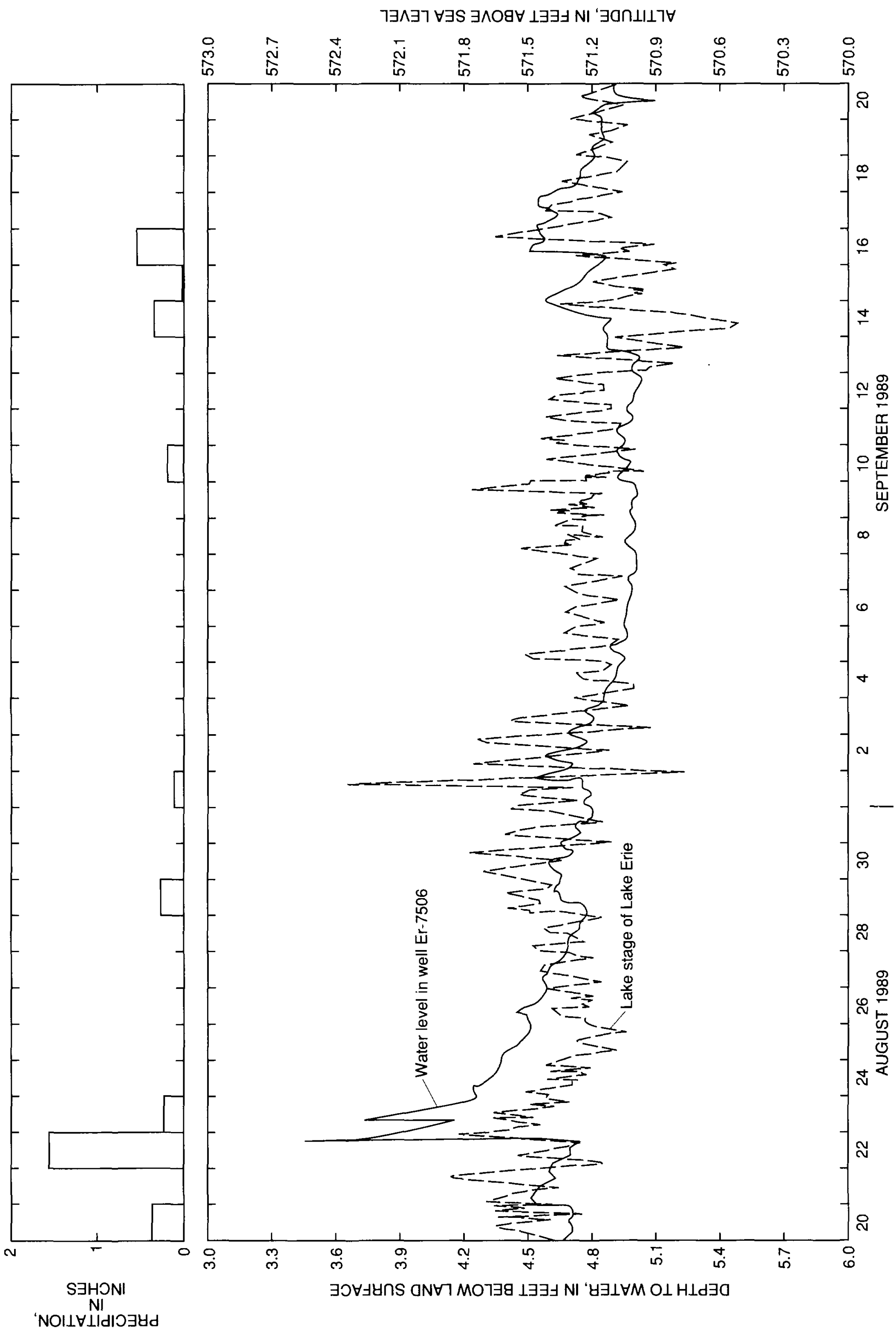


**Figure 11.** Comparison of lake stage of Lake Erie, water level in well Er-7506, and precipitation, Erie County, Pennsylvania.

Specific capacity is the well yield divided by the drawdown (pumping water level minus static water level) necessary to produce this yield. Specific capacity is usually expressed in gallons per minute per foot.

A summary of reported well yields and specific capacities are provided in table 10 for the unconsolidated deposits of Erie County. Well locations and other data such as well depths, casing data, and depths-to-water-bearing zones are provided in Richards and others (1987, p. 55–101). Information was compiled for about 1,700 water wells in Erie County in that report. Appendix 2 of this report provides water-well data for about 120 additional wells.

Most of the reported well yields and specific capacities in table 10 were derived from water-well completion reports from well drillers. Most well yield and specific capacity estimates for domestic wells were based on data for short time periods (minutes) at the conclusion of drilling. Long-term well yields or specific capacities are generally not available and generally would be less than short-term estimates. Drillers completion tests may not be long enough to distinguish between well-bore storage and well yield, especially in deep wells with low yield. Pumping rates affect specific capacity estimates. For aquifer tests of equal length, specific capacity generally decreases with increasing pumping rate because of increases in well losses (for example, frictional losses because of turbulence) and, in some cases, the decline of the pumping water level below water-bearing zones.

As evident from table 10, nondomestic wells, which include municipal, industrial, and commercial wells, generally have greater reported yields than domestic wells. Large nondomestic well yields are prevalent because (1) municipalities, businesses, and corporations in need of large well yields have more capital to invest in test well drilling and ground-water exploration; (2) low yield wells are not used; (3) average diameters of nondomestic wells are greater than domestic wells; (4) sand and gravel domestic wells are completed with open end casing whereas, in nondomestic wells screens are in common use; (5) ground-water consultants, skilled in ground-water exploration techniques, commonly supervise the siting, drilling, construction, and pumpage of nondomestic wells; and (6) many of the larger domestic well yields are underestimated because drillers commonly do not have the equipment or take the time to determine exact discharges exceeding those considered adequate for household use.

The range in well yield or specific capacity is great for the unconsolidated deposits. Some beach deposits can yield significant quantities of water to wells, but many are relatively small in areal extent. Lacustrine sediments dominated by silt and sand were deposited on the flat lake plain between the beach ridge and Lake Erie; they commonly have poor ground-water yields. Till generally is a low-yield aquifer tapped mostly by domestic wells. Recent alluvium also has minor significance in terms of ground-water availability. Bedrock aquifers have well yields commonly sufficient for domestic use but not for high-yield nondomestic supplies. Well yields in excess of 50 gal/min are rare in bedrock aquifers.

**Table 10.** Summary of yields and specific-capacity data for domestic and nondomestic wells in Erie County, Pennsylvania

[Modified from Richards and others, 1987, p. 8]

| Hydrogeologic unit | Reported yield (gallons per minute) | | | Specific capacity (gallons per minute per foot) | | |
|---|---|---|---|---|---|---|
| | Number of wells | Median | Range | Number of wells | Median | Range |
| | | | Domestic wells | | | |
| Beach deposits | 59 | 7 | 0.1–30 | 24 | 0.80 | 0.05–10 |
| Outwash | 395 | 15 | .1–360 | 170 | 1.2 | .04–30 |
| Till | 252 | 5 | .1–50 | 125 | .26 | .009–30 |
| | | | Nondomestic wells | | | |
| Beach | 47 | 75 | 1–850 | 20 | 17 | .03–270 |
| Outwash | 39 | 60 | 1–1,000 | 20 | 9 | .1–140 |
| Till | 8 | 11.5 | .1–50 | 3 | 1.5 | .47–3.3 |

Outwash and beach deposits generally provide the largest ground-water supplies on the basis of median well yield and median specific-capacity statistics. However, these deposits pose special problems in mapping and development for water supply. Some outwash deposits are composed of well-sorted sand and gravel producing large well yields. These deposits are in many cases the result of deposition by meltwater streams. Subsequent erosion of layers or complete segments of these outwash deposits followed by deposition of less permeable sediments, such as till, have resulted in discontinuous sand and gravel deposits with widely varying hydraulic characteristics, thickness, and extent. Thus, estimation of the aquifer geometry and of the ground-water recharge rates to outwash aquifers is difficult. In the analysis of the ground-water resources of western Crawford County, Schiner and Gallaher (1979, p. 11) state that large-yield glacial outwash deposits are not easy to find. Additionally, test drilling and aquifer tests are necessary to locate production wells that have large yields. For example, in a buried valley in western Crawford County, at least 153 test holes were drilled to find sites for 7 production wells (yields of 650 to 1,340 gal/min) for the Keystone Ordinance Works during World War II.

Estimation of ground-water availability in areas of Erie County with scanty data generally requires some ground-water exploration. Extensive scientific literature is available describing the many scientific methods applicable to ground-water exploration for large-yield aquifers. Parizek (1990, p. 96–112) has provided a summary of methods applicable to Pennsylvania and discusses outwash deposits in the Edinboro area of Erie County. Additional techniques for ground-water exploration that are applicable for glacial deposits of Erie County are discussed by Driscoll (1986, p. 150–204).

The largest production wells from outwash or beach deposits in Erie County are plotted on figure 12. All of the beach wells with yields of 100 gal/min or greater are southwest of Presque Isle. The well number, latitude, longitude, yield, and depth of wells with yields greater than 100 gal/min are listed in table 11. Specific information concerning the construction of these wells are in table 12 of Richards and others (1987, p. 55–101) or in Appendix 2 of this report.

Additional production from the deposits that yield water to wells shown in figure 12 may be possible without decreasing the yields of existing wells. If substantial additional withdrawals from these aquifers are possible, test drilling, installation of new production wells, aquifer testing, and development of ground-water flow models may be necessary. Complex operating schedules of production wells in a well field may be required to maximize production, especially if annual recharge varies considerably because of drought or other influences. An observation well network may be necessary to successfully monitor water-level fluctuation in a large well field. Further aquifer development and the exploration for undeveloped aquifers may, in either case, be costly with no guarantees of success if large water supplies are required.

Some high-yield municipal wells in Erie County were removed from service because of excessive concentrations of iron and manganese in the water. With modern cost-effective water-treatment technology, some of these wells could be put back into production.

Ground water could be developed from beach deposits at Presque Isle State Park. Additional exploration and aquifer tests would be necessary to determine availability of such a water supply. A series of production wells screened in beach deposits could be sited parallel to the Lake Erie shoreline. Most production probably would come from induced infiltration of lake water through the beach deposits to the wells. The beach deposits potentially would act as a large filter; the well discharge would be free of zebra mussel infestations presently posing a costly and difficult problem to surface-water intakes and water treatment plants utilizing Lake Erie for a water supply. In a following section of this report, entitled "Presque Isle (Site 3)" a short aquifer test is described with a yield of 26 gal/min produced from a small diameter production well screened in beach deposits at Presque Isle State Park. In order to fully evaluate the ground-water availability of selected beach-deposit aquifers of Presque Isle State Park, it would be necessary to do multi-well aquifer tests with higher discharge rates. Pumped wells could be large diameter screened wells, well point systems, or infiltration galleries (Driscoll, 1986, p. 734–769).

## Hydraulic Properties of Pleistocene Deposits

Transmissivity, storage coefficient, and horizontal hydraulic conductivity of pleistocene deposits at four sites—McKean Township, Millcreek Township, Presque Isle, and North East Township—were estimated by means of five constant discharge rate drawdown and recovery aquifer tests.

A constant discharge rate drawdown test consists of pumping a production well at a constant discharge and recording the resulting water-level fluctuations in the production well and nearby observation wells. A recovery test consists of measuring water levels in the production and observation wells after pumping ceases. Measurements are continued until the water levels return to near prepumping conditions.

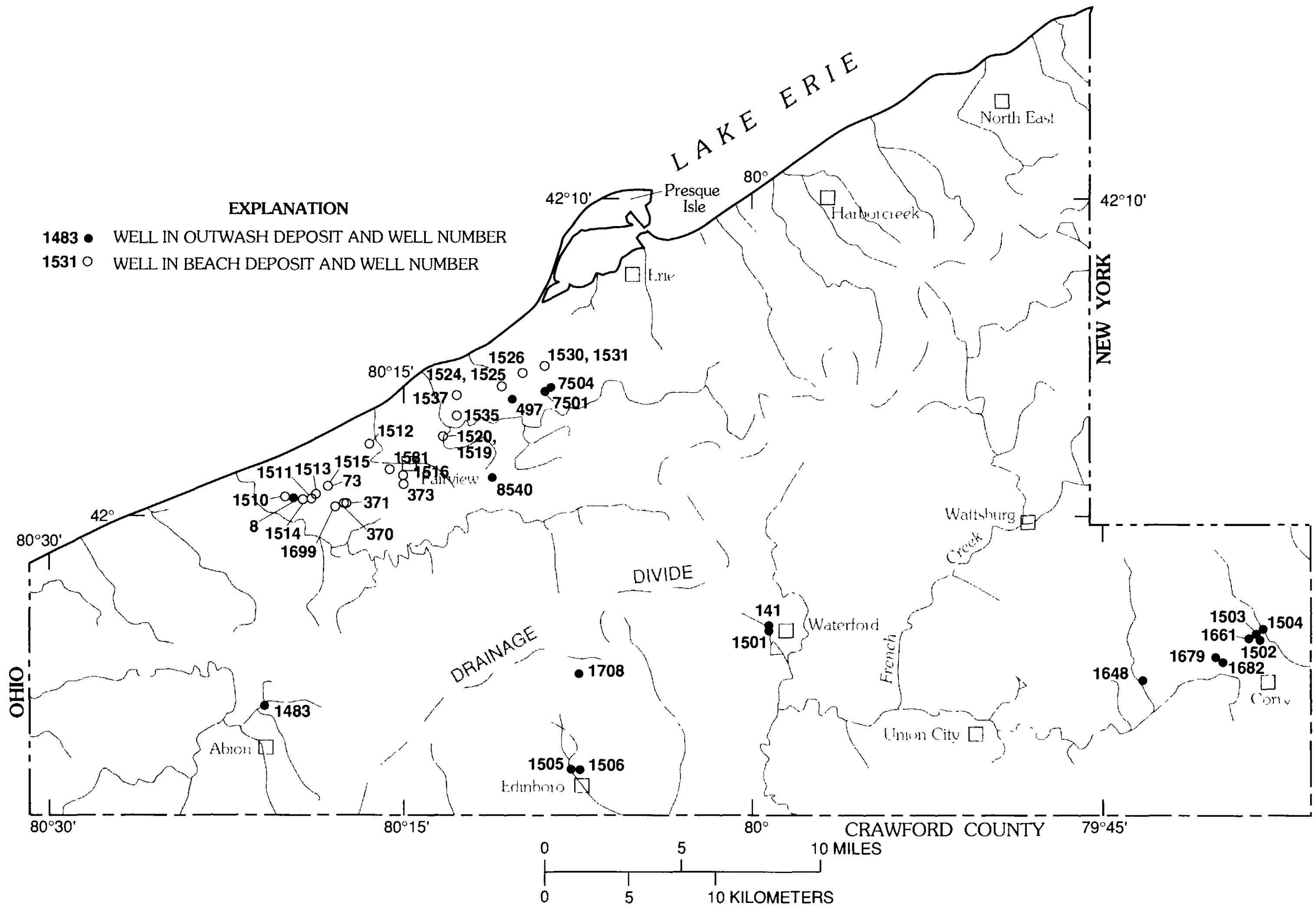


**Figure 12.** Wells with yields of 100 gallons per minute or greater in outwash or beach deposits in Erie County, Pennsylvania.

**Table 11.** Wells in outwash or beach deposits with yields of 100 gallons per minute or greater in Erie County, Pennsylvania

[Locations of wells shown in figure 12; °, degree; ', minute; ", second]

| Well number | Location: Latitude | Location: Longitude | Borough or township | Yield (gallons per minute) | Depth of well (feet) |
|---|---|---|---|---|---|
| | | | **Outwash deposits** | | |
| Er-8 | 42°00'45" | 80°20'10" | Lake City Borough | 110 | 36 |
| 141 | 41°56'18" | 79°59'30" | Waterford Borough | 360 | 96 |
| 497 | 42°03'57" | 80°10'36" | Millcreek Township | 180 | 44 |
| 1483 | 41°54'16" | 80°21'28" | Conneaut Township | 235 | 70 |
| 1501 | 41°56'16" | 79°59'30" | Waterford Borough | 1,000 | 100 |
| 1502 | 41°56'28" | 79°38'36" | Wayne Township | 250 | 32 |
| 1503 | 41°56'36" | 79°38'37" | Wayne Township | 500 | 65 |
| 1504 | 41°56'37" | 79°38'36" | Wayne Township | 400 | 65 |
| 1505 | 41°52'22" | 80°07'59" | Edinboro Borough | 350 | 20 |
| 1506 | 41°52'23" | 80°07'57" | Edinboro Borough | 500 | 38 |
| 1648 | 41°55'04" | 79°43'29" | Concord Township | 360 | 138 |
| 1661 | 41°56'32" | 79°38'39" | Wayne Township | 400 | 71 |
| 1679 | 41°55'48" | 79°40'19" | Wayne Township | 100 | 82 |
| 1682 | 41°55'48" | 79°40'18" | Wayne Township | 290 | 140 |
| 1708 | 41°55'14" | 80°07'44" | Washington Township | 155 | 30 |
| 7501 | 42°04'17" | 80°09'02" | Millcreek Township | 100 | 63 |
| 7504 | 42°04'24" | 80°08'43" | Millcreek Township | 170 | 68 |
| 8540 | 42°01'26" | 80°11'28" | McKean Township | 150 | 72 |
| | | | **Beach deposits** | | |
| Er-73 | 42°01'10" | 80°18'30" | Girard Borough | 183 | 12 |
| 370 | 42°00'37" | 80°17'51" | Girard Township | 600 | 61 |
| 371 | 42°00'33" | 80°17'43" | Girard Township | 490 | 51 |
| 373 | 42°01'25" | 80°15'24" | Fairview Borough | 100 | 40 |
| 1510 | 42°00'45" | 80°20'27" | Lake City Borough | 250 | 16 |
| 1511 | 42°00'55" | 80°19'10" | Girard Township | 600 | 44 |
| 1512 | 42°02'35" | 80°16'49" | Fairview Township | 100 | 17 |
| 1513 | 42°00'51" | 80°19'14" | Girard Township | 850 | 30 |
| 1514 | 42°00'44" | 80°19'37" | Girard Township | 300 | 17 |
| 1515 | 42°01'07" | 80°18'30" | Girard Borough | 200 | 12 |
| 1516 | 42°01'17" | 80°15'23" | Fairview Borough | 120 | 43 |
| 1519 | 42°02'47" | 80°13'34" | Fairview Township | 200 | 46 |
| 1520 | 42°02'47" | 80°13'36" | Fairview Township | 100 | 65 |
| 1524 | 42°04'22" | 80°10'58" | Millcreek Township | 200 | 32 |
| 1525 | 42°04'22" | 80°10'58" | Millcreek Township | 150 | 30 |
| 1526 | 42°04'46" | 80°10'02" | Millcreek Township | 100 | 29 |
| 1530 | 42°05'02" | 80°09'08" | Millcreek Township | 200 | 25 |
| 1531 | 42°05'02" | 80°09'08" | Millcreek Township | 100 | 24 |
| 1535 | 42°03'27" | 80°12'57" | Fairview Township | 160 | 20 |
| 1537 | 42°04'01" | 80°13'00" | Fairview Township | 100 | 17 |
| 1581 | 42°01'41" | 80°15'54" | Fairview Township | 300 | 49 |
| 1699 | 42°00'30" | 80°18'14" | Fairview Township | 490 | 51 |

**Table 12.** Summary of aquifer tests in outwash and beach deposits in Erie County, Pennsylvania

[$ft^2/d$, square foot per day; ft/d, foot per day; --, no data; sites are shown in figure 13]

| Site number | Well number | Aquifer | Well depth (feet) | Aquifer thickness (b) (feet) | Transmissivity (T) ($ft^2/d$) | | Storage coefficient | Horizontal hydraulic conductivity (T/b) (ft/d) |
|---|---|---|---|---|---|---|---|---|
| | | | | | Drawdown | Recovery | | |
| 1 | [1]Er-8540 | Outwash | 72 | 15 | [2]15,200 | -- | 0.006 | 1,010 |
| | Er-8541 | Outwash | 69 | 15 | [3]18,900 | -- | [3].01 | 1,260 |
| | Er-8542 | Outwash | 70 | 12 | [4]20,900 | -- | [4].05 | 1,740 |
| | | | | | [3]19,600 | -- | [3].05 | 1,635 |
| | Er-8543 | Outwash | 84 | 12 | [4]19,150 | -- | [4].04 | 1,595 |
| | | | | | [3]19,600 | -- | [3].04 | 1,635 |
| | Er-8544 | Outwash | 85 | 11 | [4]22,300 | -- | [4].03 | 2,030 |
| 2 | Er-7502 | Outwash | 62 | 8 | [3]860 | -- | [3].02 | 110 |
| | | | | | -- | [5]870 | -- | 110 |
| | Er-7503 | Outwash | 60 | -- | [3]925 | -- | [3].00009 | -- |
| | | | | | -- | [5]850 | -- | -- |
| | [1]Er-7504 | Outwash | 68 | 18 | -- | [5]3,870 | -- | 215 |
| | Er-7505 | Outwash | 55 | -- | [4]4,340 | -- | [4].00003 | -- |
| | | | | | [3]4,475 | -- | [3].00002 | -- |
| 3 | Er-7506 | Beach | 14 | 19 | [3]4,080 | -- | [3].03 | 215 |
| | | | | | [4]2,300 | -- | [2].50 | 120 |
| | Er-7507 | Beach | 19 | 19 | [3]3,820 | -- | [3].01 | 200 |
| 4 | Er-3023 | Beach | 115 | -- | [3]262 | -- | -- | -- |
| | [1]Er-3022 | Beach | 40 | -- | -- | [4]235 | -- | -- |

[1]Pumping well.
[2]Cooper-Jacob distance-drawdown analysis (at minute 8,000).
[3]Cooper-Jacob time-drawdown analysis.
[4]Theis-type-curve match.
[5]Theis recovery method.

Various analytical methods are available to interpret aquifer tests and aquifer systems. Method selection depends on the type of test, aquifer conditions, and acceptable assumptions. The methods used in this study were Theis-type-curve matching (Theis, 1935), Cooper-Jacob straight-line (Cooper and Jacob, 1946), and Theis recovery (Theis, 1935). The assumptions that apply to these methods are documented in the literature (Driscoll, 1986, p. 218).

The Theis-type-curve matching method was developed for nonsteady state or nonequilibrium aquifer systems. For the nonequilibrium solutions, the water levels within the cone of depression need not have stabilized or reached equilibrium.

## Methods

### Theis-Type-Curve Method

Transmissivity (T) and storage coefficient (S) values are calculated by the following Theis curve match equations (Heath, 1983, p. 37):

$$T = \frac{15.3QW(u)}{s}, \qquad (5)$$

where

- $T$ is transmissivity, in feet squared per day;
- $Q$ is pumping rate, in gallons per minute;
- $W(u)$ is Theis well function of variable u, dimensionless;
- $s$ is drawdown, in feet;

$$u = \frac{r^2 S}{4Tt}, \qquad (6)$$

where

- $S$ is storage coefficient, dimensionless;
- $r$ is distance from pumped well to observation well, in feet;
- $t$ is time since pumping began, in minutes.

and

$$S = \frac{Ttu}{360r^2}. \qquad (7)$$

### Cooper-Jacob Straight-Line Method

Time-drawdown analysis can be applied to aquifer tests with a pumping well and an observation well. The equations for calculating the transmissivity (T) and storage coefficient (S) are (Heath, 1983, p. 39)

$$T = \frac{35Q}{\Delta s}, \qquad (8)$$

and

$$S = \frac{Tt_0}{640r^2}, \qquad (9)$$

where

- $T$ is transmissivity, in feet squared per day;
- $Q$ is pumping rate, in gallons per minute;
- $\Delta s$ is drawdown difference over one log cycle (t), in feet;
- $t_0$ is intercept of straight line at zero drawdown;
- $s$ is 0, in minutes; and
- $r$ is distance from pumped well to observation well, in feet.

Although this method was developed for confined aquifer conditions, the following Jacob correction factor for unconfined aquifers can be used if the drawdowns are small in relation to the saturated thickness (Todd, 1980; Driscoll, 1986):

$$st = s_0 - \left(\frac{s_0^2}{2b}\right), \qquad (10)$$

where

- $st$ is drawdown adjusted to its theoretical value, in feet;
- $s_0$ is measured drawdown, in feet; and
- $b$ is aquifer saturated thickness, in feet.

Distance-drawdown analysis can be applied to aquifer tests with at least three observation wells located at different distances from the pumping well. The transmissivity and storage coefficient are calculated by use of the following equations (Heath, 1983, p. 40):

$$T = \frac{70Q}{\Delta s}, \text{ and} \qquad (11)$$

$$S = \frac{Tt}{640r_0^2}, \qquad (12)$$

where

$T$ is transmissivity, in feet squared per day;

$S$ is storage coefficient, dimensionless;

$Q$ is pumping rate, in gallons per minute;

$\Delta s$ is drawdown across one log cycle, in feet;

$t$ is time at which drawdowns were measured, in minutes; and

$r_0$ is the distance from the pumping well to the point where the straight line intersects the zero drawdown line, s = 0, in feet.

According to Lohman (1972, p. 19), the time-drawdown and distance-drawdown equations can be applied to those aquifer sections achieving steady-state conditions when variable u, defined by equation 2, is equal to or less than about 0.01.

### Theis Recovery Method

The Theis recovery method is based on the same assumptions as the Cooper-Jacob straight-line analyses; therefore, variable u must be less than or equal to 0.01. The transmissivity is calculated by use of the following equation:

$$T = \frac{35Q}{s'}, \tag{13}$$

where

$T$ is transmissivity, feet squared per day;

$Q$ is pumping rate, gallons per day;

$s'$ is residual drawdown difference over one log cycle t/t', in feet;

$t$ is time since pumping started, in minutes; and

$t'$ is time since pumping stopped, in minutes.

Residual drawdown data, s′, are the differences between the depth to water at a given instant during the recovery period and the nonpumping water level extrapolated from the observed trend prior to the pumping period (Ferris and others, 1962). The residual-drawdown data were plotted as a function of the ratio t/t′ on semi-logarithmic graph paper.

## Test Results

### McKean Township (site 1)

Aquifer test site 1 is in northwest McKean Township (fig. 13). The site is north of Interstate 90 near Interchange 5 and west of State Route 832 (fig. 14). This site was chosen for test well drilling because previous investigations in the vicinity indicated the potential for a high-yield aquifer (Moody, 1966).

The site has a production well, four 8-in.-inside-diameter (i.d.) and nine 2-in.-i.d. observation wells. Initially, the four 8-in.-i.d. observation wells were test wells drilled to select a site for the production well. Well depths and aquifer-thickness data are summarized in table 12. Eight of the 2-in.-i.d. wells are grouped in pairs; three sets of well pairs—WP-2, WP-3, and WP-4—were located near observation wells (fig. 14). The paired wells were approximately 10 ft apart. The well pairs monitored water levels in shallow and intermediate zones to estimate vertical leakage. The depth of the shallow wells range from 11 to 23 ft below land surface datum. The depth of the intermediate wells range from 35 to 50 ft below land surface datum. These 2-in.-i.d. observation wells are equipped with 5-ft-long slotted well screens and are completed in glacial till.

An additional 2-in-i.d. observation well, Er-8545, was drilled to a depth of 132 ft about 850 ft northwest of the test area (fig. 14). Contact was made with bedrock or dense glacial till at this depth (fig. 15). Split spoon samples were collected every 5 ft to determine lithology during the drilling. The well is screened in glacial till with lenses of sand and gravel less than 1-ft thick. A 10-ft-long slotted well screen was set in the interval 62 to 72 ft below land surface datum. This interval was selected for screening because it was the only apparent water-bearing zone of the entire thickness of unconsolidated deposits. The screened interval has a yield less than 0.5 gal/min.

The production well was drilled to a depth of 72 ft below land surface datum and has a 5-ft-long stainless steel screen set in the interval 62 to 67 ft below land surface datum. The four observation wells have open end completions with eight 8-in. slots cut vertically in a circular pattern 5 ft above the casing bottom. The casing string was positioned with the slots intercepting the same productive sand and gravel interval, which has an altitude of about 885 to 902 ft above sea level. Land-surface elevations of these wells were surveyed for accurate water-level comparisons. The altitudes of ground-water levels in these wells showed a relatively flat potentiometric surface. The following simultaneous measurements of ground-water levels on

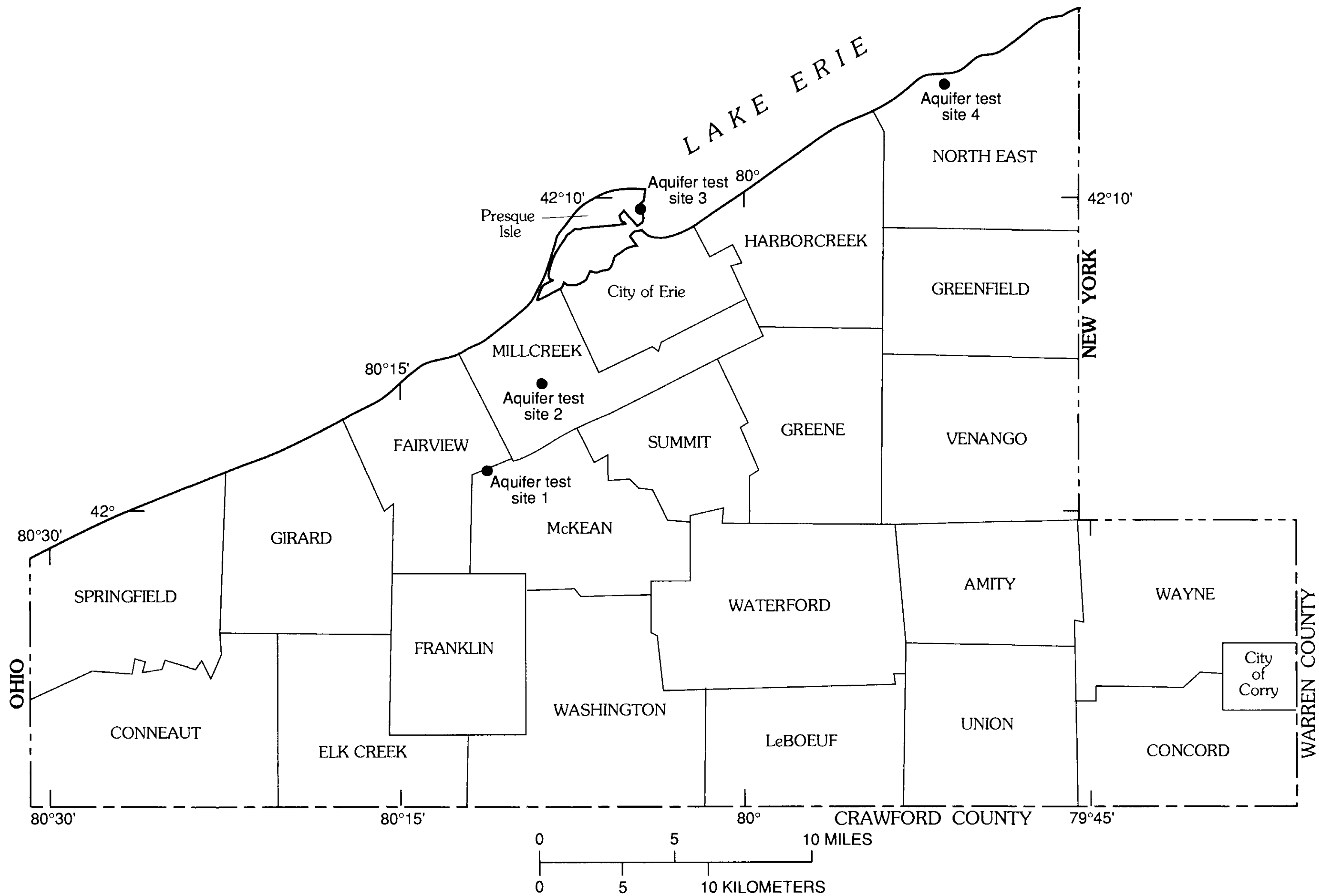


**Figure 13.** Locations of aquifer test sites in Erie County, Pennsylvania.

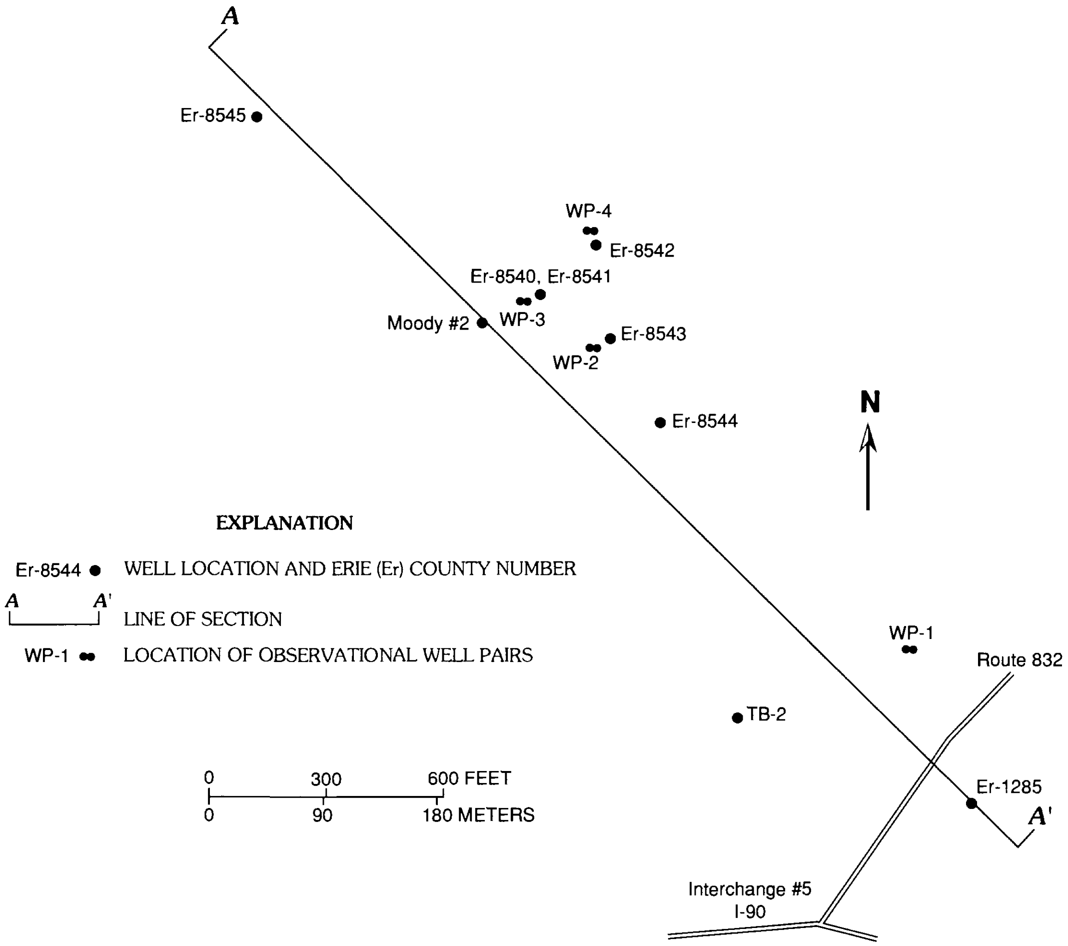


**Figure 14.** Aquifer test site 1, Erie County, Pennsylvania (geologic section shown in figure 15).

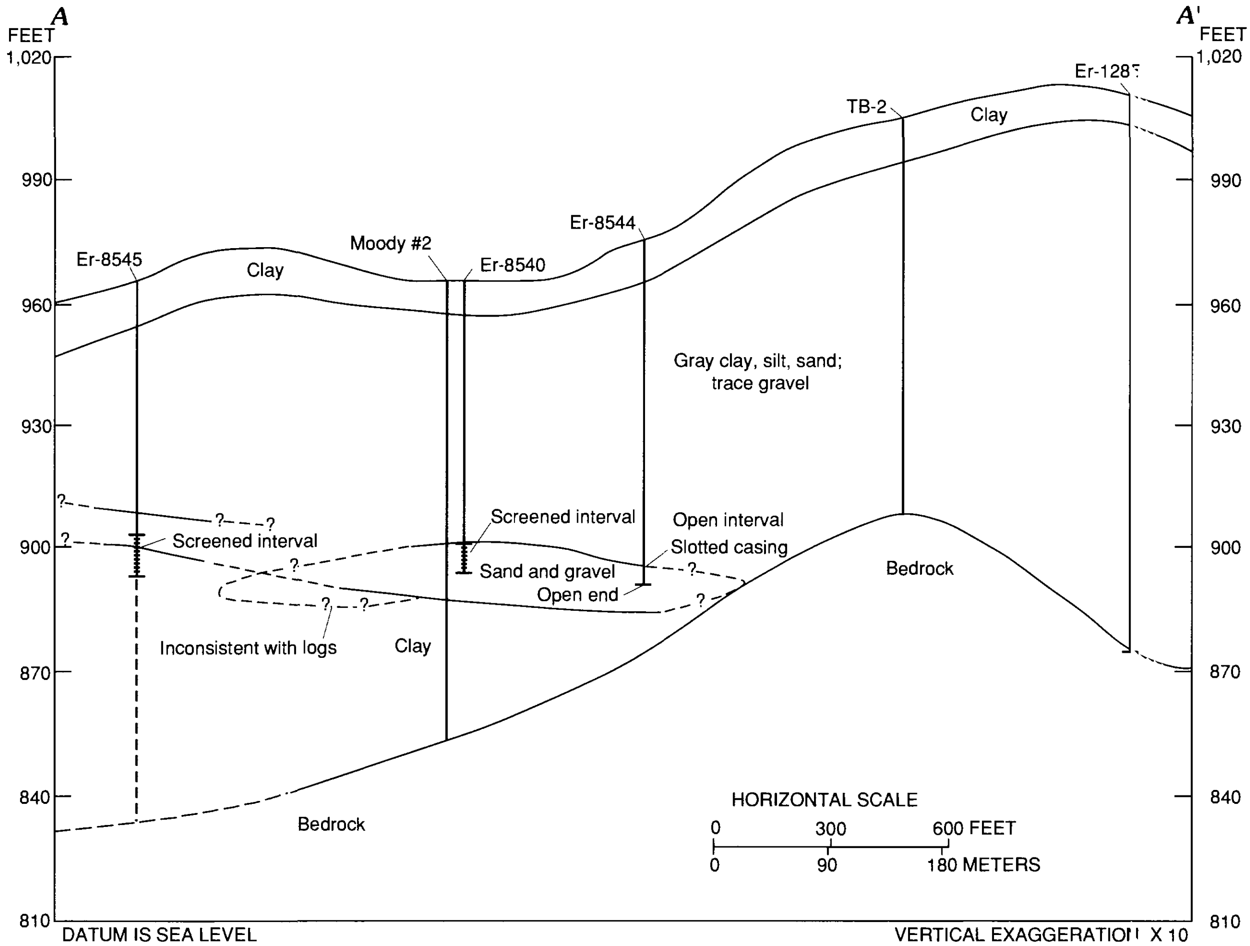


**Figure 15.** Generalized geologic section at aquifer test site 1, Erie County, Pennsylvania (line of section shown in figure 14).

December 9, 1988, are typical of the flat potentiometric surface:

| Observation well | Altitude of ground-water level, in feet above sea level | Distance, in feet and direction from production well Er-8540 |
|---|---|---|
| Er-8541 | 911.49 | 11 E |
| Er-8542 | 911.49 | 202 NE |
| Er-8543 | 911.53 | 238 E |
| Er-8544 | 911.60 | 488 SE |

A geologic section of the test site was constructed from drillers logs (fig. 15). The following are typical drillers logs for the site:

The production well, Er-8540, and the four 8-in. observation wells tap a sand and gravel outwash aquifer. This outwash aquifer is overlain by glacial till composed of clay and silt. The potentiometric-surface altitude is greater than the altitude of the sand and gravel aquifer; ground-water levels show no response to precipitation events, which is characteristic of confined or artesian aquifers. The lithologic data from driller's logs indicate that a relatively impermeable clay and silt interval overlies the sand and gravel aquifer. Thus, the intrinsic aquifer conditions are presumed to be confined with nonleaky confining units.

| Er-8545 | | Moody #2 | | Er-8540 | |
|---|---|---|---|---|---|
| Depth interval (feet) | Lithology | Depth interval (feet) | Lithology | Depth interval (feet) | Lithology |
| 0–3 | Light brown sand and gravel loam | 0–8 | Brown clay and gravel | 0–9 | Yellow clay, trace gravel |
| 3–10 | Dark brown sand loam | 8–66 | Gray clay and gravel | 9–48 | Gray clay and silt with trace gravel |
| 10–37 | Gray clay and silt, trace gravel | 66–77 | Gray sand and gravel | 48–55 | Gray silty clay and gravel |
| 37–45 | Gray clay and gravel | 77–82 | Silty sand gravel with clay | 55–70 | Gray gravel and sand |
| 45–52 | Gray clay, sand and gravel | 82–106 | Clay | 70–72 | Gray clay and silt with gravel |
| 52–53 | Gray fine sand | 106–110 | Clay and gravel | | |
| 53–67 | Gray and black sand and gravel | 110–112 | Clay and shale | | |
| 67–127 | Layered gray brown silt and sand | | | | |
| 127–132 | Gray clay and rock fragments | | | | |

The methods of analysis chosen for this site were the Theis type-curve match and the Cooper-Jacob straight-line method. The Theis recovery method was not used because of insufficient prepumping water-level data. The methods were applied only to the four 8-in. observation wells. Well Er-8540 was pumped at a constant 150 gal/min for 6 days from November 2–8, 1988. The 2-in.-i.d. observation wells were intermittently measured throughout the test's duration. No drawdown was observed in the wells, which indicates that no measurable leakage passes through the upper confining units.

A deviation from the Theis theoretical drawdown curve occurred at minute 3,500, when water levels in the four 8-in. observation wells began rising (fig. 16). The discharge was checked routinely and remained constant. Recharge from precipitation, a surface-water body, or discharge water was unlikely because of the low permeability of the upper confining unit. In addition, the rise was not detected in the 2-in. observation wells. Further study revealed the rising water levels were caused by atmospheric pressure effects.

Water levels in many artesian aquifers respond to changes in atmospheric pressure (U.S. Bureau of Reclamation, 1977). The confined aquifer's response is an inverse relation to barometric pressure. The response can be quantified by the ratio of incremental water-level changes to incremental barometric-pressure changes. This ratio is termed barometric efficiency; it can be as high as 80 percent. The barometric efficiency is used to adjust the recorded water levels.

The barometric efficiency at site 1 was 70 percent or 0.70. Thus, a barometric-pressure decrease of 0.10 ft of water would have caused a water-level increase of 0.07 ft. Barometric-pressure data in 4-hour intervals were obtained from the National Weather Service site at the Erie airport. For the test duration, these barometric-pressure readings were interpolated in order to adjust the drawdown data used in the aquifer-test analyses (fig. 17).

The Theis curve-match analysis was used on the middle-time data from minute 500 to minute 4,500. Data after minute 4,500 were not used because the cone of depression had contacted an impermeable boundary.

The calculated transmissivities for wells Er-8542, Er-8543, and Er-8544 are 20,900, 19,150, and 22,300 $ft^2/d$, respectively (table 12). The storage coefficients for wells Er-8542, Er-8543, and Er-8544 are about 0.052, 0.041, and 0.034, respectively. Because well Er-8541 is only 11 ft from the production well, the transmissivity and storage coefficient were not calculated.

The Cooper-Jacob time-drawdown method was used for comparative results. Data between minute 500 and minute 5,000 were used for well Er-8541 and data between minute 1,500 and minute 5,000 were used for wells Er-8542 and Er-8543. Well Er-8544 could not be used in this analysis because the steady state stipulation that u be less than or equal to 0.01 was not satisfied. For the time-drawdown analysis, the calculated transmissivities for wells Er-8541, Er-8542, and Er-8543 are 18,900, 19,600, and 19,600 $ft^2/d$, respectively. The storage coefficients are about 0.010, 0.052, and 0.039, respectively. The straight-line method drawdown plot for well Er-8542 is shown in figure 18.

The distance-drawdown analysis at minute 8,000 is shown in figure 19. The calculated transmissivity is 15,200 $ft^2/d$, and the storage coefficient is 0.006. The transmissivity agrees well with the results from the Theis curve-match method and the time-drawdown analysis of the Cooper-Jacob method. However, the storage coefficient was an order of magnitude lower.

#### Millcreek Township (site 2)

Aquifer test site 2 is located in western Millcreek Township along West 38th Street (fig. 20). Two aquifer tests were done at this site.

Production well Er-7504 is 68 ft deep and has a 2-ft stainless steel screen set 58 to 60 ft below land surface datum. The observation well is 55 ft deep. Well Er-7505 is 325 ft northeast of production well Er-7504. Production well Er-7501 is 64.5 ft deep and has a 4-ft stainless steel screen set in the interval 55 to 59 ft below land surface datum. Observation well Er-7502 is 11 ft south of the production well Er-7501, and observation well Er-7503 is 310 ft southwest of production well Er-7501 (fig. 20). Well depths and aquifer-thickness data are summarized in table 12 and Appendix 2. The two production wells are presumed to be screened in the same continuous sand and gravel outwash aquifer. According to drillers' well logs, this aquifer was not penetrated in nearby domestic wells on West 38th Street. This indicates that the aquifer is a buried meltwater stream channel. A geologic section was constructed from driller's logs (fig. 21).

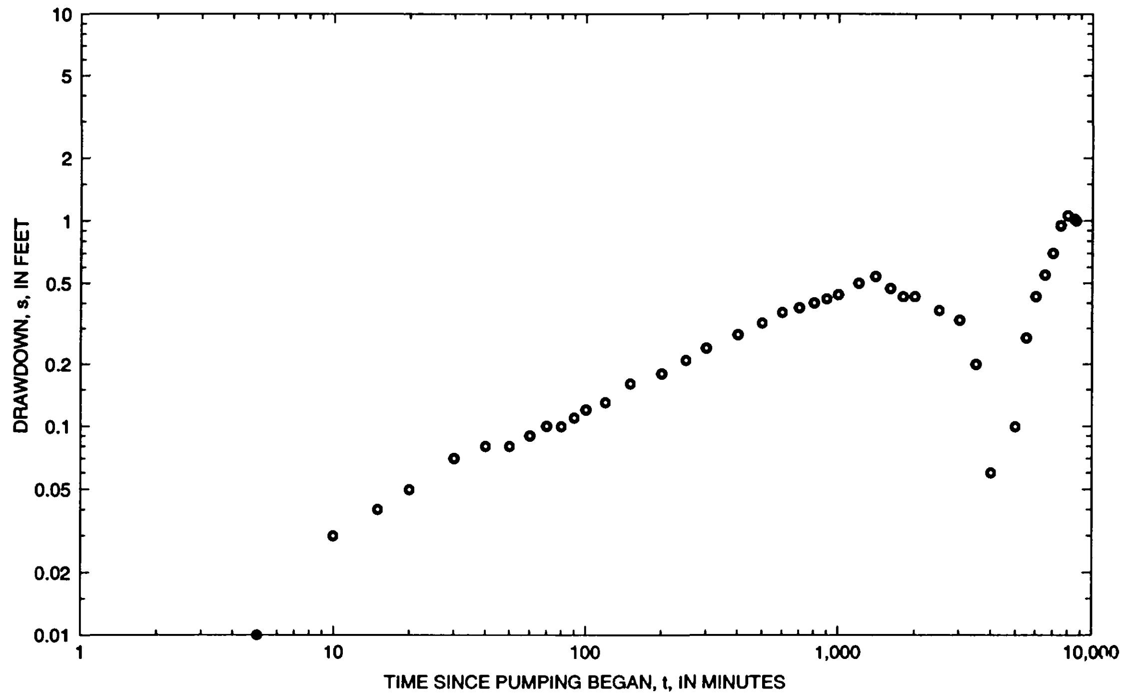


**Figure 16.** Drawdown plot of unadjusted data for Theis-type curve for well Er-8542, Erie County, Pennsylvania.

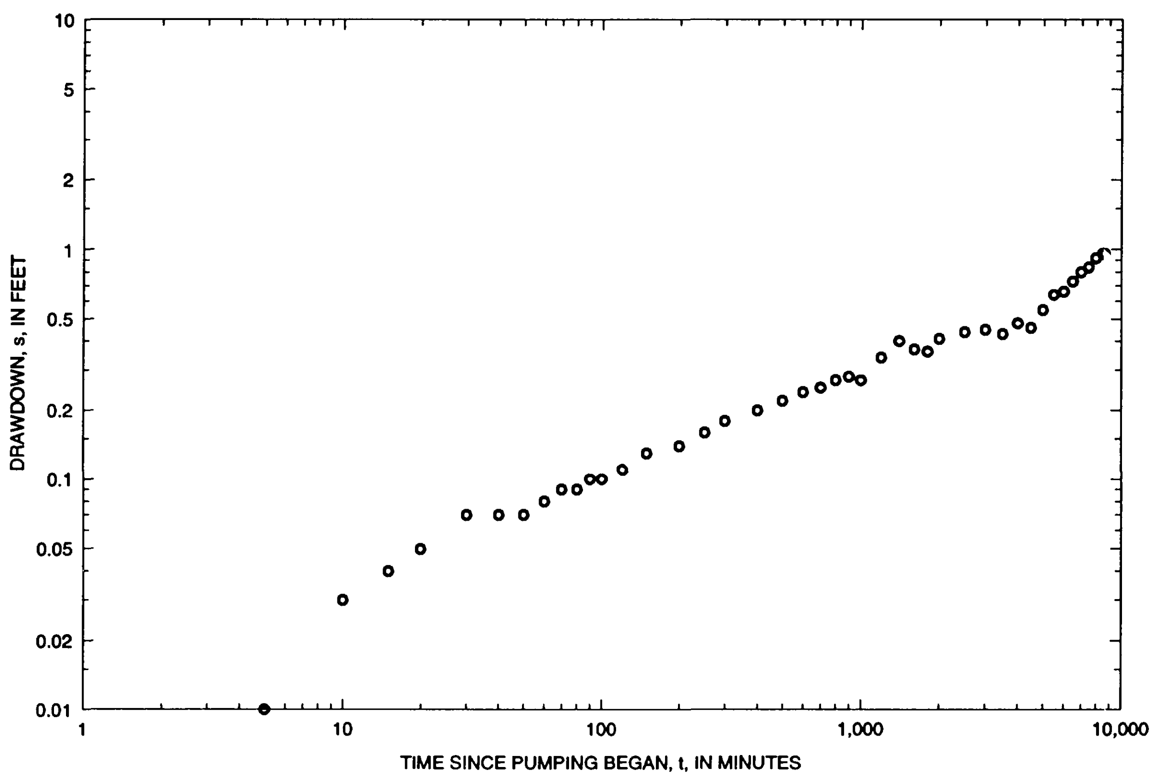


**Figure 17.** Drawdown plot of adjusted data for Theis-type curve for well Er-8542, Erie County, Pennsylvania.

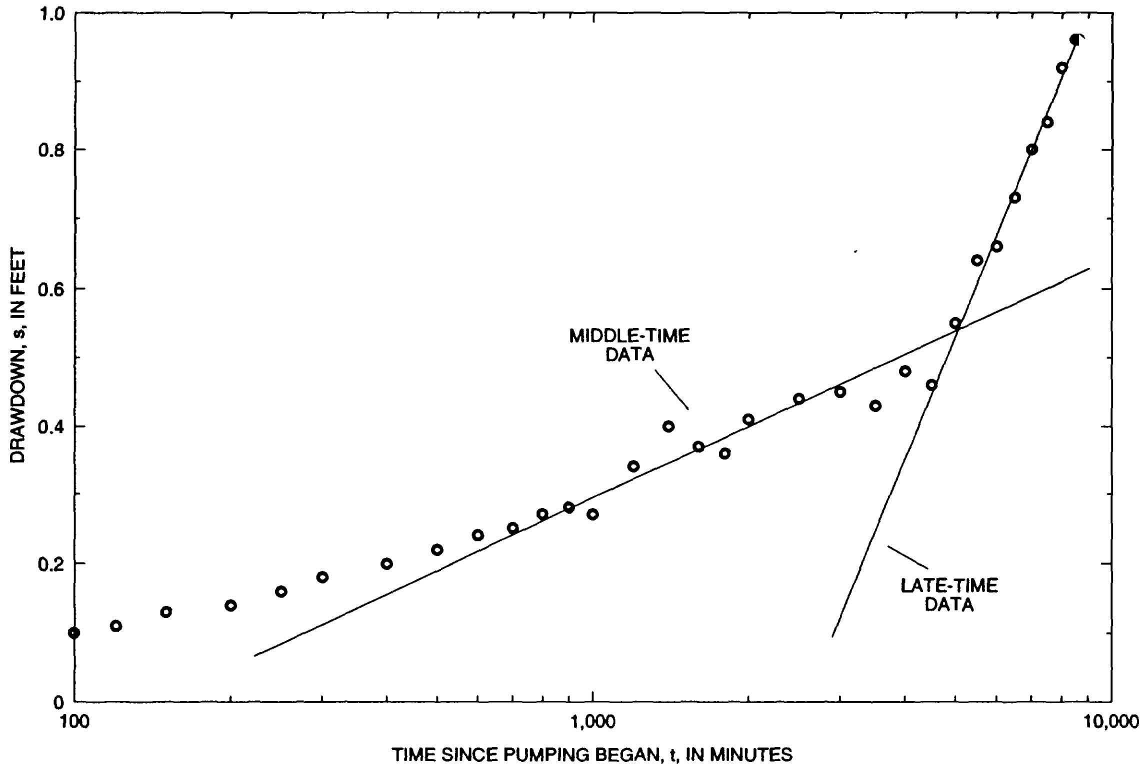


**Figure 18.** Drawdown plot of adjusted data for straight-line method for well Er-8542, Erie County, Pennsylvania.

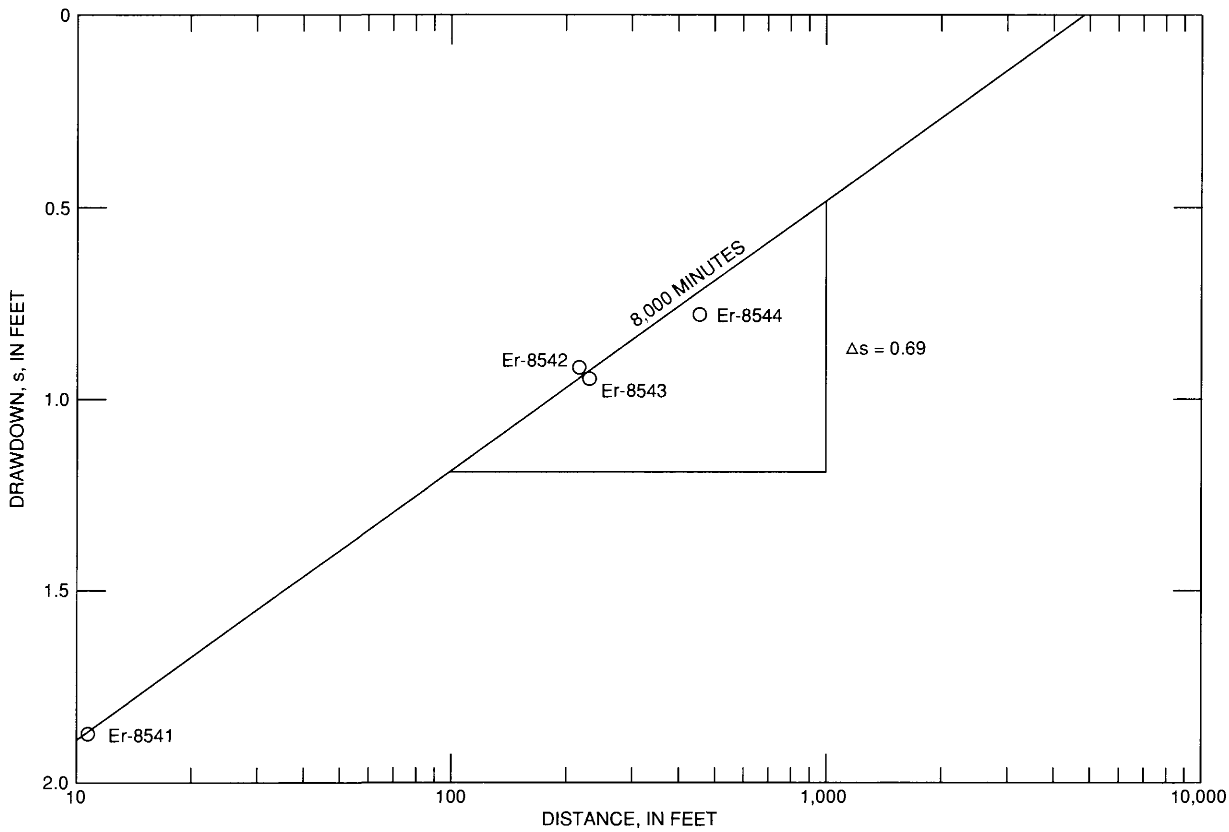


**Figure 19.** Distance-drawdown analysis for time of 8,000 minutes at site 1, Erie County, Pennsylvania.

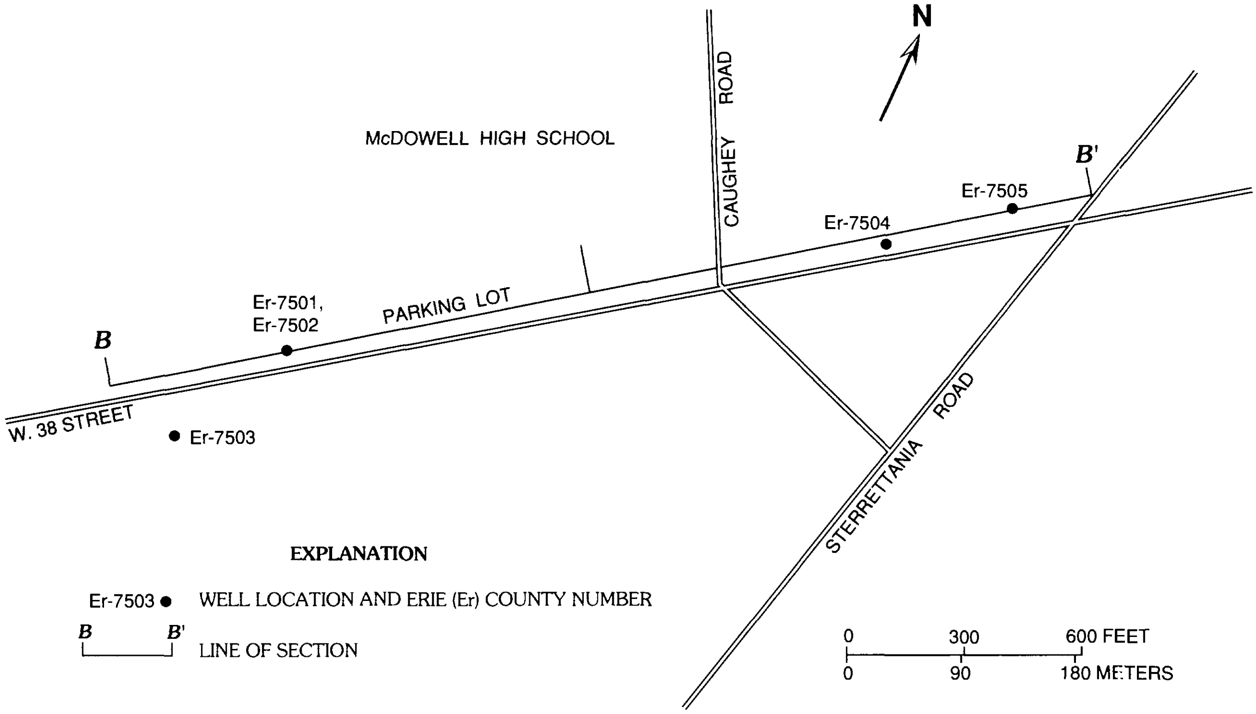


**Figure 20.** Aquifer test site 2, Erie County, Pennsylvania (geologic section shown in figure 21).

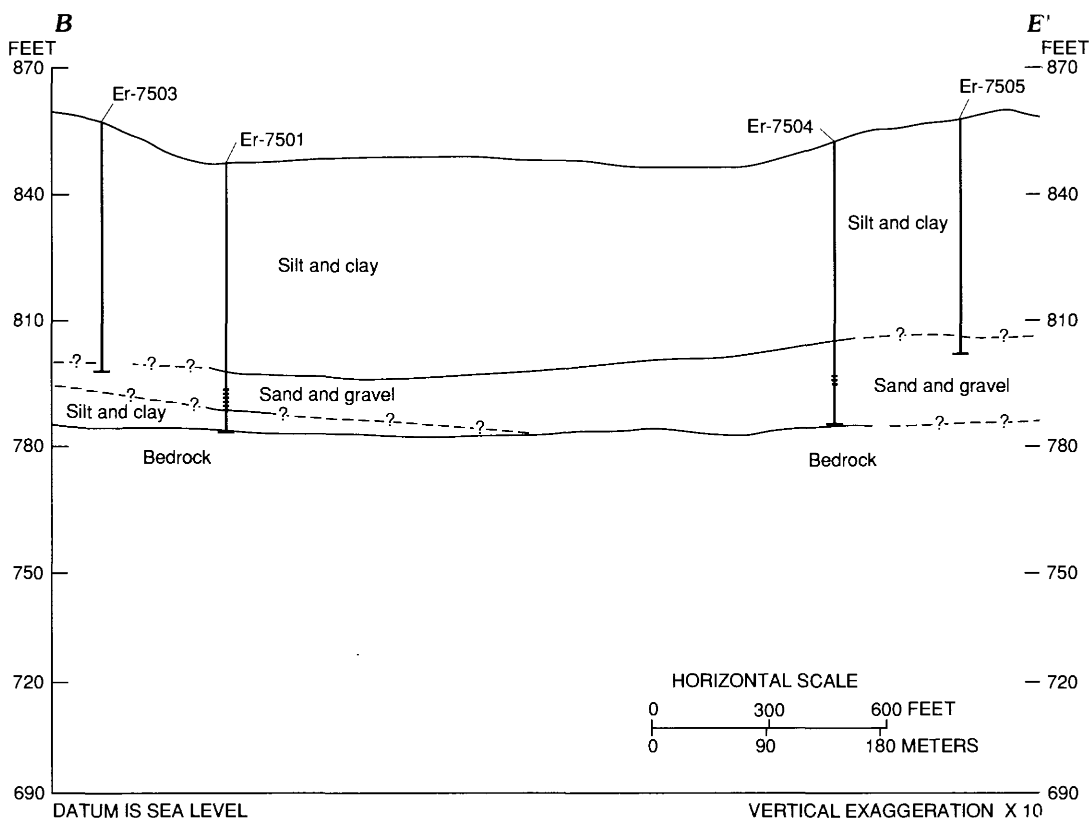


**Figure 21.** Generalized geologic section at aquifer test site 2, Erie County, Pennsylvania (line of section shown in figure 20).

The following are typical driller's logs for the site:

| Er-7501 | | Er-7504 | |
|---|---|---|---|
| Depth interval (feet) | Lithology | Depth interval (feet) | Lithology |
| 0–6 | Brown silty clay and gravel | 0–10 | Yellow clay |
| 6–13 | Gray silty clay and gravel | 10–48 | Gray silty clay and gravel |
| 13–28 | Fine gray gravel and sand gravel | 48–67 | Coarse gray gravel to silty clay |
| 28–46 | Gummy gray silty clay and gravel | 67–68 | Gray shale |
| 46–47 | Fine gray gravel and sand | | |
| 47–50 | Gray clay and gravel | | |
| 50–58 | Medium gray gravel and sand | | |
| 58–64 | Gray silty clay and gravel | | |
| 64–64.5 | Gray shale | | |

On the basis of drillers' logs, the aquifer is confined with nonleaky confining units. For the first aquifer test at this site, well Er-7501 was pumped for a constant 100 gal/min for 48 hours from August 7–9, 1989 (fig. 20). The Cooper-Jacob time-drawdown and Theis recovery methods were used to analyze the data for both observation wells.

Prior to the test, graphical water-level recorders were installed on all three wells to determine antecedent water-level trends. Also, a barometric-pressure recorder was installed at the test site for a few weeks. Data from the two instruments yielded the aquifer response to atmospheric-pressure effects. The correlation was sporadic and often masked by nearby residential pumpage. Therefore, corrections based on barometric pressure were not applied.

The transmissivity and storage coefficient at well Er-7502 calculated from the Cooper-Jacob time-drawdown straight-line method are 860 $ft^2/d$ and about 0.015, respectively (table 12). The data between minute 100 and minute 500 were used in the analysis. The transmissivity and storage coefficient for well Er-7503 at time greater than minute 400 are 925 $ft^2/d$ and 0.00009, respectively. A straight-line method plot of drawdown as a function of time for well Er-7503 is shown in figure 22. The drawdown plot decreases in slope for time greater than minute 600. This indicates either leaky confining layers or a recharge boundary (fig. 22). Although the drawdown rate decreased, the curve still shows transient behavior for the late-time data. Therefore, use of an alternate curve matching analysis that includes matching with theoretical leakage-type curves was not possible. The slope change was probably caused by a recharge boundary. The cone of depression may have reached an area of the aquifer that was more transmissive or thicker, thus slowing the drawdown rate.

Recovery data were collected at the observation wells. A recovery data plot for well Er-7503 is shown in figure 23. The transmissivities calculated by use of the Theis recovery-test method for wells Er-7502 and Er-7503 are 870 and 850 $ft^2/d$, respectively (table 12). Storage coefficients were not determined.

For the second test, production well Er-7504 was pumped for 24 hours from October 10–11, 1989, and well Er-7505 observed. Data collected prior to the test indicate that nearby pumping and barometric pressure had no perceptible effect on water levels. Therefore, adjustments to the drawdown data were not necessary.

The Theis type-curve method and the Cooper-Jacob time-drawdown method were used to analyze the observation-well data. The Theis recovery method was used for the data from the production well. For the Theis type-curve match, the transmissivity and storage coefficient for well Er-7505 are 4,340 $ft^2/d$ and 0.00003, respectively (table 12). The curve match was applied to the drawdown curve after minute 120 because of a pumping-rate adjustment. The pumping rate was constant for the remainder of the test. The initial discharge rate was 190 gal/min, but at minute 120 the discharge rate was decreased to 170 gal/min. A type curve drawdown plot for Er-7505 is shown in figure 24.

The Cooper-Jacob time-drawdown method was also used after minute 120 for well Er-7505. The transmissivity and storage coefficient are 4,475 $ft^2/d$ and 0.00002, respectively (table 12). A straight-line method plot of time as a function of drawdown for well Er-7505 is shown on figure 25. The slope for the drawdown data increases after 1,000 minutes. The increase in slope may represent interception of an impermeable boundary by the cone of depression or a thinning of the aquifer (U.S. Bureau of Reclamation, 1977).

A water-level recorder installed on well Er-7501 recorded no response to pumping well Er-7504. The data showed natural water-level fluctuations. These data were used for the recovery-test analysis.

The transmissivity calculated by the Theis recovery method from the production-well data is 3,870 $ft^2/d$ (table 12). A storage coefficient was not determined. A recovery-data plot for well Er-7504 is shown in figure 26.

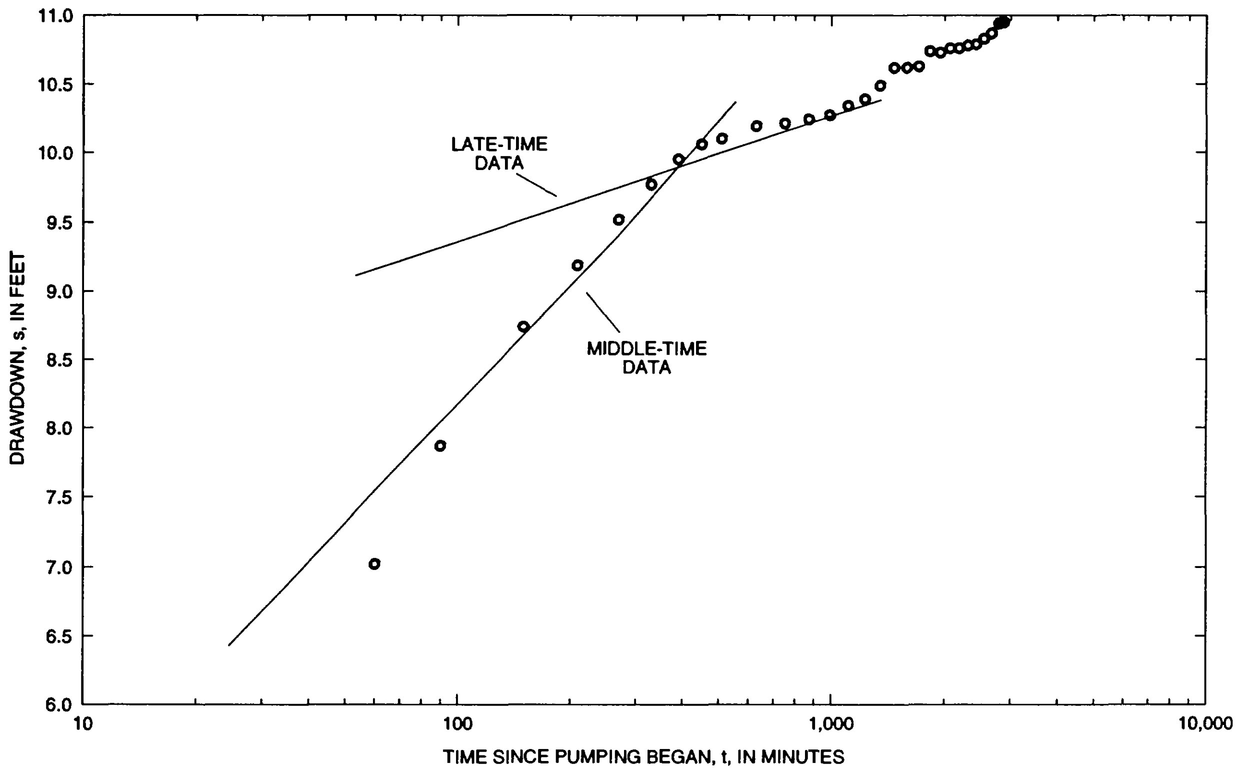


**Figure 22.** Drawdown plot for straight-line method for well Er-7502, Erie County, Pennsylvania.

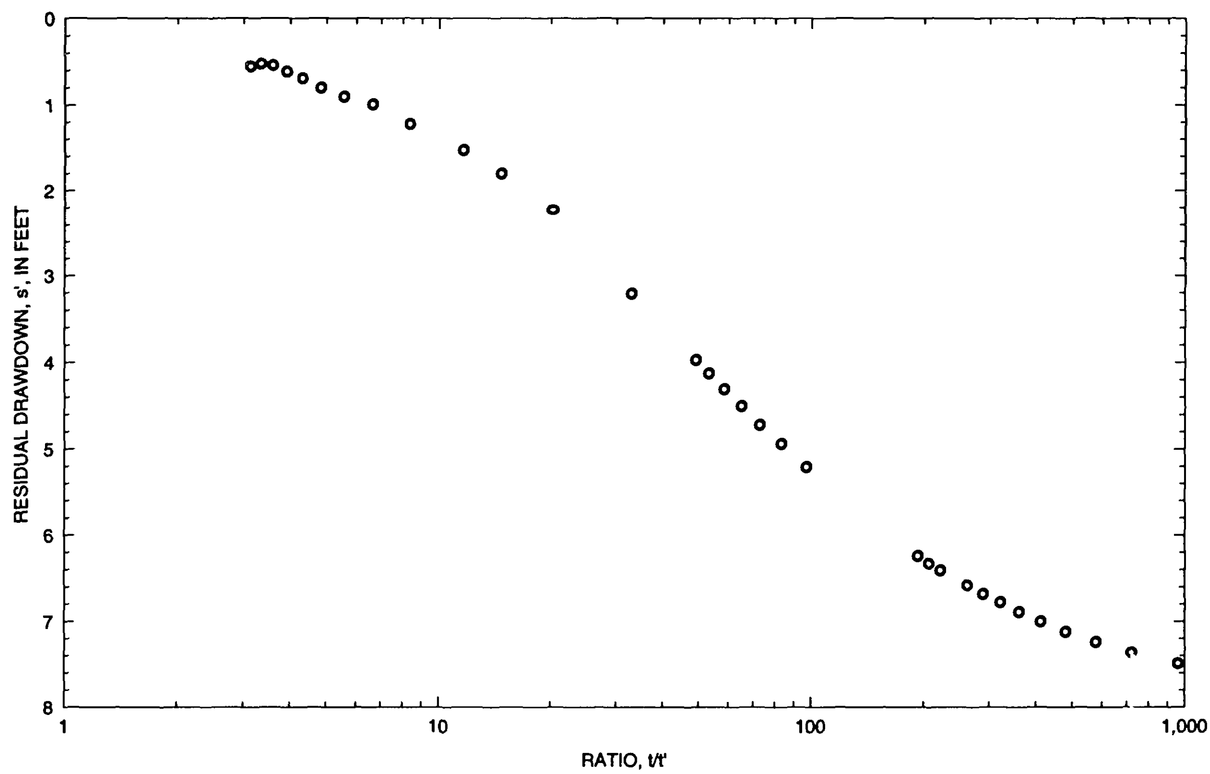


**Figure 23.** Recovery data plot for Theis recovery method for well Er-7503, Erie County, Pennsylvania.

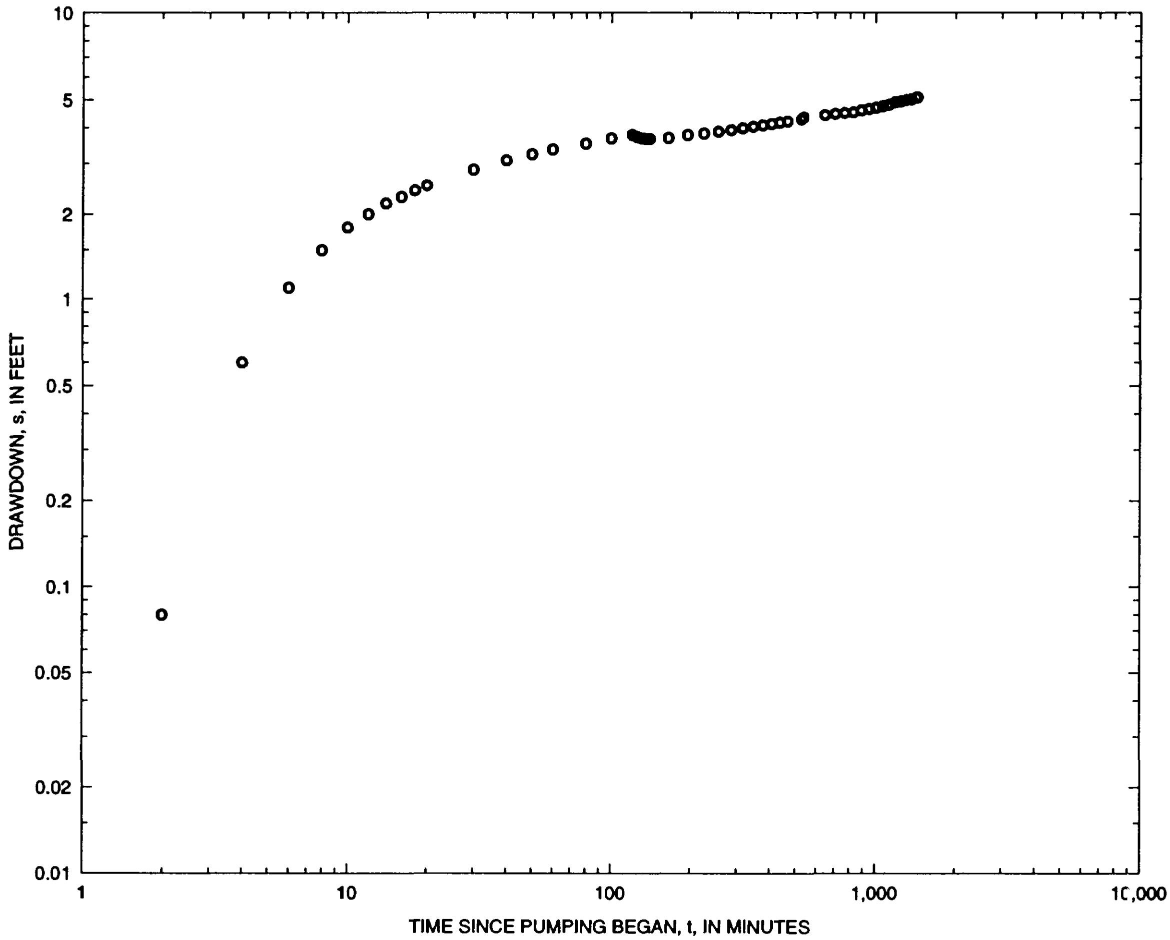


**Figure 24.** Drawdown plot for Theis-type-curve method for well Er-7505, Erie County, Pennsylvania.

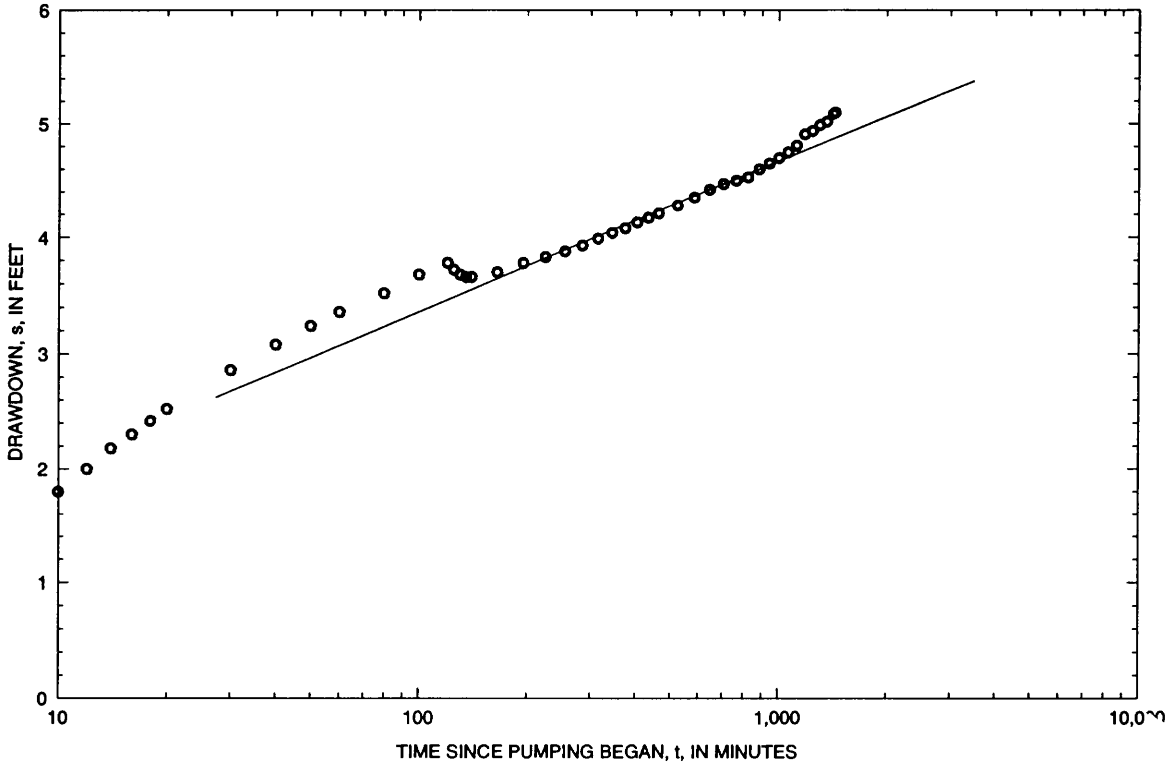


**Figure 25.** Drawdown plot for straight-line method for well Er-7505, Erie County, Pennsylvania.

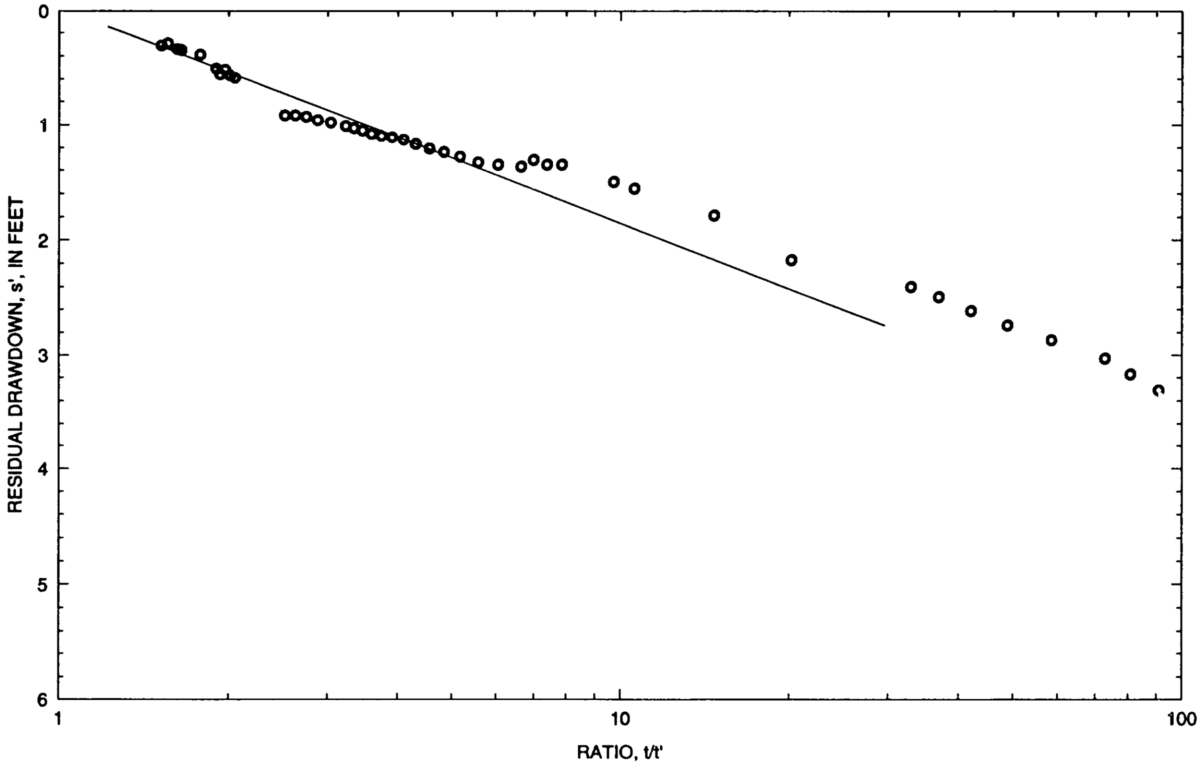


**Figure 26.** Recovery data plot for Theis recovery method for well Er-7504, Erie County, Pennsylvania.

### Presque Isle (site 3)

Aquifer test site 3 is on Presque Isle (fig. 13). The site is nearest to beach 11 about 1,200 ft north of Presque Isle's north pier. A screened production well Er-7508 was pumped for 6 hours on September 21, 1989, and water levels in two screened wells were observed. Additionally, water levels in two well points were measured intermittently, and the data were used in distance-drawdown analysis.

Experimental well installation techniques were used at the site. The production well Er-7508 and the two observation wells Er-7507 and Er-7506 were installed by water jetting. Well point L1 was installed with a combination of hollow stem auger drilling and driving. Well point L5 was installed by driving with a portable tripod and gasoline-powered cathead. The well points L1 and L5 are 21 ft long, 1.25-in diameter galvanized pipe with 24 in. of screen.

Well Er-7508 was jetted to 18.7 ft below land surface datum and a 10-ft slotted polyvinyl chloride screen was set in the interval 8.7 to 18.7 ft below land surface datum. During well development, 5 ft of fine sand filled the bottom of the well screen. Therefore, the well depth was 13.7 ft below land surface datum at test time. Observation well Er-7507 is 17 ft from the pumped well. Observation well Er-7506 is 35 ft from the pumped well. Well depths and aquifer thicknesses are summarized in table 12 and Appendix 2, and the locations of the wells are shown on figure 27.

The aquifer consists of poorly sorted beach deposits that are mostly a mixture of silt, fine to coarse-grained sand, and thin layers of shingle. The Presque Isle Peninsula is in constant northeastward migration. Jennings (1930) calculated an average growth rate of 0.5 mi/100 years. Research by Jennings (1930) indicates the shallow beach deposits at site 3 were formed by shoreline migration in the 1900's.

On the basis of the type of deposit and its proximity to the surface, the aquifer is unconfined. The Cooper-Jacob time-drawdown and distance-drawdown methods, which include the Jacob correction factor for unconfined aquifers, were used to analyze the data. The pumping rate was held constant at 26 gal/min. The analysis was applied after minute 100. The transmissivities calculated from the corrected time-drawdown analysis at wells Er-7506 and Er-7507 are 4,080 and 3,820 $ft^2$/day, respectively (table 12). The corresponding storage coefficients are 0.03 and 0.01, respectively. The relation between time and drawdown for well Er-7506 is shown in figure 28.

A distance-drawdown analysis was done at a time of 320 minutes after the pumping began. Corrected data for the two observation wells and well points L1 and L5 were used. The transmissivity is calculated to be 2,300 $ft^2$/d. The corresponding storage coefficient was 0.5 (table 12).

### North East Township (site 4)

Aquifer test site 4 is in north-central North East Township, approximately 1 mi northwest of North East Borough (figs. 13 and 29), approximately 1,700 ft south of the Lake Erie shoreline.

The production well Er-3022 was drilled to a depth of 40 ft below land surface datum and screen set in the interval 29.6 ft to 31.6 ft below land surface datum. Laboratory grain-size analysis of aquifer material resulted in the selection of a 0.080-in. slot screen size. Observation well Er-3023 has 8-in. casing to a depth of 54 ft below land surface datum. A string of 6-in. casing was installed inside the 8-in. casing and drilling continued to a depth of 115 ft below land surface datum. The well penetrated shale at 113 ft below land surface datum. High-yielding water-bearing zones were not found in the interval 54 to 115 ft below land surface datum. Well Er-3023 is 10 ft from the production well (fig. 29). Wells Er-3019, Er-3020, and Er-3021 were drilled to depths of 55, 50, and 41 ft below land surface datum, respectively.

The wells tap thin beach deposits that are discontinuous in areal extent. A geologic cross section was constructed from drillers logs (fig. 30). The following are typical driller's logs for the site:

| Er-3022 | | Er-3023 | | Er-3020 | |
|---|---|---|---|---|---|
| **Depth interval (feet)** | **Lithology** | **Depth interval (feet)** | **Lithology** | **Depth interval (feet)** | **Lithology** |
| 0–13 | Brown sand and gravel | 0–12 | Brown gravel and sand | 0–18 | Brown gravel and sand |
| 13–20 | Gray clay and gravel | 12–26 | Brown silt with gravel | 18–22 | Brown sand with gravel |
| 20–25 | Gray sand with gravel | 26–30 | Brown gravel with silt | 22–44 | Brown sand and silt with gravel |
| 25–27 | Brown sand with silt and gravel | 30–33 | Gray gravel with silt | 44–50 | Gray silt and clay with gravel |
| 27–33 | Brown gravel with sand and silt | 33–48 | Gray sand and silt with gravel | | |
| 33–40 | Brown sand with gravel and silt | 48–113 | Gray silt and clay with sand and gravel | | |
| | | 113–115 | Shale | | |

On the basis of the interpretation of driller's logs and water levels, the aquifer is semiconfined. The Cooper-Jacob time-drawdown method was used to analyze data from observation well Er-3023, and the Theis recovery test method was used to analyze data from the production well Er-3022.

Well Er-3022 was pumped for 27 hours from April 26–27, 1988, and well Er-3023 was observed. Three additional wells—Er-3019, Er-3020, and Er-3021—in the vicinity did not respond to pumping. The production well pumping rate was a constant 12 gal/min. The time-drawdown analysis for well Er-3023 was applied after minute 100. The transmissivity determined from the observation-well data is 262 $ft^2/d$ (table 12). The drawdown data for observation well Er-3023 is shown in figure 31.

The transmissivity value using the recovery analysis for data from well Er-3022 is 235 $ft^2/d$ (table 12). A plot of recovery data is shown in figure 32.

## WATER QUALITY

### Base Flow

Streamflow during extended periods of little or no precipitation (base flow) is predominantly groundwater discharge from shallow aquifers. Base flow is indicative of water quality in shallow aquifers upstream of the sampling site. Base flow at some sites, however, may be affected by point-source and nonpoint-source discharges.

In Erie County, about 106 sewage-treatment plants and many industries discharge treated effluent to streams. In many cases, discharges from the sewage-treatment plants are extremely small with respect to the base flow of the receiving stream and the water quality of the receiving stream is not substantially altered. Also, concentrations of some constituents may change when ground water enters the stream. Iron, for example, may precipitate or react with other constituents in the stream resulting in lower concentrations in the base-flow samples as compared to concentrations in shallow aquifers. However, many constituents such as chloride and sulfate are relatively unreactive and are indicative of water quality in the shallow aquifers.

Base-flow samples collected from streams in Erie County generally reflect ground-water quality derived from multiple aquifers. These aquifers may include one or more unconsolidated aquifers and one or more fractured bedrock aquifers. When base flow is composed of ground-water discharge from several aquifers, estimates of the percentage contribution from each aquifer are difficult to determine.

Upper stream reaches receive ground-water discharge that is predominantly from recharge areas with relatively short ground-water-flow paths and minimal ground-water residence time. Lower stream reaches of streams receive ground-water discharges that generally have had longer ground-water flow paths, longer ground-water residence time, and subsequently more mineralization. Generally higher dissolved-solids concentrations in ground-water discharge areas (valleys) as opposed to generally lower dissolved-solids concentrations in recharge areas (highlands) have been documented by the USGS in ground-water studies on the Appalachian Plateaus physiographic province in western Pennsylvania including the Clarion River Basin (Buckwalter and others, 1981) and Greene County (Stoner and others, 1987).

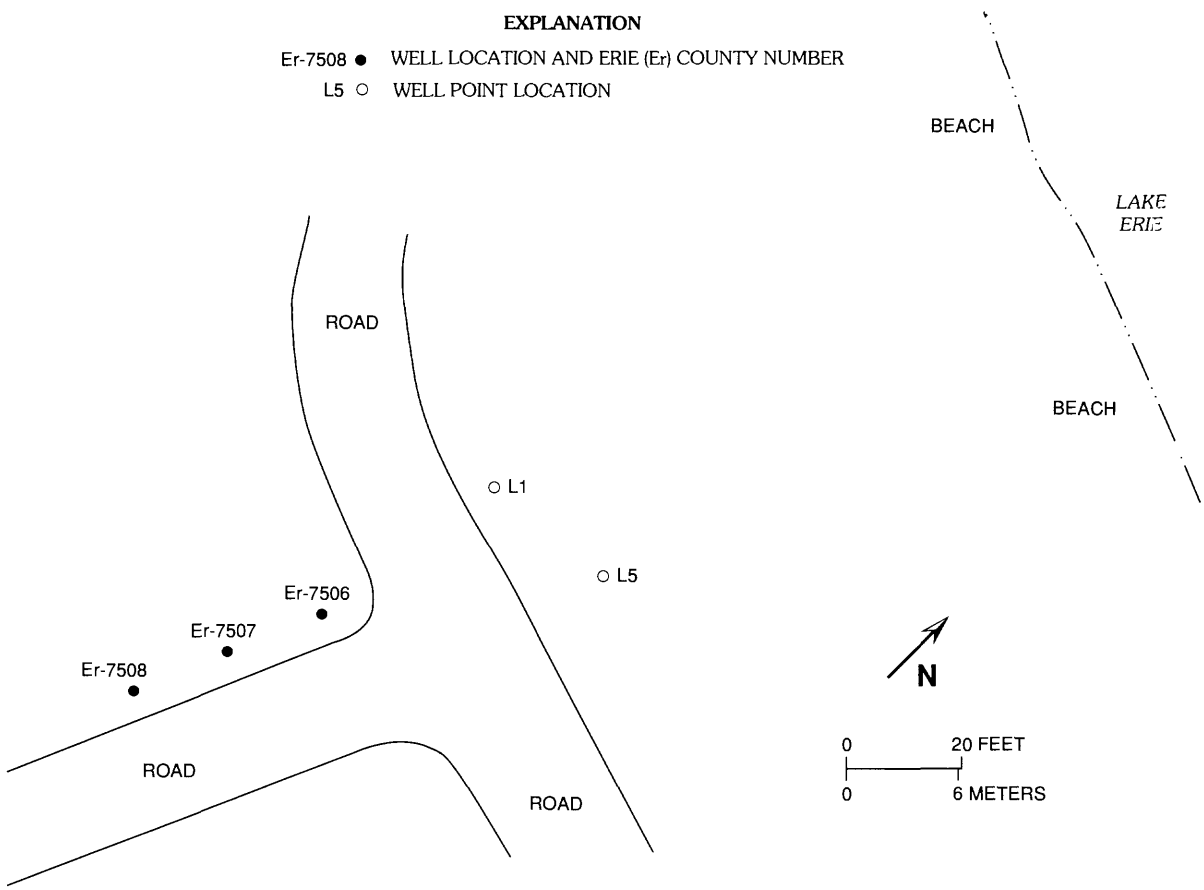


**Figure 27.** Aquifer test site 3, Erie County, Pennsylvania.

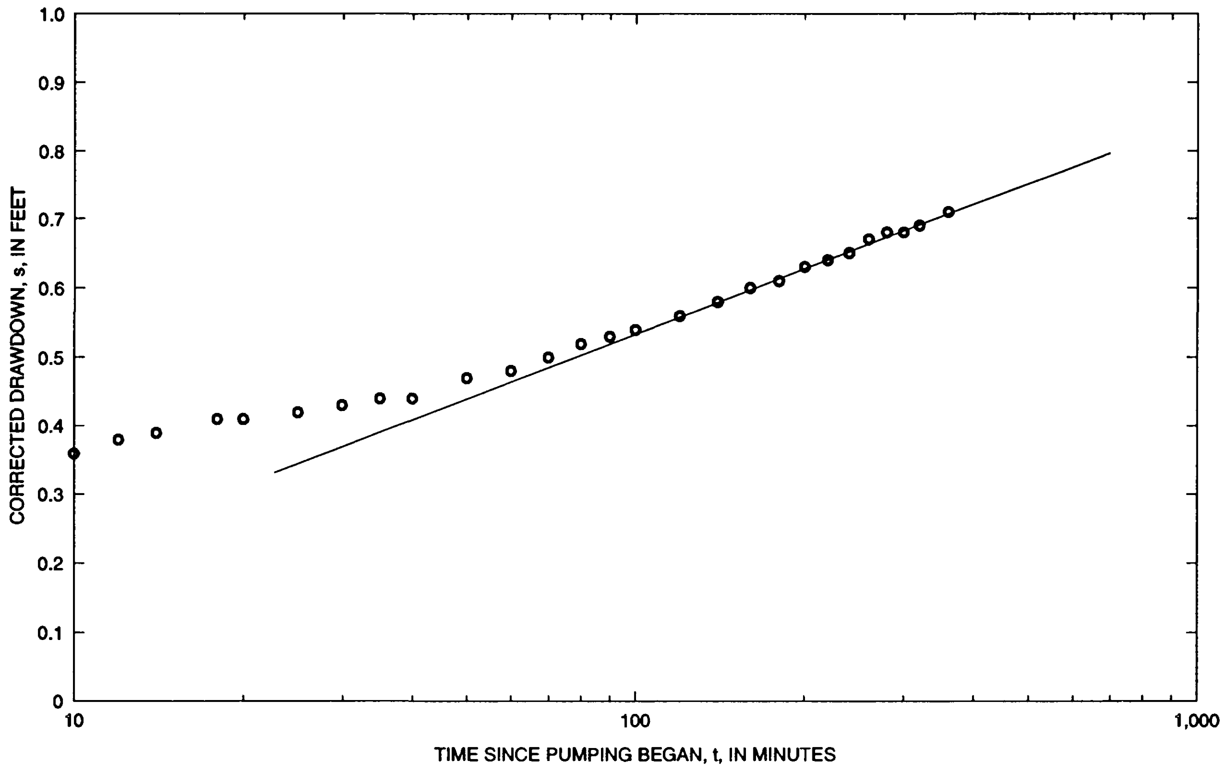


**Figure 28.** Drawdown plot for straight-line method for well Er-7506, Presque Isle, Erie County, Pennsylvania.

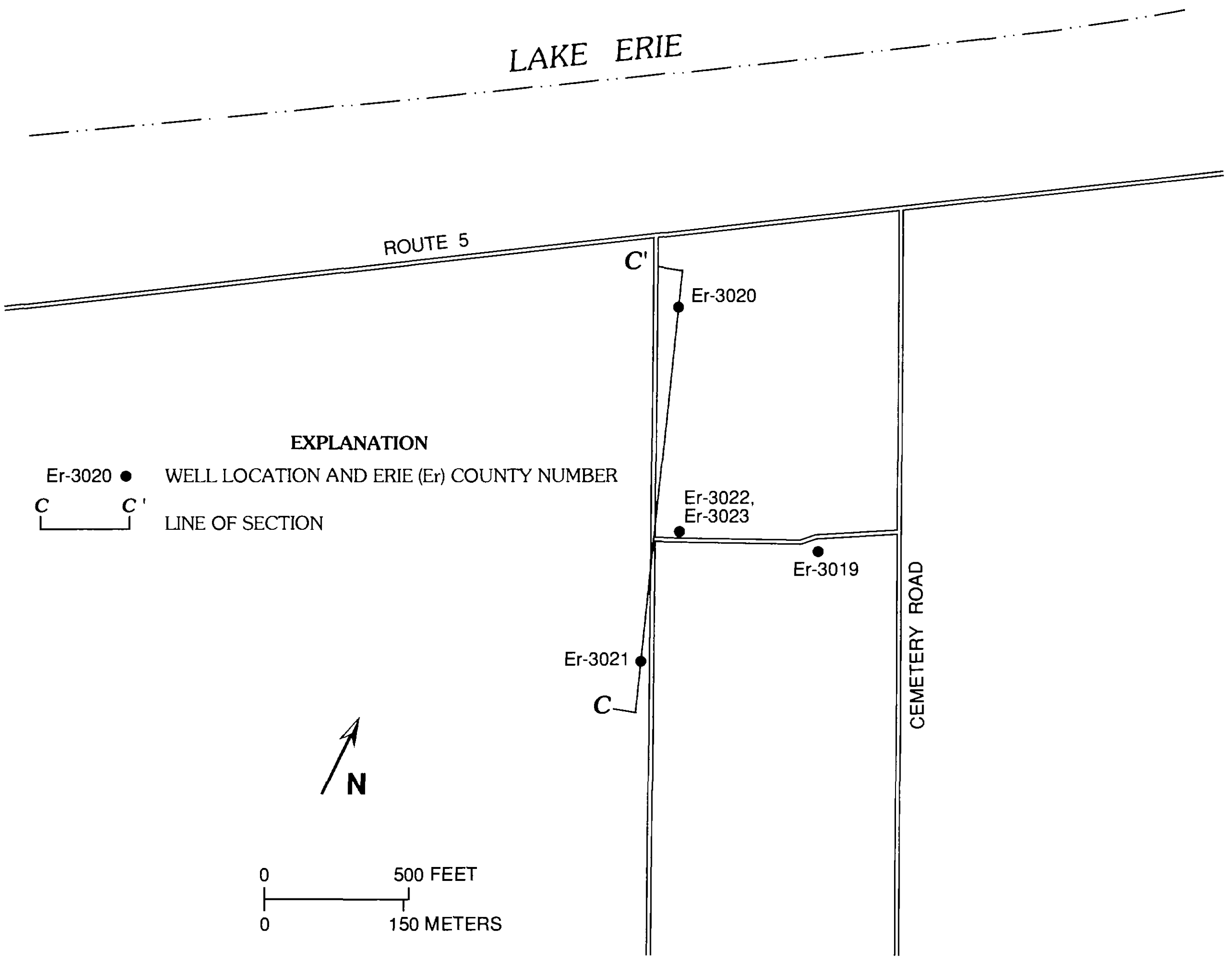


**Figure 29.** Aquifer test site 4, Erie County, Pennsylvania (geologic section shown in figure 30).

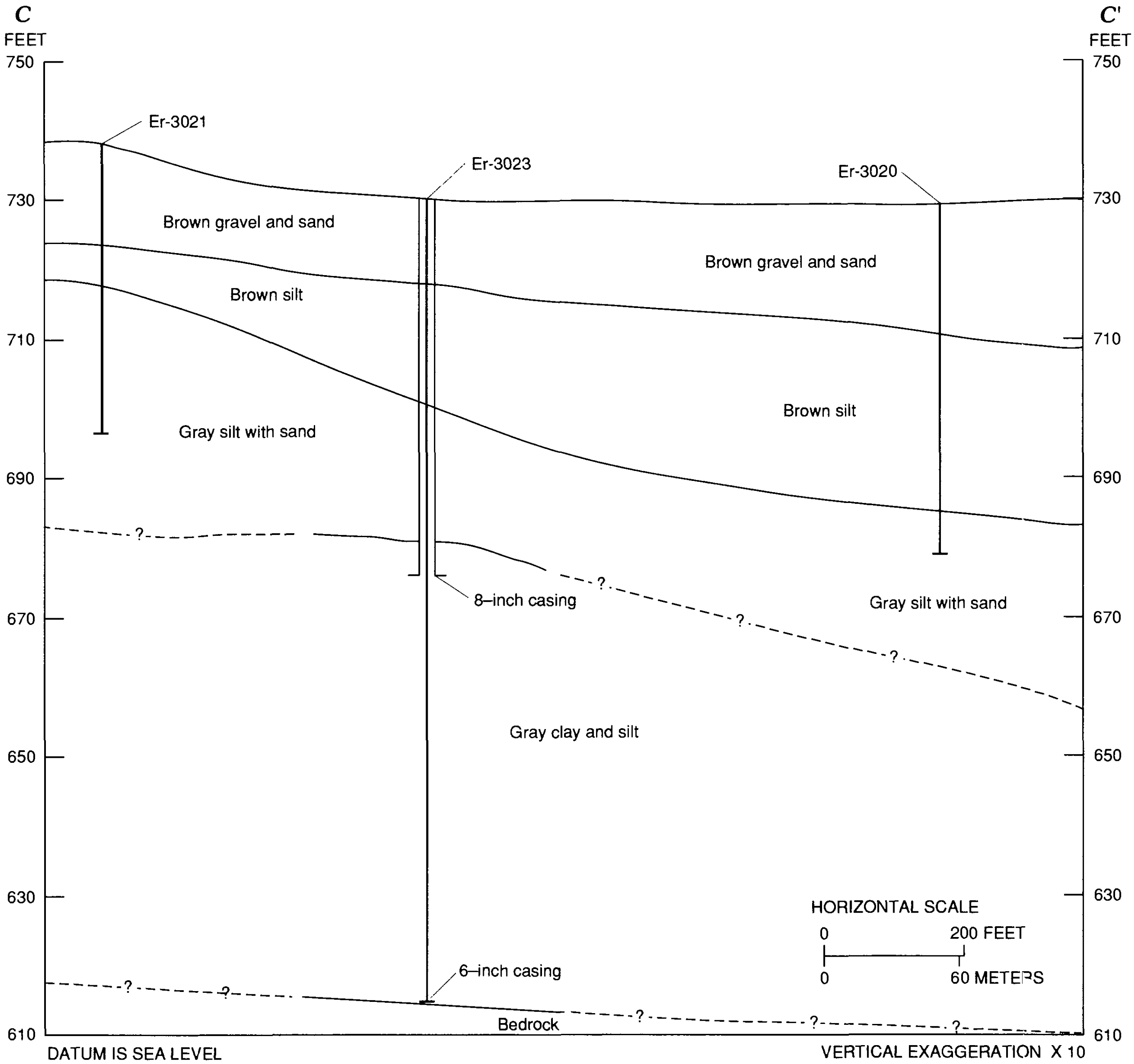


**Figure 30.** Generalized geologic section at aquifer test site 4, Erie County, Pennsylvania (line of section shown in figure 29).

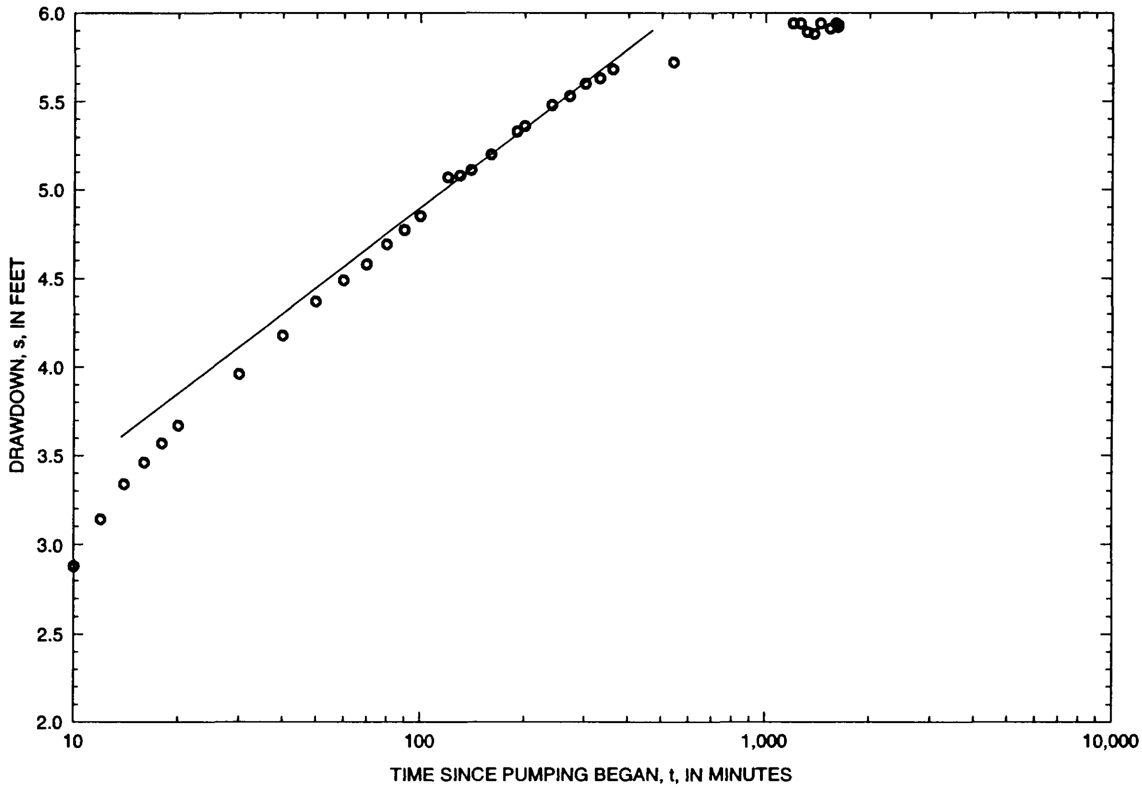


**Figure 31.** Drawdown plot for straight-line method for well Er-3023, Erie County, Pennsylvania.

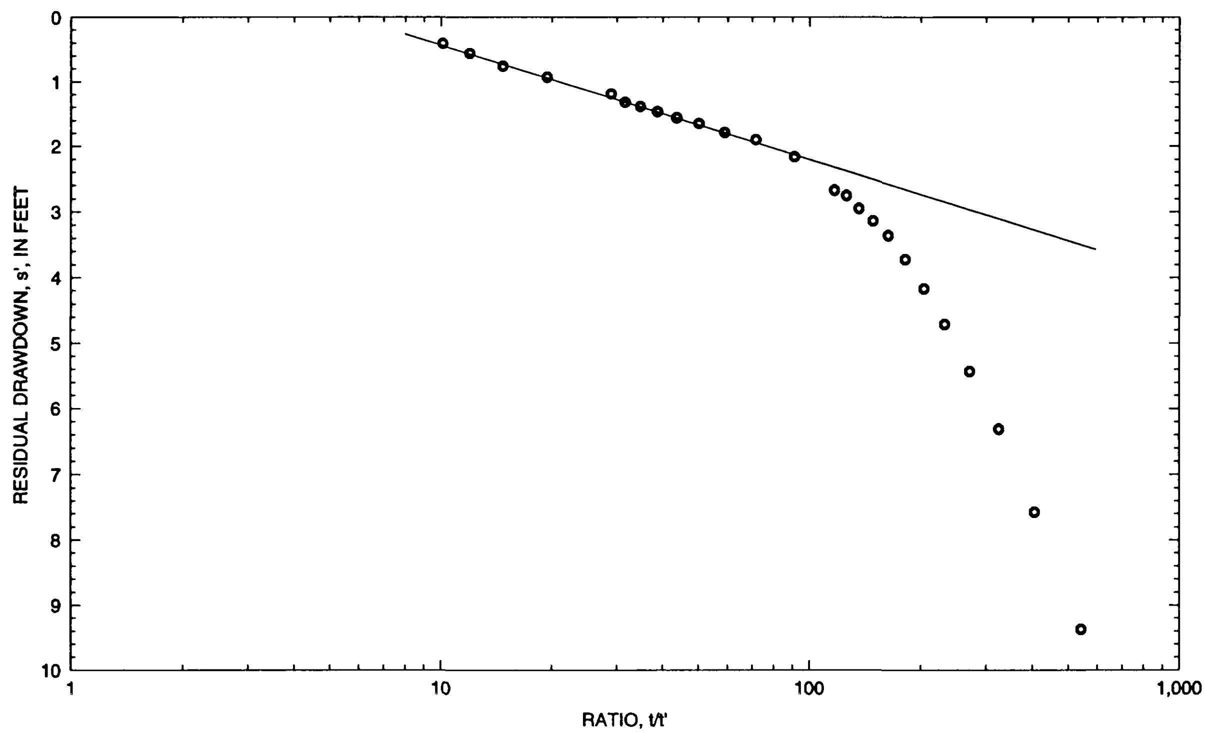


**Figure 32.** Recovery data plot for Theis recovery method for well Er-3022, Erie County, Pennsylvania.

County-wide base-flow samples were collected twice during the summers of 1987–88. The first sampling run was during August 24–26, 1987, at 57 sites. The second sampling run was during July 11–13, 1988, at 42 sites, 23 of which had been sampled on August 24–26, 1987. The sampling sites are listed in table 13. Results of the laboratory analyses are given in table 14, and the locations are shown in figure 33.

The USEPA has established maximum contaminant levels (MCL's)[1] for public drinking-water systems and secondary maximum contaminant levels (SMCL's)[2] for certain constituents, some of which are listed in table 15. Concentrations for arsenic, barium, cadmium, chromium, fluoride, lead, mercury, and selenium did not exceed the MCL in any of the base-flow samples. Concentrations of chloride, copper, sulfate, and zinc (table 14) did not exceed the SMCL in any of the samples.

Total-iron concentrations exceeded the SMCL of 300 μg/L at 15 sites; the dissolved-iron concentrations for those 15 sites were considerably below the SMCL. Concentrations of iron greater than the SMCL in base-flow samples are attributable in part to the natural occurrence of iron in ground water (Richards and others, 1987, p. 49–53).

Concentrations of dissolved manganese exceeded the SMCL of 50 μg/L at 28 of 74 sites. A general trend in dissolved manganese is shown in figure 34; most concentrations of dissolved manganese less than the SMCL are on the Lake Plain and Escarpment Slope and concentrations greater than the SMCL are in the Upland Plateau. The manganese data in figure 34 includes concentrations from 35 sites sampled in 1987, 17 sites sampled in 1988, and the mean concentrations for 22 sites sampled in 1987 and 1988. Sites with concentrations of dissolved manganese greater than the SMCL in 1987 generally were greater than the SMCL in 1988. Similarly, sites with concentrations of dissolved manganese less than the SMCL in 1987 generally were less than the SMCL in 1988. Therefore, comparing the mean concentrations at the 22 sites with the single concentrations at the 52 sites is acceptable. The following statistics were derived from the collected data:

| Physiographic division | Median dissolved manganese concentrations (mg/L) | Number of sites |
|---|---|---|
| Lake Plain | 13 | 21 |
| Escarpment Slope | 21 | 14 |
| Upland Plateau | 68 | 40 |

The higher concentrations of dissolved manganese during base flow in streams of the Upland Plateau when compared to the concentrations in streams of the Lake Plain may be related to the higher manganese concentrations generally found in unconsolidated deposits and lower manganese concentrations observed in the bedrock aquifers. This is documented in data published by Engineering-Science, Inc. (1976), which includes data for Erie County from major unconsolidated aquifers (110 samples) and from major bedrock aquifers (98 samples).

Measurements of pH in July 1988 at site 54 and site 71 were slightly higher (table 14) than the recommended range (6.5 to 8.5) for unknown reasons. Site 54 had been measured within the acceptable range in August 1987. Site 71 was not sampled in 1987.

The dissolved-solids concentration only exceeded the SMCL (500 mg/L) at site 87A (944 mg/L). This high concentration most likely reflects some combination of point or nonpoint-source discharges in this small, urban drainage area (0.3 $mi^2$).

Hardness is a physical-chemical characteristic of water attributable to the presence of cations, primarily calcium and magnesium. These cations tend to form insoluble compounds with soap. Hardness is usually expressed as an equivalent concentration of calcium carbonate ($CaCO_3$). The USEPA has no drinking water limit for hardness. The following classification (Durfor and Becker, 1964, p. 27) is commonly used to define hardness:

| Hardness description | Hardness range (mg/L as $CaCO_3$) |
|---|---|
| Soft | 0–60 |
| Moderately hard | 61–120 |
| Hard | 121–180 |
| Very hard | More than 180 |

Hardness in base flow ranged from 54 to 410 mg/L (table 14). Hardness generally was higher at the Lake Plain sites than at the Upland Plateau sites (fig. 35). Very hard water at stream sites on the Lake Plain is largely a function of very hard water in the beach deposits of the Lake Plain. A median hardness

[1] Maximum contaminant levels (MCL's) are levels of drinking-water contaminants that could cause health effects if exceeded, and are enforceable by law.

[2] Secondary maximum contaminant levels (SMCL's) are levels of drinking-water contaminants that are not health related and are intended to protect public welfare by establishing unenforceable guidelines on the taste, odor, or color of drinking water.

**Table 13.** Station names and drainage areas for base-flow sites in Erie County, Pennsylvania

[mi², square mile]

| Site number | Station number | Location | | Station name | Drainage area (mi²) |
|---|---|---|---|---|---|
| | | Latitude | Longitude | | |
| 1 | 415753080303801 | 41°57'53" | 80°30'38" | Turkey Creek at Pennsylvania-Ohio State line | 7.0 |
| 1A | 415749080293701 | 41°57'49" | 80°29'37" | Turkey Creek near West Springfield, Pa. | 8.0 |
| 2 | 415321080311001 | 41°53'21" | 80°31'10" | Ashtabula Creek at Pennsylvania-Ohio State line | 5.2 |
| 4 | 04213040 | 41°56'42" | 80°26'51" | Raccoon Creek near West Springfield, Pa. | 2.5 |
| 5 | 415505080280601 | 41°55'05" | 80°28'06" | Conneaut Creek at Cherry Hill, Pa. | 148.3 |
| 6 | 420007080255401 | 42°00'07" | 80°25'54" | Crooked Creek at North Springfield, Pa. | 20.0 |
| 7 | 420023080211301 | 42°00'23" | 80°21'13" | Elk Creek at Lake City, Pa. | 95.0 |
| 8 | 420330080162201 | 42°03'30" | 80°16'22" | Trout Run at Avonia, Pa. | 7.0 |
| 9 | 04213075 | 41°59'31" | 80°17'29" | Brandy Run near Girard, Pa. | 4.4 |
| 10 | 415851080184701 | 41°58'51" | 80°18'47" | Halls Run near Girard, Pa. | 5.2 |
| 11 | 415738080171001 | 41°57'38" | 80°17'10" | Little Elk Creek near Platea, Pa. | 17.4 |
| 12 | 415338080221301 | 41°53'38" | 80°22'13" | East Branch Conneaut Creek at Albion, Pa. | 20.1 |
| 13 | 415342080204701 | 41°53'42" | 80°20'47" | Temple Creek at Lundys Lane, Pa. | 18.8 |
| 14 | 415212080243201 | 41°52'12" | 80°24'32" | West Branch Conneaut Creek near Pennside, Pa. | 33.0 |
| 15 | 415104080245701 | 41°51'04" | 80°24'57" | Conneaut Creek at Pennside, Pa. | 65.3 |
| 16 | 420427080140701 | 42°04'27" | 80°14'07" | Walnut Creek near mouth | 37.7 |
| 17 | 420321080084201 | 42°03'21" | 80°08'42" | Walnut Creek near Kearsarge, Pa. | 23.7 |
| 18 | 415949080095501 | 41°59'49" | 80°09'55" | Elk Creek at Middleboro, Pa. | 21.1 |
| 19 | 415948080090301 | 41°59'48" | 80°09'03" | Lamson Run at Middleboro, Pa. | 9.6 |
| 20 | 415126080131201 | 41°51'26" | 80°13'12" | Cussewago Creek near Lavery, Pa. | 10.0 |
| 21 | 420708080065201 | 42°07'08" | 80°06'52" | West Branch Cascade Creek at Erie, Pa. | 7.0 |
| 22 | 420552080043401 | 42°05'52" | 80°04'34" | Mill Creek above tunnel at Erie, Pa. | 8.7 |
| 23 | 420021080051301 | 42°00'21" | 80°05'13" | Elk Creek above Lamson Run near Middleboro, Pa. | 10.0 |
| 24 | 420930080013201 | 42°09'30" | 80°01'32" | Fourmile Creek at mouth | 12.0 |
| 25 | 415122080070001 | 41°51'22" | 80°07'00" | Conneauttee Creek at Edinboro, Pa. | 25.0 |
| 26 | 415150080032601 | 41°51'50" | 80°03'26" | Little Conneauttee Creek near Edinboro, Pa. | 19.7 |
| 27 | 421028079591101 | 42°10'28" | 79°59'11" | Sixmile Creek near mouth | 18.5 |
| 28 | 421049079582101 | 42°10'49" | 79°58'21" | Sevenmile Creek near mouth | 8.3 |
| 30 | 421229079545301 | 42°12'29" | 79°54'53" | Twelvemile Creek near mouth | 12.9 |
| 31 | 421423079495201 | 42°14'25" | 79°49'52" | Sixteenmile Creek near mouth | 18.8 |
| 32 | 421423079495202 | 42°15'05" | 79°47'55" | Unnamed tributary near North East, Pa. | 4.1 |
| 33 | 421538079464401 | 42°15'38" | 79°46'44" | Twentymile Creek near mouth | 34.6 |
| 34 | 421032079491101 | 42°10'32" | 79°49'11" | Sixteenmile Creek below Smith Reservoir | 3.0 |
| 35 | 421128079474501 | 42°11'28" | 79°47'45" | Sixteenmile Creek below Grahamville Reservoir | 1.6 |
| 36 | 420822079454501 | 42°08'22" | 79°45'45" | West Branch French Creek below Howard Eaton Reservoir | 1.5 |
| 37 | 03021410 | 42°04'54" | 79°51'02" | West Branch French Creek near Hornby, Pa. | 52.3 |
| 38 | 420537079510501 | 42°05'37" | 79°51'05" | Townley Run near Hornby, Pa. | 4.4 |
| 39 | 420337079515001 | 42°03'37" | 79°51'50" | Alder Brook near Phillipsville, Pa. | 5.0 |
| 40 | 420214079492101 | 42°02'14" | 79°49'21" | Bailey Brook at Lowville, Pa. | 4.4 |
| 41 | 03021350 | 42°00'55" | 79°46'58" | French Creek near Wattsburg, Pa. | 92.0 |
| 42 | 420108079460401 | 42°01'08" | 79°46'04" | Unnamed tributary near Wattsburg, Pa. | 4.1 |
| 43 | 420115079582601 | 42°01'15" | 79°58'26" | East Branch LeBoeuf Creek near Hammet, Pa. | 20.3 |
| 47 | 420229080004301 | 42°02'29" | 80°00'43" | Walnut Creek near Hammet, Pa. | 1.3 |

**Table 13.** Station names and drainage areas for base-flow sites in Erie County, Pennsylvania--Continued

| Site number | Station number | Location | | Station name | Drainage area (mi²) |
|---|---|---|---|---|---|
| | | Latitude | Longitude | | |
| 48 | 415652079580201 | 41°56'52" | 79°58'02" | LeBoeuf Creek at Waterford, Pa. | 47.7 |
| 49 | 03021520 | 41°55'01" | 79°54'05" | French Creek near Union City, Pa. | 221.0 |
| 50 | 415255079595801 | 41°52'55" | 79°59'58" | French Creek near Mill Village, Pa. | 370.0 |
| 51 | 415628079592701 | 41°56'28" | 79°59'27" | Trout Run at Waterford, Pa. | 7.1 |
| 52 | 415336079560601 | 41°53'36" | 79°56'06" | Unnamed tributary near Mill Village, Pa. | 7.5 |
| 54 | 415442079485601 | 41°54'42" | 79°48'56" | Benley Run below Union City Reservoir | 2.3 |
| 55 | 415350079500701 | 41°53'50" | 79°50'07" | South Branch French Creek at Union City, Pa. | 75.0 |
| 56 | 415255079465201 | 41°52'55" | 79°46'52" | Hungry Run near Union City, Pa. | 4.2 |
| 57 | 415340079441401 | 41°53'40" | 79°44'14" | Beaver Run at Elgin, Pa. | 5.9 |
| 58 | 415413079431201 | 41°54'13" | 79°43'12" | Slaughter Run near Elgin, Pa. | 5.9 |
| 59 | 415458079393501 | 41°54'58" | 79°39'35" | South Branch French Creek at Corry, Pa. | 7.2 |
| 60 | 415750079395301 | 41°57'50" | 79°39'53" | Hare Creek near Corry, Pa. | 7.3 |
| 61 | 415533079370001 | 41°55'33" | 79°37'00" | Hare Creek at Corry, Pa. | 19.3 |
| 62 | 415955079372101 | 41°59'55" | 79°37'21" | Brokenstraw Creek at New York-Pennsylvania State line | 40.8 |
| 62A | 415500079363601 | 41°55'00" | 79°36'36" | Unnamed tributary at Corry, Pa. | 3.9 |
| 63 | 03021700 | 41°55'53" | 80°05'02" | Little Conneauttee Creek near McLane, Pa. | 3.6 |
| 64 | 420112079500101 | 42°01'12" | 79°50'01" | Unnamed tributary at Lowville, Pa. | .1 |
| 65 | 415319079495001 | 41°53'19" | 79°49'50" | Unnamed tributary near Union City, Pa. | .6 |
| 66 | 415800079505901 | 41°58'00" | 79°50'59" | Alder Run near Arbuckle, Pa. | 6.6 |
| 71 | 420838079582001 | 42°08'38" | 79°58'20" | Sixmile Creek near Harborcreek, Pa. | 14.9 |
| 72 | 420932079584401 | 42°09'32" | 79°58'44" | Sixmile Creek at Harborcreek, Pa. | 17.2 |
| 73 | 415826079591001 | 42°10'58" | 79°59'10" | LeBoeuf Creek near Waterford, Pa. | 39.8 |
| 75 | 420603079543601 | 42°06'03" | 79°54'36" | Sixmile Creek near Hornby, Pa. | 3.5 |
| 76 | 415422080211201 | 41°54'22" | 80°21'12" | East Branch Conneaut Creek at Cranesville, Pa. | 3.9 |
| 77 | 415642080220501 | 41°56'42" | 80°22'05" | Crooked Creek near Platea, Pa. | 4.4 |
| 79 | 420150080163501 | 42°01'50" | 80°16'35" | Trout Run at Fairview, Pa. | 2.7 |
| 80 | 415817080275501 | 41°58'17" | 80°27'55" | Raccoon Creek near North Springfield, Pa., | 7.1 |
| 81 | 420217080112001 | 42°02'17" | 80°11'20" | Bear Run near Swanville, Pa. | .8 |
| 82 | 420210080094301 | 42°02'10" | 80°09'43" | Unnamed tributary near Swanville, Pa. | 2.0 |
| 83 | 420455080121001 | 42°04'55" | 80°12'10" | Unnamed tributary at Swanville, Pa. | .5 |
| 85 | 420642080065201 | 42°06'42" | 80°06'52" | Unnamed tributary at Erie, Pa. | 3.1 |
| 86A | 420406080022201 | 42°04'06" | 80°02'22" | Walnut Creek near Kearsarge, Pa. | 7.0 |
| 87A | 420913080022801 | 42°09'13" | 80°02'28" | Unnamed tributary near Wesleyville, Pa. | .3 |

**Table 14.** Water-quality analyses for base-flow sites sampled in August 1987 and July 1988, in Erie County, Pennsylvania

[80020, U.S. Geological Survey, National Water-Quality Laboratory, Denver, Colorado; 1028, U.S. Geological Survey; $ft^3/s$, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data; <, less than]

| Site number | Station name | Date | Time | Agency analyzing sample (code number) | Streamflow, instantaneous ($ft^3/s$) | Specific conductance (µS/cm) | pH (standard units) |
|---|---|---|---|---|---|---|---|
| 1 | Turkey Creek at Pennsylvania-Ohio State line | 08-25-87 | 1430 | 80020 | 0.11 | 650 | 8.1 |
| 1A | Turkey Creek near West Springfield, Pa. | 07-11-88 | 1730 | 80020 | .13 | 815 | 7.0 |
| 2 | Ashtabula Creek at Pennsylvania-Ohio State line | 08-25-87 | 1115 | 80020 | .01 | 275 | 8.0 |
| 4 | Raccoon Creek near West Springfield, Pa. | 08-25-87 | 1300 | 80020 | .04 | 850 | 7.7 |
| 5 | Conneaut Creek at Cherry Hill, Pa. | 08-25-87 | 1030 | 80020 | 19 | 360 | 7.9 |
| 6 | Crooked Creek at North Springfield, Pa. | 08-25-87 | 1500 | 80020 | 3.5 | 415 | 8.2 |
| | | 07-12-88 | 0925 | 80020 | 3.1 | 420 | 8.0 |
| 7 | Elk Creek at Lake City, Pa. | 08-25-87 | 1600 | 80020 | 6.7 | 475 | 8.5 |
| | | 07-12-88 | 1135 | 80020 | 5.1 | 600 | 8.2 |
| 8 | Trout Run at Avonia, Pa. | 08-25-87 | 1900 | 80020 | 2.8 | 530 | 8.1 |
| | | 07-12-88 | 1450 | 80020 | 2.9 | 560 | 8.1 |
| 9 | Brandy Run near Girard, Pa. | 08-25-87 | 1700 | 80020 | .79 | 475 | 7.8 |
| | | 07-12-88 | 1245 | 80020 | .79 | 475 | 7.8 |
| 10 | Halls Run near Girard, Pa. | 08-25-87 | 1730 | 80020 | .38 | 540 | 8.4 |
| | | 07-12-88 | 1055 | 80020 | .38 | 540 | 8.0 |
| 11 | Little Elk Creek near Platea, Pa. | 08-25-87 | 1800 | 80020 | .19 | 285 | 8.2 |
| | | 07-12-88 | 1030 | 80020 | .17 | 345 | 8.3 |
| 12 | East Branch Conneaut Creek at Albion, Pa. | 08-25-87 | 0840 | 80020 | .99 | 355 | 7.9 |
| 13 | Temple Creek at Lundys Lane, Pa. | 08-25-87 | 0815 | 80020 | .30 | 295 | 7.9 |
| | | 07-11-88 | 1500 | 80020 | .02 | 375 | 7.7 |
| 14 | West Branch Conneaut Creek near Pennside, Pa. | 08-25-87 | 0920 | 80020 | .26 | 152 | 8.1 |
| 15 | Conneaut Creek at Pennside, Pa. | 08-25-87 | 0940 | 80020 | 11 | 325 | 7.8 |
| 16 | Walnut Creek near mouth | 08-25-87 | 1930 | 80020 | 5.5 | 460 | 7.9 |
| | | 07-12-88 | 1810 | 80020 | 5.5 | 510 | 8.0 |
| 17 | Walnut Creek near Kearsarge, Pa. | 08-24-87 | 2010 | 80020 | 1.1 | 525 | 7.5 |
| 18 | Elk Creek at Middleboro, Pa. | 08-24-87 | 1645 | 80020 | .34 | 375 | 8.4 |
| 19 | Lamson Run at Middleboro, Pa. | 08-24-87 | 1430 | 80020 | .74 | 340 | 8.4 |
| | | 07-12-88 | 1930 | 80020 | .49 | 380 | 7.6 |
| 20 | Cussewago Creek near Lavery, Pa. | 08-25-87 | 0750 | 80020 | .12 | 295 | 7.7 |
| 21 | West Branch Cascade Creek at Erie, Pa. | 08-25-87 | 0700 | 80020 | 8.9 | 380 | -- |
| | | 07-12-88 | 1655 | 80020 | 3.9 | 600 | 8.1 |
| 22 | Mill Creek above tunnel at Erie, Pa. | 08-24-87 | 1930 | 80020 | 2.4 | 440 | 7.9 |
| | | 07-11-88 | 1020 | 80020 | 2.5 | 480 | 7.9 |
| 23 | Elk Creek above Lamson Run near Middleboro, Pa. | 08-24-87 | 1815 | 80020 | .49 | 365 | 8.4 |
| 24 | Fourmile Creek at mouth | 08-25-87 | 0830 | 80020 | 1.0 | 480 | -- |
| | | 07-12-88 | 0815 | 1028 | .84 | 610 | 7.7 |
| 25 | Conneauttee Creek at Edinboro, Pa. | 08-25-87 | 0730 | 80020 | 5.2 | 500 | 6.1 |
| 26 | Little Conneauttee Creek near Edinboro, Pa. | 08-25-87 | 0815 | 80020 | 1.9 | 340 | 7.5 |
| 27 | Sixmile Creek near mouth | 08-25-87 | 0915 | 80020 | 1.2 | 340 | -- |
| | | 07-12-88 | 0920 | 1028 | 1.2 | 395 | 8.1 |
| 28 | Sevenmile Creek near mouth | 08-25-87 | 1000 | 80020 | .20 | 420 | -- |
| 30 | Twelvemile Creek near mouth | 08-25-87 | 1100 | 80020 | 1.5 | 380 | -- |
| | | 07-12-88 | 1030 | 1028 | 1.2 | 420 | 8.1 |
| 31 | Sixteenmile Creek near mouth | 08-25-87 | 1145 | 80020 | 7.0 | 540 | -- |
| | | 07-11-88 | 1305 | 1028 | 5.6 | 620 | 7.5 |

**Table 14.** Water-quality analyses for base-flow sites sampled in August 1987 and July 1988, in Erie County, Pennsylvania --Continued

| Site number | Station name | Date | Time | Agency analyzing sample (code number) | Streamflow, instantaneous ($ft^3/s$) | Specific conductance (µS/cm) | pH (standard units) |
|---|---|---|---|---|---|---|---|
| 32 | Unnamed tributary near North East, Pa. | 08-25-87 | 1230 | 80020 | 0.86 | 525 | -- |
| 33 | Twentymile Creek near mouth | 08-25-87 | 1315 | 80020 | 3.7 | 355 | -- |
| | | 07-12-88 | 1150 | 1028 | 2.4 | 365 | 8.2 |
| 34 | Sixteenmile Creek below Smith Reservoir | 08-25-87 | 1450 | 80020 | .01 | 345 | -- |
| 35 | Sixteenmile Creek below Grahamville Reservoir | 08-25-87 | 1545 | 80020 | .10 | 310 | -- |
| 36 | West Branch French Creek below Howard Eaton Reservoir | 08-25-87 | 1655 | 80020 | .08 | 200 | -- |
| 37 | West Branch French Creek near Hornby, Pa. | 08-25-87 | 1815 | 80020 | -- | 260 | -- |
| 38 | Townley Run near Hornby, Pa. | 08-25-87 | 1745 | 80020 | .16 | 210 | -- |
| | | 07-11-88 | 1605 | 1028 | .12 | 210 | 7.1 |
| 39 | Alder Brook near Phillipsville, Pa. | 08-25-87 | 1850 | 80020 | .43 | 310 | -- |
| 40 | Bailey Brook at Lowville, Pa. | 08-26-87 | 0830 | 80020 | .01 | 255 | -- |
| 41 | French Creek near Wattsburg, Pa. | 08-26-87 | 0900 | 80020 | 11 | 290 | -- |
| 42 | Unnamed tributary near Wattsburg, Pa. | 08-26-87 | 0915 | 80020 | .23 | 250 | -- |
| 43 | East Branch LeBoeuf Creek near Hammet, Pa. | 08-24-87 | 1745 | 80020 | 2.9 | 260 | 8.2 |
| 47 | Walnut Creek near Hammet, Pa. | 08-24-87 | 1545 | 80020 | .01 | 305 | -- |
| 48 | LeBoeuf Creek at Waterford, Pa. | 08-25-87 | 1310 | 80020 | 6.2 | 260 | 7.0 |
| 49 | French Creek near Union City, Pa. | 08-25-87 | 1000 | 80020 | 48 | 300 | 7.1 |
| 50 | French Creek near Mill Village, Pa. | 08-25-87 | 0730 | 80020 | 98 | 320 | 7.3 |
| 51 | Trout Run at Waterford, Pa. | 08-25-87 | 1130 | 80020 | 1.7 | 480 | 7.1 |
| | | 07-11-88 | 1150 | 1028 | 1.6 | 451 | 7.6 |
| 52 | Unnamed tributary near Mill Village, Pa. | 08-25-87 | 0850 | 80020 | .34 | 360 | 7.0 |
| 54 | Benley Run below Union City Reservoir | 08-26-87 | 0800 | 80020 | .17 | 235 | 7.1 |
| | | 07-12-88 | 1815 | 1028 | .07 | 195 | 8.9 |
| 55 | South Branch French Creek at Union City, Pa. | 08-25-87 | 0945 | 80020 | 18 | 300 | 7.9 |
| 56 | Hungry Run near Union City, Pa. | 08-25-87 | 1100 | 80020 | .01 | 280 | 7.2 |
| | | 07-12-88 | 1910 | 1028 | .07 | 280 | 7.6 |
| 57 | Beaver Run at Elgin, Pa. | 08-26-87 | 0845 | 80020 | 3.5 | 345 | 6.8 |
| | | 07-12-88 | 1630 | 1028 | 3.8 | 360 | 8.1 |
| 58 | Slaughter Run near Elgin, Pa. | 08-26-87 | 0915 | 80020 | .55 | 265 | 7.0 |
| | | 07-12-88 | 1550 | 1028 | .36 | 305 | 7.7 |
| 59 | South Branch French Creek at Corry, Pa. | 08-26-87 | 1100 | 80020 | .48 | 275 | 7.2 |
| 60 | Hare Creek near Corry, Pa. | 08-25-87 | 1230 | 80020 | 1.3 | 200 | 6.5 |
| 61 | Hare Creek at Corry, Pa. | 08-26-87 | 1030 | 80020 | 5.8 | 500 | 7.2 |
| | | 07-12-88 | 1400 | 1028 | 5.1 | 555 | 7.4 |
| 62 | Brokenstraw Creek at New York-Pennsylvania State line | 08-25-87 | 1345 | 80020 | 12 | 235 | 7.6 |
| 62A | Unnamed tributary at Corry, Pa. | 07-12-88 | 1500 | 1028 | .06 | 360 | 7.0 |
| 63 | Little Conneauttee Creek near McLane, Pa. | 08-25-87 | 0700 | 80020 | .18 | 265 | 7.7 |
| 64 | Unnamed tributary at Lowville, Pa. | 07-11-88 | 1545 | 1028 | .01 | 220 | 7.6 |
| 65 | Unnamed tributary near Union City, Pa. | 07-13-88 | 1100 | 1028 | .01 | 380 | 7.3 |
| 66 | Alder Run near Arbuckle, Pa. | 07-13-88 | 1000 | 1028 | 1.0 | 320 | 8.1 |
| 71 | Sixmile Creek near Harborcreek, Pa. | 07-11-88 | 1745 | 1028 | 1.0 | 315 | 8.7 |
| 72 | Sixmile Creek at Harborcreek, Pa. | 07-11-88 | 1845 | 1028 | 1.6 | 360 | 8.4 |
| 73 | LeBoeuf Creek near Waterford, Pa. | 07-11-88 | 1415 | 1028 | -- | 410 | 7.7 |
| 75 | Sixmile Creek near Hornby, Pa. | 07-11-88 | 1645 | 1028 | .26 | 350 | 8.1 |
| 76 | East Branch Conneaut Creek at Cranesville, Pa. | 07-11-88 | 1530 | 80020 | .43 | 385 | 7.2 |

**Table 14.** Water-quality analyses for base-flow sites sampled in August 1987 and July 1988, in Erie County, Pennsylvania --Continued

| Site number | Station name | Date | Time | Agency analyzing sample (code number) | Stream-flow, instantaneous ($ft^3/s$) | Specific conductance (µS/cm) | pH (standard units) |
|---|---|---|---|---|---|---|---|
| 77 | Crooked Creek near Platea, Pa. | 07-12-88 | 0955 | 80020 | 0.32 | 355 | 7.7 |
| 79 | Trout Run at Fairview, Pa. | 07-12-88 | 1320 | 80020 | .49 | 570 | 7.5 |
| 80 | Raccoon Creek near North Springfield, Pa. | 07-11-88 | 1655 | 1028 | .35 | 500 | 7.6 |
| 81 | Bear Run near Swanville, Pa. | 07-12-88 | 1840 | 1028 | .07 | 545 | 8.1 |
| 82 | Unnamed tributary near Swanville, Pa. | 07-12-88 | 1900 | 80020 | .45 | 440 | 8.2 |
| 83 | Unnamed tributary at Swanville, Pa. | 07-12-88 | 1730 | 80020 | 1.1 | 790 | 8.2 |
| 85 | Unnamed tributary at Erie, Pa. | 07-12-88 | 0820 | 80020 | 1.6 | 515 | 8.0 |
| 86A | Walnut Creek near Kearsarge, Pa. | 07-11-88 | 1120 | 80020 | .04 | 750 | 7.7 |
| 87A | Unnamed tributary near Wesleyville, Pa. | 07-11-88 | 1205 | 80020 | .06 | 1,590 | 7.9 |

| Site number | Temperature, water (°C) | Hardness, total (mg/L as $CaCO_3$) | Calcium, dissolved (mg/L as Ca) | Magnesium, dissolved (mg/L as Mg) | Sodium, dissolved (mg/L as Na) | Potassium dissolved (mg/L as K) | Alkalinity, lab (mg/L as $CaCO_3$) | Sulfate, dissolved (mg/L as $SO_4$) | Chloride, dissolved (mg/L as Cl) | Fluoride, dissolved (mg/L as F) | Silica, dissolved (mg/L as $SiO_2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 17.0 | 170 | 53 | 9.3 | 61 | 4.5 | 129 | 44 | 88 | 0.10 | 7.6 |
| 1A | 22.5 | 200 | 62 | 11 | 74 | 2.2 | 126 | 55 | 130 | .10 | 7.1 |
| 2 | 17.0 | 120 | 34 | 7.7 | 14 | 4.4 | 101 | 21 | 17 | .20 | 10 |
| 4 | 15.0 | 210 | 64 | 12 | 88 | 2.3 | 163 | 41 | 130 | .20 | 6.6 |
| 5 | 18.5 | 160 | 47 | 10 | 13 | 2.9 | 116 | 36 | 20 | .10 | 2.9 |
| 6 | 18.0 | 190 | 57 | 11 | 14 | 2.4 | 120 | 53 | 22 | .10 | 5.3 |
| | 20.0 | 190 | 57 | 11 | 13 | 2.3 | 118 | 52 | 21 | .10 | 7.5 |
| 7 | 21.0 | 190 | 56 | 11 | 24 | 2.9 | 117 | 57 | 40 | .10 | 3.1 |
| | 23.5 | 210 | 62 | 13 | 42 | 1.4 | 137 | 67 | 62 | .10 | 4.0 |
| 8 | 18.0 | 220 | 67 | 13 | 25 | 2.8 | 160 | 50 | 37 | .20 | 8.1 |
| | 21.5 | 230 | 67 | 14 | 26 | 2.7 | 155 | 50 | 37 | .20 | 8.6 |
| 9 | 19.0 | 210 | 66 | 12 | 17 | 1.8 | 145 | 53 | 26 | .10 | 8.1 |
| | 19.0 | 220 | 66 | 13 | 15 | 1.6 | 157 | 52 | 21 | .10 | 8.2 |
| 10 | 21.5 | 230 | 68 | 14 | 25 | 2.7 | 134 | 68 | 35 | .20 | 5.5 |
| | 23.5 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 11 | 18.0 | 110 | 31 | 7.0 | 12 | 2.4 | 60 | 47 | 18 | .10 | 1.8 |
| | 21.5 | 130 | 36 | 8.6 | 15 | 2.8 | 77 | 51 | 18 | .20 | 3.1 |
| 12 | 17.0 | 150 | 45 | 9.3 | 15 | 2.9 | 99 | 42 | 25 | .10 | 4.0 |
| 13 | 15.5 | 120 | 34 | 7.6 | 15 | 2.4 | 90 | 25 | 24 | .10 | 3.4 |
| | 22.0 | 130 | 39 | 9.0 | 17 | 4.9 | 96 | 33 | 27 | .10 | 4.4 |
| 14 | 15.5 | 54 | 15 | 3.9 | 4.8 | 2.7 | 33 | 20 | 8.7 | .10 | 1.9 |
| 15 | 17.0 | 150 | 44 | 8.9 | 9.0 | 3.5 | 102 | 32 | 17 | .10 | 5.8 |
| 16 | 20.0 | 180 | 51 | 13 | 27 | 2.5 | 116 | 52 | 44 | .10 | 4.2 |
| | 25.0 | 190 | 54 | 14 | 27 | 2.5 | 119 | 55 | 49 | .20 | 5.8 |
| 17 | 19.5 | 180 | 52 | 11 | 39 | 3.0 | 113 | 39 | 76 | .10 | 2.3 |
| 18 | 19.0 | 170 | 48 | 11 | 21 | 3.0 | 118 | 30 | 41 | .10 | 1.4 |
| 19 | 23.0 | 170 | 48 | 11 | 13 | 2.5 | 132 | 27 | 21 | .10 | 2.4 |
| | 25.5 | 150 | 43 | 11 | 15 | 2.0 | 126 | 30 | 22 | .10 | 3.6 |
| 20 | 15.5 | 130 | 38 | 7.5 | 12 | 2.9 | 99 | 21 | 18 | .10 | 2.9 |
| 21 | 21.5 | 180 | 53 | 11 | 19 | 2.1 | 111 | 44 | 32 | .20 | 3.9 |
| | 22.0 | 230 | 69 | 14 | 34 | 2.6 | 150 | 55 | 60 | .10 | 5.9 |

**Table 14.** Water-quality analyses for base-flow sites sampled in August 1987 and July 1988, in Erie County, Pennsylvania --Continued

| Site number | Temperature, water (°C) | Hardness, total (mg/L as $CaCO_3$) | Calcium, dissolved (mg/L as Ca) | Magnesium, dissolved (mg/L as Mg) | Sodium, dissolved (mg/L as Na) | Potassium dissolved (mg/L as K) | Alkalinity, lab (mg/L as $CaCO_3$) | Sulfate, dissolved (mg/L as $SO_4$) | Chloride, dissolved (mg/L as Cl) | Fluoride, dissolved (mg/L as F) | Silica, dissolved (mg/L as $SiO_2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 19.0 | 170 | 50 | 11 | 24 | 2.2 | 118 | 41 | 42 | 0.10 | 2.6 |
| | 20.5 | 190 | 56 | 12 | 27 | 2.7 | 128 | 40 | 46 | .10 | 3.5 |
| 23 | 18.0 | 150 | 46 | 7.8 | 9.3 | 2.0 | 123 | 16 | 15 | .10 | 4.8 |
| 24 | 15.0 | 190 | 56 | 12 | 33 | 3.5 | 96 | 84 | 51 | .20 | .1 |
| | -- | 190 | 56 | 12 | 37 | 3.9 | -- | 110 | 55 | -- | 1.9 |
| 25 | -- | 210 | 63 | 12 | 22 | 3.2 | 157 | 24 | 33 | .10 | 7.0 |
| 26 | 12.5 | 160 | 49 | 9.2 | 11 | 2.0 | 113 | 24 | 32 | .20 | 3.1 |
| 27 | 15.0 | 150 | 44 | 9.1 | 17 | 2.5 | 101 | 46 | 25 | .10 | .4 |
| | 22.0 | 130 | 40 | 7.8 | 13 | 2.5 | -- | 50 | 29 | -- | 1.7 |
| 28 | 14.5 | 150 | 45 | 8.9 | 32 | 2.8 | 91 | 45 | 56 | .10 | 3.2 |
| 30 | 15.5 | 160 | 50 | 8.9 | 17 | 2.3 | 85 | 57 | 35 | .10 | 7.1 |
| | 21.5 | 130 | 42 | 7.2 | 13 | 2.4 | -- | 53 | 32 | -- | 8.4 |
| 31 | 19.0 | 230 | 75 | 9.2 | 31 | 7.1 | 146 | 51 | 55 | .40 | 4.9 |
| | 24.5 | 250 | 84 | 9.0 | 32 | 11 | -- | 49 | 42 | -- | 6.5 |
| 32 | 15.0 | 220 | 71 | 11 | 30 | 2.6 | 156 | 49 | 50 | .10 | 7.0 |
| 33 | 21.5 | 150 | 46 | 8.3 | 10 | 2.0 | 100 | 53 | 13 | .10 | 2.1 |
| | 22.0 | 140 | 42 | 7.3 | 9.4 | 2.1 | -- | 54 | 16 | -- | 3.9 |
| 34 | 17.5 | 120 | 35 | 6.7 | 26 | 3.2 | 71 | 38 | 45 | .10 | 4.8 |
| 35 | 15.5 | 130 | 41 | 7.7 | 12 | 1.7 | 92 | 26 | 23 | .10 | 5.3 |
| 36 | 15.0 | 110 | 33 | 6.0 | 2.1 | .90 | 100 | 15 | 2.0 | .10 | 7.8 |
| 37 | 20.0 | 130 | 40 | 7.6 | 7.0 | 1.7 | 114 | 11 | 11 | .10 | 2.8 |
| 38 | 17.0 | 100 | 31 | 5.4 | 7.1 | 1.4 | 93 | 10 | 10 | .10 | 5.4 |
| 38 | 23.0 | 85 | 26 | 4.7 | 4.8 | 1.1 | -- | 14 | 6.0 | -- | 5.4 |
| 39 | 17.5 | 160 | 48 | 9.6 | 7.6 | 1.1 | 139 | 14 | 13 | .10 | 5.9 |
| 40 | 15.0 | 120 | 38 | 6.8 | 6.7 | 3.4 | 102 | 15 | 12 | .10 | 2.4 |
| 41 | 15.5 | 150 | 45 | 8.6 | 8.4 | 2.3 | 125 | 16 | 15 | .10 | 2.5 |
| 42 | 14.5 | 130 | 41 | 7.5 | 6.7 | 2.3 | 112 | 13 | 14 | .10 | 1.8 |
| 43 | 21.0 | 110 | 34 | 6.3 | 6.9 | 2.3 | 95 | 15 | 14 | .10 | 2.6 |
| 47 | 16.5 | 110 | 34 | 7.0 | 12 | 3.5 | 80 | 24 | 26 | .10 | 4.9 |
| 48 | 16.0 | 130 | 41 | 7.5 | 7.0 | 1.6 | 116 | 11 | 14 | .10 | 4.5 |
| 49 | 14.5 | 140 | 43 | 8.1 | 7.3 | 1.4 | 124 | 18 | 13 | .10 | 2.7 |
| 50 | 16.0 | 140 | 43 | 8.0 | 8.1 | 1.4 | 118 | 19 | 14 | .10 | 2.9 |
| 51 | 12.5 | 230 | 71 | 12 | 14 | 1.4 | 148 | 26 | 29 | .10 | 7.0 |
| | 20.0 | 210 | 64 | 11 | 14 | 2.1 | -- | 19 | 38 | -- | 6.8 |
| 52 | 13.0 | 170 | 53 | 8.9 | 11 | 1.3 | 126 | 26 | 24 | .10 | 6.2 |
| 54 | 19.0 | 110 | 33 | 6.4 | 3.1 | .80 | 93 | 10 | 7.6 | .10 | 5.0 |
| | 26.5 | 93 | 25 | 7.6 | 4.0 | .78 | -- | 17 | 11 | -- | 2.3 |
| 55 | 14.0 | 130 | 41 | 7.8 | 6.5 | 2.1 | 109 | 18 | 12 | .10 | 4.1 |
| 56 | 15.0 | 120 | 37 | 5.9 | 11 | 3.5 | 92 | 19 | 15 | .10 | 6.3 |
| | 20.5 | 140 | 45 | 6.2 | 3.3 | 1.8 | -- | 11 | 6.0 | -- | 8.9 |
| 57 | 14.0 | 160 | 51 | 9.1 | 7.7 | 1.5 | 136 | 18 | 14 | .10 | 6.0 |
| | 22.0 | 160 | 49 | 9.7 | 6.7 | 1.3 | -- | 19 | 17 | -- | 6.2 |
| 58 | 16.0 | 120 | 37 | 7.0 | 6.6 | 1.9 | 93 | 20 | 11 | .10 | 4.6 |
| | 25.0 | 140 | 42 | 8.2 | 6.3 | 1.9 | -- | 23 | 12 | -- | 3.6 |
| 59 | 14.5 | 110 | 35 | 6.4 | 8.5 | 2.2 | 91 | 18 | 14 | .10 | 4.2 |
| 60 | 14.0 | 85 | 25 | 5.4 | 5.0 | 1.6 | 69 | 13 | 9.0 | .10 | 5.2 |
| 61 | 14.0 | 200 | 60 | 12 | 22 | 3.0 | 165 | 26 | 33 | .10 | 9.1 |
| | 23.0 | 200 | 58 | 13 | 25 | 4.2 | -- | 33 | 42 | -- | 11 |
| 62 | 16.0 | 150 | 47 | 9.1 | 7.0 | 1.7 | 121 | 17 | 15 | .10 | 4.1 |
| 62A | 21.5 | 120 | 37 | 6.1 | 10 | 3.0 | -- | 28 | 18 | -- | 7.0 |
| 63 | 13.5 | 130 | 40 | 7.5 | 4.0 | 2.0 | 115 | 11 | 7.4 | .10 | 5.2 |

**Table 14.** Water-quality analyses for base-flow sites sampled in August 1987 and July 1988, in Erie County, Pennsylvania --Continued

| Site number | Temperature, water (°C) | Hardness, total (mg/L as $CaCO_3$) | Calcium, dissolved (mg/L as Ca) | Magnesium, dissolved (mg/L as Mg) | Sodium, dissolved (mg/L as Na) | Potassium dissolved (mg/L as K) | Alkalinity, lab (mg/L as $CaCO_3$) | Sulfate, dissolved (mg/L as $SO_4$) | Chloride, dissolved (mg/L as Cl) | Fluoride, dissolved (mg/L as F) | Silica, dissolved (mg/L as $SiO_2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 64 | 23.0 | 78 | 24 | 4.6 | 3.7 | 2.0 | -- | 22 | 5.0 | -- | 7.4 |
| 65 | 16.5 | 200 | 60 | 12 | 3.9 | 1.4 | -- | 28 | 9.0 | -- | 8.3 |
| 66 | 21.5 | 170 | 50 | 10 | 4.0 | 1.3 | -- | 20 | 9.0 | -- | 6.2 |
| 71 | 26.0 | 120 | 36 | 7.8 | 12 | 2.0 | -- | 29 | 24 | -- | 2.6 |
| 72 | 25.5 | 130 | 39 | 8.0 | 13 | 2.2 | -- | 39 | 26 | -- | 2.7 |
| 73 | 23.0 | 170 | 51 | 9.3 | 10 | 1.6 | -- | 18 | 25 | -- | 5.9 |
| 75 | 21.0 | 160 | 47 | 9.9 | 5.3 | 1.6 | -- | 23 | 18 | -- | 5.9 |
| 76 | 14.0 | 150 | 44 | 8.7 | 10 | 2.0 | 84 | 53 | 16 | 0.10 | 7.0 |
| 77 | 19.5 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 79 | 21.0 | 190 | 54 | 13 | 44 | 5.1 | 149 | 47 | 46 | .70 | 8.6 |
| 80 | 22.5 | 190 | 58 | 11 | 22 | 2.2 | 137 | 41 | 37 | .10 | 7.1 |
| 81 | 21.0 | 230 | 66 | 16 | 23 | 1.8 | 180 | 42 | 35 | .10 | 9.1 |
| 82 | 18.5 | 190 | 55 | 12 | 17 | 1.1 | 149 | 31 | 25 | .10 | 7.2 |
| 83 | 17.0 | 310 | 96 | 18 | 34 | 2.0 | 152 | 100 | 63 | .10 | 10 |
| 85 | 18.5 | 230 | 69 | 14 | 18 | 2.2 | 148 | 65 | 30 | .20 | 7.0 |
| 86A | 21.5 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 87A | 18.0 | 410 | 110 | 33 | 180 | 18 | 345 | 190 | 170 | 0.20 | 12 |

| Site number | Solids, residue at 180°C dissolved (mg/L) | Solids, residue at 105°C, dissolved (mg/L) | Aluminum, total recoverable (µg/L as Al) | Aluminum, dissolved (µg/L as Al) | Arsenic, total (µg/L) as As) | Arsenic, dissolved (µg/L as As) | Barium, total recoverable (µg/L as Ba) | Barium, dissolved (µg/L as Ba) | Beryllium, total recoverable (µg/L as Be) | Beryllium, dissolved (µg/L as Be) | Boron, dissolved (µg/L as B) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 360 | -- | -- | <10 | -- | 1 | -- | 56 | -- | <0.5 | 50 |
| 1A | 451 | -- | -- | 10 | -- | <1 | -- | 72 | -- | <.5 | -- |
| 2 | 167 | -- | -- | 10 | -- | 1 | -- | 39 | -- | <.5 | 40 |
| 4 | 458 | -- | -- | <10 | -- | 1 | -- | 59 | -- | <.5 | 60 |
| 5 | 208 | -- | -- | 10 | -- | 1 | -- | 47 | -- | <.5 | 50 |
| 6 | 241 | -- | -- | <10 | -- | 1 | -- | 51 | -- | <.5 | 50 |
| | 246 | -- | -- | <10 | -- | <1 | -- | 55 | -- | <.5 | -- |
| 7 | 272 | -- | -- | 10 | -- | 1 | -- | 55 | -- | .5 | 70 |
| | 364 | -- | -- | 10 | -- | 1 | -- | 71 | -- | <.5 | -- |
| 8 | 308 | -- | -- | <10 | -- | 1 | -- | 97 | -- | .5 | 70 |
| | 322 | -- | -- | 20 | -- | 1 | -- | 110 | -- | <.5 | -- |
| 9 | 283 | -- | -- | <10 | -- | 2 | -- | 74 | -- | .5 | 30 |
| | 287 | -- | -- | <10 | -- | <1 | -- | 77 | -- | <.5 | -- |
| 10 | 318 | -- | -- | <10 | -- | 1 | -- | 51 | -- | .5 | 60 |
| | -- | -- | 60 | -- | 1 | -- | <100 | -- | <10 | -- | -- |
| 11 | 163 | -- | -- | <10 | -- | <1 | -- | 47 | -- | .5 | 40 |
| | 195 | -- | -- | <10 | -- | 1 | -- | 61 | -- | <.5 | -- |
| 12 | 211 | -- | -- | <10 | -- | 1 | -- | 50 | -- | <.5 | 60 |
| 13 | 176 | -- | -- | <10 | -- | 1 | -- | 43 | -- | <.5 | 190 |
| | 216 | -- | -- | <10 | -- | 1 | -- | 58 | -- | <.5 | -- |
| 14 | 83 | -- | -- | 20 | -- | 1 | -- | 26 | -- | <.5 | 40 |
| 15 | 193 | -- | -- | 20 | -- | 1 | -- | 50 | -- | <.5 | 30 |
| 16 | 265 | -- | -- | 10 | -- | <1 | -- | 64 | -- | <.5 | 40 |
| | 321 | -- | -- | <10 | -- | <1 | -- | 73 | -- | <.5 | -- |
| 17 | 305 | -- | -- | <10 | -- | 1 | -- | 70 | -- | <.5 | 60 |
| 18 | 233 | -- | -- | 20 | -- | 1 | -- | 57 | -- | <.5 | 50 |

**Table 14.** Water-quality analyses for base-flow sites sampled in August 1987 and July 1988, in Erie County, Pennsylvania --Continued

| Site number | Solids, residue at 180°C dissolved (mg/L) | Solids, residue at 105°C, dissolved (mg/L) | Aluminum, total recoverable (µg/L as Al) | Aluminum, dissolved (µg/L as Al) | Arsenic, total (µg/L) as As) | Arsenic, dissolved (µg/L as As) | Barium, total recoverable (µg/L as Ba) | Barium, dissolved (µg/L as Ba) | Beryllium, total recoverable (µg/L as Be) | Beryllium, dissolved (µg/L as Be) | Boron, dissolved (µg/L as B) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | 201 | – | – | <10 | – | 1 | – | 57 | – | <.5 | 30 |
| | 216 | – | – | 10 | – | 1 | – | 57 | – | <0.5 | – |
| 20 | 175 | – | – | <10 | – | 2 | – | 31 | – | <.5 | 70 |
| 21 | 240 | – | – | 120 | – | <1 | – | 45 | – | <.5 | 50 |
| | 351 | – | – | 60 | – | <1 | – | 70 | – | <.5 | |
| 22 | 250 | – | – | 80 | – | <1 | – | 53 | – | <.5 | 20 |
| | 286 | – | – | 100 | – | <1 | – | 65 | – | – | – |
| 23 | 184 | – | – | 20 | – | 1 | – | 30 | – | <.5 | 30 |
| 24 | 300 | – | – | 10 | – | <1 | – | 59 | – | <.5 | 150 |
| | – | 400 | <130 | <130 | <4 | <4 | 80 | 75 | – | – | – |
| 25 | 282 | – | – | <10 | – | 2 | – | 65 | – | .5 | 50 |
| 26 | 208 | – | – | <10 | – | 1 | – | 50 | – | <.5 | 30 |
| 27 | 215 | – | – | <10 | – | <1 | – | 53 | – | <.5 | 50 |
| | – | 236 | <130 | <130 | <4 | <4 | 60 | 61 | – | – | – |
| 28 | 268 | – | – | <10 | – | <1 | – | 65 | – | <.5 | 50 |
| 30 | 241 | – | – | <10 | – | <1 | – | 70 | – | <.5 | 20 |
| | – | 292 | 40 | <130 | <4 | <4 | 80 | 72 | – | – | – |
| 31 | 347 | – | – | <10 | – | <1 | – | 57 | – | <.5 | 70 |
| | – | 352 | <130 | <130 | <4 | <4 | 60 | 62 | – | – | – |
| 32 | 317 | – | – | 10 | – | <1 | – | 84 | – | <.5 | 20 |
| 33 | 195 | – | – | 20 | – | 1 | – | 42 | – | <.5 | 10 |
| | – | 212 | 140 | <130 | <4 | <4 | 50 | 46 | – | – | – |
| 34 | 213 | – | – | 30 | – | 1 | – | 48 | – | <.5 | 30 |
| 35 | 183 | – | – | <10 | – | 1 | – | 48 | – | <.5 | 90 |
| 36 | 126 | – | – | <10 | – | 1 | – | 22 | – | <.5 | <10 |
| 37 | 156 | – | – | 10 | – | 2 | – | 32 | – | <.5 | 20 |
| 38 | 125 | – | – | <10 | – | 1 | – | 27 | – | <.5 | 30 |
| | – | 124 | 150 | <130 | <4 | <4 | 20 | 24 | – | – | – |
| 39 | 185 | – | – | <10 | – | 2 | – | 51 | – | <.5 | 20 |
| 40 | 151 | – | – | <10 | – | 1 | – | 37 | – | <.5 | 30 |
| 41 | 180 | – | – | <10 | – | 1 | – | 40 | – | <.5 | 30 |
| 42 | 170 | – | – | <10 | – | 1 | – | 29 | – | <.5 | 20 |
| 43 | 142 | – | – | 10 | – | 1 | – | 34 | – | .5 | 30 |
| 47 | 175 | – | – | <10 | – | 2 | – | 42 | – | <.5 | 60 |
| 48 | 162 | – | – | 10 | – | 1 | – | 44 | – | <.5 | 30 |
| 49 | 179 | – | – | 10 | – | <1 | – | 38 | – | <.5 | 20 |
| 50 | 175 | – | – | 40 | – | 1 | – | 39 | – | <.5 | 20 |
| 51 | 266 | – | – | 20 | – | <1 | – | 78 | – | <.5 | 30 |
| | – | 304 | 340 | <130 | <4 | <4 | 80 | 77 | – | – | – |
| 52 | 210 | – | – | 10 | – | <1 | – | 46 | – | <.5 | 20 |
| 54 | 139 | – | – | <10 | – | 2 | – | 52 | – | <.5 | 10 |
| | 200 | – | <130 | <130 | <4 | <4 | 20 | 21 | – | – | – |
| 55 | 160 | – | – | 20 | – | 1 | – | 40 | – | <.5 | 50 |
| 56 | 158 | – | – | <10 | – | <1 | – | 37 | – | <.5 | 30 |
| | 136 | – | 310 | <130 | <4 | <4 | 20 | 20 | – | – | – |
| 57 | 194 | – | – | <10 | – | 1 | – | 38 | – | <.5 | 20 |
| | 220 | – | 180 | <130 | <4 | <4 | 40 | 38 | – | – | – |
| 58 | 162 | – | – | 20 | – | 2 | – | 40 | – | <.5 | <10 |
| | 180 | – | 250 | <130 | <4 | <4 | 40 | 42 | – | – | – |
| 59 | 143 | – | – | <10 | – | <1 | – | 41 | – | <.5 | 20 |
| 60 | 113 | – | – | 90 | – | 1 | – | 31 | – | .5 | 20 |
| 61 | 276 | – | – | 10 | – | 2 | – | 91 | – | <.5 | 90 |

**Table 14.** Water-quality analyses for base-flow sites sampled in August 1987 and July 1988, in Erie County, Pennsylvania --Continued

| Site number | Solids, residue at 180°C dissolved (mg/L) | Solids, residue at 105°C, dissolved (mg/L) | Aluminum, total recoverable (µg/L as Al) | Aluminum, dissolved (µg/L as Al) | Arsenic, total (µg/L) as As) | Arsenic, dissolved (µg/L as As) | Barium, total recoverable (µg/L as Ba) | Barium, dissolved (µg/L as Ba) | Beryllium, total recoverable (µg/L as Be) | Beryllium, dissolved (µg/L as Be) | Boron, dissolved (µg/L as B) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 456 | -- | 320 | <130 | <4 | <4 | 70 | 58 | -- | -- | -- |
| 62 | 187 | -- | -- | 20 | -- | 1 | -- | 57 | -- | <0.5 | 20 |
| 62A | -- | 232 | 470 | <130 | <4 | <4 | 70 | 58 | -- | -- | -- |
| 63 | 147 | -- | -- | <10 | -- | 1 | -- | 41 | -- | <.5 | 40 |
| 64 | -- | 152 | 560 | <130 | <4 | <4 | 30 | 25 | -- | -- | -- |
| 65 | -- | 260 | 440 | 80 | <4 | <4 | 50 | 40 | -- | -- | -- |
| 66 | -- | 228 | 860 | <130 | <4 | <4 | 70 | 60 | -- | -- | -- |
| 71 | -- | 220 | <130 | <130 | <4 | <4 | 50 | 49 | -- | -- | -- |
| 72 | -- | 220 | 160 | <130 | <4 | <4 | 60 | 58 | -- | -- | -- |
| 73 | -- | 232 | 480 | 160 | <4 | <4 | 80 | 70 | -- | -- | -- |
| 75 | -- | 224 | 190 | <130 | <4 | <4 | 60 | 64 | -- | -- | -- |
| 76 | 210 | -- | -- | 10 | -- | <1 | -- | 36 | -- | <.5 | -- |
| 77 | -- | -- | 70 | -- | 1 | -- | <100 | -- | <10 | -- | -- |
| 79 | 327 | -- | 200 | 20 | 1 | 1 | <100 | 81 | <10 | <.5 | -- |
| 80 | 276 | -- | -- | <10 | -- | 1 | -- | 76 | -- | <.5 | -- |
| 81 | 309 | -- | -- | <10 | -- | 1 | -- | 110 | -- | <.5 | -- |
| 82 | 244 | -- | -- | 20 | -- | <1 | -- | 85 | -- | <.5 | -- |
| 83 | 456 | -- | -- | <10 | -- | <1 | -- | 86 | -- | <.5 | -- |
| 85 | 291 | -- | 200 | 100 | 1 | <1 | <100 | 46 | <10 | <.5 | -- |
| 86A | 436 | -- | 40 | -- | 3 | -- | <100 | -- | <10 | -- | -- |
| 87A | 944 | -- | 50 | 30 | 1 | <1 | <100 | 65 | <10 | <.5 | -- |

| Site number | Cadmium, total recoverable (µg/L as Cd) | Cadmium, dissolved (µg/L as Cd) | Chromium, total recoverable (µg/L as Cr) | Chromium, dissolved (µg/L as Cr) | Cobalt, total recoverable (µg/L as Co) | Cobalt, dissolved (µg/L as Co) | Copper, total recoverable (µg/L as Cu) | Copper, dissolved (µg/L as Cu) | Iron total recoverable (µg/L as Fe) | Iron, dissolved (µg/L as Fe) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -- | <1 | -- | <1 | -- | 4 | -- | 1 | -- | 95 |
| 1A | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 45 |
| 2 | -- | 1 | -- | <1 | -- | 10 | -- | 2 | -- | 520 |
| 4 | -- | 1 | -- | <1 | -- | <3 | -- | 1 | -- | 40 |
| 5 | -- | <1 | -- | <5 | -- | <3 | -- | <10 | -- | 16 |
| 6 | -- | <1 | -- | <1 | -- | <3 | -- | 3 | -- | 24 |
| | -- | <1 | -- | <1 | -- | <3 | -- | 3 | -- | 26 |
| 7 | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 17 |
| | -- | <1 | -- | <1 | -- | <3 | -- | 5 | -- | 14 |
| 8 | -- | 1 | -- | <1 | -- | <3 | -- | 2 | -- | 16 |
| | -- | <1 | -- | <1 | -- | <3 | -- | 4 | -- | 19 |
| 9 | -- | <1 | -- | 1 | -- | <3 | -- | 1 | -- | 23 |
| | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 14 |
| 10 | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 16 |
| | <1 | -- | <1 | -- | 2 | -- | 5 | -- | 180 | -- |
| 11 | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 6 |
| | -- | <1 | -- | <1 | -- | <3 | -- | 5 | -- | 7 |
| 12 | -- | 1 | -- | <1 | -- | <3 | -- | 3 | -- | 61 |
| 13 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 18 |
| | -- | <1 | -- | <1 | -- | <3 | -- | 5 | -- | 13 |
| 14 | -- | <1 | -- | <1 | -- | 7 | -- | 2 | -- | 250 |
| 15 | -- | 1 | -- | <1 | -- | <3 | -- | 2 | -- | 79 |

**Table 14.** Water-quality analyses for base-flow sites sampled in August 1987 and July 1988, in Erie County, Pennsylvania --Continued

| Site number | Cadmium, total recov-erable (µg/L as Cd) | Cadmium, dissolved (µg/L as Cd) | Chromium, total recov-erable (µg/L as Cr) | Chromium, dissolved (µg/L as Cr) | Cobalt, total recov-erable (µg/L as Co) | Cobalt, dissolved (µg/L as Co) | Copper, total recov-erable (µg/L as Cu) | Copper, dissolved (µg/L as Cu) | Iron, total recov-erable (µg/L as Fe) | Iron, dissolved (µg/L as Fe) |
|---|---|---|---|---|---|---|---|---|---|---|
| 16 | -- | <1 | -- | 3 | -- | <3 | -- | 1 | -- | 6 |
| | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 11 |
| 17 | -- | <1 | -- | <1 | -- | <3 | -- | 3 | -- | 25 |
| 18 | -- | <1 | -- | <1 | -- | <3 | -- | 4 | -- | 28 |
| 19 | -- | <1 | -- | <1 | -- | <3 | -- | 5 | -- | 13 |
| | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 22 |
| 20 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 140 |
| 21 | -- | <1 | -- | 2 | -- | <3 | -- | 2 | -- | 43 |
| | -- | <1 | -- | 1 | -- | <3 | -- | 2 | -- | 10 |
| 22 | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 13 |
| | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 22 |
| 23 | -- | 4 | -- | <1 | -- | <3 | -- | 4 | -- | 34 |
| 24 | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 13 |
| | <1 | <1 | <50 | <50 | <20 | <20 | 20 | 20 | 60 | 18 |
| 25 | -- | <1 | -- | <1 | -- | <3 | -- | 4 | -- | 32 |
| 26 | -- | <1 | -- | <1 | -- | <3 | -- | 3 | -- | 10 |
| 27 | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 8 |
| | <1 | <1 | <50 | <50 | <20 | <20 | 21 | <10 | 50 | 11 |
| 28 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 17 |
| 30 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 8 |
| | <1 | <1 | <50 | <50 | <20 | <20 | 13 | 13 | 230 | 21 |
| 31 | -- | <1 | -- | <1 | -- | <3 | -- | 4 | -- | 17 |
| | <1 | <1 | <50 | <50 | <20 | <20 | 15 | 15 | 120 | 12 |
| 32 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 9 |
| 33 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 3 |
| | <1 | <1 | <50 | <50 | <20 | <20 | 15 | 14 | 30 | 46 |
| 34 | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 25 |
| 35 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 14 |
| 36 | -- | <1 | -- | <1 | -- | 20 | -- | 1 | -- | 120 |
| 37 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 47 |
| 38 | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 120 |
| | <1 | <1 | <50 | <50 | <20 | <20 | 13 | <10 | 240 | 81 |
| 39 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 130 |
| 40 | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 26 |
| 41 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 24 |
| 42 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 8 |
| 43 | -- | 1 | -- | <1 | -- | 3 | -- | 4 | -- | 9 |
| 47 | -- | <1 | -- | 10 | -- | <3 | -- | 3 | -- | 85 |
| 48 | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 52 |
| 49 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 28 |
| 50 | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 100 |
| 51 | <1 | <1 | -- | <1 | -- | <3 | -- | <1 | -- | 21 |
| | -- | <1 | <50 | <50 | <20 | <20 | 36 | 10 | 550 | 54 |
| 52 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 41 |
| 54 | -- | <1 | -- | <1 | -- | 10 | -- | <1 | -- | 640 |
| | <1 | <1 | <50 | <50 | 20 | 20 | <10 | <10 | 230 | 54 |
| 55 | -- | 2 | -- | <1 | -- | <3 | -- | 3 | -- | 87 |
| 56 | -- | 2 | -- | <1 | -- | <3 | -- | 2 | -- | 220 |
| | <1 | <1 | <50 | <50 | 20 | 20 | 11 | 11 | 580 | 94 |
| 57 | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 38 |
| | <1 | <1 | <50 | <50 | 30 | <20 | <10 | <10 | 400 | 48 |
| 58 | -- | <1 | -- | <1 | -- | 6 | -- | 3 | -- | 370 |

**Table 14.** Water-quality analyses for base-flow sites sampled in August 1987 and July 1988, in Erie County, Pennsylvania --Continued

| Site number | Cadmium, total recov-erable (µg/L as Cd) | Cadmium, dissolved (µg/L as Cd) | Chromium, total recov-erable (µg/L as Cr) | Chromium, dissolved (µg/L as Cr) | Cobalt, total recov-erable (µg/L as Co) | Cobalt, dissolved (µg/L as Co) | Copper, total recov-erable (µg/L as Cu) | Copper, dissolved (µg/L as Cu) | Iron, total recov-erable (µg/L as Fe) | Iron, dissolved (µg/L as Fe) |
|---|---|---|---|---|---|---|---|---|---|---|
| | <1 | <1 | <50 | <50 | 30 | <20 | <10 | <10 | 690 | 240 |
| 59 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 53 |
| 60 | -- | 1 | -- | <1 | -- | 7 | -- | 4 | -- | 290 |
| 61 | -- | <1 | -- | <1 | -- | <3 | -- | 4 | -- | 37 |
| | 1 | 1 | 50 | <50 | 30 | 30 | 26 | 20 | 1,100 | 40 |
| 62 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 69 |
| 62A | <1 | 1 | <50 | <50 | 20 | 20 | 16 | 10 | 990 | 58 |
| 63 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 36 |
| 64 | <1 | <1 | <50 | <50 | <20 | <20 | 14 | 14 | 620 | 40 |
| 65 | <1 | <1 | <50 | <50 | <20 | <20 | <10 | <10 | 730 | 15 |
| 66 | <1 | 1 | <50 | <50 | <20 | <20 | <10 | <10 | 1,300 | 55 |
| 71 | <1 | <1 | <50 | <50 | <20 | <20 | 11 | 11 | 110 | 29 |
| 72 | <1 | <1 | <50 | 40 | <20 | <20 | 17 | 16 | 130 | 49 |
| 73 | <1 | 1 | <50 | <50 | <20 | <20 | 12 | 12 | 740 | 60 |
| 75 | <1 | <1 | <50 | <50 | 30 | 30 | 11 | 11 | 140 | 31 |
| 76 | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 15 |
| 77 | <1 | -- | <1 | -- | <1 | -- | 3 | -- | 350 | -- |
| 79 | <1 | <1 | 1 | <1 | 1 | <3 | 10 | 7 | 430 | 39 |
| 80 | -- | <1 | -- | <1 | -- | <3 | -- | 2 | -- | 26 |
| 81 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 17 |
| 82 | -- | <1 | -- | 3 | -- | <3 | -- | 1 | -- | 6 |
| 83 | -- | <1 | -- | <1 | -- | <3 | -- | 1 | -- | 6 |
| 85 | <1 | <1 | 2 | <1 | 1 | <3 | 2 | 1 | 420 | <3 |
| 86A | <1 | -- | <1 | -- | 1 | -- | 7 | -- | 670 | -- |
| 87A | <1 | <1 | 1 | <1 | 4 | <3 | 3 | 3 | 1,000 | 35 |

| Site number | Lead, total recov-erable (µg/L as Pb) | Lead, dissol-ved (µg/L as Pb) | Lithium, total recov-erable (µg/L as Li) | Lithium, dissol-ved (µg/L as Li) | Manganese, total recov-erable (µg/L as Mn) | Manganese, dissolved (µg/L as Mn) | Mercury, total recov-erable (µg/L as Hg) | Mercury, dissolved (µg/L as Hg) | Molyb-denum, total recov-erable (µg/L as Mo) | Molyb-denum, dissolved (µg/L as Mo) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -- | <5 | -- | <4 | -- | 62 | -- | <0.1 | -- | <10 |
| 1A | -- | <5 | -- | 7 | -- | 41 | -- | <.1 | -- | <10 |
| 2 | -- | <5 | -- | <4 | -- | 340 | -- | <.1 | -- | <10 |
| 4 | -- | <5 | -- | <4 | -- | 170 | -- | <.1 | -- | <10 |
| 5 | -- | <10 | -- | <4 | -- | 7 | -- | <.1 | -- | <10 |
| 6 | -- | <5 | -- | <4 | -- | 29 | -- | <.1 | -- | <10 |
| | -- | <5 | -- | 9 | -- | 8 | -- | <.1 | -- | <10 |
| 7 | -- | <5 | -- | 5 | -- | 10 | -- | <.1 | -- | <10 |
| | -- | <5 | -- | 10 | -- | 13 | -- | <.1 | -- | <10 |
| 8 | -- | <5 | -- | <4 | -- | 13 | -- | <.1 | -- | <10 |
| | -- | <5 | -- | 10 | -- | 13 | -- | <.1 | -- | <10 |
| 9 | -- | <5 | -- | 4 | -- | 31 | -- | <.1 | -- | <10 |
| | -- | <5 | -- | 10 | -- | 11 | -- | <.1 | -- | 10 |
| 10 | -- | <5 | -- | 6 | -- | 38 | -- | <.1 | -- | <10 |
| | <5 | -- | <10 | -- | 40 | -- | <0.10 | -- | 6 | -- |
| 11 | -- | <5 | -- | <4 | -- | 2 | -- | <.1 | -- | <10 |
| | -- | <5 | -- | <4 | -- | 3 | -- | <.1 | -- | <10 |
| 12 | -- | <5 | -- | <4 | -- | 26 | -- | <.1 | -- | <10 |

**Table 14.** Water-quality analyses for base-flow sites sampled in August 1987 and July 1988, in Erie County, Pennsylvania --Continued

| Site number | Lead, total recov-erable (µg/L as Pb) | Lead, dissol-ved (µg/L as Pb) | Lithium, total recov-erable (µg/L as Li) | Lithium, dissol-ved (µg/L as Li) | Manganese, total recov-erable (µg/L as Mn) | Manganese, dissolved (µg/L as Mn) | Mercury, total recov-erable (µg/L as Hg) | Mercury, dissolved (µg/L as Hg) | Molyb-denum, total recov-erable (µg/L as Mo) | Molyb-denum, dissolved (µg/L as Mo) |
|---|---|---|---|---|---|---|---|---|---|---|
| 13 | -- | <5 | -- | <4 | -- | 13 | -- | <.1 | -- | <10 |
| | -- | <5 | -- | <4 | -- | 7 | -- | <0.1 | -- | <10 |
| 14 | -- | <5 | -- | <4 | -- | 63 | -- | <.1 | -- | <10 |
| 15 | -- | <5 | -- | <4 | -- | 52 | -- | <.1 | -- | <10 |
| 16 | -- | <5 | -- | 7 | -- | 7 | -- | <.1 | -- | <10 |
| | -- | <5 | -- | 11 | -- | 7 | -- | <.1 | -- | <10 |
| 17 | -- | <5 | -- | 7 | -- | 11 | -- | <.1 | -- | <10 |
| 18 | -- | <5 | -- | <4 | -- | 9 | -- | <.1 | -- | <10 |
| 19 | -- | <5 | -- | <4 | -- | 13 | -- | <.1 | -- | <10 |
| | -- | <5 | -- | 8 | -- | 15 | -- | <.1 | -- | <10 |
| 20 | -- | <5 | -- | <4 | -- | 190 | -- | <.1 | -- | <10 |
| 21 | -- | <5 | -- | 6 | -- | 37 | -- | <.1 | -- | <10 |
| | -- | <5 | -- | 7 | -- | 15 | -- | <.1 | -- | <10 |
| 22 | -- | <5 | -- | <4 | -- | 21 | -- | .1 | -- | <10 |
| | -- | <5 | -- | 12 | -- | 17 | -- | <.1 | -- | <10 |
| 23 | -- | <5 | -- | <4 | -- | 42 | -- | <.1 | -- | <10 |
| 24 | -- | <5 | -- | 18 | -- | 6 | -- | <.1 | -- | <10 |
| | <4 | <4 | -- | -- | 16 | 12 | <1.0 | <1.0 | -- | -- |
| 25 | -- | <5 | -- | <4 | -- | 150 | -- | <.1 | -- | <10 |
| 26 | -- | <5 | -- | <4 | -- | 5 | -- | <.1 | -- | <10 |
| 27 | -- | <5 | -- | <4 | -- | 4 | -- | <.1 | -- | <10 |
| | <4 | <4 | -- | -- | <10 | <10 | <1.0 | <1.0 | -- | -- |
| 28 | -- | <5 | -- | <4 | -- | 5 | -- | <.1 | -- | <10 |
| 30 | -- | <5 | -- | <4 | -- | 3 | -- | <.1 | -- | <10 |
| | <4 | <4 | -- | -- | <10 | <10 | <1.0 | <1.0 | -- | -- |
| 31 | -- | 5 | -- | <4 | -- | 17 | -- | <.1 | -- | 30 |
| | <4 | <4 | -- | -- | 10 | <10 | <1.0 | <1.0 | -- | -- |
| 32 | -- | <5 | -- | <4 | -- | 7 | -- | <.1 | -- | <10 |
| 33 | -- | <5 | -- | <4 | -- | 1 | -- | <.1 | -- | <10 |
| | <4 | <4 | -- | -- | <10 | <10 | <1.0 | <1.0 | -- | -- |
| 34 | -- | <5 | -- | <4 | -- | 160 | -- | <.1 | -- | <10 |
| 35 | -- | <5 | -- | <4 | -- | 20 | -- | <.1 | -- | <10 |
| 36 | -- | <5 | -- | <4 | -- | 37 | -- | <.1 | -- | <10 |
| 37 | -- | <5 | -- | <4 | -- | 39 | -- | <.1 | -- | <10 |
| 38 | -- | <5 | -- | <4 | -- | 210 | -- | <.1 | -- | <10 |
| | 5 | <4 | -- | -- | 67 | 52 | <1.0 | <1.0 | -- | -- |
| 39 | -- | <5 | -- | <4 | -- | 100 | -- | <.1 | -- | <10 |
| 40 | -- | <5 | -- | <4 | -- | 71 | -- | <.1 | -- | <10 |
| 41 | -- | <5 | -- | 4 | -- | 25 | -- | <.1 | -- | <10 |
| 42 | -- | <5 | -- | <4 | -- | 16 | -- | <.1 | -- | <10 |
| 43 | -- | <5 | -- | <4 | -- | 65 | -- | <.1 | -- | <10 |
| 47 | -- | <5 | -- | <4 | -- | 170 | -- | <.1 | -- | <10 |
| 48 | -- | <5 | -- | <4 | -- | 140 | -- | <.1 | -- | <10 |
| 49 | -- | <5 | -- | <4 | -- | 26 | -- | <.1 | -- | <10 |
| 50 | -- | <5 | -- | <4 | -- | 19 | -- | -- | -- | <10 |
| 51 | -- | <5 | -- | <4 | -- | 49 | -- | <.1 | -- | <10 |
| | <4 | <4 | -- | -- | 68 | 57 | <1.0 | <1.0 | -- | -- |
| 52 | -- | <5 | -- | <4 | -- | 190 | -- | <.1 | -- | <10 |
| 54 | -- | <5 | -- | <4 | -- | 900 | -- | <.1 | -- | <10 |
| | <4 | <4 | -- | -- | 130 | 37 | <1.0 | <1.0 | -- | -- |

**Table 14.** Water-quality analyses for base-flow sites sampled in August 1987 and July 1988, in Erie County, Pennsylvania --Continued

| Site number | Lead, total recov-erable (µg/L as Pb) | Lead, dissol-ved (µg/L as Pb) | Lithium, total recov-erable (µg/L as Li) | Lithium, dissol-ved (µg/L as Li) | Manganese, total recov-erable (µg/L as Mn) | Manganese, dissolved (µg/L as Mn) | Mercury, total recov-erable (µg/L as Hg) | Mercury, dissolved (µg/L as Hg) | Molyb-denum, total recov-erable (µg/L as Mo) | Molyb-denum, dissolved (µg/L as Mo) |
|---|---|---|---|---|---|---|---|---|---|---|
| 55 | – | 9 | – | <4 | – | 26 | – | <.1 | – | <10 |
| 56 | – | <5 | – | <4 | – | 300 | – | <0.1 | – | <10 |
| | <4 | <4 | – | – | 660 | 540 | <1.0 | <1.0 | – | – |
| 57 | – | <5 | – | <4 | – | 23 | – | <.1 | – | <10 |
| | <4 | <4 | – | – | 40 | 27 | <1.0 | <1.0 | – | – |
| 58 | – | <5 | – | <4 | – | 140 | – | <.1 | – | <10 |
| | <4 | <4 | – | – | 220 | 180 | <1.0 | <1.0 | – | – |
| 59 | – | <5 | – | <4 | – | 25 | – | <.1 | – | <10 |
| 60 | – | <5 | – | <4 | – | 150 | – | <.1 | – | <10 |
| 61 | – | <5 | – | 6 | – | 120 | – | <.1 | – | <10 |
| | 4 | <4 | – | – | 200 | 170 | <1.0 | <1.0 | – | – |
| 62 | – | <5 | – | <4 | – | 61 | – | <.1 | – | <10 |
| 62A | <4 | <4 | – | – | 500 | 480 | <1.0 | <1.0 | – | – |
| 63 | – | <5 | – | <4 | – | 100 | – | <.1 | – | <10 |
| 64 | <4 | <4 | – | – | 23 | <10 | <1.0 | <1.0 | – | – |
| 65 | <4 | <4 | – | – | 730 | 460 | <1.0 | <1.0 | – | – |
| 66 | <4 | <4 | – | – | 370 | 340 | <1.0 | <1.0 | – | – |
| 71 | <4 | <4 | – | – | <10 | <10 | <1.0 | <1.0 | – | – |
| 72 | <4 | <4 | – | – | 14 | 11 | <1.0 | <1.0 | – | – |
| 73 | 40 | 5 | – | – | 460 | 340 | <1.0 | <1.0 | – | – |
| 75 | <4 | <4 | – | – | 12 | <10 | <1.0 | <1.0 | – | – |
| 76 | – | <5 | – | 7 | – | 32 | – | <.1 | – | <10 |
| 77 | <5 | – | <10 | – | 110 | – | <.10 | – | 4 | – |
| 79 | <5 | <5 | 10 | 7 | 50 | 25 | <.10 | <.1 | 13 | 10 |
| 80 | – | <5 | – | 16 | – | 41 | – | <.1 | – | <10 |
| 81 | – | <5 | – | 15 | – | 14 | – | <.1 | – | <10 |
| 82 | – | <5 | – | 13 | – | 2 | – | <.1 | – | <10 |
| 83 | – | <5 | – | 17 | – | 16 | – | <.1 | – | <10 |
| 85 | <5 | <5 | 10 | 15 | 150 | <1 | <.10 | <.1 | 6 | 10 |
| 86A | <5 | – | 10 | – | 780 | – | <.10 | – | 5 | – |
| 87A | <5 | <5 | 190 | 190 | 320 | 300 | <.10 | <.1 | 3 | <10 |

**Table 14.** Water-quality analyses for base-flow sites sampled in August 1987 and July 1988, in Erie County, Pennsylvania --Continued

| Site number | Nickel, total recov-erable (µg/L as Ni) | Nickel, dissolved (µg/L as Ni) | Selenium, total (µg/L as Se) | Selenium, dissolved (µg/L as Se) | Silver, total recov-erable (µg/L as Ag) | Silver, dissolved (µg/L as Ag) | Strontium, dissolved (µg/L as Sr) | Vanadium, dissolved (µg/L as V) | Zinc, total recov-erable (µg/L as Zn) | Zinc, dissolved (µg/L as Zn) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -- | <1 | -- | <1 | -- | <1.0 | 150 | <6 | -- | 4 |
| 1A | -- | <1 | -- | <1 | -- | <1.0 | 180 | <6 | -- | 7 |
| 2 | -- | <1 | -- | <1 | -- | <1.0 | 120 | <6 | -- | 37 |
| 4 | -- | <1 | -- | <1 | -- | <1.0 | 190 | <6 | -- | 14 |
| 5 | -- | <10 | -- | 2 | -- | <1.0 | 130 | <6 | -- | 3 |
| 6 | -- | <1 | -- | <1 | -- | <1.0 | 140 | <6 | -- | 10 |
| | -- | 1 | -- | <1 | -- | <1.0 | 140 | <6 | -- | 23 |
| 7 | -- | <1 | -- | <1 | -- | <1.0 | 130 | <6 | -- | 11 |
| | -- | <1 | -- | <1 | -- | <1.0 | 140 | <6 | -- | 14 |
| 8 | -- | <1 | -- | <1 | -- | <1.0 | 120 | <6 | -- | 6 |
| | -- | 2 | -- | <1 | -- | 1.0 | 130 | <6 | -- | 13 |
| 9 | -- | <1 | -- | <1 | -- | <1.0 | 130 | <6 | -- | 10 |
| | -- | 1 | -- | <1 | -- | 1.0 | 130 | <6 | -- | 6 |
| 10 | -- | <1 | -- | <1 | -- | <1.0 | 190 | <6 | -- | 14 |
| | 6 | -- | <1 | -- | <1 | -- | -- | -- | 60 | -- |
| 11 | -- | <1 | -- | <1 | -- | <1.0 | 110 | <6 | -- | 8 |
| | -- | <1 | -- | <1 | -- | <1.0 | 130 | <6 | -- | 7 |
| 12 | -- | <1 | -- | <1 | -- | <1.0 | 120 | <6 | -- | 12 |
| 13 | -- | <1 | -- | <1 | -- | <1.0 | 110 | <6 | -- | 10 |
| | -- | <1 | -- | <1 | -- | <1.0 | 130 | <6 | -- | 10 |
| 14 | -- | <1 | -- | <1 | -- | <1.0 | 54 | <6 | -- | 11 |
| 15 | -- | <1 | -- | <1 | -- | <1.0 | 110 | <6 | -- | 9 |
| 16 | -- | <1 | -- | <1 | -- | <1.0 | 160 | <6 | -- | <3 |
| | -- | <1 | -- | <1 | -- | <1.0 | 140 | <6 | -- | 40 |
| 17 | -- | <1 | -- | <1 | -- | <1.0 | 230 | <6 | -- | 11 |
| 18 | -- | <1 | -- | <1 | -- | <1.0 | 160 | <6 | -- | 12 |
| 19 | -- | <1 | -- | <1 | -- | <1.0 | 120 | <6 | -- | 15 |
| | -- | <1 | -- | <1 | -- | <1.0 | 120 | <6 | -- | 7 |
| 20 | -- | <1 | -- | <1 | -- | <1.0 | 93 | <6 | -- | 4 |
| 21 | -- | <1 | -- | <1 | -- | <1.0 | 180 | <6 | -- | 8 |
| | -- | 3 | -- | <1 | -- | 1.0 | 210 | <6 | -- | 6 |
| 22 | -- | <1 | -- | <1 | -- | <1.0 | 150 | <6 | -- | 5 |
| | -- | <1 | -- | <1 | -- | <1.0 | 170 | <6 | -- | 13 |
| 23 | -- | <1 | -- | <1 | -- | <1.0 | 80 | <6 | -- | 10 |
| 24 | -- | <1 | -- | <1 | -- | <1.0 | 240 | <6 | -- | 6 |
| | 37 | 37 | <6 | <6 | -- | -- | 270 | -- | 10 | 10 |
| 25 | -- | <1 | -- | <1 | -- | <1.0 | 96 | <6 | -- | 19 |
| 26 | -- | <1 | -- | <1 | -- | <1.0 | 190 | <6 | -- | 6 |
| 27 | -- | <1 | -- | <1 | -- | <1.0 | 140 | <6 | -- | <3 |
| | 48 | <25 | <6 | <6 | -- | -- | 150 | -- | 20 | 13 |
| 28 | -- | <1 | -- | <1 | -- | 2.0 | 120 | <6 | -- | 4 |
| 30 | -- | <1 | -- | <1 | -- | <1.0 | 120 | <6 | -- | 11 |
| | 40 | 40 | <6 | <6 | -- | -- | 110 | -- | 20 | 20 |
| 31 | -- | <1 | -- | <1 | -- | <1.0 | 140 | <6 | -- | 16 |
| | <25 | <25 | <6 | <6 | -- | -- | 130 | -- | <10 | <10 |
| 32 | -- | <1 | -- | <1 | -- | <1.0 | 120 | <6 | -- | 6 |
| 33 | -- | <1 | -- | <1 | -- | <1.0 | 100 | <6 | -- | 6 |
| | 36 | 36 | <6 | <6 | -- | -- | 110 | -- | 20 | 22 |
| 34 | -- | <1 | -- | <1 | -- | <1.0 | 170 | <6 | -- | 23 |
| 35 | -- | <1 | -- | <1 | -- | <1.0 | 100 | <6 | -- | 4 |
| 36 | -- | <1 | -- | <1 | -- | <1.0 | 57 | <6 | -- | 12 |

**Table 14.** Water-quality analyses for base-flow sites sampled in August 1987 and July 1988, in Erie County, Pennsylvania --Continued

| Site number | Nickel, total recov-erable (µg/L as Ni) | Nickel, dissolved (µg/L as Ni) | Selenium, total (µg/L as Se) | Selenium, dissolved (µg/L as Se) | Silver, total recov-erable (µg/L as Ag) | Silver, dissolved (µg/L as Ag) | Strontium, dissolved (µg/L as Sr) | Vanadium, dissolved (µg/L as V) | Zinc, total recov-erable (µg/L as Zn) | Zinc, dissolved (µg/L as Zn) |
|---|---|---|---|---|---|---|---|---|---|---|
| 37 | -- | <1 | -- | <1 | -- | <1.0 | 84 | <6 | -- | 16 |
| 38 | -- | <1 | -- | <1 | -- | <1.0 | 73 | <6 | -- | 12 |
| | 40 | 36 | <6 | <6 | -- | -- | 69 | -- | 10 | 14 |
| 39 | -- | <1 | -- | <1 | -- | <1.0 | 97 | <6 | -- | 6 |
| 40 | -- | <1 | -- | <1 | -- | <1.0 | 86 | <6 | -- | 8 |
| 41 | -- | <1 | -- | <1 | -- | <1.0 | 90 | <6 | -- | <3 |
| 42 | -- | <1 | -- | <1 | -- | <1.0 | 97 | <6 | -- | 5 |
| 43 | -- | <1 | -- | <1 | -- | <1.0 | 92 | <6 | -- | 10 |
| 47 | -- | <1 | -- | <1 | -- | <1.0 | 170 | <6 | -- | 8 |
| 48 | -- | <1 | -- | <1 | -- | <1.0 | 99 | <6 | -- | 7 |
| 49 | -- | <1 | -- | <1 | -- | <1.0 | 86 | <6 | -- | 3 |
| 50 | -- | <1 | -- | <1 | -- | <1.0 | 89 | <6 | -- | 10 |
| 51 | -- | <1 | -- | <1 | -- | <1.0 | 120 | <6 | -- | 3 |
| | 51 | <25 | <6 | <6 | -- | -- | 180 | -- | 20 | 24 |
| 52 | -- | <1 | -- | <1 | -- | <1.0 | 100 | <6 | -- | 7 |
| 54 | -- | <1 | -- | <1 | -- | <1.0 | 59 | <6 | -- | 4 |
| | 29 | 27 | <6 | <6 | -- | -- | 58 | -- | <10 | <10 |
| 55 | -- | <1 | -- | <1 | -- | <1.0 | 83 | <6 | -- | 9 |
| 56 | -- | 1 | -- | <1 | -- | <1.0 | 75 | <6 | -- | 12 |
| | 35 | 31 | <6 | <6 | -- | -- | 90 | -- | 10 | 14 |
| 57 | -- | <1 | -- | <1 | -- | <1.0 | 89 | <6 | -- | 5 |
| | 340 | <25 | <6 | <6 | -- | -- | 95 | -- | <10 | <10 |
| 58 | -- | <1 | -- | <1 | -- | <1.0 | 84 | <6 | -- | 8 |
| | <25 | <25 | <6 | <6 | -- | -- | 100 | -- | <10 | <10 |
| 59 | -- | <1 | -- | <1 | -- | <1.0 | 88 | <6 | -- | 5 |
| 60 | -- | <1 | -- | <1 | -- | <1.0 | 63 | <6 | -- | 17 |
| 61 | -- | <1 | -- | <1 | -- | <1.0 | 120 | <6 | -- | 26 |
| | <25 | <25 | <6 | <6 | -- | -- | 130 | -- | 20 | 20 |
| 62 | -- | <1 | -- | <1 | -- | <1.0 | 93 | <6 | -- | 7 |
| 62A | 33 | 33 | <6 | <6 | -- | -- | 98 | -- | 30 | 26 |
| 63 | -- | <1 | -- | <1 | -- | <1.0 | 83 | <6 | -- | 10 |
| 64 | 40 | <25 | <6 | <6 | -- | -- | 76 | -- | 30 | 29 |
| 65 | 30 | 30 | <6 | <6 | -- | -- | 110 | -- | <10 | <10 |
| 66 | 30 | 30 | <6 | <6 | -- | -- | 97 | -- | <10 | <10 |
| 71 | 38 | 38 | <6 | <6 | -- | -- | 100 | -- | <10 | <10 |
| 72 | 49 | 68 | <6 | <6 | -- | -- | 120 | -- | 20 | 32 |
| 73 | 45 | 45 | <6 | <6 | -- | -- | 120 | -- | 20 | 20 |
| 75 | 38 | 33 | <6 | <6 | -- | -- | 110 | -- | 10 | 10 |
| 76 | -- | <1 | -- | <1 | -- | <1.0 | 89 | <6 | -- | 17 |
| 77 | 3 | -- | <1 | -- | <1 | -- | -- | -- | 30 | -- |
| 79 | 2 | <1 | <1 | <1 | <1 | <1.0 | 130 | <6 | 30 | 29 |
| 80 | -- | <1 | -- | <1 | -- | <1.0 | 220 | <6 | -- | 13 |
| 81 | -- | <1 | -- | <1 | -- | 1.0 | 140 | <6 | -- | 53 |
| 82 | -- | 1 | -- | <1 | -- | 1.0 | 95 | <6 | -- | 13 |
| 83 | -- | 2 | -- | <1 | -- | <1.0 | 220 | <6 | -- | 10 |
| 85 | 10 | 1 | <1 | <1 | <1 | <1.0 | 210 | <6 | 20 | <3 |
| 86A | 6 | -- | <1 | -- | <1 | -- | -- | -- | 40 | -- |
| 87A | 7 | 5 | <1 | <1 | <1 | <1.0 | 730 | <6 | 20 | 15 |

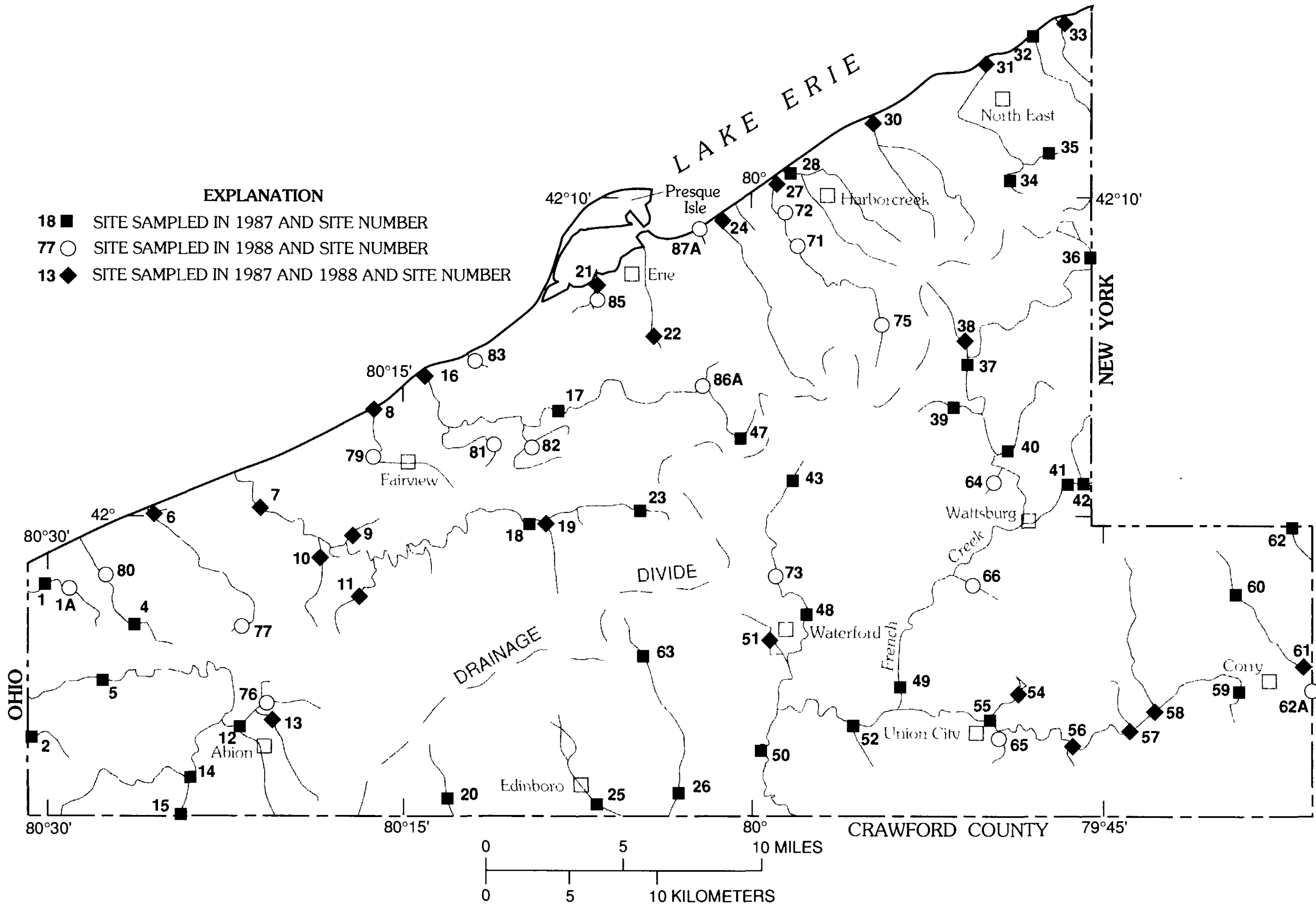


**Figure 33.** Stream sites sampled at base flow in Erie County, Pennsylvania.

**Table 15.** U.S. Environmental Protection Agency primary and secondary regulations for selected constituents in drinking water

[Limits in micrograms per liter, except as indicated; mg/L, milligrams per liter; --, no limit]

| Constituent | Primary regulation (maximum contaminant level) | Secondary regulation (secondary maximum contaminant level) |
|---|---|---|
| Arsenic | 50 | -- |
| Barium | 2,000 | -- |
| Beryllium | 4 | -- |
| Cadmium | 5 | -- |
| Chloride (mg/L) | -- | 250 |
| Chromium | 100 | -- |
| Copper (mg/L) | [1] 1.3 | 1 |
| Fluoride (mg/L) | 4 | -- |
| Iron | -- | 300 |
| Lead | [1] 15 | -- |
| Manganese | -- | 50 |
| Mercury | 2 | -- |
| Nickel | 100 | -- |
| Nitrate as nitrogen (mg/L) | 10 | -- |
| pH (units) | -- | 6.5 – 8.5 |
| Selenium | 50 | -- |
| Sulfate (mg/L) | -- | 250 |
| Thallium | 2 | -- |
| Dissolved solids (mg/L) | -- | 500 |
| Zinc (mg/L) | -- | 5 |

[1] Action level.

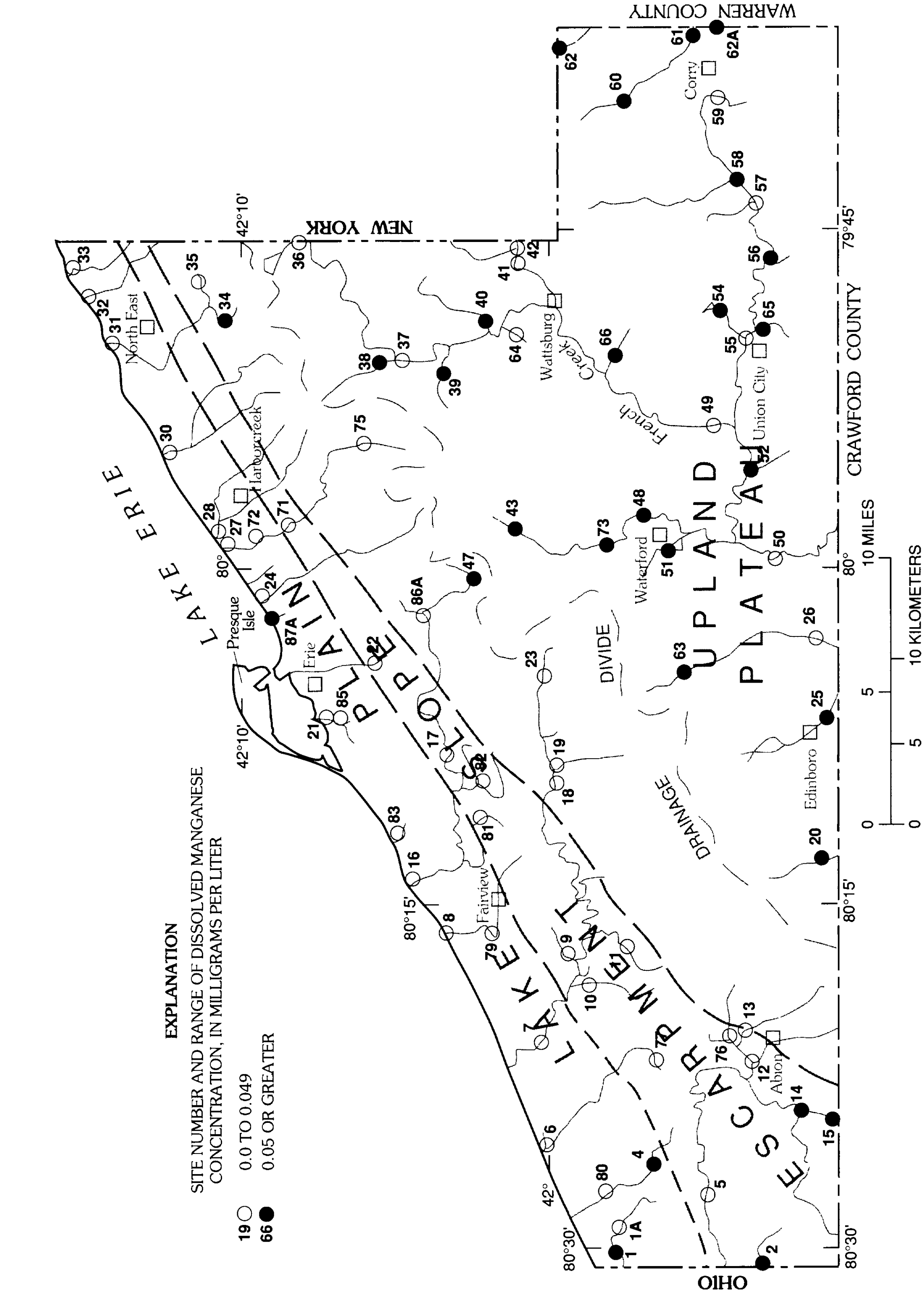


**Figure 34.** Dissolved manganese concentrations at base flow in Erie County, Pennsylvania.

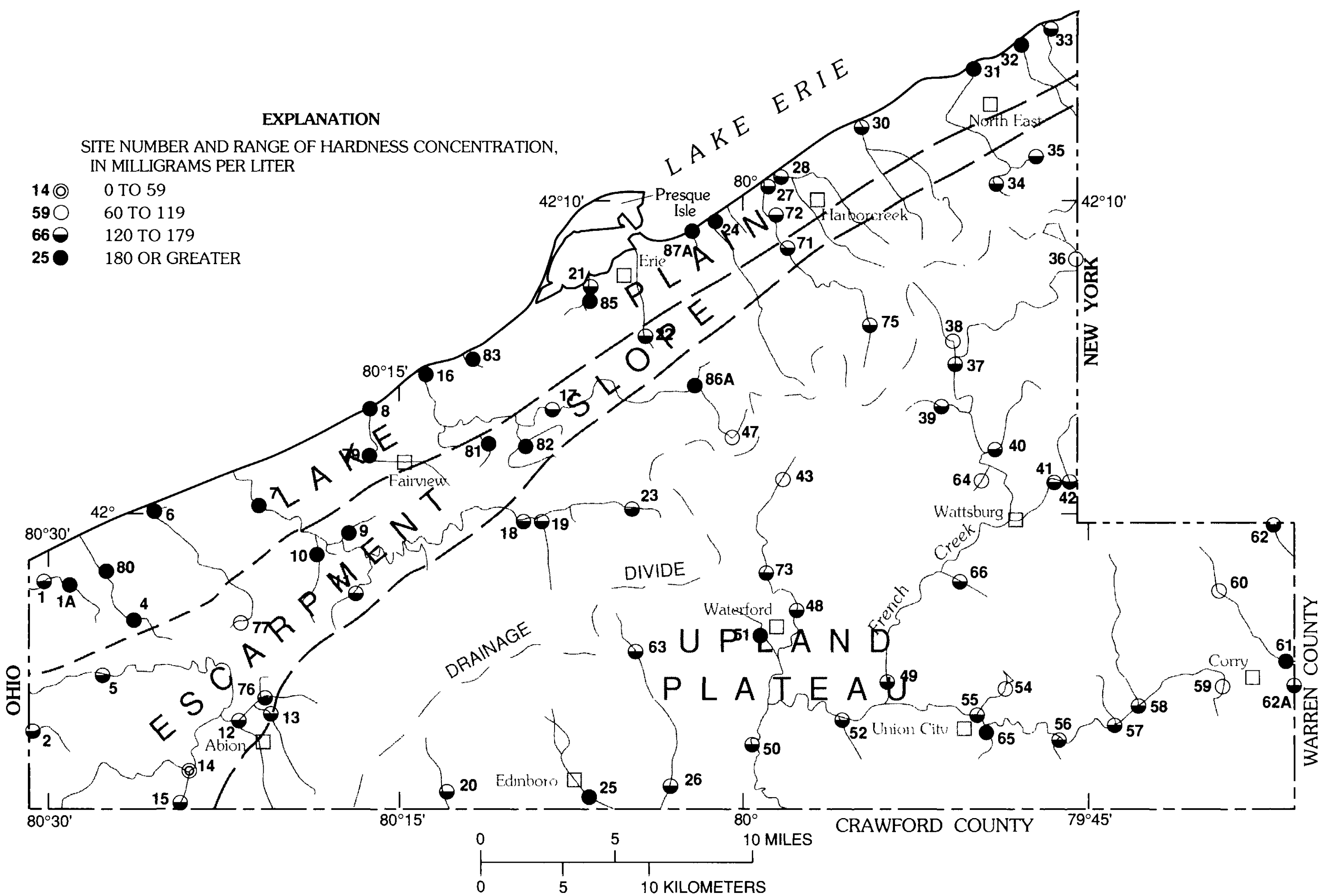


**Figure 35.** Hardness of streams at base flow in Erie County, Pennsylvania.

of 220 mg/L from 77 wells tapping beach deposits was the highest median hardness of all aquifers sampled in Erie County (Richards and others, 1987, p. 14). Sewage-treatment plants in the Lake Erie drainage basin probably contribute, in part, to the elevated hardness of many streams. Conventional sewage-treatment-plant processes generally do not remove the elevated inorganic salts common to domestic wastewaters and sewage (Linsley and Franzini, 1979, p. 563, 589).

Specific conductance is the ability of water to conduct an electrical current. Total dissolved solids can be estimated from the specific-conductance data provided in Appendix 2. The concentration of dissolved solids (in milligrams per liter) generally ranges from 55 to 75 percent of the specific conductance. The median ratio of dissolved solids to specific conductance of all stream samples in Erie County was 0.59.

The specific conductance of water from the wells generally is higher than the specific conductance of the nearby receiving streams. For example, at the Corry (fig. 2) municipal well field, the average specific conductance of several wells is 310 µS/cm. Hare Creek, which flows through the well field, was sampled in 1983 in the middle of the well field and had a specific conductance of 230 µS/cm. At site 60 on Hare Creek, about 2 mi upstream of the well field, the specific conductance at base flow on August 25, 1987, was 200 µS/cm (table 14). The wells used for water supply for Corry are screened in outwash deposits with higher dissolved-solids concentration than the adjacent stream. The production wells average about 60 ft deep. At site 61 on Hare Creek located below the discharge of the Corry sewage treatment plant, the specific conductances on August 26, 1987, and July 12, 1988, at base flow were 500 and 555 µS/cm, respectively. These elevated conductances may be related to the sewage-treatment-plant discharge.

A general trend in specific conductance is evident in figure 36 with lower specific conductances at stream sites in the Upland Plateau and higher specific conductance at sites on the Lake Plain. The lowest specific conductances were observed in water at headwater sites in the Upland Plateau (fig. 36) in eastern Erie County. The specific-conductance data used in the compilation of figure 36 include 34 measurements at sites sampled in 1987, 18 measurements at sites sampled in 1988, and the mean of measurements for 22 sites sampled in 1987 and 1988. Hardness and specific conductance generally are directly correlated as shown in figures 35 and 36. High hardness was measured in water at sites that also had high specific conductances.

## Ground Water

### Inorganic Constituents

#### Major Constituents

Major inorganic constituents sampled during this study include calcium, magnesium, sodium, potassium, bicarbonate, carbonate, chloride, sulfate, and nitrate. Concentrations of selected major constituents in samples from wells are provided in tables 16 and 17. Some of the wells were sampled seasonally. Concentrations of selected constituents in water from wells sampled at aquifer test sites 1, 2, 3, and 4 (fig. 13) are given in table 17.

Chloride concentrations in water from all sampled wells were below the recommended SMCL of 250 mg/L. As estimated from specific conductance data, water from five wells (Er-3014, Er-6007, Er-9553, Er-9560, and Er-9561) probably exceeded the SMCL of 500 mg/L for dissolved solids (Appendix 2).

One or more samples from each of three wells (Er-1800, Er-1810, and Er-10509) exceeded the MCL of 10 mg/L for nitrate. High nitrate concentrations in ground water commonly are caused by fertilizers or livestock manure. Nitrate concentrations greater than 10 mg/L as nitrogen can adversely affect humans, especially infants (U.S. Environmental Protection Agency, 1976, p. 108). Infants ingesting excessive nitrate in their first several months may suffer from methemoglobinemia, or blue-baby disease. Newborns have a higher gastric pH that permits bacteria to convert nitrate to nitrite. The nitrite blocks the blood's ability to carry oxygen. Nitrates may be removed or reduced to acceptable concentrations by water treatment including some ion exchange resins, reverse osmosis, electrodialysis, and distillation.

Additional reports on ground-water quality of Erie County relating to the major constituents include Mangan and others (1952), Engineering-Science Inc. (1976), and Richards and others (1987).

#### Trace Constituents

Trace constituents analyzed for during this study include arsenic, barium, cadmium, chromium, copper, fluoride, iron, lead, manganese, mercury, selenium, silver, and zinc. Selected trace inorganic constituents for samples from 21 wells are shown in tables 16 and 17. Most of these were in a network of wells sampled for trace elements and pesticides in farming areas (fig. 37). Concentrations of total iron exceeded the SMCL of 300 µg/L in 1 or more samples from 9 of the 21 wells.

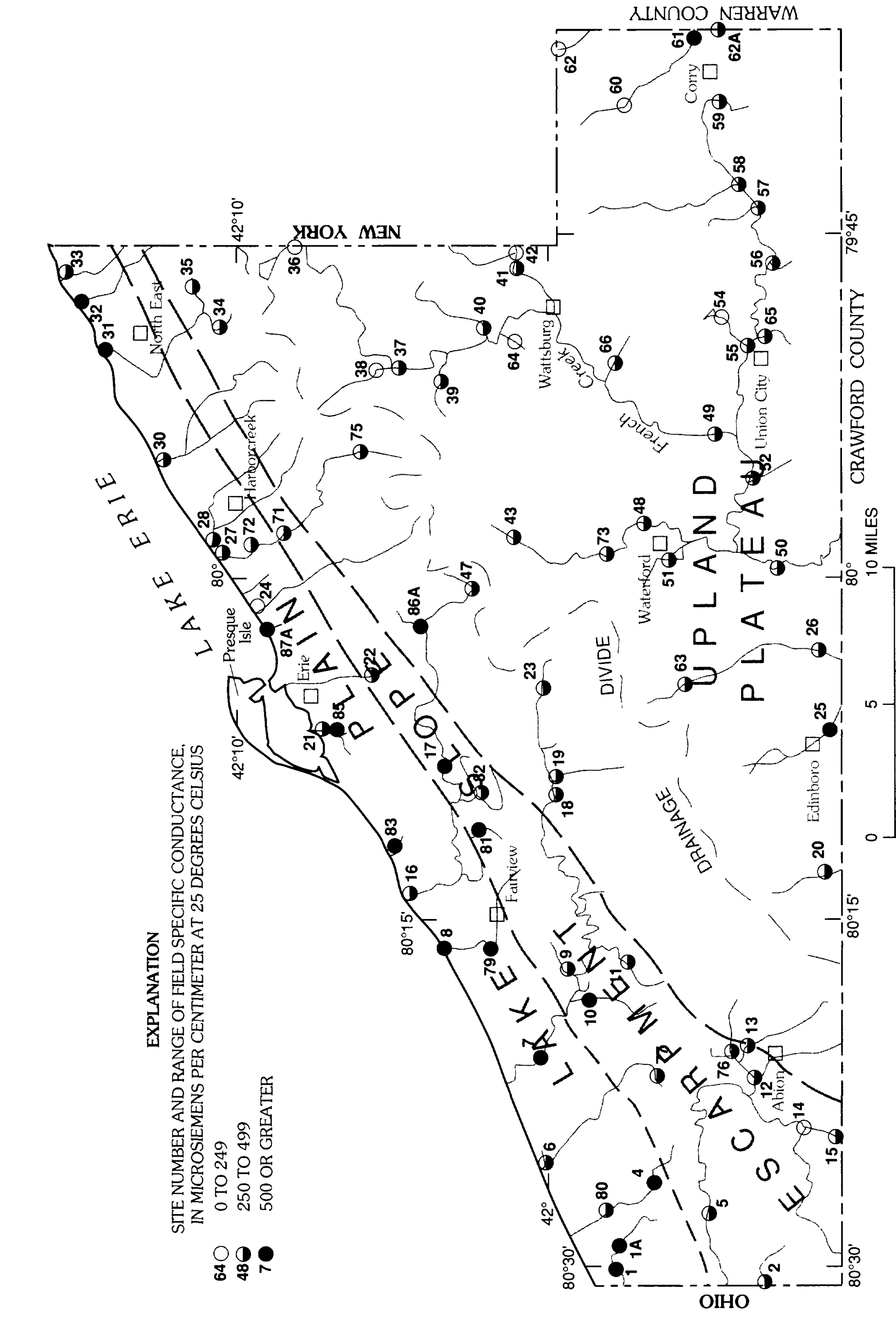


**Figure 36.** Field specific conductance of streams at base flow in Erie County, Pennsylvania.

**Table 16.** Water-quality analyses for wells in Erie County, Pennsylvania

[See figure 37 for locations of wells; see Appendix 2 for well-construction data and hydrogeologic-unit codes; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; 112OTSH, glacial outwash deposits; 112BECH, glacial beach deposits; <, less than; --, no data; tot. rec, total recoverable; ND, no detection]

| Well number | Hydro-geologic unit | Date | Specific conduc-tance (µS/cm) | pH (stand-ard units) | Hard-ness, total (mg/L as $CaCO_3$) | Sodium, total recov-erable (mg/L as Na) | Alka-linity (mg/L as $CaCO_3$) | Chloride, dis-solved (mg/L as Cl) | Fluoride, total (mg/L as F) | Residue at 105°C, dis-solved (mg/L) | Nitrogen, nitrate total (mg/L as N) | Nitrogen, nitrite total (mg/L as N) | Nitrogen, ammonia total (mg/L as N) | Phos-phorus, total (mg/L as P) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1800 | 112OTSH | 10-22-87 | 485 | 7.9 | 220 | 14 | 174 | 27 | <0.1 | 300 | 3.30 | <0.004 | <0.020 | – |
| | | 01-19-88 | 435 | 7.6 | 170 | 18 | 98 | 38 | .2 | 298 | 10.1 | <.004 | .030 | 0.060 |
| | | 01-19-88 | 490 | 8.0 | 210 | 13 | 164 | 29 | <.1 | 294 | 2.52 | <.004 | <.020 | .040 |
| 1803 | 112OTSH | 10-22-87 | 525 | 7.2 | 240 | 15 | 112 | 38 | <.1 | 354 | 5.06 | <.004 | .020 | – |
| | | 01-20-88 | 611 | 7.1 | 210 | 19 | 84 | 78 | <.1 | 410 | 8.80 | <.004 | <.020 | .080 |
| | | 05-02-88 | 470 | 7.1 | 220 | 20 | 104 | 66 | <.1 | 540 | 7.26 | <.004 | <.020 | .020 |
| | | 08-17-89 | – | – | – | – | – | – | – | – | – | – | – | – |
| 1804 | 112OTSH | 10-22-87 | 520 | 7.2 | 220 | 14 | 102 | 40 | <.1 | 346 | 5.28 | <.004 | <.020 | – |
| | | 01-20-88 | 619 | 7.2 | 230 | 19 | 104 | 70 | <.1 | 374 | 7.48 | <.004 | <.020 | .060 |
| | | 05-02-88 | 415 | 7.9 | 230 | 13 | 178 | 27 | <.1 | 336 | 3.08 | <.004 | <.020 | .020 |
| 1805 | 112OTSH | 10-21-87 | 550 | 7.8 | – | 26 | 176 | 68 | <.1 | 358 | 5.04 | <.004 | <.020 | -- |
| | | 01-26-88 | 540 | 7.4 | 200 | 26 | 170 | 48 | <.1 | – | 3.96 | <.004 | .040 | <.020 |
| | | 05-23-88 | 490 | – | 180 | 56 | – | 45 | .2 | 316 | <.040 | <.004 | .400 | .020 |
| 1806 | 112OTSH | 10-21-87 | 585 | 7.9 | 180 | 52 | 226 | 45 | .3 | 388 | .040 | <.004 | .380 | – |
| | | 01-26-88 | 620 | 7.6 | 180 | 56 | 214 | 50 | .2 | 402 | <.040 | <.004 | .410 | .020 |
| | | 05-23-88 | 730 | 7.8 | 75 | 180 | 120 | 160 | .2 | 552 | <.040 | <.004 | .330 | .020 |
| 1807 | 112OTSH | 10-21-87 | 700 | 8.3 | 67 | 130 | 114 | 140 | .3 | 416 | <.040 | <.004 | .280 | – |
| | | 01-26-88 | 790 | 7.7 | 75 | 140 | 114 | 160 | .3 | 426 | <.040 | <.004 | .320 | .020 |
| 1808 | 112OTSH | 01-27-88 | 610 | 6.8 | 150 | 61 | 90 | 110 | <.1 | 418 | 5.50 | <.004 | <.020 | <.020 |
| | | 05-25-88 | 549 | 7.2 | 170 | 75 | – | 110 | <.1 | 424 | 4.84 | <.004 | <.020 | .020 |
| 1810 | 112BECH | 10-22-87 | 175 | 6.6 | 73 | 3.6 | 16 | 2 | <.1 | 156 | 10.9 | <.004 | .060 | -- |
| 1811 | 112OTSH | 02-01-88 | 320 | 6.9 | 150 | 7.4 | 132 | 4 | <.1 | 214 | 5.28 | <.004 | <.020 | .020 |
| | | 05-04-88 | 210 | 7.4 | 110 | 6.1 | 90 | 4 | <.1 | 164 | 5.72 | <.004 | <.020 | .020 |
| 1812 | 112OTSH | 02-01-88 | 445 | 7.2 | 200 | 12 | 150 | 36 | <.1 | 304 | 2.85 | .010 | .030 | <.020 |
| | | 05-04-88 | 390 | 7.9 | 210 | 13 | 166 | 38 | <.1 | 300 | 2.86 | <.004 | .060 | <.020 |
| 1813 | 112OTSH | 01-19-88 | – | 8.2 | 140 | 5.1 | 112 | 13 | <.1 | 192 | .600 | <.004 | .020 | .040 |
| | | 05-04-88 | 275 | 8.1 | 150 | 4.3 | 122 | 12 | <.1 | 224 | .680 | <.004 | <.020 | <.020 |
| 1814 | 112OTSH | 10-20-87 | 380 | 7.0 | 180 | 8.4 | 160 | 3 | .1 | – | 4.84 | <.004 | <.020 | -- |
| 1816 | 112OTSH | 01-19-88 | 435 | 8.1 | 200 | 3.8 | 154 | 7 | <.1 | 284 | 5.50 | <.004 | <.020 | .050 |
| | | 05-04-88 | 335 | 7.8 | 200 | 2.8 | 166 | 6 | <.1 | 284 | 5.06 | <.004 | <.020 | <.020 |
| 1819 | 112OTSH | 10-22-87 | 225 | 6.6 | 95 | 7.1 | 48 | 17 | <.1 | 170 | 2.16 | .004 | .020 | – |
| | | 01-20-88 | 231 | 6.6 | 87 | 6.5 | – | 15 | <.1 | 156 | 1.61 | .008 | .020 | .060 |
| | | 05-23-88 | – | – | – | – | – | – | – | – | – | -- | -- | – |
| 1822 | 112OTSH | 02-01-88 | 290 | 6.9 | 140 | 3.2 | 124 | 3 | <.1 | 184 | 1.08 | <.004 | <.020 | .020 |
| | | 05-16-88 | 265 | 7.2 | 160 | 3.2 | 136 | 3 | <.1 | 232 | 1.08 | <.004 | <.020 | .020 |
| 10509 | 112OTSH | 10-22-87 | 450 | 7.5 | 180 | 21 | 100 | 43 | <.1 | 312 | 9.66 | <.004 | <.020 | – |
| | | 01-19-88 | 435 | 7.6 | 170 | 18 | 98 | 38 | .2 | 298 | 10.1 | <.004 | .030 | .060 |
| | | 05-02-88 | 360 | 7.4 | 170 | 15 | 102 | 29 | <.1 | 360 | 12.1 | <.004 | <.020 | .020 |

**Table 16.** Water-quality analyses for wells in Erie County, Pennsylvania--Continued

| Well number | Hydro-geologic unit | Date | Arsenic, total (µg/L as As) | Chro-mium, total recover-able (µg/L as Cr) | Iron, total recover-able (µg/L as Fe) | Lead, total recover-able (µg/L as Pb) | Manga-nese, total recover-able (µg/L as Mn) | Mercury, total recover-able (µg/L as Hg) | 1,2-Dichloro-propane, total (µg/L) | 2,4-D, total (µg/L) | Silvex, total (µg/L) | 2,4,5-T, total (µg/L) | Metola-chlor, water, whole, tot. rec (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1800 | 112OTSH | 10-22-87 | <4 | -- | <100 | <4 | <50 | <1.0 | <0.4 | <0.40 | <0.10 | <0.10 | -- |
| | | 01-19-88 | <4 | <20 | 130 | <4 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 01-19-88 | <4 | <4 | <100 | <4 | <50 | <1.0 | <.4 | <.40 | .10 | <.10 | -- |
| 1803 | 112OTSH | 10-22-87 | <5 | -- | <100 | <4 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | ND |
| | | 01-20-88 | <4 | <4 | 520 | <4 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | 0.30 |
| | | 05-02-88 | <4 | 5 | <100 | <4 | <50 | -- | <.8 | <.80 | <.20 | <.20 | 2.7 |
| | | 08-17-89 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | .20 |
| 1804 | 112OTSH | 10-22-87 | <4 | -- | <100 | <4 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 01-20-88 | <4 | <4 | 140 | <4 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 05-02-88 | <4 | 7 | <100 | <4 | <50 | -- | <.8 | <.80 | <.20 | <.20 | -- |
| 1805 | 112OTSH | 10-21-87 | <4 | -- | 1,100 | <4 | 70 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 01-26-88 | <4 | <4 | <100 | <4 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 05-23-88 | <4 | 4 | 590 | <4 | 90 | -- | <.8 | <.80 | <.20 | <.20 | -- |
| 1806 | 112OTSH | 10-21-87 | <4 | -- | 460 | <4 | 90 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 01-26-88 | <4 | <4 | 440 | <4 | 160 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 05-23-88 | <4 | 4 | 180 | 6 | <50 | -- | <.8 | <.80 | <.20 | <.20 | -- |
| 1807 | 112OTSH | 10-21-87 | <4 | -- | 220 | <4 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 01-26-88 | <4 | <4 | 190 | <4 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| 1808 | 112OTSH | 01-27-88 | <4 | <4 | <100 | 19 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 05-25-88 | <4 | 4 | 130 | <4 | <50 | -- | <.8 | <.80 | <.20 | <.20 | -- |
| 1810 | 112BECH | 10-22-87 | <4 | -- | 4,100 | 50 | 70 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| 1811 | 112OTSH | 02-01-88 | <4 | <4 | <100 | <4 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 05-04-88 | <4 | <4 | <100 | <4 | <50 | -- | <.8 | <.80 | <.20 | <.20 | -- |
| 1812 | 112OTSH | 02-01-88 | <4 | <4 | 170 | <4 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 05-04-88 | <4 | <4 | 140 | <4 | <50 | -- | <.8 | <.80 | <.20 | <.20 | -- |
| 1813 | 112OTSH | 01-19-88 | <4 | <4 | 250 | 4 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 05-04-88 | <4 | <4 | 130 | <4 | <50 | -- | <.8 | <.80 | <.20 | <.20 | -- |
| 1814 | 112OTSH | 10-20-87 | <4 | -- | 100 | <4 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| 1816 | 112OTSH | 01-19-88 | <4 | <20 | <100 | <4 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 05-04-88 | <4 | <4 | <100 | <4 | <50 | -- | <.8 | <.80 | <.20 | <.20 | -- |
| 1819 | 112OTSH | 10-22-87 | <4 | -- | 12,000 | <4 | 50 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 01-20-88 | <4 | <4 | 17,000 | <4 | 60 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 05-23-88 | -- | -- | -- | -- | -- | -- | <.8 | <.80 | <.20 | <.20 | -- |
| 1822 | 112OTSH | 02-01-88 | <4 | <4 | 100 | <4 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 05-16-88 | <4 | <4 | <100 | <4 | <50 | -- | <.8 | <.80 | <.20 | <.20 | -- |
| 10509 | 112OTSH | 10-22-87 | <4 | -- | <100 | <4 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 01-19-88 | <4 | <20 | 130 | <4 | <50 | <1.0 | <.4 | <.40 | <.10 | <.10 | -- |
| | | 05-02-88 | <4 | 8 | 120 | <4 | <50 | -- | <.8 | <.80 | <.20 | <.20 | -- |

**Table 17.** Water-quality analyses for wells pumped during aquifer tests in Erie County, Pennsylvania

[See Appendix 2 for well-construction data; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; 112OTSH, glacial outwash deposits; 112BECH, glacial beach deposits; <, less than; --, no data]

| Well number | Hydrogeologic unit | Date | Specific conductance (µS/cm) | pH, water, whole, field (standard units) | Temperature (°C) | Hardness, total (mg/L as $CaCO_3$) | Calcium, total (mg/L as $CaCO_3$) | Sodium, total recoverable (mg/L as Na) | Sulfate, total (mg/L as $SO_4$) | Chloride, dissolved (mg/L as Cl) | Fluoride, total (mg/L as F) | Residue at 105°C, dissolved (mg/L) | Nitrogen, nitrate total (mg/L as N) | Nitrogen, nitrite total (mg/L as N) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [1]3022 | 112BECH | 04-26-88 | -- | 7.4 | -- | 170 | 60 | 5.2 | 70 | 6.0 | <0.1 | 230 | <0.040 | <0.004 |
| [2]7501 | 112OTSH | 08-09-89 | 430 | 7.7 | 12.5 | 300 | 66 | 9.1 | 100 | 6.0 | .1 | 334 | <.040 | .008 |
| [2]7504 | 112OTSH | 10-11-89 | 470 | 6.8 | 11.5 | 300 | 99 | 8.3 | 91 | 31 | <.1 | 446 | <.040 | <.004 |
| [3]7508 | 112BECH | 09-21-89 | 370 | 6.7 | 12.0 | 190 | 69 | 5.1 | 32 | 4.0 | <.1 | 269 | <.040 | <.004 |
| [4]8540 | 112OTSH | 11-03-88 | 350 | 8.0 | 9.5 | 190 | 55 | 7.9 | 32 | 6.0 | .2 | 184 | <.040 | <.004 |

| Nitrogen, ammonia total (mg/L as N) | Arsenic, dissolved (µg/L as As) | Barium, total recoverable (µg/L as Ba) | Cadmium, total recoverable (µg/L as Cd) | Chromium, total recoverable (µg/L as Cr) | Copper, total recoverable (µg/L as Cu) | Iron, total recoverable (µg/L as Fe) | Lead, total recoverable (µg/L as Pb) | Manganese, total recoverable (µg/L as Mn) | Mercury, total recoverable (µg/L as Hg) | Selenium, total (µg/L as Se) | Silver, total recoverable (µg/L as Ag) | Zinc, total recoverable (µg/L as Zn) | 1,2-Dichloropropane, total (µg/L) | 2,4-D, total (µg/L) | 2,4,5-T, total (µg/L) | Silvex, total (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -- | <4 | <500 | <0.2 | <4 | <50 | 480 | <4 | 70 | <1.0 | <6 | <30 | 20 | <0.8 | <0.8 | <0.2 | <0.2 |
| -- | <4 | <500 | <.2 | <4 | <50 | 890 | 6.0 | 70 | <1.0 | <6 | <30 | 10 | -- | -- | -- | -- |
| -- | -- | <500 | <.2 | <4 | <50 | 1,500 | <4 | 170 | <1.0 | -- | <30 | 30 | -- | -- | -- | -- |
| -- | 30 | <500 | <.2 | <4 | <50 | 3,300 | <4 | 1,300 | <1.0 | <6 | <30 | 10 | -- | -- | -- | -- |
| 0.150 | <4 | <500 | <.2 | <4 | <50 | 760 | <4 | 80 | <1.0 | <6 | <30 | 10 | <.8 | <.8 | <.2 | <.2 |

[1]Location of well shown in figure 29.
[2]Locations of wells shown in figure 20.
[3]Location of well shown in figure 27.
[4]Location of well shown in figure 14.

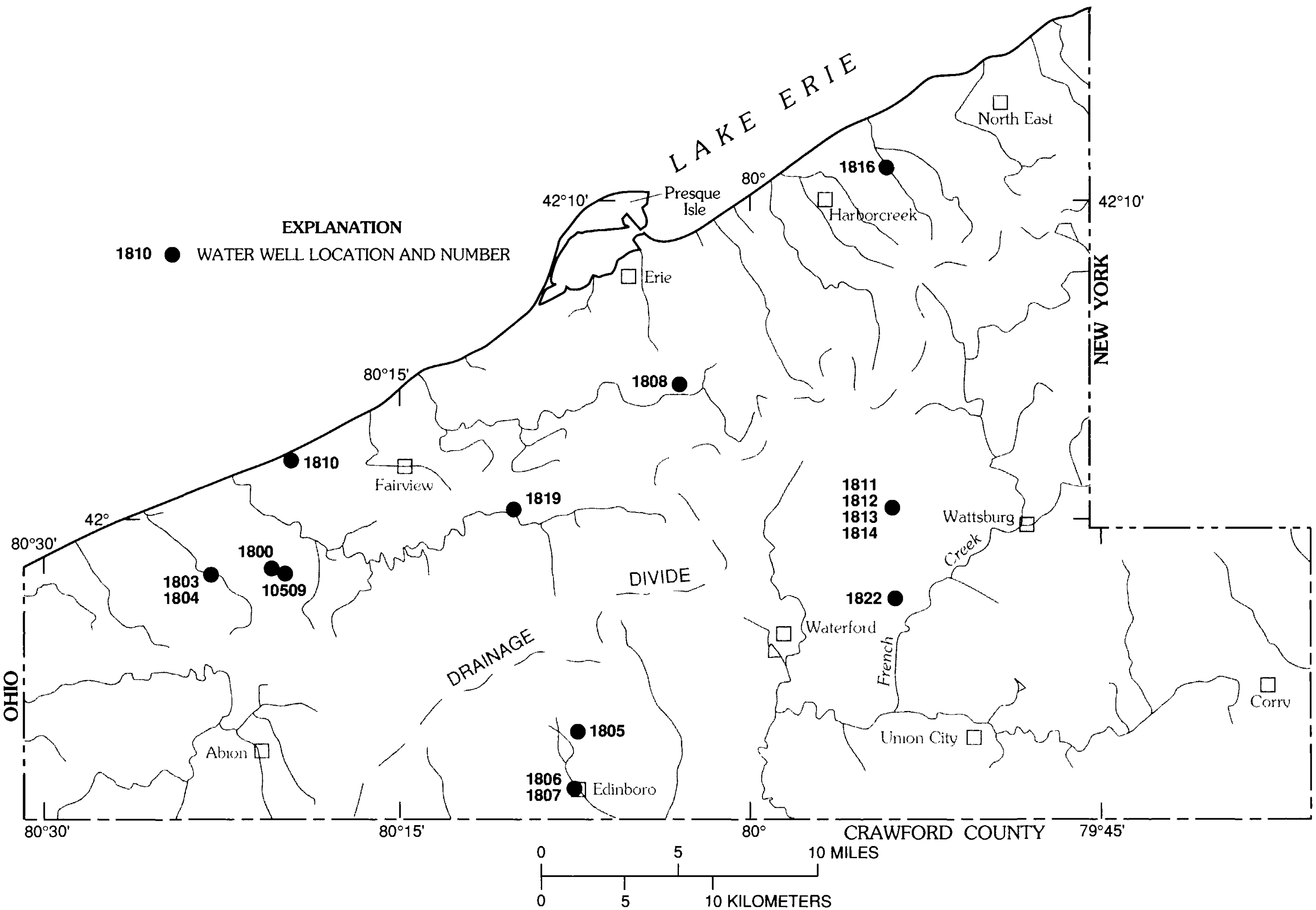


**Figure 37.** Wells sampled for pesticide analysis in Erie County, Pennsylvania.

Total manganese concentrations exceeded the SMCL of 50 µg/L in 1 or more samples from 9 of the 21 wells.

Water in wells located at aquifer test sites 1, 2, 3, and 4 were sampled for a broader spectrum of trace constituents as shown in table 17. Concentrations of arsenic, barium, cadmium, chromium, fluoride, lead, mercury, nitrate, selenium, and silver in water from these wells were below the MCL (table 15). Concentrations of the nontoxic elements, iron and manganese, in water from all five wells exceeded the SMCL's of 300 mg/L and 50 mg/L, respectively.

Total arsenic concentrations greater than the MCL of 50 µg/L were documented intermittently in some water samples from three wells located on a golf course in North East Township (Erie County Department of Health, written commun., 1988). Those wells presumably are open to bedrock of the Chadakoin Formation, but the unconsolidated deposits at the site may be affected. The source of the arsenic in the ground water of the three wells on the golf course remains unknown, but the arsenic may be natural in origin or may be related to pesticide applications.

## Organic Constituents

### Herbicides and Pesticides

The presence of herbicides and pesticides in ground water is an issue for regulatory agencies, the agricultural community, and ground-water users. Herbicides and pesticides may be transported from agricultural areas to streams by overland flow, by tile drains, and by ground-water discharge to streams. Herbicides in ground and surface water have been studied in the Midwest by Burkart and others (1989) and in southeastern Pennsylvania by Fishel and Lietman (1986). Selected pesticides in ground-water samples from agricultural tile drains and water wells were analyzed for this report.

#### Tile drains

Tile drains are engineered drainage systems installed in agricultural fields and are composed of a series of perforated pipes and connecting mains. Tile drains are designed to lower water tables, especially during spring and early summer. Tile drains can disrupt the normal ground-water-flow system by short circuiting shallow ground water to nearby streams. Some tile drains flow all year with shallow ground-water tables lowered permanently. Those that do flow during the growing season contribute to the low streamflows that generally occur at this time of year, augment water in farm ponds, or fill drainage ditches that flow intermittently to streams. Many tile drains, however, are dry in late summer and early fall.

A reconnaissance survey was done in agricultural areas to confirm the presence or absence of detectable concentrations of triazine herbicides in shallow ground water. The triazine herbicides were selected for analysis because they are widely used and have been found in detectable concentrations (especially atrazine) in ground-water samples in many localities including southeastern Pennsylvania (Fishel and Lietman, 1986) and in at least 12 other States (Williams and others, 1988).

Samples were collected in August and September 1989 to coincide with low streamflows. Tile drains flowing at this time were located and a qualitative immunoassay was used to test for triazines and their metabolites (degradation products) at 10 of these sites (TD1–TD10). The locations of all 12 drains sampled for this study are shown on figure 38. The discharges of the drains were low; the maximum discharge was 2.25 gal/min. The immunoassay test results were positive for 3 (TD2, TD3, and TD7) of the 10 drains. This indicates that the total combined concentration of triazines and selected metabolites were equal to or greater than the detection range of 0.5 to 10 µg/L. Samples for laboratory analyses also were collected in August and September for triazine herbicides and alachlor, metolachlor, and trifluralin at the three drains with positive immunoassay results (TD2, TD3, and TD7) and at four other drains (TD9 and TD10, which had negative immunoassay results, and TD11 and TD12, which were not previously sampled). The results of the laboratory analyses are given in table 18.

Concentrations of cyanazine were detected in the water sampled from one tile drain, prometone from another, and simazine from a third (table 18). Atrazine was at the detection limit in one sample and exceeded the detection limit in four of the seven samples. Atrazine concentrations did not exceed the USEPA proposed MCL of 3.0 µg/L. Because only seven samples were collected from tile drains for laboratory analysis, comprehensive statements about herbicide concentrations in tile drains are inappropriate. However, the data do indicate that some tile drains are moving low concentrations of herbicides from the ground-water system to surface water.

Many factors are responsible for the occurrence of atrazine in ground water including its high solubility in water. Triazines are degraded by a variety of chemical and biological processes. Some of the degradation products or metabolites are sorbed by soils.

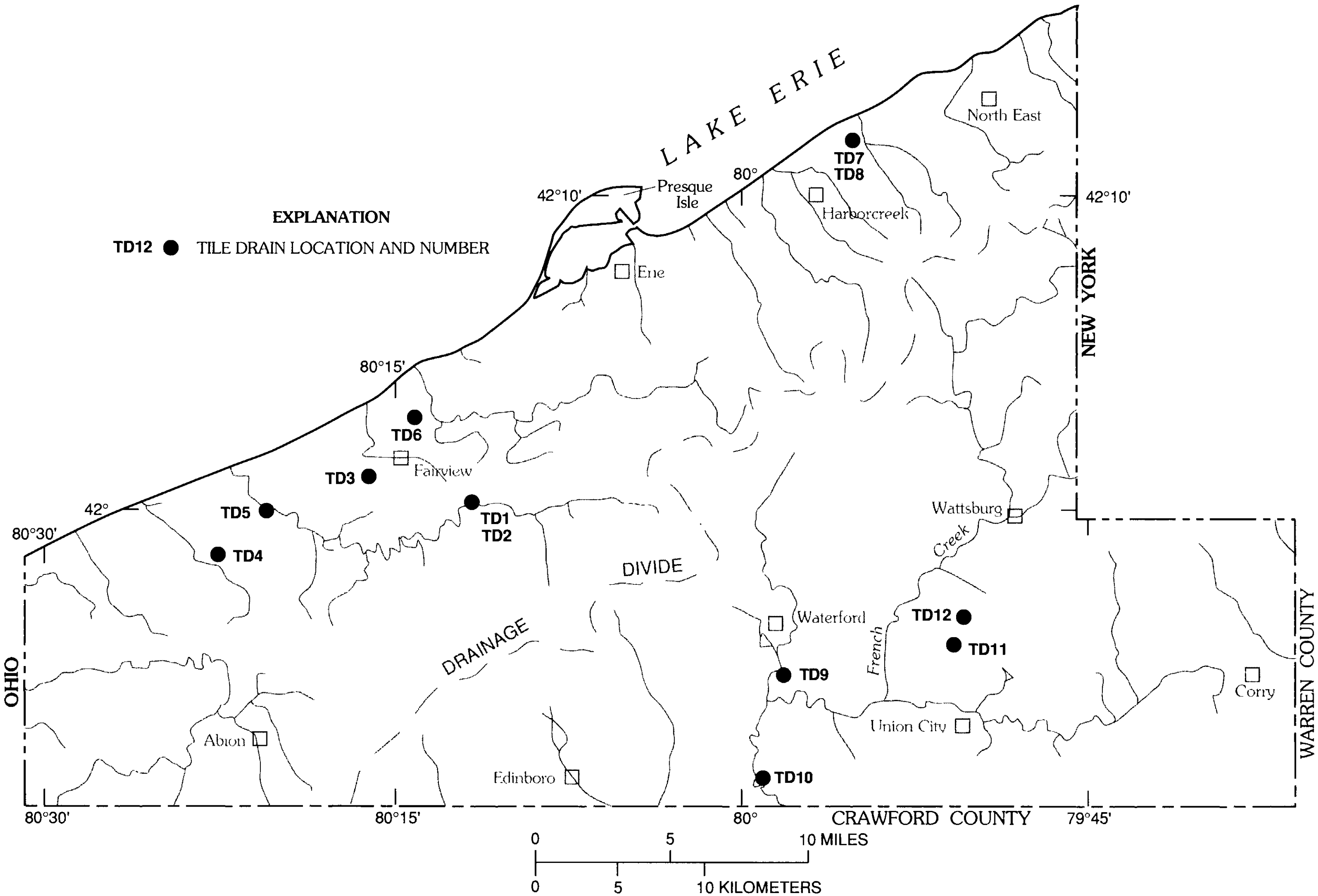


**Figure 38.** Tile drains sampled for pesticide analysis in Erie County, Pennsylvania.

**Table 18.** Herbicides in ground-water samples from tile drains in Erie County, Pennsylvania

[Locations of tile drains shown in figure 38; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; µg/L, micrograms per liter; <, less than; --, no data]

| Tile drain number | Date | Specific conductance (µS/cm) | pH (standard units) | Temperature, water (°C) | Propazine, total (µg/L) | Trifluralin, total recoverable (µg/L) | Simetryne, total (µg/L) | Simazine, total (µg/L) | Prometone, total (µg/L) | Prometryne, total (µg/L) | Atrazine, total (µg/L) | Alachlor, total recoverable (µg/L) | Cyanazine, total (µg/L) | Ametryne, total (µg/L) | Metribuzin, water, whole, total recoverable (µg/L) | Metolachlor, water, whole, total recoverable (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TD2 | 08-16-89 | 610 | 6.70 | 16.5 | <0.10 | <0.10 | <0.1 | <0.10 | <0.1 | <0.1 | 0.20 | <0.10 | <0.10 | <0.10 | <0.1 | <0.1 |
| TD3 | 08-17-89 | 495 | 8.03 | 19.0 | <.10 | <.10 | <.1 | <.10 | <.1 | <.1 | .40 | <.10 | <.10 | <.10 | <.1 | <.1 |
| TD7 | 08-23-89 | 1,550 | 8.10 | 21.0 | <.10 | <.10 | <.1 | .10 | <.1 | <.1 | <.10 | <.10 | <.10 | <.10 | <.1 | <.1 |
| TD9 | 09-06-89 | 235 | 7.53 | 18.5 | <.10 | <.10 | <.1 | <.10 | <.1 | <.1 | <.10 | <.10 | <.10 | <.10 | <.1 | <.1 |
| TD10 | 09-06-89 | 175 | 7.63 | 17.5 | <.10 | <.10 | <.1 | <.10 | .1 | <.1 | .20 | <.10 | <.10 | <.10 | <.1 | <.1 |
| TD11 | 09-06-89 | -- | -- | -- | <.10 | <.10 | <.1 | <.10 | <.1 | <.1 | .20 | <.10 | .10 | <.10 | <.1 | <.1 |
| TD12 | 09-06-89 | -- | -- | -- | <.10 | .10 | <.1 | <.10 | <.1 | <.1 | .10 | <.10 | <.10 | <.10 | <.1 | <.1 |

#### Supply wells

Few laboratory analyses for pesticides are available or published for domestic or agricultural supply wells in farming areas in Erie County. Therefore, 16 domestic or agricultural wells, mostly in farming areas, were selected to be sampled for routine inorganic constituents and four pesticides (table 16). The locations of these wells are shown in figure 37, and physical data are given in Appendix 2. Seven of the wells were sampled three times (fall, winter, and spring) to look for seasonal trends.

The four pesticides that were analyzed for were (1) 1,2-Dichloropropane; (2) 2,4-Dichlorophenoxyacetic acid (2,4 D); (3) 2,4,5-Trichlorophenoxyacetic acid (2,4,5 T); and (4) 2,4,5-Trichlorophenoxypropionic acid (2,4,5 TP or Silvex). Concentrations were below detection limits in water from all the wells sampled.

Samples for analysis of the same four pesticides as in other wells were collected at aquifer test sites 1 (well Er-8540) and 4 (well Er-3022); the data are given in table 17. Concentrations of the four pesticides were below detection levels in water samples from these wells.

Metolachlor was detected at concentrations ranging from 0.2 to 0.3 µg/L in three samples from well Er-1803. These concentrations are well below the proposed lifetime health advisory level (PLHAL) of 10 µg/L. The well-construction data for Er-1803 is unknown, but the well probably is in Pleistocene outwash.

#### Volatile Organic Compounds

Wells Er-8540, Er-7501, and Er-7504 at the aquifer sites were sampled for volatile organic compounds (see figs. 14 and 20 for the locations of these wells). The samples were analyzed by the PaDER laboratory by gas chromatography followed by quantitative mass spectrometry. No volatile organic compounds were detected.

### Bacteria

Total coliform bacteria commonly are used as an indicator of the possible presence of pathogenic bacteria. Coliform bacteria originate primarily, but not exclusively, in the intestinal tract of warm-blooded animals and are associated with their feces. Coliform bacteria are normally nonpathogenic, but the presence of coliform bacteria in ground-water samples indicates that conditions are favorable for the presence of pathogenic organisms. The USEPA MCL for total coliform bacteria is 1 coliform bacterium per 100 mL of water (U.S. Environmental Protection Agency, 1988). Laboratory analyses for total coliform bacteria in water from wells at the aquifer test sites are given in table 19.

**Table 19.** Coliform bacteria in water from wells in Erie County, Pennsylvania

[ml, milliliters; <, less than; --, no data]

| Aquifer test site | Well number | Date | Time | Total coliform bacteria per 100 mL | Fecal coliform bacteria per 100 mL |
|---|---|---|---|---|---|
| 1 | Er-8540 | November 3, 1988 | -- | 0 | -- |
| 2 | Er-7501 | August 9, 1989 | -- | 0 | -- |
| | Er-7504 | October 11, 1989 | -- | 0 | -- |
| 3 | Er-7508 | September 21, 1989 | 1200 | <2 | 0 |
| | | September 21, 1989 | 1430 | 2 | <2 |
| 4 | Er-3022 | April 26, 1988 | -- | 0 | -- |

Fecal coliform bacteria are a better indicator of pathogens than total coliform because they come only from the intestinal tract of warm-blooded animals. Fecal coliform concentrations were zero and less than 2 per 100 mL in ground-water samples from well Er-7508 at Presque Isle State Park (table 19). Additional data and research concerning coliform contamination of the surface and ground water of Presque Isle are available in reports by the Erie County Department of Health (1989, 1990, and 1991).

## SUMMARY

Unconsolidated deposits are used for the water supplies of homes, farms, municipalities, and industries in Erie County. Low-relief beach ridges, and lake deposits cover most of the lake plain areas of the county adjacent to Lake Erie. Till and outwash deposits cover much of the upland area to the southeast where steep-walled, flat-bottomed valleys were scoured and filled by Pleistocene glaciers. Alluvium is deposited along modern stream valleys.

Unconsolidated deposits cover most of the bedrock of Erie County. Thickness of the unconsolidated deposits range from 60 to 400 ft at 30 sites surveyed by seismic refraction and reflection methods. Water wells, mostly in the unconsolidated deposits, provide adequate domestic supplies. Wells in fractured bedrock can generally provide small domestic supplies; however, droughts can affect some of the domestic water wells.

Ground-water withdrawals accounted for 10 Mgal/d of the water used in Erie County in 1984. Surface-water withdrawals, other than thermoelectric power, used about 100 Mgal/d. Thermoelectric power used 300 Mgal/d in 1984.

Mean annual precipitation ranged from about 42 to 47 in. per year in Erie County from 1961 through 1990; the southeastern region of the county generally receives more precipitation than the lake shore region to the north. Overland runoff to three segments of the French Creek watershed in the upland area ranged from about 13 to 19 in. per year, and base flow ranged from 14 to about 18 in. per year from 1975 to 1992. Evapotranspiration ranged from about 13 to 16 in. per year for those segments.

Beach and outwash deposits generally provide the largest supplies of water to wells in Erie County. A median specific capacity of 17 (gal/min)/ft of drawdown was determined from records of nondomestic wells in beach deposits and 9 (gal/min)/ft of drawdown in outwash. Mean specific capacity for wells in till deposits was 1.5 (gal/min)/ft. The range in yield and specific capacity, however, was great for the unconsolidated deposits, and high-yield outwash deposits are sometimes difficult to locate beneath till and valley-fill deposits.

Hydraulic conductivities from three aquifer tests of outwash deposits (sand and gravel) at separate sites ranged from 110 to 2,030 ft/d. Hydraulic conductivities from another aquifer test of sand and silt in the water table at Presque Isle ranged from 120 to 215 ft/d. Transmissivities from a third aquifer test of beach sand and gravel ranged from 235 to 262 $ft^2/d$.

Water-quality samples from streams at base flow generally reflect ground-water discharge derived from multiple aquifers. Streams were sampled at 57 sites throughout Erie County during base flow on August 24–26, 1987, and 42 sites on July 11–13, 1988. Laboratory analyses of stream samples indicate that concentrations for arsenic, barium, cadmium, chromium, fluoride, lead, mercury, and selenium did not exceed the MCL's established by the USEPA. Concentrations of nontoxic elements, iron and manganese, exceed USEPA SMCL's in samples from some stream sites. Manganese concentrations exceeded the SMCL of 0.05 mg/L at 19 of 30 stream sites sampled in the Upland Plateau section of Erie County.

A total of 21 wells, many in farming areas, were sampled for inorganic constituents and selected pesticides. Concentrations of total iron exceeded the SMCL in 1 or more samples from 9 of the 21 wells. Concentrations of total manganese exceeded the SMCL in 1 or more samples from 7 of the 21 wells. Total arsenic concentrations greater than the MCL of 50 µg/L were observed intermittently in three wells. One or more samples from each of three wells (Er-1800, Er-1810, and Er-10509) exceeded the MCL of 10 mg/L for nitrate.

Laboratory analysis of water from six of seven tile drains sampled in agricultural fields confirmed detectable but low concentrations of selected herbicides in shallow ground water. These samples document the transport of these herbicides from the shallow ground-water system to local streams. Concentrations of cyanazine were detected in the water sampled from one tile drain, prometone from another, and simazine from a third. Atrazine concentrations in samples from tile drains did not exceed the USEPA proposed MCL of 3.0 µg/L.

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## GLOSSARY

Alkalinity. The capacity of a water for neutralizing an acid solution. Alkalinity in natural water is caused primarily by the presence of carbonate and bicarbonate.

Alluvium. A general term for clay, silt, sand, gravel, or other similar material deposited in a streambed, on a flood plain, delta, or at the base of a mountain during comparatively recent geologic time.

Aquifer. A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield usable quantities of water to wells and springs.

Aquifer test. A test or controlled field experiment involving either the withdrawal of measured quantities of water from, or addition of water to, a well (or wells) and the measurement of resulting changes in head in the aquifer both during and after the period of discharge or addition.

Base flow. Discharge entering stream channels as effluent from the ground-water reservoir; the dry-weather flow of streams.

Bedding plane. A planar or nearly planar bedding surface that visibly separates each successive layer of stratified rock (of the same or different lithology) from the preceding or following layer; a plane of deposition.

Bedrock. A general term for the rock, generally solid, that underlies soil or other unconsolidated or semiconsolidated surficial material.

Confined aquifer. An aquifer which is bounded above and below by relatively impermeable rocks.

Cubic feet per second. ($ft^3/s$). The rate of discharge representing a volume of one cubic foot passing a given point during one second (equivalent to 7.48 gallons per second or 448.8 gallons per minute).

Cubic feet per second per square mile. [$(ft^3/s)/mi^2$]. The average number of cubic feet of water per second flowing from each square mile of area drained by a stream, assuming that the runoff is distributed uniformly, in time and area.

Diamict. A general term that includes diamictite and diamicton. Diamicitite is a comprehensive term for a nonsorted or poorly sorted, noncalcareous, terrigenous sedimentary rock that contains a wide range of particle sizes, such as a rock with sand and/or larger particles in a muddy matrix. Diamicton is the nonlithified equivalent of a diamictite, for example, a till.

Dip. The angle or rate of drop at which a layer of rock is inclined from the horizontal.

Dissolved. Refers to that material in a representative water sample which passes through a 0.45-micrometer membrane filter. This is a convenient operational definition used by Federal agencies that collect water data. Determinations of dissolved constituents are made on subsamples of the filtrate.

Dissolved solids. The dissolved mineral constituents in water; they form the residue after evaporation and drying at a temperature of 105 degrees Celsius; they also may be calculated by adding concentrations of anions and cations.

Drawdown. The lowering of the water table or potentiometric surface caused by pumping (or artesian flow) of a well.

Drift. Any rock material deposited by an ice sheet or by meltwaters of that ice sheet.

End moraine. A moraine that is being produced at the front of an actively flowing glacier at any given time; a moraine that has been deposited at the lower or outer end of a glacier.

Evapotranspiration. The evaporation from water bodies, wetted surfaces, and moist soil by direct evaporation and vapor that escapes from living plants by the process of transpiration.

Formation. The fundamental unit in rock-stratigraphic classification. It is a body of internal homogeneous rock; it is prevailingly but not necessarily tabular and is mappable at the earth's surface or traceable in the subsurface.

Fracture. A break in the rock.

Gaging station. A particular site on a stream, canal, lake, or reservoir where systematic observations of hydrologic data are obtained.

Ground moraine. An accumulation of till after it has been deposited or released from the ice during ablation, to form an extensive area of low relief devoid of transverse linear elements.

Ground water. That part of the subsurface water in the zone of saturation.

Ground-water discharge. Release of water by springs, seeps, or wells from the ground-water reservoir.

Ground-water recharge. Addition of water to the ground-water reservoir by infiltrating precipitation or seepage from a streambed.

Group. A stratigraphic unit consisting of two or more formations.

Hardness. A physical-chemical characteristic that commonly is recognized by the increased quantity of soap required to produce lather. It is attributable to the presence of alkaline earths (principally calcium and magnesium) and is expressed as equivalent calcium carbonate ($CaCO_3$).

Hydraulic conductivity (K). The volume of water (at the existing viscosity and temperature) that will move at right angles through a unit cross-sectional area in unit time and by a unit hydraulic gradient. It is a measure of the capacity of the material to transmit fluid. The hydraulic gradient is expressed in feet of hydraulic head per foot of flow distance (dimensionless), and hydraulic conductivity is expressed in cubic feet per day per square foot [$(ft^3/d)/ft^2$] or feet per day (ft/d). The hydraulic conductivity was determined from well tests by dividing the determined value of transmissivity by the thickness of the aquifer tested, thus representing an average formation property measured in a horizontal direction.

Induced infiltration. Recharge to ground water by infiltration, either natural or manmade, from a body of surface water as a result of the lowering of the ground-water head below the surface-water level.

Kame. A mound composed chiefly of sand and gravel deposited in contact with the ice by meltwaters.

Kame terrace. A linear group of kames, having at times a terrace-like appearance, deposited from meltwaters in the long, narrow depression or hollow between glacial ice and a valley wall.

Lacustrine. Having to do with lakes or their deposits.

Lithology. The physical characteristics of a rock, generally as determined by examination with the naked eye or with the aid of a low-power magnifier.

Micrograms per liter (μg/L). A unit expressing the concentration of chemical constituents in solution as mass (micrograms) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter.

Milligrams per liter (mg/L). A unit for expressing the concentration of chemical constituents in solution. Milligrams per liter represent the mass of solute per unit volume (liter) of water.

Moraine. A mound, ridge, or other distinct accumulation of unsorted, unstratified glacial drift, predominantly till, deposited chiefly by direct action of glacier ice, in a variety of topographic landforms that are independent of control by the surface on which the drift lies.

Outwash. Stratified drift deposited by meltwater streams.

pH. A measure of the acidity or alkalinity of water. Mathematically, the pH is the negative logarithm of the hydrogen ion activity; pH=-log10 [H+], where [H+] is the hydrogen-ion concentration in moles per liter. A pH of 7.0 indicates a neutral condition. An acid solution has a pH less then 7.0 and a basic or alkaline solution has a pH more than 7.0.

Permeability. The capacity of a porous rock, sediment, or soil to transmit a fluid under a hydraulic head; it is a measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient.

Potentiometric surface. A surface that represents the static head of an aquifer.

Runoff. That part of the precipitation that appears in streams. It is the same as streamflow unaffected by diversions, storage, or other works of man in or on the stream channels.

Secondary permeability. The increase or decrease in permeability in the soil or rock caused by fracturing, solution or cementation.

Seiche. An oscillation of the surface of a lake or landlocked sea that varies in period from a few minutes to several hours.

Shingle. Coarse loose well-rounded waterworn detritus or alluvial material of various sizes; especially beach gravel, composed of smooth and spheroidal or flattened pebbles, cobbles, and sometimes small boulders. It occurs typically on the higher parts of a beach.

Specific capacity. The well yield divided by the drawdown (pumping water level minus static water level) necessary to produce this yield. It is usually expressed as gallons per minute per foot [(gal/min)/ft].

Specific conductance. Is a measure of the ability of a water to conduct an electrical current. It is expressed in microsiemens per centimeter at 25 degrees Celsius. Specific conductance is related to the type and concentration of ions in the solution and can be used for approximating the dissolved-solids content of the water. Commonly, the concentration of dissolved solids (in milligrams per liter) is about 65 percent of the specific conductance (in microsiemens). This relation is not constant from stream to stream, and it may vary in the same source with changes in the composition of the water.

Storage coefficient. The volume of water that an aquifer releases from, or takes into, storage per unit surface area of the aquifer per unit change in head normal to that surface. Because volume, area, and hydraulic head are expressed in consistent units, storage coefficient is a dimensionless quantity. Streamflow is the discharge that occurs in a natural channel. Although the term discharge can be applied to the flow of a canal, the word streamflow uniquely describes the discharge in a surface stream course. The term streamflow is more general than runoff as streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

Till. Dominantly unsorted and unstratified drift, generally unconsolidated, deposited directly by and underneath a glacier without subsequent reworking by meltwater, and consisting of a heterogeneous mixture of clay, silt, sand, gravel, and boulders ranging widely in size and shape.

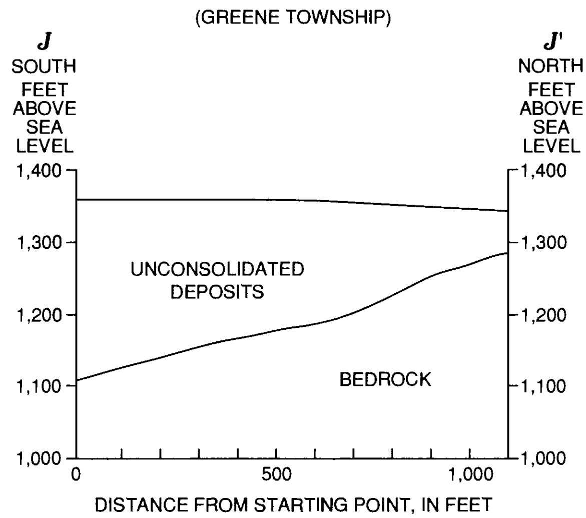
Transmissivity. Transmissivity, T, is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It may be expressed in cubic feet per day per foot or, feet squared per day ($ft^2/d$).

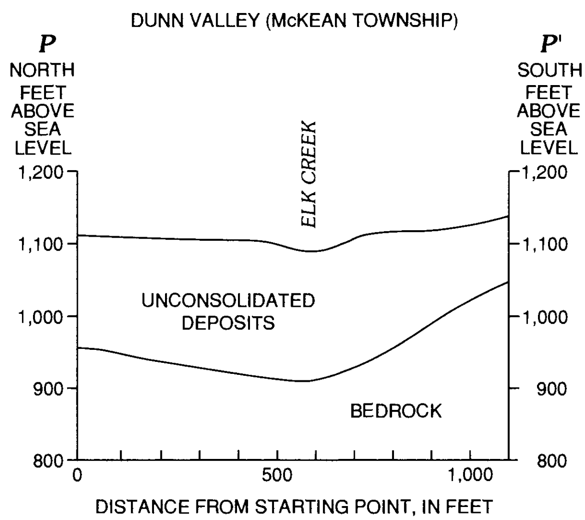
Unconfined aquifer. An aquifer which contains the water table.

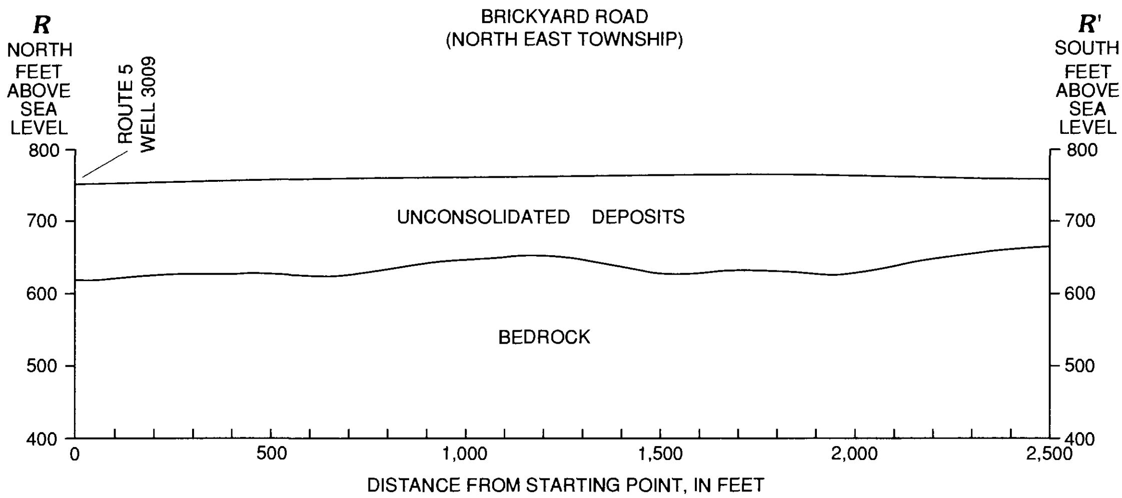
Valley train. Outwash deposited as a long, narrow band confined within a valley which carried a stream of meltwater flowing away from the ice.

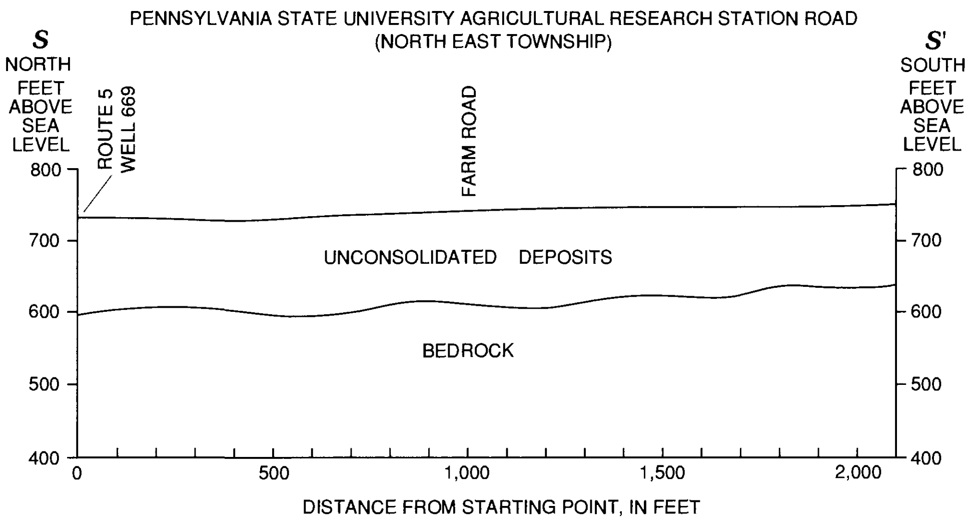
Water table. The upper surface of the zone of saturation.

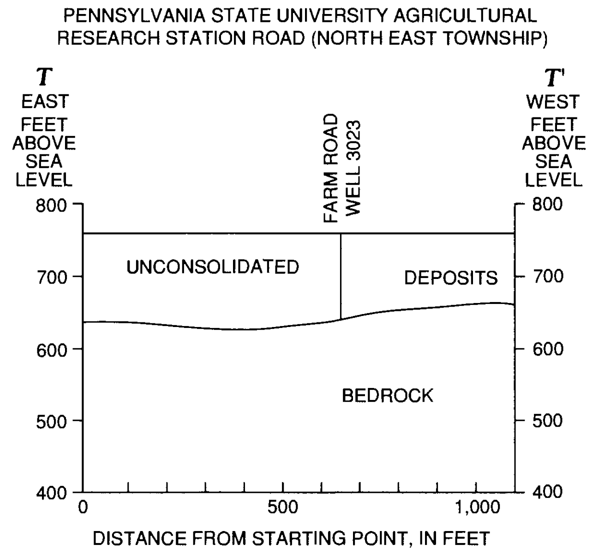
**Appendix 1.** Geologic sections showing depth to bedrock at sections J-J', P-P', R-R', S-S', T-T', U-U', V-V', and W-W', Erie County, Pennsylvania. Geologic sections prepared from interpretation of seismic data. Locations of lines of section shown in figure 4. Table 3 provides latitude and longitude of end points of lines of section and average depth to bedrock.

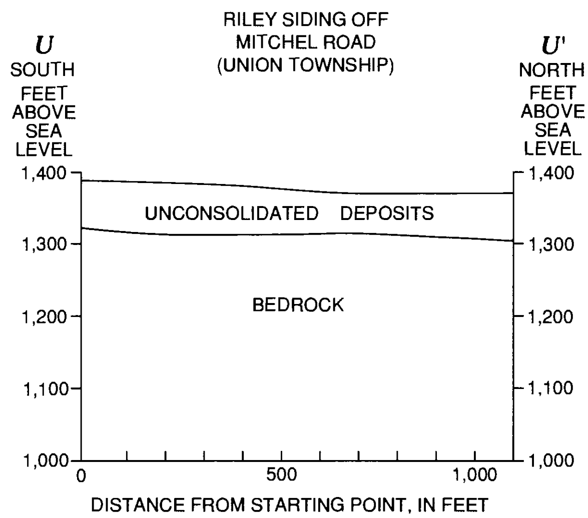

(GREENE TOWNSHIP)
J
SOUTH
FEET ABOVE SEA LEVEL
J'
NORTH
FEET ABOVE SEA LEVEL
1,400
1,300
1,200
1,100
1,000
UNCONSOLIDATED DEPOSITS
BEDROCK
0
500
1,000
DISTANCE FROM STARTING POINT, IN FEET

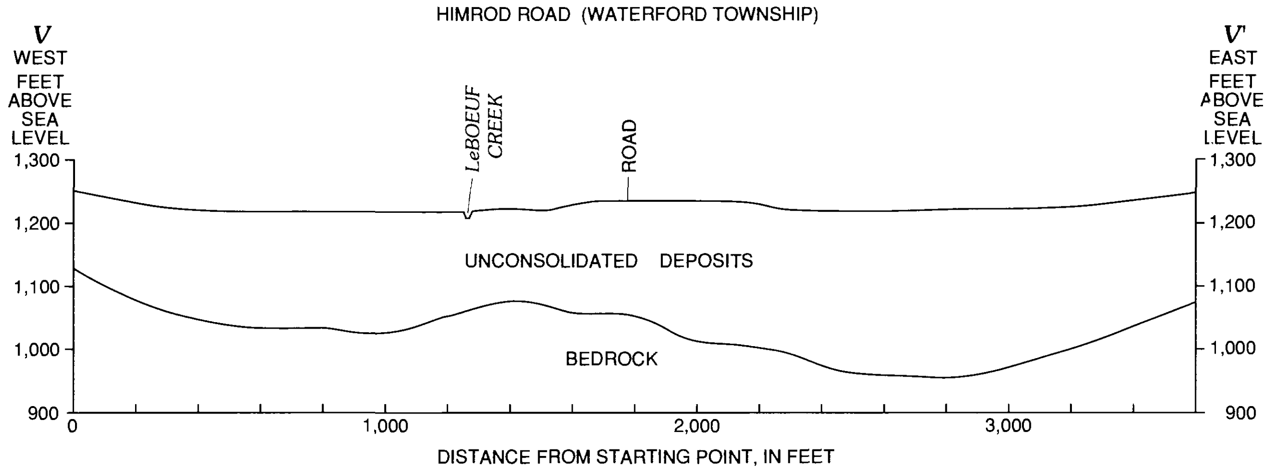

DUNN VALLEY (McKEAN TOWNSHIP)
P
NORTH
FEET ABOVE SEA LEVEL
P'
SOUTH
FEET ABOVE SEA LEVEL
ELK CREEK
1,200
1,100
1,000
900
800
UNCONSOLIDATED DEPOSITS
BEDROCK
0
500
1,000
DISTANCE FROM STARTING POINT, IN FEET

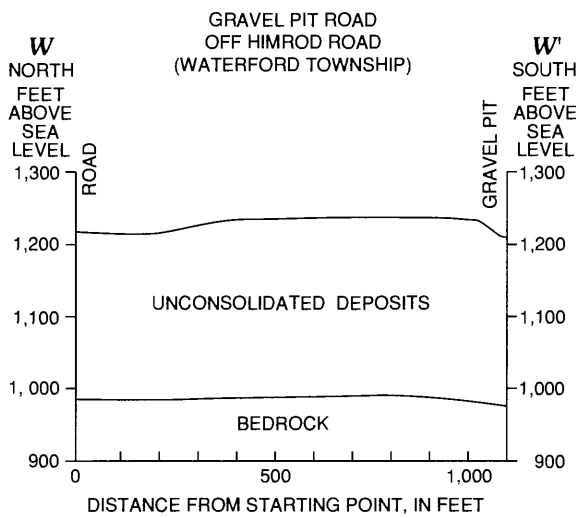

R
NORTH
FEET ABOVE SEA LEVEL
BRICKYARD ROAD
(NORTH EAST TOWNSHIP)
R'
SOUTH
FEET ABOVE SEA LEVEL
ROUTE 5
WELL 3009
UNCONSOLIDATED DEPOSITS
BEDROCK
800
700
600
500
400
0
500
1,000
1,500
2,000
2,500
DISTANCE FROM STARTING POINT, IN FEET


PENNSYLVANIA STATE UNIVERSITY AGRICULTURAL RESEARCH STATION ROAD
(NORTH EAST TOWNSHIP)
S
NORTH
FEET ABOVE SEA LEVEL
S'
SOUTH
FEET ABOVE SEA LEVEL
ROUTE 5
WELL 669
FARM ROAD
UNCONSOLIDATED DEPOSITS
BEDROCK
800
700
600
500
400
0
500
1,000
1,500
2,000
DISTANCE FROM STARTING POINT, IN FEET


PENNSYLVANIA STATE UNIVERSITY AGRICULTURAL
RESEARCH STATION ROAD (NORTH EAST TOWNSHIP)
T
EAST
FEET ABOVE SEA LEVEL
T'
WEST
FEET ABOVE SEA LEVEL
FARM ROAD
WELL 3023
UNCONSOLIDATED
DEPOSITS
BEDROCK
800
700
600
500
400
0
500
1,000
DISTANCE FROM STARTING POINT, IN FEET


RILEY SIDING OFF
MITCHEL ROAD
(UNION TOWNSHIP)
U
SOUTH
FEET ABOVE SEA LEVEL
U'
NORTH
FEET ABOVE SEA LEVEL
UNCONSOLIDATED DEPOSITS
BEDROCK
1,400
1,300
1,200
1,100
1,000
0
500
1,000
DISTANCE FROM STARTING POINT, IN FEET


HIMROD ROAD (WATERFORD TOWNSHIP)
V
WEST
FEET ABOVE SEA LEVEL
V'
EAST
FEET ABOVE SEA LEVEL
LeBOEUF CREEK
ROAD
UNCONSOLIDATED DEPOSITS
BEDROCK
1,300
1,200
1,100
1,000
900
0
1,000
2,000
3,000
DISTANCE FROM STARTING POINT, IN FEET


GRAVEL PIT ROAD
OFF HIMROD ROAD
(WATERFORD TOWNSHIP)
W
NORTH
FEET ABOVE SEA LEVEL
W'
SOUTH
FEET ABOVE SEA LEVEL
ROAD
GRAVEL PIT
UNCONSOLIDATED DEPOSITS
BEDROCK
1,300
1,200
1,100
1, 000
900
0
500
1,000
DISTANCE FROM STARTING POINT, IN FEET

## **Appendix 2.** Record of wells, Erie County, Pennsylvania

County well number: The number that is assigned to identify the well. The prefix Er before the well number signifies that the well is located in Erie County.

Primary use of site: O, observation; T, test; W, withdrawal.

Primary use of water: A, air conditioning; C, commercial; H, domestic; I, irrigation; N, Industrial; P, public supply; Q, agriculture; U, unused.

Topographic setting: F, flat; H, hilltop; S, hillside; V, valley flat.

Hydrogeologic unit: 112BECH, glacial beach deposits; 112OTSH, glacial outwash deposits; 112TILL, glacial till deposits; 341CDKN, Chadakoin Formation; 341VNNG, Venango Formation; 341NRTS, Northeast Shale; UNKNOWN, unknown hydrogeologic unit due to insufficient data.

Lithology: GRVL, gravel; SAND, sand; SDGL, sand and gravel; SDST, sand and silt; SHLE, shale; STCL, silt and clay.

Reported yield: gal/min, gallons per minute.

Specific capacity: [(gal/min/)ft], gallons per minute per foot of drawdown.

Measured yield discharge: gal/min, gallons per minute.

Specific conductance: µS/cm, microsiemens per centimeter at 25 degrees Celsius.

Other abbreviations: DDMMSS, degrees, minutes, and seconds; --, no data.

Driller license numbers and drillers names:

0410 Moody Drilling Co., Inc.

0674 Ralph C. Parmenter

0714 J.W. Waterhouse

0975 Alfred L. Burch

0976 Waible Drilling

1065 Hermann Drilling Co.

1094 George H. Ackerman

1300 Lorenze Lee Hall

1373 Michael W. Burch

1491 Robert P. Rindfuss, Jr.

1664 McCray Drilling

**Appendix 2.** Record of wells, Erie County, Pennsylvania

| USGS well number | Location: Latitude (DDMMSS) | Location: Longitude (DDMMSS) | Township or borough | Owner | Driller license number | Year drilled | Primary: Use of site | Primary: Use of water | Elevation of land surface (feet) | Topo-graphic setting | Hydro-geologic unit |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Er-82 | 415607 | 0800446 | Washington Twp. | U.S. Geological Survey | 0410 | 1966 | O | U | 1,419 | S | 341VNNG |
| 825 | 420021 | 0800726 | McKean Twp. | Krautter, Lauren | 0975 | 1967 | W | H | 1,040 | F | 112TILL |
| 1285 | 420115 | 0801110 | McKean Twp. | Sun Oil Co. | 1065 | 1977 | W | C | 1,100 | H | 112OTSH |
| 1800 | 415842 | 0802039 | Girard Twp. | Boyce, Bruce | 0005 | 1975 | W | A | 840 | F | 112OTSH |
| 1802 | 415824 | 0793845 | Wayne Twp. | Katren, Ed | – | – | W | H | 1,565 | S | 341VNNG |
| 1803 | 415830 | 0802319 | Springfield Twp. | Fairview Evergreen Nursery | | – | W | H | 725 | F | 112OTSH |
| 1804 | 415828 | 0802319 | Springfield Twp. | Boyce, Bruce | – | – | W | H | 725 | F | 112OTSH |
| 1805 | 415345 | 0800738 | Washington Twp. | Warnshuis, Burton | – | – | W | H | 1,255 | F | 112OTSH |
| 1806 | 415202 | 0800751 | Washington Twp. | Woods, Dan | – | 1960 | W | Q | 1,200 | F | 112OTSH |
| 1807 | 415200 | 0800749 | Washington Twp. | Woods, Dan | – | 1960 | W | H | 1,200 | F | 112OTSH |
| 1808 | 420438 | 0800312 | Millcreek Twp. | Monroe, Mark | – | 1978 | W | H | 1,040 | S | 112OTSH |
| 1809 | 420435 | 0800317 | Millcreek Twp. | Granahan, Don | – | 1972 | W | H | 1,030 | S | 341CDKN |
| 1810 | 420150 | 0801938 | Girard Twp. | Fairview Evergreen Nursery | – | – | W | Q | 695 | F | 112BECH |
| 1811 | 420043 | 0795412 | Venango Twp. | Allen, Merle | – | 1977 | W | H | 1,350 | S | 112OTSH |
| 1812 | 420043 | 0795415 | Greene Twp. | Lake Pleasant Methodist Ch | – | 1987 | W | H | 1,365 | S | 112OTSH |
| 1813 | 420046 | 0795414 | Greene Twp. | Allen, Merle | – | – | W | H | 1,365 | S | 112OTSH |
| 1814 | 420045 | 0795404 | Venango Twp. | Allen, Merle | – | – | W | H | 1,335 | S | 112OTSH |
| 1816 | 421114 | 0795416 | Harborcreek Twp. | Penoyer, Gary | – | – | W | H | 755 | F | 112OTSH |
| 1819 | 420038 | 0801027 | McKean Twp. | Burch, Michael W. | – | – | W | H | 980 | F | 112OTSH |
| 1820 | 415639 | 0794510 | Wayne Twp. | Sill, Calvin | – | 1971 | W | H | 1,475 | F | 341VNNG |
| 1821 | 415641 | 0794510 | Wayne Twp. | Sill, Lynn | – | 1937 | W | H | 1,475 | F | 341VNNG |
| 1822 | 415759 | 0795409 | Waterford Twp. | Parsons, Carol | – | 1979 | W | H | 1,450 | S | 112OTSH |
| 1823 | 420049 | 0795138 | Venango Twp. | Vogel, P. | – | 1987 | W | I | 1,490 | S | 341VNNG |
| 1826 | 421102 | 0794859 | North East Twp. | Lakeview Country Club | – | – | W | U | 1,240 | F | 341CDKN |
| 2002 | 415739 | 0793825 | Wayne Twp. | McAvoy, Alfred | – | 1969 | W | H | 1,475 | F | 112OTSH |
| 2003 | 415741 | 0793859 | Wayne Twp. | Leisure Lake Campground | – | – | W | P | 1,465 | S | 112OTSH |
| 3010 | 421332 | 0795113 | North East Twp. | Gierke, Richard | – | – | W | H | 740 | F | 112BECH |
| 3011 | 421333 | 0795113 | North East Twp. | Gierke, Richard | – | – | W | Q | 740 | F | 112BECH |
| 3014 | 421110 | 0794936 | North East Twp. | Craig, Gary | – | 1986 | W | H | 1,150 | S | 112TILL |
| 3015 | 421057 | 0794931 | North East Twp. | Renolds, K.R. | 0674 | 1975 | W | H | 1,225 | S | 341CDKN |
| 3016 | 421303 | 0795255 | North East Twp. | Page, Bert | 0714 | 1962 | W | H | 745 | F | 112BECH |
| 3019 | 421341 | 0795119 | North East Twp. | Penn State University | 1373 | 1988 | O | U | 730 | F | 112BECH |
| 3020 | 421349 | 0795124 | North East Twp. | Penn State University | 1373 | 1988 | O | U | 730 | F | 112BECH |
| 3021 | 421338 | 0795126 | North East Twp. | Penn State University | 1373 | 1988 | O | U | 740 | F | 112BECH |
| 3022 | 421342 | 0795126 | North East Twp. | Penn State University | 1373 | 1988 | W | I | 730 | F | 112BECH |
| 3023 | 421342 | 0795123 | North East Twp. | Penn State University | 1373 | 1988 | O | U | 730 | F | 341NRTS |
| 4000 | 420115 | 0795007 | Venango Twp. | Brumagin, Bernard | 1664 | 1968 | W | H | 1,340 | S | 112OTSH |
| 4001 | 420114 | 0795006 | Venango Twp. | Brumagin, Bernard | 1664 | 1950 | W | H | 1,340 | S | 112OTSH |
| 4002 | 420110 | 0795005 | Venango Twp. | Douglas | 0674 | 1970 | W | H | 1,340 | S | 112OTSH |
| 4003 | 420300 | 0795211 | Venango Twp. | Gorniak, Steven | 0975 | 1976 | W | H | 1,480 | S | 341CDKN |
| 4004 | 420300 | 0795310 | Venango Twp. | Laskowski | 1373 | 1979 | W | H | 1,360 | V | 112OTSH |
| 4005 | 420300 | 0795312 | Venango Twp. | Panighetti, R. | 1373 | – | W | H | 1,370 | V | 112OTSH |
| 4006 | 420015 | 0794923 | Venango Twp. | Parsons, J. | 1300 | 1983 | W | H | 1,385 | H | 341CDKN |

**Appendix 2.** Record of wells, Erie County, Pennsylvania--Continued

| Lithology | Depth of well (feet) | Casing | | Depth to water-bearing zones (feet) | Water level (feet) | Date water level measured | Reported yield (gal/min) | Measured yield | | | Field water quality | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Depth (feet) | Diameter (inches) | | | | | Specific capacity [(gal/min)/ft] | Discharge (gal/min) | Pumping period (hours) | Date measured | Specific conductance (µS/cm) | pH (standard units) |
| SHLE | 82 | 56 | 6 | -- | 16.98 | 06-21-66 | -- | 0.19 | 1.0 | 1 | 07-20-89 | 230 | -- |
| GRVL | 31 | 31 | 8 | 5/21/31 | -- | -- | 20 | 1.3 | 20 | 2 | 06-07-88 | 470 | 5.5 |
| SDGL | 145 | 140 | 8 | 75/134 | 78 | 04-04-77 | 20 | .5 | 20 | 4 | 04-04-77 | -- | -- |
| SDGL | 48 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 01-19-88 | 485 | 6.8 |
| -- | 45 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 10-21-87 | 260 | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 10-22-87 | 405 | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 01-20-88 | 485 | 6.8 |
| GRVL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 01-26-88 | 530 | 7.1 |
| GRVL | 30 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 01-26-88 | 600 | 7.2 |
| GRVL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 10-21-87 | 750 | -- |
| GRVL | 15 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| SHLE | 113 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 10-22-87 | 200 | -- |
| -- | 27 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 10-20-87 | 300 | -- |
| -- | 46 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 02-01-88 | 450 | 6.7 |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 01-19-88 | 320 | 7.8 |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 01-19-88 | 315 | 7.8 |
| GRVL | 28 | -- | -- | -- | 18.00 | 00-00-88 | 5 | -- | -- | -- | 01-19-88 | 420 | 7.4 |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 10-22-87 | 175 | -- |
| -- | 180 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 10-20-87 | 330 | -- |
| -- | 150 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 10-21-87 | 560 | -- |
| GRVL | 9 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 02-01-88 | -- | 7.2 |
| -- | 70 | -- | -- | -- | -- | -- | 6 | -- | -- | -- | 10-20-87 | 480 | -- |
| -- | 40 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 07-11-89 | 375 | 7.8 |
| -- | 95 | -- | -- | -- | 15.00 | 06-14-88 | <1 | -- | -- | -- | -- | -- | -- |
| -- | 30 | 28 | 8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | 18 | -- | -- | -- | 12.30 | 06-08-88 | <1 | -- | -- | -- | 06-08-88 | 400 | -- |
| -- | 14 | 14 | 2 | -- | -- | -- | -- | -- | -- | -- | 06-08-88 | 405 | -- |
| -- | 20 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 06-08-88 | 1,090 | -- |
| -- | 45 | -- | -- | -- | 11.50 | 06-08-88 | <3 | -- | -- | -- | 06-08-88 | 1,110 | -- |
| -- | 35 | 35 | 8 | -- | 18.40 | 06-08-88 | <17 | -- | -- | -- | 06-08-88 | 519 | -- |
| -- | 55 | 47 | 6 | 22/33/45 | 11.40 | 08-02-88 | -- | -- | -- | -- | -- | -- | -- |
| STCL | 50 | 52 | 8 | 20 | 26.60 | 04-26-88 | -- | -- | -- | -- | -- | -- | -- |
| SDGL | 41 | 41 | 8 | 32 | -- | -- | 6 | -- | -- | 2 | -- | -- | -- |
| SDGL | 40 | 40 | 8 | 27 | -- | -- | -- | -- | 12 | 27 | 04-26-88 | -- | -- |
| -- | 115 | 113 | 6 | 16/27/43/114 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | 80 | 80 | 8 | -- | -- | -- | 10 | -- | -- | -- | 06-21-88 | 295 | 7.0 |
| -- | 98 | 98 | 8 | -- | 30.00 | 00-00-50 | 15 | -- | -- | -- | 06-21-88 | 256 | 7.8 |
| -- | 85 | 85 | 8 | -- | 30.00 | 00-00-70 | 10 | -- | -- | -- | -- | -- | -- |
| SHLE | 60 | 57 | 8 | 37/57 | -- | -- | 10 | -- | -- | 2 | 08-04-88 | 240 | -- |
| SDGL | 52 | 52 | 8 | 47 | 6.00 | 06-00-79 | 25 | -- | -- | -- | 08-04-88 | 321 | -- |
| SDGL | 70 | 70 | 8 | 59/61 | 17.60 | 08-04-88 | 30 | -- | -- | -- | 08-04-88 | 300 | -- |
| SHLE | 109 | 82 | 6 | 85 | 50.40 | 08-04-88 | -- | .06 | 5 | 2 | 08-04-88 | 308 | -- |

**Appendix 2.** Record of wells, Erie County, Pennsylvania--Continued

| USGS well number | Location: Latitude (DDMMSS) | Location: Longitude (DDMMSS) | Township or borough | Owner | Driller license number | Year drilled | Primary: Use of site | Primary: Use of water | Elevation of land surface (feet) | Topo-graphic setting | Hydro-geologic unit |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5001 | 415346 | 0794647 | Union Twp. | Ramsey, Kenneth | 1664 | -- | W | H | 1,335 | S | 112OTSH |
| 5002 | 415356 | 0794658 | Union Twp. | Peterson, David | 1491 | -- | W | H | 1,360 | S | 112OTSH |
| 5501 | 421132 | 0795554 | Harborcreek Twp. | Hill, Jack | -- | 1913 | W | H | 670 | F | 112BECH |
| 6001 | 420200 | 0795430 | Greene Twp. | Malliard, Jon | 0714 | -- | W | H | 1,325 | F | 112OTSH |
| 6002 | 420144 | 0795451 | Greene Twp. | Ganzer Sand & Gravel | -- | -- | W | C | 1,355 | S | 112OTSH |
| 6004 | 420412 | 0795444 | Greene Twp. | Hannah, Robert G. | -- | -- | W | H | 1,330 | F | 112OTSH |
| 6005 | 420408 | 0795444 | Greene Twp. | Kitelinger, Rebecca | 1300 | -- | W | H | 1,330 | F | 112OTSH |
| 6006 | 420412 | 0795451 | Greene Twp. | Mrozowski, John | -- | -- | W | H | 1,320 | S | 112OTSH |
| 6007 | 420413 | 0795507 | Greene Twp. | O'Leary, Shirley | -- | -- | W | H | 1,315 | S | 112OTSH |
| 6010 | 420327 | 0795424 | Greene Twp. | Sayban, Steve | 1373 | -- | W | H | 1,340 | S | 112OTSH |
| 6011 | 420415 | 0795813 | Greene Twp. | Vallimont | 1065 | -- | W | H | 1,270 | S | 112OTSH |
| 6012 | 420425 | 0795807 | Greene Twp. | Kreger, D. | 1373 | -- | W | H | 1,210 | S | 341CDKN |
| 6013 | 420148 | 0795600 | Greene Twp. | Filley, E. | 1094 | -- | W | H | 1,400 | H | 112OTSH |
| 6014 | 420226 | 0795603 | Greene Twp. | Price, Wayne | 1094 | -- | W | C | 1,380 | H | 112OTSH |
| 7501 | 420417 | 0800902 | Millcreek Twp. | Millcreek Twp. | 1373 | 1989 | W | P | 845 | F | 112OTSH |
| 7502 | 420417 | 0800902 | Millcreek Twp. | Millcreek Twp. School | 1065 | 1988 | O | U | 845 | F | 112OTSH |
| 7503 | 420414 | 0800905 | Millcreek Twp. | Hudson | -- | -- | W | H | 855 | F | 112OTSH |
| 7504 | 420424 | 0800843 | Millcreek Twp. | Millcreek Twp. School | 1373 | 1989 | W | I | 855 | F | 112OTSH |
| 7505 | 420425 | 0800840 | Millcreek Twp. | Hardy, Michael | -- | 1965 | O | C | 860 | F | 112OTSH |
| 7506 | 420927 | 0800431 | Presque Isle | U.S. Geological Survey | 1373 | 1989 | O | U | 575 | F | 112BECH |
| 7507 | 420927 | 0800432 | Presque Isle | U.S. Geological Survey | 1373 | 1989 | O | U | 575 | F | 112BECH |
| 7508 | 420927 | 0800432 | Presque Isle | U.S. Geological Survey | 1373 | 1989 | T | U | 575 | F | 112BECH |
| 8540 | 420126 | 0801128 | McKean Twp. | U.S. Geological Survey | 1373 | 1988 | T | U | 960 | F | 112OTSH |
| 8541 | 420126 | 0801128 | McKean Twp. | U.S. Geological Survey | 1373 | 1988 | T | U | 960 | F | 112OTSH |
| 8542 | 420128 | 0801125 | McKean Twp. | U.S. Geological Survey | 1373 | 1988 | T | U | 965 | F | 112OTSH |
| 8543 | 420125 | 0801124 | McKean Twp. | U.S. Geological Survey | 1373 | 1988 | T | U | 975 | F | 112OTSH |
| 8544 | 420123 | 0801122 | McKean Twp. | U.S. Geological Survey | 1373 | 1988 | T | U | 980 | F | 112OTSH |
| 8545 | 420128 | 0801139 | McKean Twp. | U.S. Geological Survey | -- | 1988 | O | U | 970 | F | 112TILL |
| 8546 | 420024 | 0800521 | McKean Twp. | U.S. Geological Survey | -- | 1988 | O | U | 1,100 | F | 112TILL |
| 9503 | 420236 | 0801428 | Fairview Twp. | Grimm Industries | 0976 | -- | W | N | 810 | F | 112OTSH |
| 9505 | 420226 | 0801443 | Fairview Twp. | Grimm Industries | 0976 | -- | W | N | 800 | F | 112OTSH |
| 9508 | 420128 | 0801239 | Fairview Twp. | Hetz, Richard | 0975 | -- | W | H | 945 | S | 112OTSH |
| 9517 | 420149 | 0801428 | Fairview Twp. | Craft, G. | 1094 | -- | W | H | 830 | H | 112OTSH |
| 9525 | 420044 | 0801533 | Fairview Twp. | Traut, Kenneth | 0976 | -- | W | H | 910 | S | 112OTSH |
| 9528 | 420131 | 0801153 | Fairview Twp. | McCain, Willard | 0976 | -- | W | H | 980 | S | Unknown |
| 9529 | 420130 | 0801155 | Fairview Twp. | McCain, Willard | 0976 | -- | W | H | 970 | S | Unknown |
| 9530 | 420148 | 0801224 | Fairview Twp. | McCain, Lydia | -- | -- | W | H | 880 | S | 112OTSH |
| 9531 | 420130 | 0801418 | Fairview Twp. | Borecky | -- | -- | W | H | 835 | F | 112OTSH |
| 9532 | 420204 | 0801055 | Fairview Twp. | Cross, James | 0976 | -- | W | H | 920 | S | 112OTSH |
| 9533 | 420218 | 0801220 | Fairview Twp. | Terry, Don | 1094 | -- | W | H | 825 | F | 112OTSH |
| 9534 | 420156 | 0801320 | Fairview Twp. | Niebauer, Joseph | -- | -- | W | H | 830 | F | 112OTSH |
| 9535 | 420108 | 0801436 | Fairview Twp. | Benson, Jim | 0975 | -- | W | H | 880 | S | 112OTSH |
| 9538 | 420029 | 0801319 | Fairview Twp. | Terella, Thomas | -- | -- | W | H | 960 | F | 112OTSH |
| 9540 | 420159 | 0801211 | Fairview Twp. | Tubbs, Art | -- | -- | W | H | 860 | S | 112OTSH |

**Appendix 2.** Record of wells, Erie County, Pennsylvania--Continued

| Lithol-ogy | Depth of well (feet) | Casing | | Depth to water-bearing zones (feet) | Water level (feet) | Date water level meas-ured | Repor-ted yield (gal/min) | Measured yield | | | Field water quality | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Depth (feet) | Diam-eter (inches) | | | | | Specific capacity [(gal/min)/ft] | Dis-charge (gal/min) | Pump-ing period (hours) | Date meas-ured | Spec-ific con-duc-tance (µS/cm) | pH (stand-ard units) |
| – | 165 | – | – | – | – | – | – | – | – | – | – | – | – |
| – | 230 | 230 | 6 | – | 5.05 | 06-14-88 | – | – | – | – | – | – | – |
| – | 18 | 22 | 24 | – | 11.10 | 06-21-88 | – | – | – | – | 06-21-88 | 339 | 7.5 |
| – | 37 | 37 | 8 | – | – | – | – | – | – | – | – | – | – |
| – | 65 | – | – | – | – | – | – | – | – | – | – | – | – |
| – | 68 | 68 | 8 | – | 10.00 | 00-00-61 | – | – | – | – | 06-15-88 | 260 | 8.6 |
| – | 36 | – | – | – | – | – | – | – | – | – | 06-15-88 | 300 | 8.5 |
| – | 12 | 12 | 26 | – | – | – | 4 | – | – | – | 06-15-88 | 390 | 7.7 |
| – | 30 | 30 | 36 | – | 6.00 | 06-15-88 | – | – | – | – | 06-15-88 | 960 | 6.1 |
| – | 105 | 103 | 8 | 32/104 | 21.40 | 03-25-85 | 20 | – | – | – | 08-08-88 | 235 | – |
| SDGL | 149 | 149 | 6 | 59/148 | – | – | – | 0.08 | 10 | 4 | 08-08-88 | 250 | – |
| SHLE | 108 | 94 | 8 | 9/24/36 | 4.00 | 08-08-88 | – | .03 | 4 | 2 | 08-08-88 | 135 | – |
| SDGL | 155 | 155 | 8 | 112/142 | 67.40 | 08-08-88 | – | .43 | 30 | 2 | 08-08-88 | 205 | – |
| – | 102 | 102 | 8 | 92 | 77.60 | 07-14-88 | – | – | – | – | 07-14-88 | 250 | 6.0 |
| SDGL | 64 | 64 | 10 | 50 | 14.30 | 08-07-89 | – | 5.3 | 100 | 48 | 08-09-89 | 430 | 7.7 |
| SDGL | 62 | 62 | 8 | 53 | 17.60 | 08-07-89 | – | – | – | – | 04-02-89 | 370 | – |
| SDGL | 60 | – | – | – | 28.20 | 08-07-89 | – | – | – | – | – | – | – |
| SDGL | 68 | 66 | 8 | 48 | 14.00 | 10-10-89 | – | 3.9 | 170 | 24 | 10-11-89 | 470 | 6.8 |
| SDGL | 55 | 55 | 8 | 52 | 18.20 | 10-10-89 | – | – | – | – | – | – | – |
| SAND | 14 | 3 | 4 | 3 | 1.98 | 07-07-89 | – | – | – | – | – | – | – |
| SAND | 19 | 3 | 2 | 3 | 1.95 | 07-07-89 | – | – | – | – | – | – | – |
| SAND | 14 | 8 | 4 | 8 | 1.93 | 07-07-89 | 26 | – | – | 6 | 07-07-89 | 370 | 6.7 |
| SDGL | 72 | 72 | 8 | – | 48.50 | 10-27-88 | – | 31 | 150 | 144 | 11-02-88 | 340 | – |
| SDGL | 69 | 69 | 8 | – | 47.90 | 10-25-88 | – | – | – | – | 10-13-88 | 330 | – |
| SDGL | 70 | 67 | 8 | – | 50.60 | 10-25-88 | – | – | – | – | 10-14-88 | 410 | – |
| SDGL | 84 | 80 | 8 | – | 62.60 | 10-25-88 | – | 3.5 | 30 | 2.5 | 10-14-88 | 340 | – |
| SDGL | 85 | 83 | 8 | – | 68.50 | 10-25-88 | – | 9.3 | 30 | 3.5 | 10-18-88 | 365 | – |
| SDST | 69 | 62 | 2 | 62 | 58.10 | 10-11-88 | – | – | – | – | 09-12-89 | 340 | 7.2 |
| – | 34 | 28 | 2 | 28 | 1.32 | 10-12-88 | – | – | – | – | 09-12-89 | 210 | 7.7 |
| GRVL | 65 | 65 | 8 | 60 | 57.70 | 05-24-88 | 20 | – | – | – | – | – | – |
| GRVL | 64 | 64 | 8 | 58 | 47.40 | 05-25-88 | 20 | – | – | – | – | – | – |
| SDGL | 71 | 71 | 8 | 60/65 | 56.00 | 05-24-88 | – | 1.4 | 20 | 2 | – | – | – |
| GRVL | 80 | 80 | 8 | 38/76 | 46.70 | 05-24-88 | – | 1.5 | 18 | 4 | – | – | – |
| GRVL | 108 | 108 | 8 | 106 | 44.50 | 05-31-88 | 20 | – | – | – | 05-31-88 | 330 | 7.0 |
| – | 160 | – | – | – | 110.00 | 05-23-88 | – | – | – | – | – | – | – |
| – | 160 | – | – | – | – | – | – | – | – | – | – | – | – |
| – | 55 | – | – | – | – | – | – | – | – | – | – | – | – |
| – | 35 | – | – | – | – | – | 20 | – | – | – | – | – | – |
| – | 70 | – | – | – | – | – | – | – | – | – | – | – | – |
| – | 60 | – | – | – | 23.70 | 05-25-88 | – | – | – | – | – | – | – |
| – | 80 | – | – | – | – | – | – | – | – | – | – | – | – |
| – | 100 | 100 | 8 | – | – | – | – | – | – | – | – | – | – |
| – | 120 | 120 | 8 | – | – | – | – | – | – | – | 05-27-88 | 365 | 7.2 |
| – | 44 | – | – | – | – | – | – | – | – | – | – | – | – |

**Appendix 2.** Record of wells, Erie County, Pennsylvania--Continued

| USGS well number | Location: Latitude (DDMMSS) | Location: Longitude (DDMMSS) | Township or borough | Owner | Driller license number | Year drilled | Primary: Use of site | Primary: Use of water | Elevation of land surface (feet) | Topo-graphic setting | Hydro-geologic unit |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9546 | 420059 | 0801449 | Fairview Twp. | Kirschner, H.C. | -- | -- | W | H | 895 | F | 112OTSH |
| 9547 | 420048 | 0801444 | Fairview Twp. | Hawley, Nina | -- | -- | W | H | 920 | F | 112OTSH |
| 9548 | 420059 | 0801442 | Fairview Twp. | Bennett, Don | 0976 | -- | W | H | 890 | F | 112OTSH |
| 9549 | 420105 | 0801451 | Fairview Twp. | Ives, Anne | -- | -- | W | H | 880 | F | 112OTSH |
| 9550 | 420040 | 0801439 | Fairview Twp. | Platz | -- | -- | W | H | 900 | S | 112OTSH |
| 9553 | 420045 | 0801443 | Fairview Twp. | Sherred, James | -- | -- | W | H | 910 | S | 112OTSH |
| 9554 | 420154 | 0801305 | Fairview Twp. | Heinlein, Thomas | 0975 | -- | W | H | 830 | S | 112OTSH |
| 9555 | 420042 | 0801211 | Fairview Twp. | Kruse, Edward | -- | -- | W | H | 960 | S | 112OTSH |
| 9556 | 420230 | 0801453 | Fairview Twp. | Farnham, K. | 1094 | -- | W | H | 800 | S | 112OTSH |
| 9559 | 420111 | 0801310 | Fairview Twp. | Evans, Art | 0976 | -- | W | H | 930 | F | 112OTSH |
| 9560 | 420048 | 0801329 | Fairview Twp. | Jareckie Industries | 1094 | -- | W | H | 930 | F | 112OTSH |
| 9561 | 420028 | 0801313 | Fairview Twp. | Dobrzynski, E. | 1065 | -- | W | H | 965 | H | 112OTSH |
| 9562 | 420138 | 0801441 | Fairview Boro. | U.S. Geological Survey | -- | 1988 | O | U | 795 | S | 112TILL |
| 9563 | 420018 | 0801343 | Fairview Twp. | U.S. Geological Survey | -- | 1988 | O | U | 950 | F | 112TILL |
| 10508 | 415843 | 0801914 | Girard Twp. | Erickson, Jesse | -- | -- | W | H | 840 | F | 112OTSH |
| 10509 | 415838 | 0802017 | Girard Twp. | Boyce, Bruce | -- | 1950 | W | H | 845 | F | 112OTSH |
| 10510 | 415832 | 0802014 | Girard Twp. | Boyce, Bruce | -- | -- | W | H | 845 | F | 112OTSH |
| 10511 | 415811 | 0802008 | Girard Twp. | Jasper, James | -- | -- | W | H | 860 | F | 112OTSH |
| 10512 | 415811 | 0801942 | Girard Twp. | Deermont, E.H. | -- | 1963 | W | H | 885 | F | 112OTSH |
| 10513 | 415812 | 0802056 | Girard Twp. | Klimek, John | -- | -- | W | H | 835 | F | 112OTSH |
| 10514 | 415811 | 0801916 | Girard Twp. | Hamilton, Robert | -- | -- | W | H | 870 | F | 112OTSH |
| 10515 | 415806 | 0801916 | Girard Twp. | Johnson, Richard M. | -- | -- | W | H | 855 | F | 112OTSH |
| 10516 | 415838 | 0802013 | Girard Twp. | Wagnor, Howard | -- | -- | W | H | 845 | F | 112OTSH |
| 10517 | 415703 | 0802006 | Girard Twp. | Babbitt, Raymond | 1094 | -- | W | H | 880 | F | 112OTSH |
| 10518 | 415701 | 0802053 | Girard Twp. | Youngs, Mark | -- | -- | W | H | 855 | F | 112OTSH |
| 10519 | 415703 | 0801954 | Girard Twp. | Sutton, Mike | -- | 1978 | W | H | 875 | F | 112OTSH |
| 10521 | 415722 | 0802033 | Girard Twp. | John Gresch Farms | -- | 1964 | W | H | 850 | F | 112OTSH |
| 10522 | 415846 | 0801915 | Girard Twp. | Gresch, John | -- | 1979 | W | C | 840 | F | 112OTSH |
| 10523 | 415742 | 0802020 | Girard Twp. | Lester Auto Repair | -- | -- | W | C | 855 | F | 112OTSH |
| 10524 | 415709 | 0801954 | Girard Twp. | Markham | -- | -- | W | H | 880 | F | 112OTSH |
| 10525 | 415813 | 0802041 | Girard Twp. | U.S. Geological Survey | -- | 1988 | O | U | 835 | F | 112TILL |

**Appendix 2.** Record of wells, Erie County, Pennsylvania--Continued

| | | Casing | | | | | | Measured yield | | | Field water quality | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lithology | Depth of well (feet) | Depth (feet) | Diameter (inches) | Depth to water-bearing zones (feet) | Water level (feet) | Date water level measured | Reported yield (gal/min) | Specific capacity [(gal/min)/ft] | Discharge (gal/min) | Pumping period (hours) | Date measured | Specific conductance (μS/cm) | pH (standard units) |
| -- | 106 | -- | -- | -- | 41.50 | 05-31-88 | -- | -- | -- | -- | 05-31-88 | 339 | 6.7 |
| -- | 80 | 80 | 8 | -- | -- | -- | -- | -- | -- | -- | 05-31-88 | 340 | 7.8 |
| -- | 38 | 38 | 8 | -- | -- | -- | -- | -- | -- | -- | 05-31-88 | 572 | 6.6 |
| -- | 40 | 40 | 8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | 14 | -- | -- | -- | 10.00 | 05-31-88 | -- | -- | -- | -- | -- | -- | -- |
| -- | 24 | 24 | 26 | -- | 15.50 | 05-31-88 | -- | -- | -- | -- | 05-31-88 | 1000 | 5.3 |
| -- | 48 | 42 | 8 | -- | -- | -- | -- | -- | -- | -- | 05-31-88 | 417 | 6.7 |
| -- | 100 | 100 | 6 | -- | 25.80 | 05-27-88 | -- | -- | -- | -- | -- | -- | -- |
| SDGL | 95 | 95 | 8 | 75/90 | 60.20 | 07-07-88 | -- | 0.94 | 16 | 3 | 07-07-88 | 748 | 7.5 |
| SDGL | 128 | 128 | 8 | 123 | 76.60 | 07-07-88 | 15 | -- | -- | -- | 07-07-88 | 540 | 8.7 |
| SDGL | 116 | 110 | 8 | 39/90 | 80.10 | 07-07-88 | -- | .44 | 11 | 2 | 07-07-88 | 1190 | 7.8 |
| -- | 135 | 127 | 8 | 64/125 | 56.90 | 07-07-88 | -- | .1 | 7 | 3 | 07-07-88 | 1150 | 8.4 |
| SDST | 33 | 28 | 2 | 28 | -- | -- | -- | -- | -- | -- | 09-11-89 | 420 | 6.8 |
| SDST | 59 | 47 | 2 | 47 | 31.40 | 10-12-88 | -- | -- | -- | -- | 09-11-89 | 370 | 6.1 |
| -- | 19 | 19 | 30 | -- | 17.00 | 06-01-88 | <1 | -- | -- | -- | 06-01-88 | 158 | 5.6 |
| -- | 38 | -- | -- | -- | 11.00 | 06-01-88 | <1 | -- | -- | -- | -- | -- | -- |
| -- | 28 | 28 | 36 | -- | 7.00 | 06-01-88 | <1 | -- | -- | -- | -- | -- | -- |
| -- | 30 | 30 | 48 | -- | -- | -- | 5 | -- | -- | -- | -- | -- | -- |
| -- | 13 | 13 | 36 | -- | -- | -- | -- | -- | -- | -- | 06-01-88 | 465 | 5.6 |
| -- | 12 | 12 | 36 | -- | 9.00 | 06-01-88 | <1 | -- | -- | -- | 06-01-88 | 390 | 5.3 |
| -- | 25 | 25 | -- | -- | -- | -- | -- | -- | -- | -- | 06-01-88 | 370 | -- |
| -- | 40 | 40 | 36 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | 30 | 30 | 36 | -- | 25.50 | 06-01-88 | <1 | -- | -- | -- | 06-01-88 | 580 | 6.7 |
| -- | 131 | -- | -- | -- | 51.00 | 00-00-68 | <1 | -- | -- | -- | 06-02-88 | 725 | 6.7 |
| -- | 15 | 15 | 36 | -- | 7.45 | 06-02-88 | 10 | -- | -- | -- | 06-02-88 | 420 | 6.7 |
| -- | 94 | 94 | 8 | -- | -- | -- | -- | -- | -- | -- | 06-02-88 | 560 | 6.5 |
| -- | 24 | 24 | 36 | -- | 18.00 | 00-00-64 | <1 | -- | -- | -- | -- | -- | -- |
| -- | 24 | 24 | 36 | -- | 18.00 | 00-00-79 | <1 | -- | -- | -- | -- | -- | -- |
| -- | 10 | 10 | 36 | -- | 6.85 | 06-02-88 | <1 | -- | -- | -- | 06-02-88 | 422 | 6.5 |
| -- | 12 | 12 | -- | -- | 6.30 | 06-02-88 | <1 | -- | -- | -- | -- | -- | -- |
| SAND | 44 | 28 | 2 | 28 | 9.46 | 10-12-88 | -- | -- | -- | -- | 09-12-89 | 365 | 7.3 |



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