Walnut Creek Watershed Environmental Quality Assessment Report

May 2007

Bridging the Gap Between Environmental Quality and Community Development

Pennsylvania Department of Environmental Protection

Walnut Creek Watershed
Environmental Quality Assessment
Draft Full Report

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FOREWORD

Looking outward, it’s not easy to see how natural and social interactions occur within a watershed, but a holistic view shows the interrelatedness of human actions and the environment. A healthy watershed is a dynamic system of water, land, air and the biota that live there. Citizens of the watershed rely on this system for the resources needed to ensure public health and safety, sustain economic stability and promote a good quality of life. A proper balance between human activities and the effects on the environment is critical to sustain the resources that we rely upon.

The Walnut Creek watershed has diverse land uses. The headwaters still remain fairly undeveloped and support farming and a rural community. The lower reaches are urbanized with commercial, light-industrial and residential uses. The watershed provides the habitat for various forms of wildlife, including several threatened and endangered animal and plant species. Its wetlands not only provide natural flood control, but also act as a huge water filter for the stream and Lake Erie. The streams are home to a diverse fish population, including natural reproducing brown and rainbow trout.

One of the most acclaimed resources of the Walnut Creek watershed is the renowned steelhead fishery. Each fall and spring steelhead trout migrate from Lake Erie up tributary streams to spawn. The steelhead run provides a great sport fishery, luring fisherman from all over the world. Not only is this a great pasttime for the locals, it is a huge source of revenue for the community. According to a recent study by the Pennsylvanian Fish and Boat Commission, the steelhead fishery in Erie County generates an estimated $10.68 million in local business supporting 219 jobs (Murry, 2004).

The activities of the people living in the watershed can actually threaten the very system they rely upon. Sewage, solid waste and air pollution are all products of our culture. Vehicle transportation through the watershed and the presence of stored chemical materials create potential sources of contamination. Land development changes the natural flow of stormwater and runoff can carry pollutants to the groundwater and surface waters. Further, overuse of a resource can threaten its viability. These threats cannot be eliminated in a developed and growing community, but they can be effectively managed and controlled.

Assessing the watershed can show sustainability of resources, potential sources of contamination and the overall health of its natural systems. The results give regulatory agencies information needed to take an introspective look at its control programs and determine if the desired outcomes are being achieved. Results can be used by local decision makers to decide what factors must be considered with future land use planning. And assessment results can stimulate community action that promotes wise use and care of the watershed resources.

ACKNOWLEDGEMENTS

The assessment team spent countless hours in the field and conducting research on the Walnut Creek watershed, to whom a very special thanks is offered.

Judy Taylor also deserves special recognition for her work with editing, formatting and publishing the report. A thanks also goes out to the staff at the Erie County Conservation District, the Erie County Department of Health, the Science Consortium and the Tom Ridge Environmental Education Center and Pennsylvania Sea Grant for the information they provided.

And most importantly, thanks to the community members who provided input and comments on the report. It is the community who will ultimately drive environmental improvement in the watershed.

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Environmental Quality Report

Department of Environmental Protection
Northwest Regional Office
Watershed Management Program

TABLE OF CONTENTS

PART 1—INTRODUCTION

1.1 Background

The Walnut Creek Watershed is arguably one of the best steelhead fisheries in the Great Lakes region, bringing in millions of dollars to the Erie community each year. It is tributary to Lake Erie, one of the nation's biggest freshwater resources providing public drinking water, recreation opportunities and commerce to northwestern Pennsylvania. This great resource gets significant pressure from urban stormwater runoff, commercial and residential development, and agricultural activities. For these reasons, in 2006 Walnut Creek was selected as the priority watershed for DEP's Northwest Region.

The Department's Watershed Management Program completed a year-long, comprehensive, watershed-based assessment to determine if the environmental conditions in the watershed are supporting public health and safety, economic stability, and quality of life for Erie County residents. The study involved a detailed look at the environmental quality of the watershed and an assessment of actual and potential impacts on its resources. The assessment included a detailed look at:

- Features and physical characteristics of the watershed
- Watershed uses
- Actual and potential pollutants to the watershed
- Efforts in place for resource conservation and environmental stewardship

This report provides a description of the overall environmental quality of the watershed and identifies actual and potential pollutant sources. The impacts on the environmental quality have been quantified, and, where possible, suggestions for abating environmental conflicts are offered. Where the health of the Walnut Creek watershed was found to be impaired, drivers for improvement are identified and recommendations on moving forward are offered.

The assessment is viewed as only the first step for environmental improvement. The findings of the report show the shortcomings of environmental initiatives, whether regulatory based, community based or individual activities. It identifies needs areas and where resources should be focused for improvement. This report can be part of the foundation to make informed environmental planning decisions to ensure public health and safety, provide for economic stability, and to promote a good quality of life for the watershed residents.

1.2 Scope and Purpose of the Assessment

The scope of the assessment was focused to characterize the health of the watershed and identify actual and potential impacts to the watershed resources. The assessment involved collecting and compiling data to determine the environmental quality of the watershed and to identify specific activities that affect it. The assessment included a detailed look at:

1. Data Standards: Evaluating Department accepted standards for data collection and defining specific data standards, sampling and analysis protocols, and Standard Operating Procedures to be used in the assessment.

2. Features and physical characteristics of the watershed: Characterizing and mapping the physical features of the watershed, including: watershed boundaries, surface water designations and uses, overall geology, hydrogeology, topography, and soils.

3. Public water supplies and source water protection activities: Identifying all public water supplies within the watershed and reviewing related Source Water Assessment Reports to evaluate susceptibility of the public water supplies to pollution and to identify potential threats. Researching and identifying any Source Water Protection activities being implemented within the watershed.

4. Surface water quality and stream use attainment: Sampling surface waters to determine if streams within the watershed are meeting Water Quality Standards as defined in Chapter 93 of the Department's regulations. Conducting surface water sampling on Walnut Creek and its tributaries at established sampling stations, for specified parameters, during cold weather low flow, cold weather high flow, warm weather low flow, and warm weather high flow conditions.

5. Groundwater quality: Evaluating ground water quality from existing USGS stations and public water supply sources. Where possible, collect groundwater quality data and compare the results to maximum contaminant levels (MCLs) to determine if the available groundwater sources are suitable for public drinking water supplies.

6. Surface water and groundwater quantity: Identifying surface water withdrawals authorized by Water Allocation permits and Act 220 registrations issued by the Department, and, where possible, any unregulated withdrawals. Investigating actual or potential impacts of the withdrawals on the watercourse. Measuring stream flows on Walnut Creek to define a model to calculate stream flows. Evaluating the influence of stormwater runoff on stream quantity and quality. Using available data, map groundwater resources and flow directions.

7. Compliance with regulatory programs: Identifying Department permitted activities within the watershed and completing a compliance evaluation. The review includes:

   Public Water Supplies
   Injection wells
   Air Quality permits
   Mining operations
   NDPES discharges (SEW, IW, MS4, SW and CAFO)
   102/105 permits
   Landfills
   HSCA/NPL/TRI sites
   Regulated Storage Tanks
   Oil & Gas operations
   Act 167 Stormwater Management Planning
   Act 537 Sewage Planning

8. Land use and planning activities: Mapping the various land uses within the watershed including: political subdivisions, zoning, cover type, and economic use. Identifying any lands restricted or protected by government action, conservancies, or easement programs.

9. Biological health and diversity: Assessing the biological conditions of Walnut Creek and its tributaries through aquatic surveys of the benthos and fish species at established sampling stations. Identifying endangered aquatic and terrestrial species through a PNDI search. Completing a desktop survey using National Wetland Inventory (NWI) maps and existing 105 permits to identify wetlands within the watershed. Conducting a corridor assessment of the Walnut Creek stream channel to identify areas of accelerated erosion, channel modification and illegal water withdrawals or discharges.

10. Potential pollutants to the surface waters and groundwater: Identifying areas and/or activities that have the potential for pollution to the watershed, such as: large agricultural operations, industrial and commercial activities, un-sewered residential areas, major transportation corridors and residential activities.

11. Efforts in place for conservation and education: Comparing compatibility and continuity of Department programs with the activities of other federal, state and local agencies. Listing activities and efforts in place for stewardship and managing environmental resources within the watershed, such as, agricultural conservation programs, education programs and any other stewardship programs done by local agencies or private groups.

12. Data analysis and summary: Compiling, validating and summarizing data for conclusions and recommendations.

The Walnut Creek Watershed Environmental Quality assessment was conducted from April 2006 – December 2006. DEP staff conducted fieldwork and collaborated with federal, state, and local agencies to collect and compile related information. The study used only DEP accepted/approved protocols and Standard Operating Procedures. Data standards were established to select available literature, existing studies, reports and fieldwork to define environmental conditions. The impacts on the environmental quality have been quantified, and, where possible, suggestions for abating environmental conflicts are offered.

Public participation was a key component of the assessment process. The best information about the conditions of the watershed often comes from individuals that live and work there. The draft *Walnut Creek Watershed Environmental Quality Assessment Report* was shared with interested parties to solicit feedback. Comments on the draft report were considered and revisions made where appropriate. The final *Walnut Creek Watershed Environmental Quality Assessment Report* is being distributed to the watershed community through scheduled meetings and is available electronically on DEP's webpage.

1.3 Data Standards and Quality Assurance

The assessment involved collecting and compiling data from various sources to determine the environmental quality of the Walnut Creek watershed and to identify the specific activities and conditions that affect it. To assure that the findings are accurate and valid, specific standards were established for the assessment.

The study used only DEP accepted/approved protocols and procedures to collect information on the environmental conditions. The data standards defined how to select available literature, existing studies and reports, sampling and analysis protocols, and specific Standard Operating Procedures to be used in the assessment.

Field sample collection and measurements were conducted by DEP staff using approved protocols for sample collection, analysis, macroinvertebrate collection and fish surveys. Specific protocols and policies used for sample collection, handling and analysis are referenced in the particular section of the report.

The DEP *Locational Data Policy* was used as the standard for collecting locational information with measurements taken in decimal degrees. GIS information was obtained form gNet and PASDA. All GIS-based mapping work was done using ArcMap 9.0 and 9.2.

The evaluation of permit compliance was accomplished using DEP's Environment Facility Application Compliance Tracking System (eFACTS). In some cases file reviews, follow-up inspections and interviews were completed as part of the compliance review.

Other resources used included relevant data collected by other government agencies and scholarly literature and reports. Where appropriate, references are provided, including geospatial data sources. Most geospatial data used to generate maps included in this report were provided from public and government sources. Metadata for this information is available upon request by contacting the *Department of Environmental Protection, Northwest Regional Office's Watershed Management Program.*

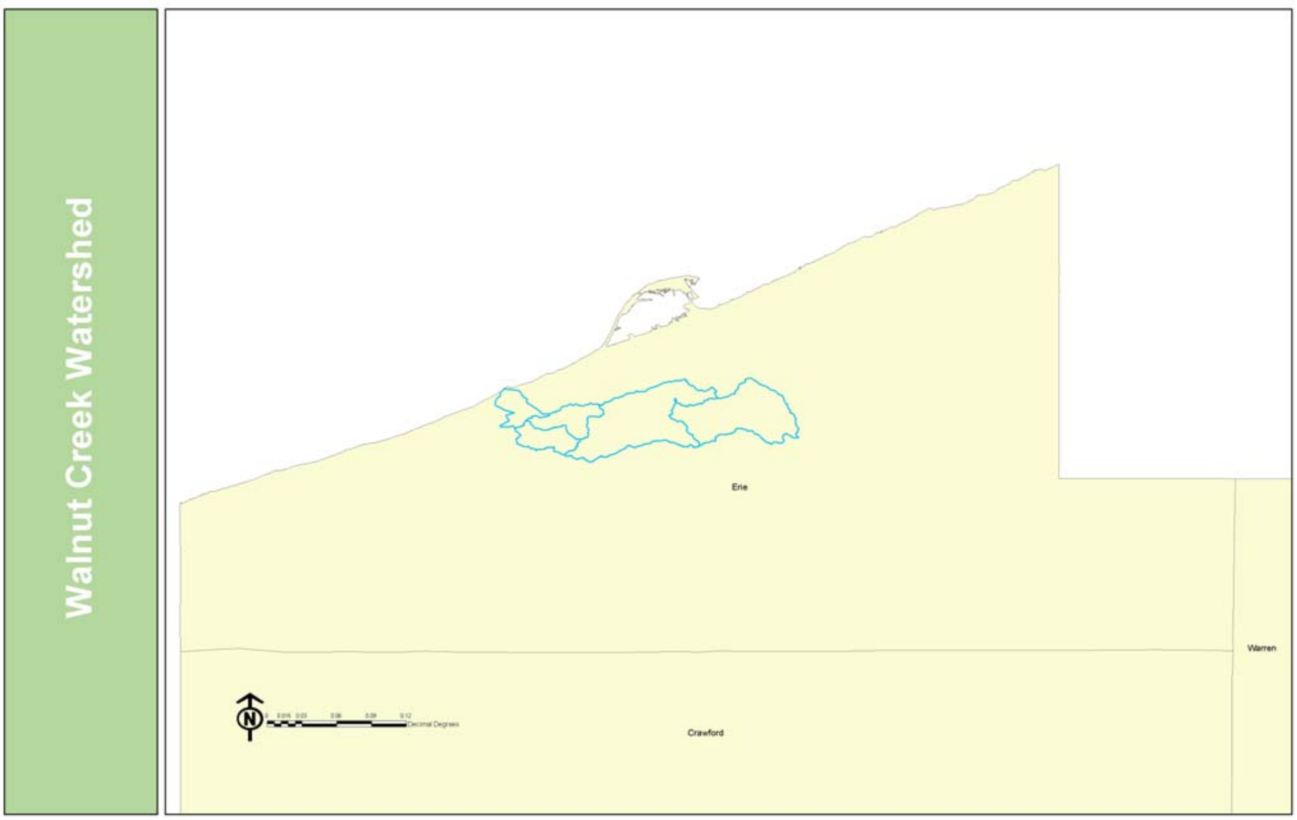
The information included in the assessment report is comprehensive, but does not include all available data concerning the conditions of the watershed. Certain conditions or sources may exist that are unknown or unavailable to the Department. This report should not be considered an all-inclusive source of information on the Walnut Creek watershed. It does provide a thorough evaluation of the watershed based on accepted protocols for data collection.

PART 2--FEATURES AND PHYSICAL CHARACTERISTICS OF THE WATERSHED

2.1 Location

The Walnut Creek Watershed is located in Erie County, Pennsylvania. By traveling north on Interstate Route 79, west on U.S. Route 20, and north on Manchester Road, one can reach the mouth of the watershed at its confluence with Lake Erie. The watershed drains in a northwesterly direction from the headwaters in Greene and Summit Townships, through Millcreek and McKean Townships, to Lake Erie at Manchester Beach, Fairview Township. The figure below depicts the location of the watershed boundary, as well as the boundaries of the five sub-watersheds, described later in this report.

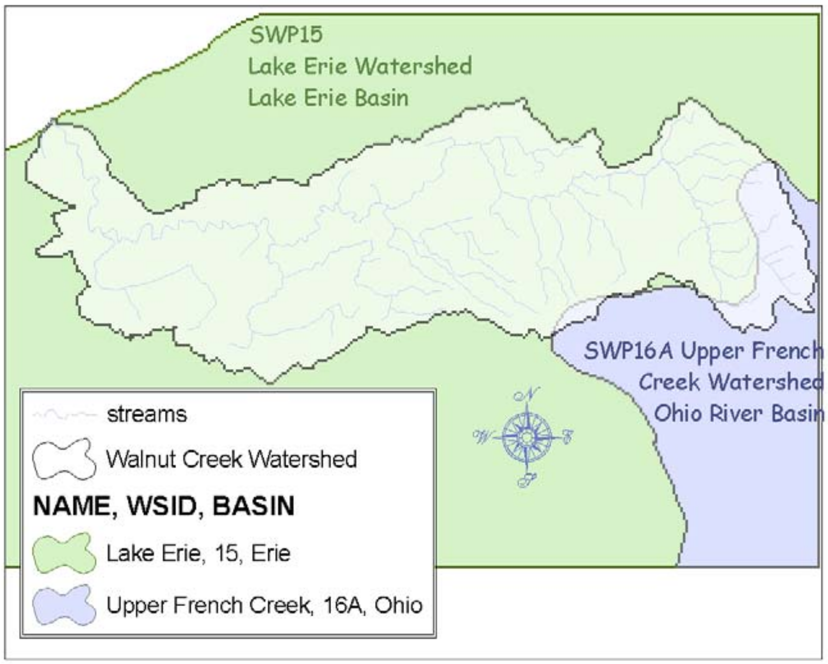
Location of Walnut Creek Watershed within Erie County



2.2 Watershed Boundaries

The Walnut Creek watershed includes 83.4 stream miles and drains a 38.2 square mile watershed area. The southeast boundary of the watershed borders the Upper French Creek watershed and constitutes a sub-continental divide between water flow to the Great Lakes and water flow to the Gulf of Mexico.

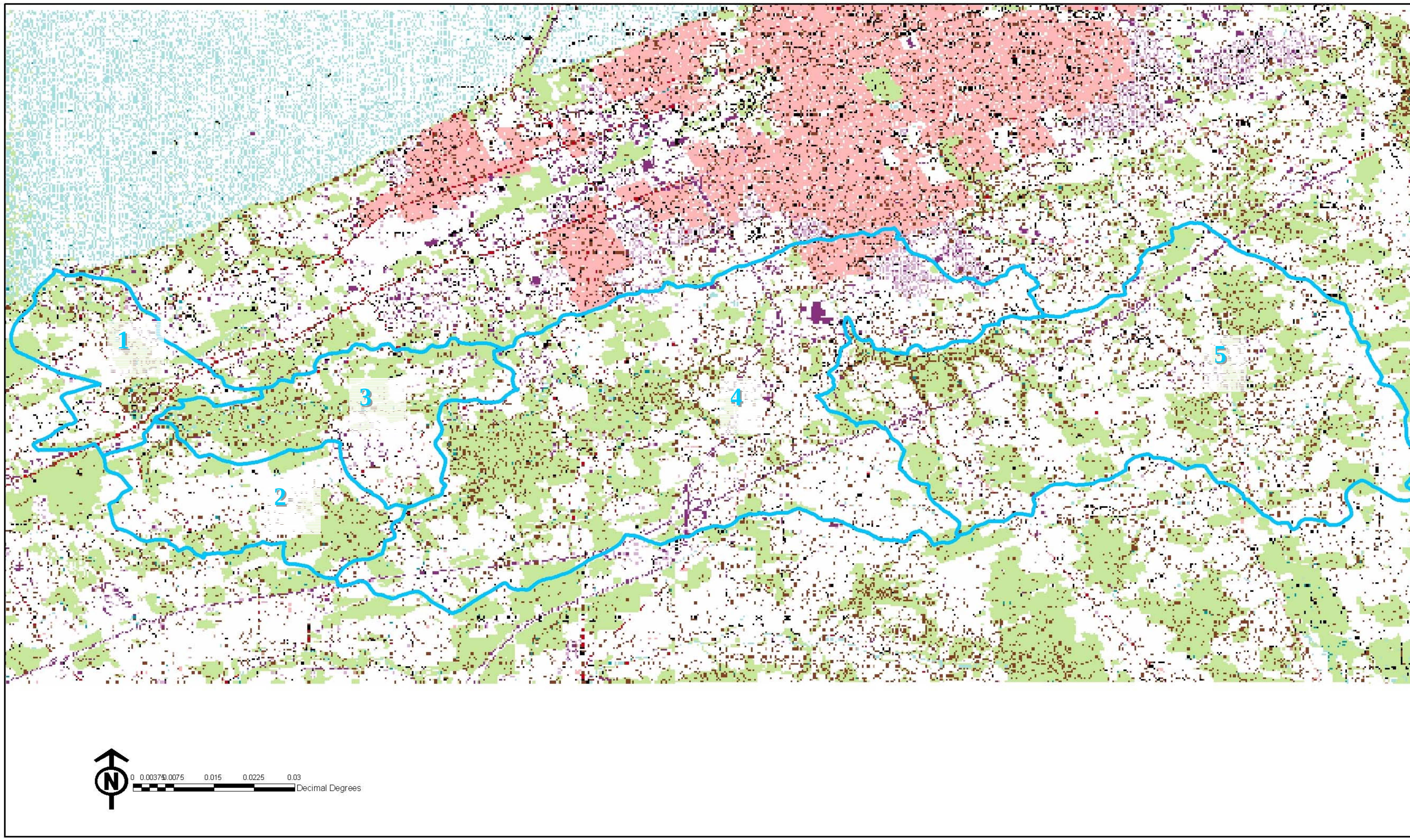
Location of Walnut Creek Watershed in Lake Erie Watershed



It is important to recognize that watershed boundaries are established using topographic and hydrologic principles. They often do not accurately reflect ground water flow, particularly at the periphery of a watershed. The two-dimensional representation of a surface water divide is often not an appropriate demarcation of ground water flow. Several more factors must be considered to establish a ground water divide, and these are inherently more difficult to establish, as compared to traditional hydrologic and cartographic techniques used to determine surface watershed boundaries. A more detailed explanation of local ground water conditions is provided further in this report.

For the purposes of this report, the overall Walnut Creek watershed has been further divided in to five sub-watersheds. These sub-watersheds are numbered one (1) through five (5), from West to East with Sub-Watershed two (2) corresponding to the southerly Bear Run drainage. The southwestern tributaries to the main stem of Walnut Creek are named locally as Bear Run and Thomas Run, west to east, respectively. The Bear Run drainage constitutes the southwesterly most of the five sub-watersheds.

Walnut Creek Sub-Watershed Boundaries



2.3 Watershed Floodplain

A ***floodplain*** is the land adjacent to a stream or river that experiences occasional or periodic flooding. The floodplain is delineated by the maximum area of land that is likely to be flooded by a 100-year flood as shown on floodplain maps produced by the Federal Emergency Management Agency (FEMA). The floodplain includes the ***floodway***--the stream channel and adjacent areas that carry flood flows, and the ***flood fringe***--the area covered by the flood, but which do not experience strong currents.

DEP regulates the floodway, or more specifically, the channel and portions of the adjoining floodplain that carry the 100-year frequency flood. A 100-year flood is described as the highest level of flooding that, on average, is likely to occur every 100 years. New structures or additions to existing structures, as well as earth moving activities in the floodway often require a permit from DEP. In some circumstances a federal permit may also be necessary.

DEP does not typically regulate private construction activities within the flood fringe (not including E&S controls and stormwater discharges associated with construction activities as required by Chapter 102). Development within the flood fringe is regulated by local ordinances. Chapter 106 of the Department's regulations does; however, require political subdivisions of the Commonwealth to obtain a permit for construction activities in the floodway and flood fringe.

The main purpose of floodway regulation is to protect people and property in floodplains from the dangers and damages of floodwaters and material that may be carried by floodwaters. In addition to the obvious impacts that flooding can have on public safety, there are numerous environmental impacts associated with flooding and floodplain development. Streams with obstructed and developed floodplains often experience severe erosion problems, changes in water temperature and resultant impairment to aquatic life.

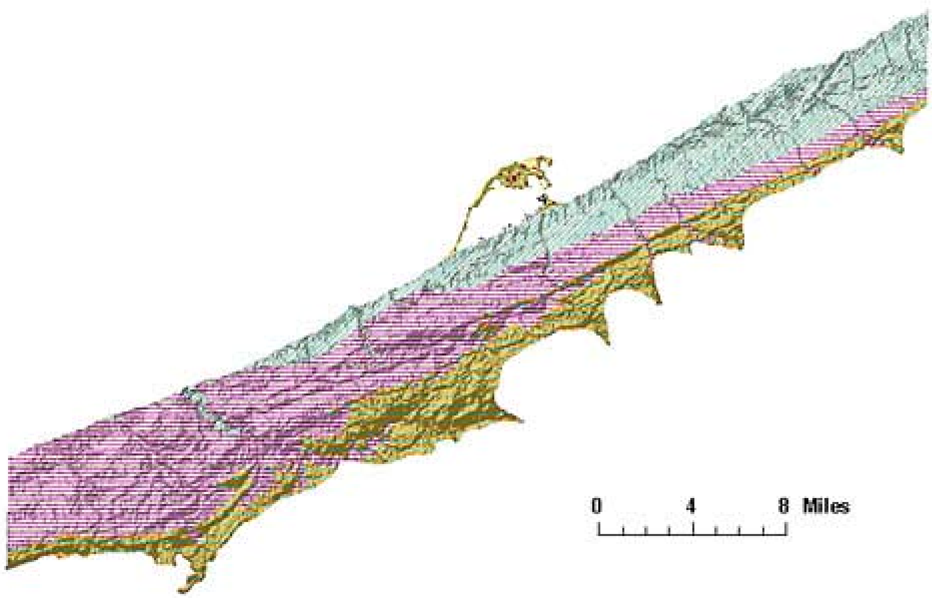
The riparian corridor is very important to the overall health of a stream. As the floodway and flood fringe of Walnut Creek is developed, much of the wetlands and vegetation is removed. When this occurs the natural water storage capacity, filtering properties and stream shading is lost. A lot of the middle and lower reaches of Walnut Creek have been developed and modified. The Stream Corridor Assessment, completed as part of this assessment, documents numerous floodway obstructions, permitted and unpermitted, diminished stream riparian buffer zones and erosion problems.

Floodplains should be carefully considered with respect to land use and development planning, with particular attention to public safety and storm water management. FEMA has completed detailed studies of much of the floodplain of the Walnut Creek watershed. FEMA mapping for Erie County can be found at:
http://msc.fema.gov/webapp/wcs/stores/servlet/StoreCatalogDisplay?storeID=10001&catalogID=10001&langID=-1&userType=G. Click on "Flood Insurance Studies".

2.4 Physiography

The Walnut Creek watershed is located in the Eastern Lake Section of the Central Lowland Physiographic Province and the Glaciated Plateau Section of the Appalachian Plateau Physiographic Province. The following descriptions are from the Pa. Geological Survey's Map 13 - Physiographic Provinces of Pennsylvania (Sevon, 2000):

Eastern Lake Section
Central and Lowland Province

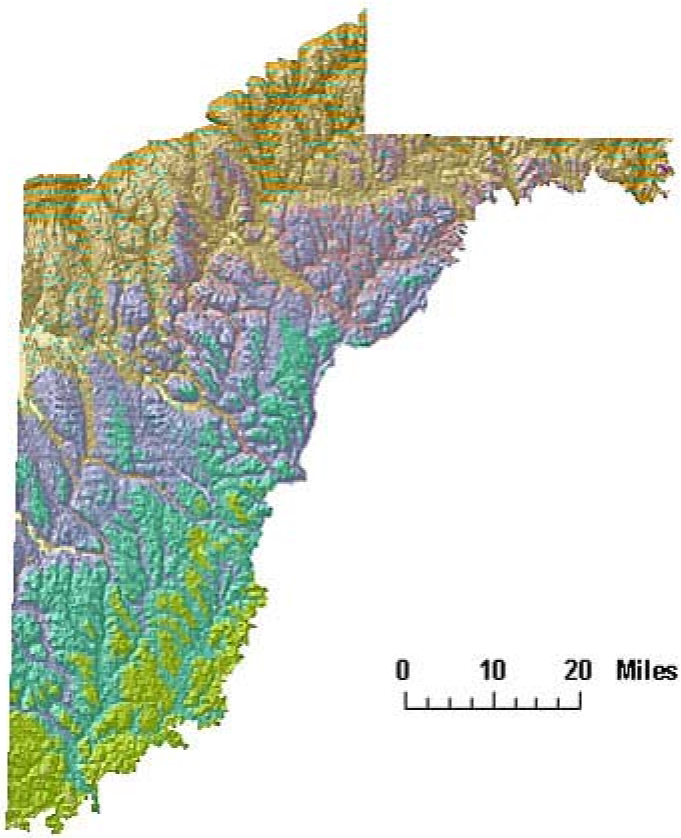


The Eastern Lake Section consists of a series of northwest-sloping, lake-parallel, low relief ridges. These ridges are made up of unconsolidated surficial materials, mainly sands and gravels, which were deposited during the most recent deglaciation of the area about 18,000 years ago. Steep-sided, narrow valleys cut through these ridges into the underlying shales and siltstones and flow into Lake Erie.

Originally, the ridge bordering Lake Erie sloped gently into the lake. Erosion of the shoreline has caused the lake-land interface to move southeastward so that today there is a steep bluff adjacent to the lake. Continued erosion of this bluff is a primary environmental problem in the area. Local relief in the section is less than 100 feet and generally half that. Elevation is 570 feet at Lake Erie and rises southward to a high of 1,000 feet. Drainage pattern is parallel and streams are oriented normal to the Lake Erie shoreline.

The Northwestern Glaciated Plateau Section consists of many broad, rounded uplands cut by long, linear valleys. The uplands have a southeast-oriented linearity that is pronounced in eastern Erie and central Crawford Counties. Elsewhere upland linearity is obscure to absent. The uplands are cut by many flat-floored, narrow to wide valleys that are separated from adjacent uplands by steep slopes on one or both sides of the valley.

Northwestern Glaciated Plateau Section
Appalachian Plateaus Province



The valleys are very linear and are oriented northwest southeast for the most part, although some valleys are normal to this orientation. The valley floors are often wetlands. There is frequently a considerable depth of unconsolidated material beneath the valley floor. Local relief between valley floor and the top of an adjacent upland may be up to 600 feet, but is generally less. Local relief on the valley floors and the uplands is less than 100 feet. Elevation ranges from 900 to 2,200 feet. Drainage pattern is dendritic. Bedrock, which is largely covered by glacial deposits, consists of a variety of sandstones, siltstones, shales, as well as some conglomerates and coal. Bedding in the rocks is horizontal. Many of these rocks are relatively soft and were easily eroded into linear landforms by the continental glaciers.

2.5 Geology

Local surficial bedrock in the Walnut Creek watershed includes siliciclastic rocks of the Devonian Period of the Paleozoic Era. Rocks of this Period date between 408 and 360 million years before the present. By definition, clastic rocks are derived from the materials of pre-existing rocks, in contrast to nonclastic rocks, which are formed through direct precipitation of minerals from solution or secretion by organisms. Carbonate rocks, such as limestone, are a common example of a nonclastic rock type. This is not to say that the rocks of the Walnut Creek watershed are entirely clastic in nature, rather, that this is the dominant type of rocks to be described.

The rock types of the Walnut Creek watershed consist of approximately 72% interbedded sedimentary rock, and 28% shale. Shale may be defined as a clastic rock, comprised of silt and clay particles, that is fissile in nature – it can be broken in to thin layers.

The universally accepted Wentworth Scale classifies clays and silts of having a particle size between 0.0039 and 0.0625 millimeters (mm). Fine sand particles being larger than silt, and very coarse sand having a maximum particle size of 2.0mm. The northwesterly occurring shales (Northeast and Girard), described below, would fall roughly in this range of clastic particle size, with the other local formations (Venango and Chadakoin) exhibiting a wider ranger of material sizes, including some particles larger than sand.

Primary sedimentary features, such as ripple marks and graded bedding, are evident upon inspection of local outcrops, particularly in exposed rocks in the streambed of Walnut Creek. These features typify a near-shore to shallow marine depositional environment. The rocks exposed in the Walnut Creek watershed today would have been deposited in a coastal, or shallow marine depositional environment, as highlands to the southeast were eroded into the Kaskaskia Sea of that era. Marine fossils are found occasionally in these rocks.

The following descriptions are modified from reports of the Pennsylvania Geological Survey: *Geologic Map of Pennsylvania - Map 1* (Berg, Geyer, Edmunds, and others; 1980), and *Water Resource Report 62 - Groundwater Resources of Erie County* (Richards, McCoy, and Gallaher 1987**):**

Venango Formation
Map Symbol - Dv
Light-gray siltstone interbedded with some flaggy, gray sandstone and some bluish-gray shale; Panama Conglomerate and Woodcock Sandstone are, respectively, the lower and upper key beds defining the formation; referred to as "Cattaraugus" by some workers; includes some red shales where it interfingers to the east and south with the Catskill Formation; marine fossils present. The Venango Formation is a good aquifer for water supply. The water quantity and quality are generally better than those of the underlying aquifers.

Chadakoin Formation
Map Symbol - Dch
Light-gray or brownish siltstone and some sandstone, interbedded with medium-gray shale; included in Conneaut Group and "Chemung" of earlier workers; marine fossils common; includes "pink rock" of drillers. The Chadakoin Formation is an extensive aquifer, which is marginally acceptable for water supply.

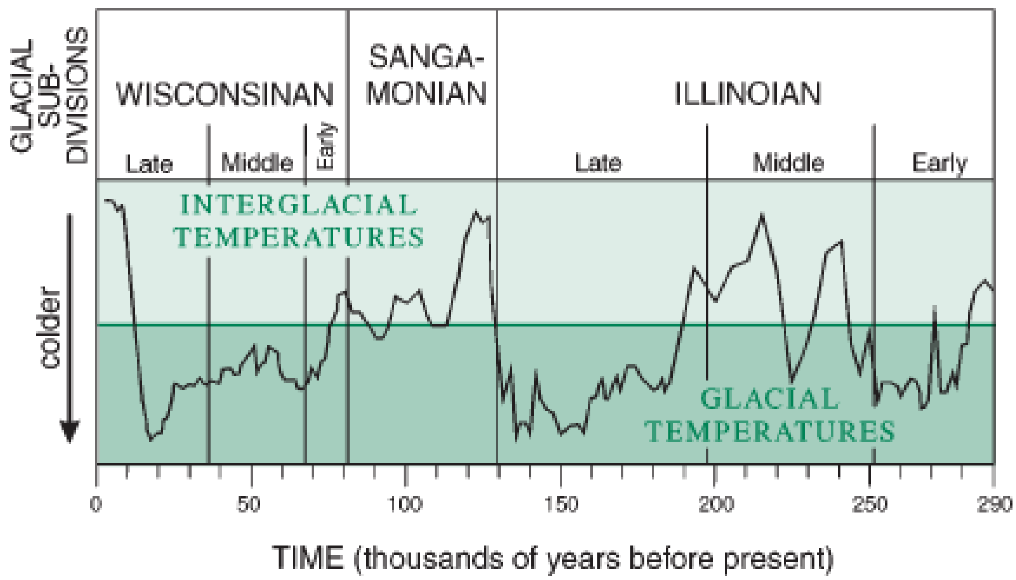
Girard Shale
Map Symbol - Dg
Argillaceous, ashen-gray, flaky shale and siltstone; included in Conneaut Group and "Chemung" of earlier workers; marine fossils rare. The Girard Shale is the poorest aquifer in Erie County, as measured by reported well yields and specific capacity

Northeast Shale
Map Symbol - Dne
Medium-gray shale and some thin light-gray siltstone interbeds; included in Canadaway Formation of New York; included in "Chemung" of earlier workers; contains sparse fossil marine fauna. The Northeast Shale does not have the potential for a good potable water supply due to generally poor water-bearing characteristics and poor water quality.

Unconsolidated glacial materials cover nearly all of the bedrock in the watershed. These materials include till, outwash deposits, and ancestral Lake Erie beach sands. These materials were deposited and eroded, periodically, during the Pleistocene and Holocene Epochs of the Quaternary Period of the Cenozoic Era, beginning about 2 million years ago, and the erosion and re-deposition of these materials is continuing today. During the peak of Pleistocene glaciations, about 30% of the Earth was covered by ice.

During the Pleistocene, glaciers advanced and receded several times, scouring exposed soils and bedrock, pushing, mixing, grinding and abrading rock particles and sediments over hundreds of miles. The most significant events, that produced glacial deposits in the Walnut Creek watershed, include the Illinoian and Wisconsin events. The following table, reflecting these periods of glacial advance and retreat, is taken from The Pennsylvania Geological Survey's Pennsylvania and the Ice Age (Sevon & Fleeger, 1999).

Glacial Events in Pennsylvania



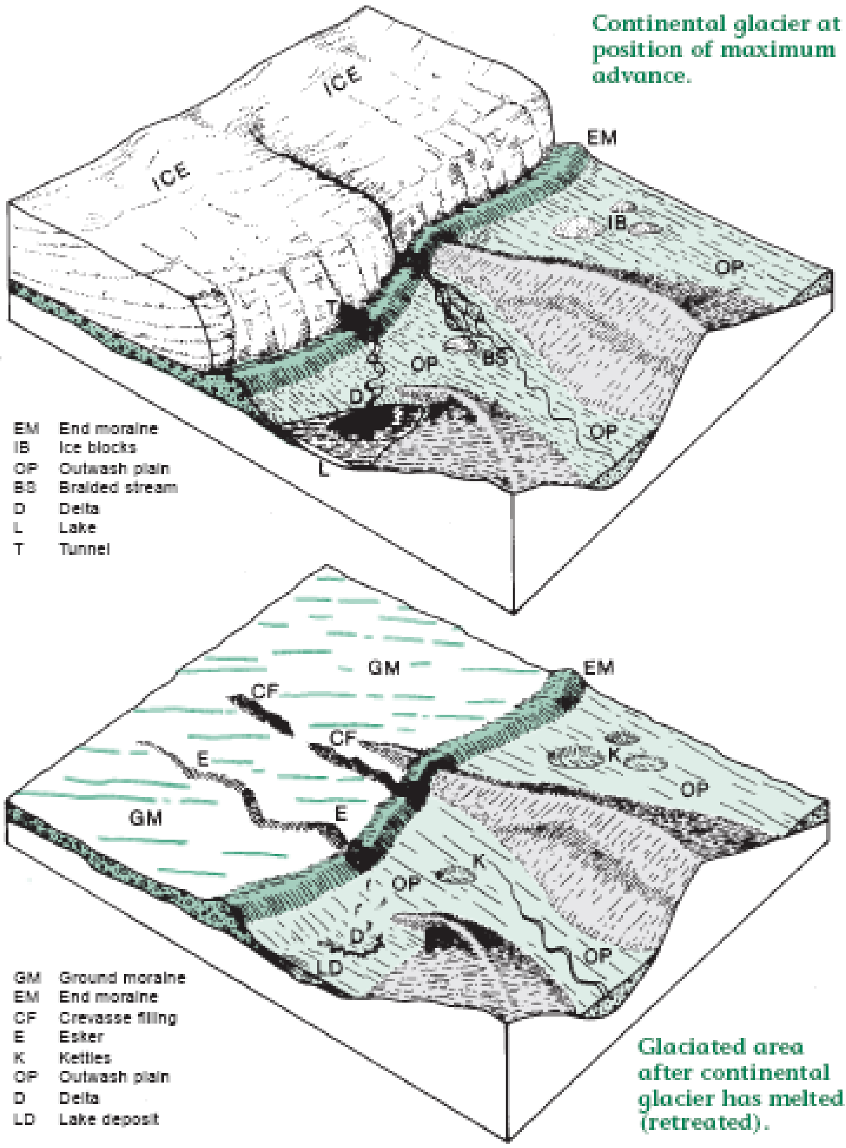
Relative temperature curve derived from foraminifera oxygen-isotope ratios.

Modified from Braun, D. D., 1988, Glacial geology of the Anthracite and North Branch Susquehanna lowland regions, in Inners, J. D., ed., Bedrock and glacial geology of the North Branch Susquehanna lowland and the Eastern Middle Anthracite field, northeastern Pennsylvania, Annual Field Conference of Pennsylvania Geologists, 53rd, Hazelton, Pa., Guidebook, Figure 5, p. 13.

The glaciofluvial and glaciolacustrine processes of melt water, from ice sheets, re-depositing these materials as lateral and end moraines, kames, eskers, drumlins, and beach sands has resulted in the complex occurrence of unconsolidated glacial materials, evident in the Walnut Creek watershed today. Most significantly, the ancestral occurrences of Lake Erie have produced extensive deposits of sands, locally known as “beach ridges”. These sands are a significant source of ground water supply for drinking water and other uses.

The process of erosion of these materials is continued in the watershed today, as Walnut Creek transports glacial and eroded bedrock materials downstream, and the waves and currents of Lake Erie move, abrade, and re-deposit them. The following figure is taken from the Pennsylvania Geological Survey’s Pennsylvania and the Ice Age, to understand the types and genesis of glacial deposits:

Glacial Features



The Pa. Geological Survey General Geology Report 32 - Glacial Geology of Northwestern Pennsylvania (Sheppa, White, Droste, and Sitler, 1959) describes the occurrence, type, and age of unconsolidated glacial materials, in the vicinity of the Walnut Creek watershed.

Maps depicting local bedrock geology and glacial deposits within and around the Walnut Creek watershed are provided in Appendix A. Both are from Pa. Geological Survey sources. Further discussion of glacial deposits, and particularly their significance to ground water occurrence and use in the watershed is provided further in this report.

2.6 Soils

The dominant hydrologic soil group or runoff potential in the Walnut Creek watershed is C. Hydrologic soils in Group C have a moderately high runoff potential and are sandy clay loam with low infiltration rates when thoroughly wetted. The average soil erodibility (K) factor in the Walnut Creek watershed is 0.34. The K-factor defines the potential of soil erosion independent of rainfall, slope, vegetation, or management practices; easily eroded soils have a K value between 0.37 and 0.7, and resistant soils have a K value less than 0.37. The Walnut Creek watershed is part of the Lake Erie basin (SWP15).

Soils maps are used to depict soil types within each of the sub-watersheds in the Walnut Creek drainage. Data for these maps was provided by the U.S. Department of Agriculture – Natural Resource Conservation Service (NRCS). The soil maps and descriptions of soil types corresponding to the map symbols are provided in Appendix A of this report, and are also available via the internet at the USDA-NRCS Official Soil Series Description site.

The nature of soil and unconsolidated material erosion within the watershed is a complex consideration. The wide range of land uses, variability in soil types, presence of exposed, unconsolidated glacial materials, with highly variable particle shapes and sizes, as well as the erosional mechanisms present - wind, water, snow, ice, plant and animal activity, human activity, and lacustrine processes, all interact to effect the movement and re-deposition of soil and unconsolidated sediments.

Human activity often increases the rate of soil erosion. Soils, and most importantly the plants and organisms that they support, provide filtration of water entering streams and aquifers. This filtration blocks sediments and contaminants, which may adversely impact water quality and affect aquatic plants, animals, and drinking water supplies. Careful attention to soil management practices should be considered by local communities, as development within the watershed places increasing stress on limited soil resources.

2.7 Ground Water Quality

A comprehensive ground water quality evaluation was beyond the scope of this assessment, but general conclusions can be made from existing reports. The U.S. Geological Survey's ***Ground-Water Quality Data in Pennsylvania - A Compilation of Computerized [Electronic] Databases***; 1979-2004; Low and Chichester, prepared in cooperation with DEP, is included in Appendix B. Based on the aforementioned, and the Pa. Geological Survey's ***Water Resource Report 62 - Groundwater Resources of Erie County*** (Richards, McCoy, and Gallaher, 1987), also included in Appendix B, several conclusions may be drawn about local ground water quality in the watershed:

- The Northeast shale and Girard shale bedrock aquifers are of poor or very poor quality with high to very high chloride, iron, and dissolved solids concentrations. These chemicals occur naturally, and are typical of these types of aquifers with low, to very low, permeabilities and transmissivities. Some wells in these formations, exhibit inorganic chemical concentrations in excess of U.S. Environmental Protection Agency Maximum Contaminant Limits for Public Water Supplies.

- The Chadakoin and Venango Formations, in the southeastern area of The Watershed, generally produce better water quality than the local shales, but quality also varies greatly, locally, and relatively high concentrations of chloride occur. As above, the chemicals present are naturally occurring and account for the relatively low quality of these formations, as aquifers for water supply. Some wells in these formations, exhibit inorganic chemical concentrations in excess of U.S. Environmental Protection Agency Maximum Contaminant Limits for Public Water Supplies.

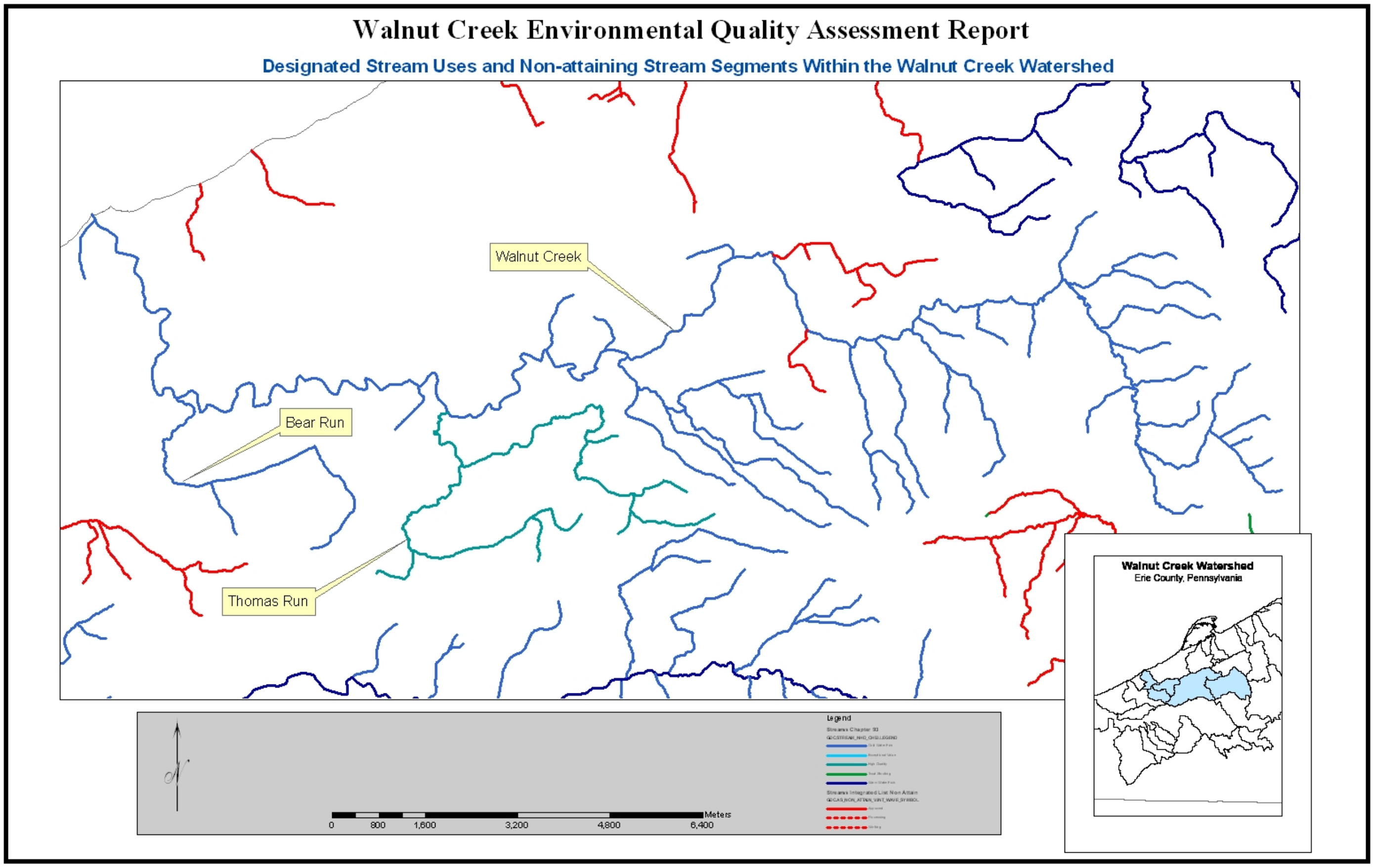
- Shallow, unconsolidated, glacial remnant materials are the predominant aquifer type for private and public water supplies within the watershed. Glacial till, outwash, and ancestral Lake Erie beach sands each vary widely in occurrence and composition, throughout the watershed, with ancestral beach sands generally exhibiting the best water quality. Each of these aquifers, exhibit wide variability in water quality, locally.

- Several wells within, or in proximity to, the watershed exhibit notably elevated nitrate concentrations. Elevated nitrate concentrations may be indicative of human-caused impact and are typically associated with agricultural activities, improperly managed storm water, or areas of poorly functioning septic/sewage systems.

2.9 Designated Stream Use and Attainment

The main stem of Walnut Creek is protected as a Cold Water Fishery and Migratory Fishery under Chapter 93 Water Quality Standards, Drainage List X. There are two major tributaries of Walnut Creek, Thomas Run and Bear Run. Thomas Run is protected as a High Quality - Cold Water Fishery and Migratory Fishery, for its entirety, under Chapter 93 Water Quality Standards, Drainage List X. Bear Run is protected as a Cold Water Fishery and Migratory Fishery as listed within Chapter 93 Water Quality Standards, Drainage List X. Other unnamed tributaries to Walnut Creek, aside from Thomas Run, have the same designation as the main stem.

The Walnut Creek watershed was previously assessed using biological screening protocols during State Surface Water Assessment Program sampling (2001). The 2001 assessments documented stream use impairments within three tributaries of Walnut Creek, as shown on the diagram below. These assessments were cursory in nature and only recognized the "worst of the worst" impairments. Nevertheless, all three of these tributaries were found to be impaired due to non point sources of pollution due to siltation stemming from urban runoff, storm sewers and residential runoff.



These impairments are listed within the 2006 Pennsylvania Integrated Water Quality Monitoring and Assessment Report. The specific impairment data for these three tributaries is as follows:

- Station 20010711-1645-TAS -- 1.2 miles of impairment due to siltation stemming from a combination of urban runoff and storm sewers;
- Station 20010711-0945-TAS -- 3.1 miles of impairment due to siltation coming from a combination of urban runoff and storm sewers;
- Station 20010711-1050-TAS -- 0.6 miles of impairment due to siltation stemming from residential runoff.

Because of the more intensive sampling protocols that were used during this particular watershed assessment, it is expected that additional stream use impairments will be documented.

2.10 Land Use Assessment

The *Walnut Creek Watershed Environmental Quality Assessment* included an evaluation of land use within the watershed. The evaluation involved identifying land use data sources in an effort to gain greater understanding of how these factors may influence the water quality and biological health of the Walnut Creek watershed.

Land use, and the resulting affects that land use has on overall health and function of watershed systems, continues to be of greater importance to watersheds that are in or around urban areas. There is often a delicate interaction of several variables such as hydrology, chemistry, and biology that exist in undeveloped watersheds that are free from anthropogenic influence. These variables and their interrelations can change when land use alterations occur within a watershed such as the introduction of urban development corridors.

2.10.1 Hydrologic Cycle

Land use influences a watershed most by altering the methods by which land reacts to precipitation, known as the hydrologic cycle. Altering the hydrologic cycle for parcels of land within watershed basins or sub-basins has a direct impact on the receiving streams and rivers. The hydrologic cycle in an undisturbed, natural watershed is a balanced system where precipitation, runoff, evapotranspiration, infiltration, groundwater recharge, and stream base flow all perform important functions.

Precipitation is distributed over the land surface, some of which runs off into a receiving waterway. Another portion of precipitation is held in puddles, ponds and lakes, or on the foliage, and is then evaporated back into the atmosphere. Precipitation also percolates into the soil where a portion is used by vegetation for transpiration and the remainder recharges groundwater and regulates the base flow of streams.

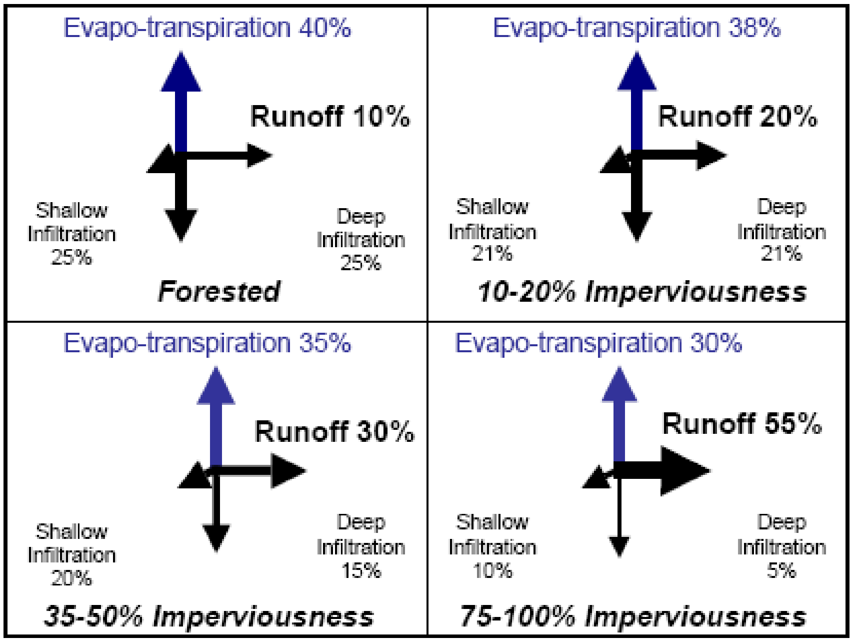
The average annual precipitation total for Erie, Pennsylvania area is approximately 42.7 inches per year (NOAA 2002, Average Annual Precipitation in Pennsylvania, 1971-1990). The following table approximates how the annual precipitation total within the Walnut Creek watershed is distributed for each pathway in the hydrologic cycle on an undisturbed acre of land.

Distribution of Annual Precipitation Total for an Undisturbed Acre
In the Walnut Creek Watershed
(all depths and percentages approximated)

	Depth (inches)	***Percentage of Total***
Annual Total Precipitation	***43 inches***	***------***
Evapotranspiration	24 inches	55%
Infiltration	11 inches	27%
Runoff	8 inches	18%

(NOAA 2002, Average Annual Precipitation in Pennsylvania, 1971-1990)

The hydrologic response of a land area and receiving waterway is altered when undisturbed areas are developed into urban commercial, industrial, or residential land uses. Watersheds experiencing these types of increases in urban development, such as the Walnut Creek watershed, see increased areas of impervious surface and compacted soils, which eliminate the ability of precipitation to infiltrate into the ground and receiving aquifers. Evaporative rates for impervious surfaces and compacted soils also are reduced from their original capabilities. Depending on soil types and the extent of development impact, the volume of stormwater runoff from a site can contribute significantly higher volumes to a receiving waterway. The figure below exhibits the hydrologic response of a tract of land as vegetation is removed and impervious and compacted surfaces are introduced (Meyer & Paul, 2001).



Progressive introduction of impervious surface and resulting affects on the hydrologic cycle
Streams in the Urban Landscape. *Annual Review of Ecology and Systematics*

2.10.2 Affects of Impervious Surface Area on Aquatic Biological Diversity

Numerous studies have addressed declining aquatic biological communities and decreased water quality in response to progressive introduction of urban development and impervious cover (Klein 1979, Booth & Jackson 1997, Roy et al 2003). This negative correlation is perhaps best demonstrated by the Urban Streams Classification Model, which can be viewed at (www.stormwatercenter.net). The model corresponds impervious surface area within a watershed to the richness, health and diversity of biological community in the waterway. The three categories consist of sensitive (<10%), impacted (10-25%), and non-supporting (>25%). Sensitive watersheds have less than 10% impervious cover and exhibit a fully functioning aquatic community. Watersheds with 10-25% of impervious surface area are designated as impacted and show signs of degradation to the aquatic biology. Watersheds that have greater than 25% impervious surface cover often show very low biodiversity that continues to decrease as imperviousness increases.

There are several reasons why impervious surface areas contribute to declines in biological communities within waterways. The losses in infiltration and evapotranspiration from urbanized land uses translate into substantial increases in runoff volume. These increased volumes are often conveyed into a receiving waterway at discharge rates differing from the undisturbed state of the land. This can lead to altered peak flow timing within a watershed, which can cause flooding and increased intensity of flow within the waterway that contributes to bed and bank erosion and increased sediment loads that affect stream biology.

Introduction of impervious and compacted surfaces within a watershed also can have serious affects on the groundwater table by reducing the quantity of precipitation infiltration. The loss of infiltration capacity reduces replenishment of aquifers that feed the base flow of dependent, localized waterways. Reduction in base flows in these waterways may have the unwanted affect of low water levels, in addition to a host of other unintended consequences. Pollutant loads that may not be impacting the waterway under normal flow conditions can become more concentrated when base flow decrease, and therefore, can have a greater affect on the biology of the stream. Lower base flow in a waterway can also affect the longstanding temperature regimes in the stream, having detrimental affects on biological communities dependent upon certain temperature parameters.

Impervious surfaces can also change the chemistry of precipitation runoff. Depending on the land use, runoff from impervious surfaces and compacted soils can have elevated levels of non-point source pollutants such as sediments, nutrients, petroleum products, polycyclic aromatic hydrocarbons, metals, *E. coli* bacteria, and temperature. These non-point source pollutants can contribute to acute and/or chronic effects in the health of the aquatic biologic community.

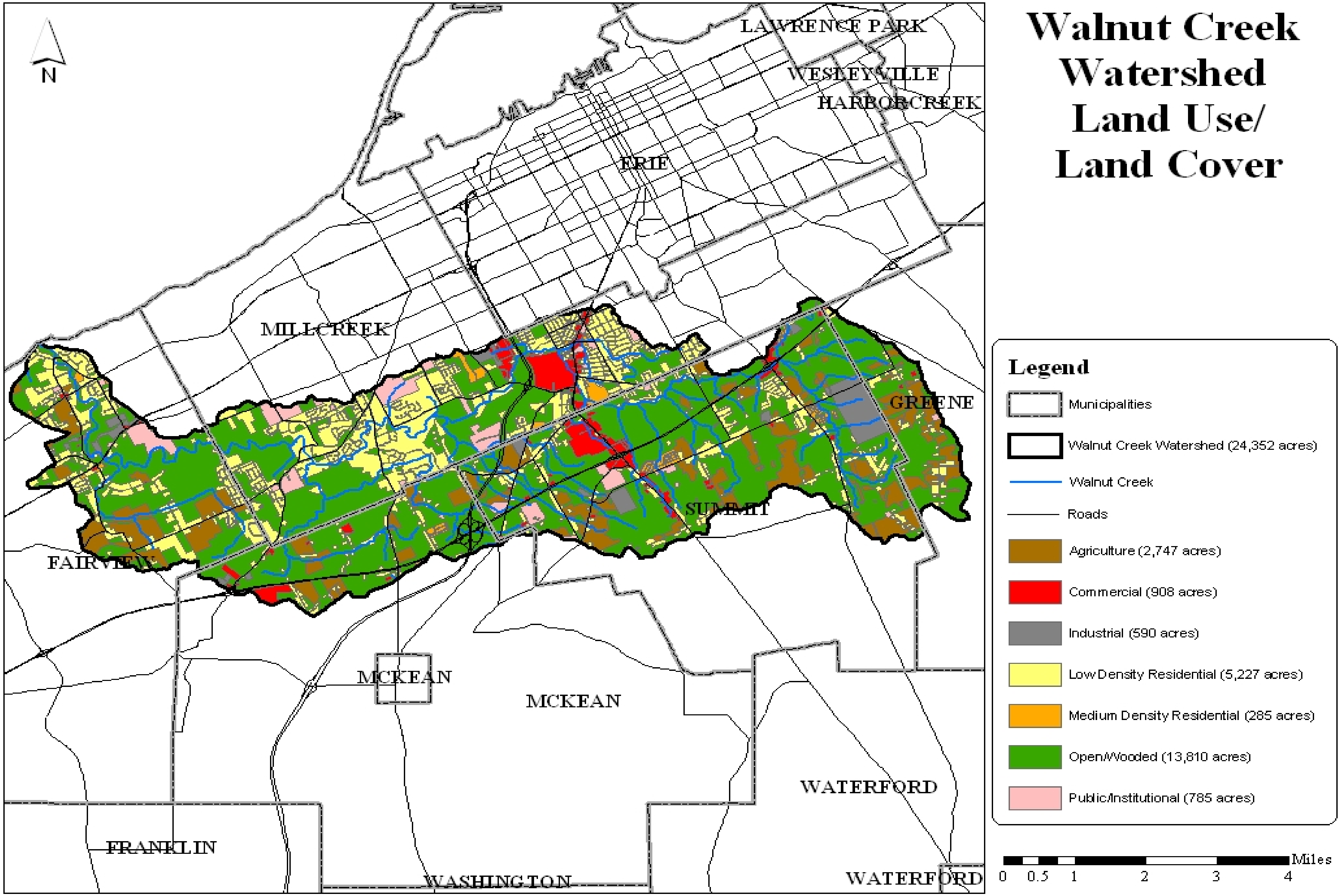
For more specific information regarding the biological status of Walnut Creek, refer to the Part 4 Biological Health and Diversity section of the report.

2.10.3 Current Walnut Creek Land Use

DEP has identified the most current land use statistics within the Walnut Creek watershed with the aid of the Lake Erie Office of Pennsylvania Sea Grant. PA Sea Grant provided geographical information system (GIS) services and materials that were produced for use in their Non-point source Education for Municipal Officials program, funded in part through a DEP Growing Greener grant. The GIS land use data was provided to PA Sea Grant from the Erie County Department of Planning. The following table presents land use distribution within the Walnut Creek watershed, followed by a map that represents the geographic locations of the different land use classifications.

Land Use Distribution In the Walnut Creek Watershed

Land Use Classification	***Acres***	***Percent of Total Acreage***
Agriculture	2,747	11.28%
Commercial	908	3.73%
Industrial	590	2.42%
Low Density Residential	5,227	21.47%
Medium Density Residential	285	1.18%
Open/Wooded	13,810	56.69%
Public/Institutional	785	3.23%
Total	24,352	100%



Watershed Land Use/Land Cover

An analysis of land use distribution in the watershed shows that approximately 13,810 acres, or 56.69% of the watershed is currently undisturbed land classified as open/wooded. In addition, agricultural areas cover another 2,747 acres, or 11.28% of the watershed. Most of these areas are on the outer edges of the Erie metropolitan area.

The next largest land use is low density residential development, which is occurring in several areas in Fairview, Millcreek, and Summit Townships. This residential pressure is a result of urban sprawl expanding in a concentric ring from the City of Erie. Access and proximity to Lake Erie at the mouth of the watershed is attracting new residential development along West Lake Road (PA 5) and West Ridge Road (US 20). Residential pressures also are found along the Sterrettania Road corridor, which provides residents with good access to Interstate 90, the City of Erie, and the Kearsarge/Peach Street commercial areas. Of particular interest are the undeveloped areas on Love Road, Zimmerly Road, Grubb Road and Hershey Road that are undergoing significant commercial and residential pressures caused by their potential for future public utilities, proximity to the Millcreek Mall/Upper Peach Street commercial complexes in the Kearsarge area, and the convenient access to Interstate 79 and Interstate 90. Other notable areas experiencing low density residential pressure are those in Summit Township along upper Peach Street, the Perry Highway, and Wattsburg Road with excellent access to Interstate 90. Medium density residential land use currently only consists of 282 acres within the watershed, and is concentrated in the Kearsarge/Upper Peach Street area.

Much of the 908 acres of commercial land use, 3.73% of the watershed area, is located in the Millcreek Mall/Upper Peach Street corridor. This area has experienced intense commercial development during the past 15-20 years and projections show continued development into the foreseeable future. The following are U.S. Geological Survey aerial photographs of the area between Interstates 79 and 90, and US Highway 19 (several tributaries and the main channel of Walnut Creek can be seen running from east to west). Significant development has occurred in this area of the watershed in recent years. It is one example of the real and potential impact of concentrated development in the vicinity of major transportation corridors. It likewise demonstrates the stress this development places on limited, sensitive, source water and riparian/aquatic habitat areas within the watershed.

September 4, 1987

May 4, 2002

Other areas of commercial land use are the Perry Highway and Wattsburg Road interchanges of Interstate 79. The Wattsburg Road interchange is expected to rapidly develop in the coming years in response to the recent opening of a large horse race track and slots parlor. Industrial and public/institutional land uses consist of 590 acres and 785 acres respectively. These figures are projected to increase much slower than residential and commercial development in the future.

PART 3—CONDITION AFFECTING PUBLIC HEALTH AND SAFETY

3.1 Public Water Supplies and Source Water Protection

3.1.1 Public Water Supplies

Most of the drinking water provided to the residents of the Walnut Creek watershed is from the City of Erie Water Authority (Water Authority). Water is withdrawn from Lake Erie, and after treatment, is conveyed to parts of Fairview, Millcreek, Summit, and McKean Townships. The Water Authority holds a Water Allocation permit for the surface water withdrawal, and Water Supply Management permits for the treatment and distribution of public drinking water. According to eFACTS, the Water Authority is compliant with its permit requirements.

The remainder of the drinking water within the watershed is obtained from either un-regulated residential wells or conveyed from small Public Water Supplies that use groundwater sources. Due to the generally poor quality and quantity of groundwater found in local bedrock aquifers, unconsolidated glacial remnants, particularly outwash channel and ancestral Lake Erie beach deposits constitute the primary aquifers for water supplies within Erie County and the watershed.

There are 16 permitted public water supplies located within the watershed, as identified by eFACTS.

Public Water Supplies in Walnut Creek Watershed
(C = Community, N = Non-Community, P = Non-Transient Non-Community)

PWSID #	Type	Name	Municipality
6250042	C	Vlasion Mobile Home Park	Fairview Twp
6250074	C	Sunnydale Subdivision	Fairview Twp
6250075	C	Millfair Heights	Millcreek Twp
6250085	C	Holly Acres Estates	Summit Twp
6250834	N	Holiday Mart	Mckean Twp
6250845	N	Hill Family Campground	Mckean Twp
6250875	N	City Of Erie Munici Golf Course	Millcreek Twp
6250878	N	Urraro Oil Company	Mckean Twp
6250919	N	Colonial Inn	Fairview Twp
6250944	N	Burger King	Mckean Twp
6250954	N	French Quarter	Summit Twp
6250973	N	Franks Farm Market	Millcreek Twp
6250985	N	Valley View Golf Club	Summit Twp
6250990	P	Accuspec Electronics Services	Mckean Twp
6250982	N	Beechwood Bar and Grill	Mckean Twp
6250968	P	Howard Industries	Mckean Twp

In general, permitted sources are relatively shallow ground water wells, transecting glacial deposit aquifers. These supplies all serve Community or Non-Community Water Systems, as defined in 25 Pa Code Ch.109. It is important to understand that though much of the public water supplied to consumers in the watershed is from outside sources, activities within the watershed have the potential to adversely affect the limited water supply aquifers available in the region. In short, groundwater is not confined by municipal, topographic, or land use boundaries. Likewise, once groundwater sources are contaminated or diminished, many difficult challenges and decisions will be faced.

3.1.2 Source Water Assessment

DEP has completed Source Water Assessments for all Public Water Supplies within the Commonwealth. The assessments were conducted through a combined effort of DEP staff and contractors. The assessments involved a susceptibility analysis of drinking water sources to contamination to identify threats and risk factors to be considered for source water protection. The following excerpt from DEP's Source Water Protection Program Plan explains source susceptibility:

> *The susceptibility of a drinking water source serving a PWS is the potential for that source to draw water, contaminated by inventoried sources of contamination, at concentrations that would pose a concern. This susceptibility is determined at the point in the water body immediately preceding collection for the PWS. A drinking water source, as a whole, is considered highly sensitive to contamination if at this point a U.S. Environmental Protection Agency establish Maximum Contaminant Limit (MCL) has been exceeded for a regulated contaminant, 50 percent of an MCL has been reached for nutrients or heavy metals, or detections have been made of Volatile Organic Compounds (VOCs) or Synthetic Organic Compounds (SOCs) above the detection limit. This does not complete the analysis of the individual potential sources of contamination for drinking water source susceptibility. The intent of a susceptibility analysis is to "narrow down" the potential contaminant sources of concern to assist the effectiveness of local voluntary Source Water Protection (SWP) programs.*

The susceptibility analysis is a qualitative measure of relative priority for concern of the different potential and existing sources of contamination based on the following:

- Drinking water source sensitivity
- Potential impacts posed by sources of contamination to the PWS source (this is a qualitative assessment of the impact on a PWS source if an uncontrolled contaminant release were to occur from a specific activity).
- Potential for release of contaminants of concern

The susceptibility analysis uses a series of matrices to determine high, medium and low values for the various factors in the process. The process is described the *Susceptibility Analysis of Drinking Water Sources to Contamination* listed in the Appendix.

Some errors were found in the contractors susceptibility analysis completed for small public water supplies. These sources are being reevaluated. The susceptibility of the 16 small Public Water Supplies within the Walnut Creek watershed are not currently available.

3.1.3 Source Water Protection Programs

The most important objective for conducting a Source Water Assessment is to support the development of local, voluntary source water protection (SWP) programs. DEP supports and promotes the development and implementation of these plans with public education, program promotions, local grants for protection program development and implementation, federal and state agency coordination, and technical assistance.

DEP, through the Bureau of Water Supply Management, has primary responsibility for regulating public water supplies. In addition, DEP has primary authority to regulate most point and non-point source discharges of potential contaminants. The role of DEP in SWP is to provide technical support and guidance to the local governments and the water supply purveyor for the development and implementation of local SWP programs, and to coordinate environmental protection programs with these programs.

DEP regional staff that conducted initial Source Water Assessments are tasked to assist in promotion and development of local SWP programs. After the assessments were completed, DEP staff presented the relationship of the source water assessment to the local water suppliers along with approaches for managing existing and potential sources of contamination. They also coordinate with existing programs to promote funding for development and implementation of local SWP programs.

There have been no documented Source Water Protection programs implemented for the 16 small public water supplies in the Walnut Creek watershed.

3.2 Pollution Sources within the Walnut Creek Watershed

Pollution is created from activities that change the natural state of the quality of the air, soils, surface water, and groundwater. Because certain facilities and operations are known to generate wastes that can cause pollution, regulatory requirements are imposed to minimize those threats. Environmental regulations mandate, among other things, waste treatment requirements, source reduction strategies, waste disposal methods and spill response planning to minimize pollution of the environment. Pollution reduction strategies and controls, when properly managed, can reduce, and in some cases, eliminate the sources and impacts of pollution.

The types of pollution sources reviewed for this assessment included existing facilities operating under DEP permits, closed or abandoned facilities where known soil or water contamination has, or continues, and non-point pollution sources. Each category has regulations to prevent impacts to public health, safety and the environment. Pollution sources reviewed during the assessment include: **DEP permitted and regulated activities**; **"Superfund", Hazardous Cleanup, National Priorities List** and **Toxic Release Inventory sites**; and **non-point pollution sources.**

3.2.1 Department Permitted and Regulated Activities

The assessment included a compliance evaluation of DEP permitted activities within the watershed. The evaluation involved identifying and determining compliance of each activity based on information from the Department's Environmental Facility Application Compliance Tracking System (eFACTS) and the Pennsylvania Safe Drinking Water Information System (PADWIS) databases. In some cases the compliance evaluation also included interviews, case file reviews and follow-up/follow-on inspections. It is important to note that the review did not include every Department permit or regulated activity. Permits and compliance information can changes on a daily basis. The types of activities reviewed and the compliance evaluation results are listed by activity, below.

Injection wells

No injection wells were found as part of the query.

Mining operations

The Department has issued one mining permit in the watershed. A permit for surface mining operations has been issued to Waste Management Disposal Services of PA, Inc. for its operations at the Lakeview Landfill. According to eFACTS, the permitee is compliant.

Air pollution control

There are three facilities within the Walnut Creek Watershed that have DEP Air Quality permits for air emissions. According to eFACTS, the facilities are compliant with permit requirements.

NDPES discharges

Point source discharges are regulated by the National Pollutant Discharge Elimination System program, a federal initiative founded by the Federal Water Pollution Control Act of 1972, later amended in 1977 as the Clean Water Act (CWA). The Act made it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions.

Pennsylvania has primacy of the NPDES program and operates under funding through federal grant agreements. DEP administers the NPDES program for the Commonwealth, which includes permitting, monitoring, enforcement, and reporting. In Erie County portions of the NPDES program have been delegated from DEP to the Erie County Department of Health through a Memorandum of Understanding and to the Erie County Conservation District through a Delegation Agreement.

Permitted NPDES point source discharges are classified as either: Sewage, Industrial Waste, Industrial Stormwater, Municipal Separate Storm Sewer System (MS4) or Groundwater Cleanup. The compliance status of each category is described below.

Sewage: The majority of the sewage waste generated from the citizens within the watershed is conveyed to the Erie Wastewater Treatment Facility for treatment and is discharged to Lake Erie approximately two miles off shore. There are; however, approximately 28 privately owned sewage treatment plants that discharge to the Walnut Creek drainage. DEP's eFACTS database indicates that the facilities are compliant with permit requirements.

Industrial Waste: There are no discharges of treated industrial waste in the watershed.

Industrial Stormwater: Certain industrial categories are required to obtain a permit to discharge stormwater to surface waters. There are three permitted industrial stormwater discharges in the watershed.

Municipal Separate Storm Sewer Systems (MS4): Summit, Millcreek and Fairview Townships have been issued MS4 permits to control stormwater discharges. MS4 permits require each municipality to control the quality and quantity of stormwater discharges by implementing minimum control measures (MCMs), including:

- Public education and outreach
- Public participation and involvement
- Illicit discharge detection and elimination
- Construction site runoff control
- Post-construction stormwater management
- Pollution prevention and good housekeeping for municipal operations

The Department inspected Summit, Millcreek and Fairview Township's MS4 programs in 2006. Summit and Fairview Townships MS4 programs were found to be compliant. Millcreek Township's MS4 program was incomplete for "illicit discharge detection and elimination" and in violation of the MS4 permit. The Department is currently working with Millcreek Township to resolve the violation.

Groundwater Cleanup: Remediation of contaminated groundwater from leaking underground storage tanks often involves a pump and treatment system. An NPDES permit is needed to discharge treated groundwater to any surface water. There are two groundwater cleanup discharges within the watershed, including Erie Petro, Inc. and Kwik Fill (M149).

102 Permits: In 2002, DEP integrated the federal Phase II NPDES requirements into the existing Phase I NPDES permit for stormwater discharges associated with construction activities (NPDES Construction Permit). Phase II requires permit coverage for small construction activities that disturb one to less than five acres, which result in a point source discharge to waters of the Commonwealth. An NPDES general permit can be used for most construction activities that require authorization under either Phase I or Phase II. Some activities; however, are not eligible for coverage under the general permit, including:

1. Activities in special protection watersheds;
2. Activities prohibited from coverage under 25 Pa. Code Chapter 92; and
3. Activities otherwise listed in the PAG-2 General Permit as ineligible.

In Erie County, DEP administers the NPDES Construction Permit Program through a delegation agreement with the Erie County Conservation District. The Conservation District processes and authorizes the permit coverage, conducts site inspections, and responds to complaints for all general permits. DEP issues all individual permits and is responsible for all compliance activities. The number of 102 permits issued within the Walnut Creek watershed is has not been determined. Several enforcement actions have been taken for Chapter 102 erosion and sedimentation violations in the watershed.

Waste operations and landfills

There are two municipal waste landfills permitted within the Walnut Creek watershed. The Lakeview Landfill, owned and operated by Waste Management of Pennsylvania, Inc. is located near the headwaters of Walnut Creek on Donation Road. Its operation involves a landfill permit, air quality emissions permits and a mining permit. Industrial wastewater from the landfill is collected and conveyed to the City of Erie Waste Water Treatment Plant for treatment. Stormwater from the site is controlled using BMPs required by the landfill permit, and discharged to Walnut Creek under authorization of an Industrial Stormwater NPDES permit. DEP's eFACTS database indicates that the facility is compliant with all permits.

The second landfill is an inactive operation named the Weiss Demolition Landfill. eFACTS indicates that the facility is compliant.

Oil & Gas operations

There are over 200 permitted Oil & Gas wells in the watershed. Most of the Oil & Gas development has occurred within the headwaters area. eFACTS indicates compliance with permit requirements.

3.2.2 "Superfund", Hazardous Cleanup, National Priorities List and TRI Sites

No state or federal "Superfund" or hazardous cleanup sites were found as part of the query.

The Toxics Release Inventory (TRI) is an EPA database that contains information on toxic chemical releases and other waste management activities reported annually by certain industrial groups. This inventory was established under the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) and the Pollution Prevention Act of 1990. The TRI lists reported chemical data for all materials released in-site, off-site or transferred off-site. The 2005 TRI reported releases form the following watershed industries:

Erie Bronze & Aluminum— 677,880 pounds of total production related waste managed, including: 4,165 pounds on-site disposal or other releases, 1,000 pounds off-site disposal or other releases of Aluminum (Fume Or Dust), Chromium Compounds, Copper, Lead, Nickel and Zinc compounds.

Eriez Manufacturing--16,915 pounds total production related waste managed, including 16,915 pounds combined pounds of 1,1,1-Trichloroethane, Chromium, and Nickel transferred off-site for further waste management.

EPA's TRI can be viewed at http://www.epa.gov/triexplorer/.

3.2.3 Non-point Source Pollution

Non-point source pollution can generally be described as contamination from activities that are dispersed, or of a low intensity, but the potential for cumulative impacts to soils and waters may be significant. These activities can range broadly from airborne depositions, residential chemical use, urban stormwater runoff, on-lot sewage disposal and agricultural operations. Certain activities that can contribute to non-point source pollution are regulated, such as stormwater management, sewage management and agricultural nutrient management. Other activities, however, are not specifically addressed through regulation, but can cause pollution.

Act 167 Stormwater Management Planning

The Stormwater Management Act (Act of October 4, 1978, P.L. 864 No. 167) requires counties to develop stormwater plans for each of the watersheds within its boundary. The Act also requires each municipality within the watershed to adopt the county plan, enact and enforce ordinances to ensure that development and changes in land-use are done with the appropriate stormwater quantity and quality controls to prevent flooding and environmental problems.

The Erie County Planning Department prepared the *Lake Erie Area Watershed Act 167 Stormwater Management Plan* for Erie County in June 1996. The Plan is focused on the Lake Erie Watershed portion of Erie County. The *Plan* takes into account physical features and characteristics of the watershed to establish criteria and standards for stormwater runoff control. Implementation is governed through municipal ordinance using a systematic approach to prioritizing and correcting drainage problems. Act 167 Plans are to be update at least every five years to reflect changes in land use, drainage and stormwater control regulations.

The original *Plan* for the Lake Erie watershed was developed in 1996 to meet the requirements of Act 167 by addressing stormwater management from a standpoint of quantity control. The *Plan* does not; however, specifically address stormwater quality. The quality of stormwater and the transport of contaminants to surface waters and groundwater are now better understood. Act 167 Plans developed today put much more emphasis on stormwater quality control.

The emphasis on stormwater quality control has been further stressed with the implementation of the federal Phase II Stormwater requirements. Several municipalities within Erie County boundaries have been identified as Municipal Separate Storm Sewer Systems (MS4), and as such, have been issued MS4 NPDES permits. These permits require affected municipalities to ensure both stormwater quantity and quality controls are in place for new land development and redevelopment.

Erie County has started the process of updating the *Lake Erie Area Watershed Act 167 Stormwater Management Plan.* The updates will consider changes in local land-use and hydraulic characteristics with an emphasis placed on stormwater quality as well as quantity.

On-lot sewage

Under the Pennsylvania Act 537-Sewage Facilities Act (Act of January 24, 1966, P.L. 1535, *as amended,* 35 P.S. §§750.1-750.20a) each municipality has the responsibility to provide for sewage treatment and disposal. As such, each municipality is required to submit a plan (537 Plan) to the Department describing how sewage services will be handled within its jurisdiction. The municipality is also responsible to address complaints and abate malfunctioning systems and illicit discharges. During the sewage planning process, the municipality identifies sewage disposal problems and needs areas for improved sewage services. The township chooses among alternatives to address the problems within a reasonable time period.

Alternatives for sewage disposal can include, among other things, publicly owned treatment works, private sewage treatment plants, sewer system conveyance of sewage to a public or private sewage treatment plant, or on-lot sewage disposal. Townships within the Walnut Creek Watershed, including Millcreek Township, Fairview Township, Summit Township, and portions of McKean and Greene Townships, use various alternatives of each of theses service types.

Millcreek Township has an approved 537 Plan that identifies the City of Erie Wastewater Treatment Facility to serve most of the Millcreek community. Either on-lot sewage disposal systems or privately owned small flow sewage treatment plants serve other portions of the township. In its 537 Plan, Millcreek Township has identified sewage problems. First, the township's Kearsarge sewage pumping station is hydraulically overloaded. To address this problem the township entered into a legal agreement with the Department and constructed an overflow retention facility to eliminate the discharge. The project was completed in Spring 2007. Second, Millcreek Township has recently identified areas where on-lot systems have had problems. These areas have been newly sewered, or are in the process of planning and installing new sewers.

Fairview Township is currently revising its 537 Plan. Similar to Millcreek Township, The City of Erie Wastewater Treatment Facility serves most of the Fairview community, while other portions are served by either on-lot sewage disposal systems or privately owned small flow sewage treatment plants. Fairview Township has identified suspect needs areas and surface water contamination from malfunctioning on-lot sewage disposal systems. The 537 plan will confirm and address these problems. An on-lot sanitary survey was started in Spring 2007.

As it's neighbors do, Summit Township also uses the services of the City of Erie Wastewater Treatment Facility to serve the populated portions of the township. Rural portions of Summit Township are served by either on-lot sewage disposal systems or privately owned small flow sewage treatment plants. Summit Township has recently completed a sewer extension in the Weber Hills area to address on-lot system malfunctions at the request of the Department. Summit Township is not proposing any additional on-lot sanitary survey's or Act 537 plan revisions at this time.

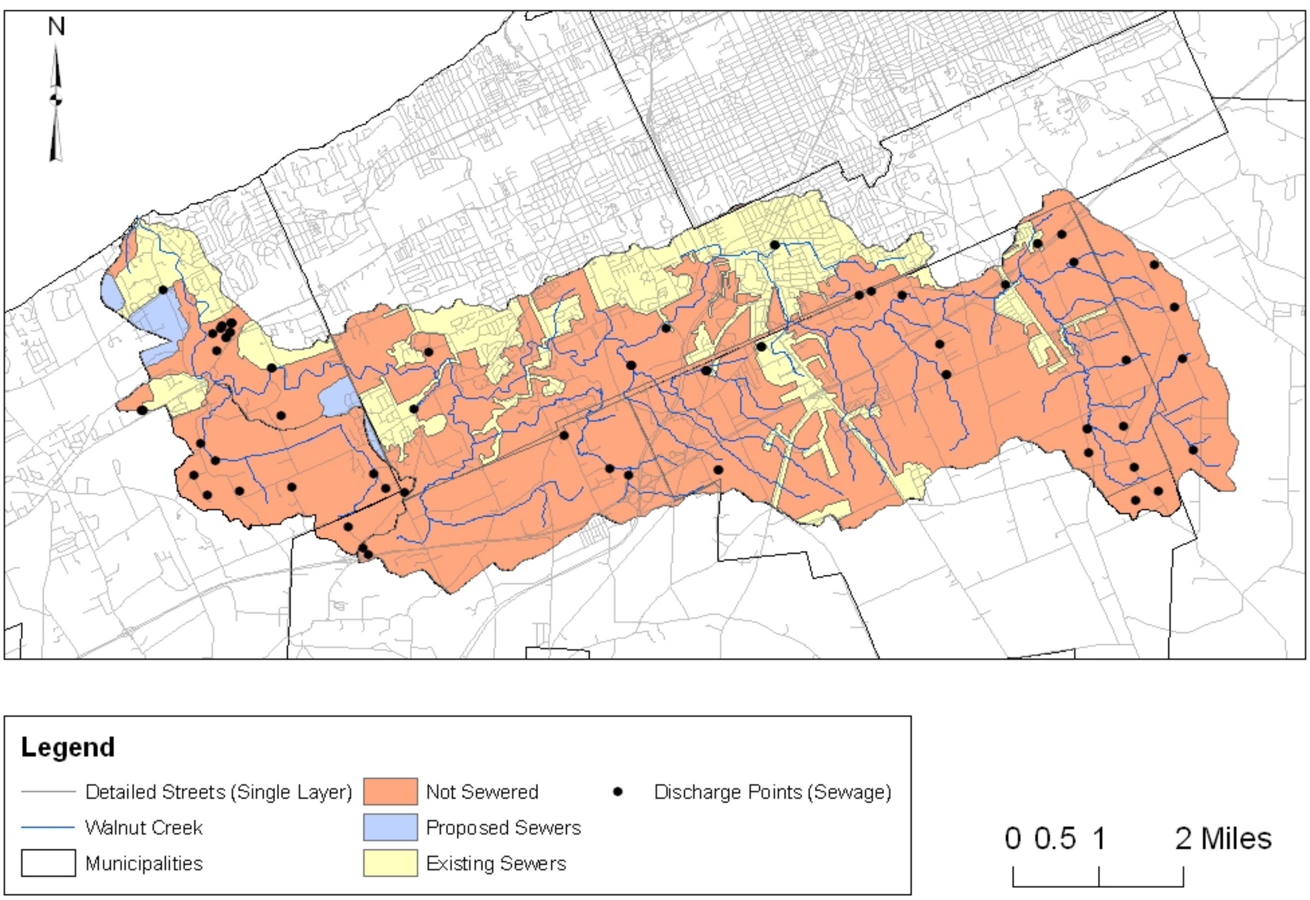
The areas of McKean and Greene Townships within the Walnut Creek watershed are served by on-lost sewage disposal systems. McKean Township has identified several areas with significant on-lot system malfunctions. McKean Township, by obligation of a legal agreement with the

Department, has submitted an Act 537 plan Update Revision in March 2007 to address these areas. The majority of the study area lies in the Elk Creek Watershed, and a small area of the Walnut Creek watershed near Township Road 514. The 537 Plan is currently under review by the Department.

Greene Township's Act 537 Plan has recently been updated to address problems with malfunctioning on-lot systems. They are currently in the design/permitting stages for the construction of a new wastewater treatment and collection system. The majority of the proposed service area lies within the Four-mile and French Creek watersheds.

The following figure shows the areas of the watershed that are served by public sewers and public and private sewage treatment plants. The map was created through a review of review township sewer maps, reports and sewage permits. The representation is a coarse illustration of sewer services areas, but is useful in identifying potential non-point sources of pollution from on-lot sewage disposal systems.

Walnut Creek Sewers and Discharge Points



Farming and Nutrient Management

Agricultural activities can cause non-point source pollution of soils and water if proper management techniques for preventing erosion, applying herbicides, pesticides and fertilizers are not considered. Stormwater run-off from barnyards and fields can have very high levels of sediment, nutrients, herbicides, pesticides, and bacteria. These pollutants can infiltrate the ground and contaminate groundwater and threaten water supplies. Stormwater runoff can become contaminated and pollute surface waters. This is of particular concern in the spring when fields have been recently tilled, fertilizer applied, and crops have yet to mature, leaving soils unstable. As will be presented further in this report, this is the time of year when snowmelt and precipitation are most significant, exacerbating the concern.

Farms are required by Chapter 102 of DEP's regulations to have a written Erosion and Sedimentation Plan for plowing or tilling activities involving areas of 5,000 square feet. These site-specific plans define the best management practices that will be implemented to minimize accelerated erosion and sedimentation. In many cases the Erosion and Sedimentation Plan is a portion of the overall conservation plan for the farm.

Farms using fertilizers and manure need to ensure that it is applied at the proper rate to prevent stormwater and groundwater contamination. Farmers can voluntarily development a Nutrient Management plan (with partial grant funding) that describes how to best apply manure and fertilizers to minimize environmental problems. In some cases, as with Concentrated Animal Feeding Operations, Nutrient Management Plans are required. There are currently no Nutrient Management Plans approved for the watershed. Although no specific pollution sources from farming operations were identified in this assessment, the potential does exists.

Airborne Deposition

Although contamination of heavy metals and nitrogen, among other things, is a known non-point source of pollution from airborne deposition, is was not assessed in this project.

3.3 Potential Sources of Contamination

Potential Sources of Contamination (PSOC) are activities or facilities that exhibit an increased risk of contamination of soils, surface water, or groundwater. PSOCs are typically referred to in terms of threats to water supplies, but can also be applied to watersheds as a whole. PSOCs include a very broad category of activities.

The most obvious PSOCs are industrial and commercial activities that deal with hazardous substances on a daily basis, like the facilities mentioned above in Section 3.2.1. A leaking underground gasoline storage tank at a gas station has the potential to contaminate a drinking water well. An anhydrous ammonia release from a manufacturing site that leaks into a stormwater drain can cause a fish kill in Walnut Creek. Although highly visible and assumed to be the most threatening, these facilities are regulated and probably the least likely to cause contamination. These activities do need compliance monitoring and should be included in

Source Water Protection planning and watershed protection strategies, but the bigger concern may be the unpermitted and unknown PSOCs.

Unregulated activities with no controls are likely to have a bigger impact, particularly with regards to stormwater contamination. This, coupled with the fact that the total extent of unregulated sources is unknown, makes it challenging to conduct a comprehensive assessment of PSOCs. Evaluating PSOCs involves making assumptions based on area land uses. The types of PSOCs reviewed during this assessment include:

- Transportation corridors
- Urban activities

Transportation Corridors

Hazardous materials and waste products are transported commercially in unregulated quantities in Erie County every day. Several significant transportation routes transect the Walnut Creek watershed, including Interstate Highways 79 and 90, numerous State Routes, and several rail lines. The Pennsylvania Department of Transportation District 1-0, headquartered in Oil City, Venango County, manages interstate and state highway routes within the watershed. Local municipal and county governments manage other roads within the watershed.

The proximity of the watershed to the City of Erie, central to the cities of Pittsburgh, Buffalo, and Cleveland, and the presence of these North/South and East/West corridors, accounts for a relatively high concentration of road and rail traffic. The Pennsylvania Department of Transportation's *Traffic Volume Map* for Erie County shows the traffic patterns and volume values, which is included as an appendix to this report. Also located near the watershed are the Erie International Airport and the Port of the City of Erie. These facilities too contribute to increased traffic in and around the watershed.

These numerous and significant transportation routes in and around the watershed increases the presence of real and potential impacts, in particular, to surface and ground water quality. Road construction can result in a loss of habitat and riparian buffer zones. Stormwater runoff from roadways can carry contaminates to waterways. Large spills from highway or rail accidents are also examples of actual and potential impacts to the watershed from transportation corridors.

Activities associated with transportation must also be taken into account when evaluating PSOCs. The high density of roadways in the watershed relates to an increased number of re-fueling stations and parking areas. Surface spills from fuel delivery or re-fueling activities and contaminants left on large parking areas, such as: volatile organic compounds, oil and grease, coolants, and de-icing compounds can cause pollution to surface water and groundwater

A unique consideration for roadways in the Walnut Creek watershed is the need for snow removal and de-icing. Due to the northerly latitude and proximity to Lake Erie, roads in the watershed receive significant amounts of snowfall through a longer portion of the year than other areas of the Commonwealth. Winter roadway maintenance involves applying de-icing (sodium chloride), anti-caking (sodium ferro cyanide), and anti-skid (sand & grit) compounds. These products, if over applied, can cause substantial impacts to surface waters, groundwater, roadside vegetation, and sensitive aquatic species. The U.S. Environmental Protection Agency, Office of Water's - Source Water Protection Practices Bulletin *Managing Highway Deicing to Prevent Contamination of Drinking Water* (EPA 816-F-02-019, August 2002) is included as an appendix to this report.

Urban Activities

The co-produced EPA and The Weather Channel television special titled, "After the Storm" *("After the Storm," Jan. 2003, EPA 833-B-03-002)*, describes the effects that residential activities can have on stormwater. Mishandled household hazardous wastes like insecticides, pesticides, paint and solvents can pollute waters and impact aquatic life. Excess fertilizers and pesticides used on lawns and gardens can be carried to streams and groundwater. Yard clippings and leaves can wash into storm drains and contribute nutrients and organic matter to streams. Car washing, degreasing auto parts at home, dumping used motor oil and other auto fluids can send contaminants into storm sewers, having the same effect as dumping them directly into the stream. Pet waste left behind can be a major source of bacteria and excess nutrients in local waters. "After the Storm" can be viewed at *weatherchannel@epa.gov*.

3.4 Pollution Source Distribution

PSOCs, particularly from non-point sources, are not easy to evaluate and quantify. On approach to better understand the distribution of regulated and non-regulated PSOCs is to review complaints filed with DEP. DEP's Complaint Tracking System was used to review complaints filed over the past three years. The number and types of complaints filed within the watershed are listed to provide an indication of the potential pollution sources and areas that may be targeted for further action.

A total of 33 public complaints were filed with the Department for activities within the Walnut Creek watershed between 2004 and 2006. Complaints were categorized as: illegal disposal or dumping; odors, burning or fugitive emissions; wetland or stream encroachments; above ground or underground storage tanks; and oil and gas wells and operations. It is important to note that in some cases complaints received by Department are referred to the responsible agency or municipality and would not be included in the system. The Pennsylvania Farm Bureau and the Erie County Conservation District handle agriculture related complaints. The Erie County Conservation District handles erosion and sedimentation complaints. Spills, illegal discharges and responses to emergencies are handled by the Erie County Department of Health. Sewage complaints are referred to the respective municipality. Below is a listing of the type of complaint and the occurrence.

Year	Disposal/Dumping	Odors/Burning	Wetland/Stream Encroachment	AST/UST Storage Tanks	Oil & Gas Wells
2004	7	1	3	1	2
2005	3	3	4	1	1
2006	3	2	1	1	0
Totals	**13**	**6**	**8**	**3**	**3**

Complaints do not indicate compliance, but they do give an indication of the types of activities occurring, citizens concerns, and level of involvement.

Creating a complete accounting of PSOCs in the watershed is not the point of the assessment. Rather, PSOCs are described to offer a setting of the large number and extent of activities that pose a risk of contamination. Evaluating and mapping the specific location and distribution of PSOCs is the next step in building local Source Water Protection plans and watershed management plans. Local planners and decision makers can use this information to take action and reduce the risk of PSOCs to public health, safety and the environment.

In summary, the most significant PSOCs identified through the assessment that should be considered are:

1. Stormwater runoff from construction activities and developed land is likely the largest PSOC to the watershed. Until Phase II Stormwater regulations went into effect in 2002, little effort was made toward stormwater *quality* control. Pre 2002 control structures were designed to handle large flood events with no treatment for stormwater quality. In some cases there is no stormwater management controls with direct discharges to Walnut Creek.

2. Municipal Separate Storm Sewer Systems (MS4) can carry large volumes of stormwater and pollutants. This PSOC requires control measures for minimizing stormwater contamination and accelerated erosion.

3. Transportation corridors are high risk, low potential sources of pollution. Accidental spills and releases cannot be directly managed, but response and control can be. Effective spill response is the best line of defense.

4. Sewage pollution from failing septic systems is also a significant PSOC. Samples results show that *E. coli* is commonly found throughout the watercourse. PCR DNA testing indicates that some of the bacteria are from human origin.

5. Privately owned sewage treatment plants, if not properly operated, pose a threat to water quality, particularly *E. coli* contamination.

6. Agricultural activities have significant potential for non-point source contamination of soils and waters if proper management techniques for mitigating erosion of soils, applying herbicides and pesticides, and using fertilizers are not considered.

3.3 West Nile Virus Protection Program

Culex restuans

Since 2000, the Department has implemented standardized mosquito surveillance in all counties to determine the presence and distribution of West Nile Virus (WNV). Information generated from this sampling is used to determine the potential for virus transmission, the need for control measures, and provides baseline knowledge regarding possible mosquito vectors across the Commonwealth. Annually, each county within the Commonwealth receives a grant from the Department to administer the mosquito surveillance and control program. In Cooperation with DEP, the Erie County Health Department administers the program in Erie County.

Culex pipiens

The Health Department's first level of surveillance for mosquitoes consists of sampling aquatic habitats (such as wetlands, flood land, sewage treatment plants, and tire piles) for larvae. When high populations of larvae are found, those areas are treated with larvicides to prevent adult mosquitoes from hatching. If sampling (light traps deployed overnight) for adult mosquitoes still indicates high populations of flying mosquitoes, spraying (fogging) of ultra low volume pesticides is conducted. Sprayers are typically mounted on the back of a pick-up truck, but may also be mounted on an ATV or a backpack. Erie County Health Department does most of the surveillance and control- DEP assists when needed.

Over the past six seasons, a total of 57 mosquito sampling sites have been established in the area surrounding the Walnut Creek watershed. Among those sites, an average of 151 samples have been collected per sampling year, with a high of 311 samples collected in 2006. The results of the 2006 surveillance dictated that 13 larval control events and 14 adult control events be conducted in the watershed.

County staff spraying pesticide

Within the watershed, since the inception of the WNV Control Program, there have been a total of eleven mosquito samples that have tested positive for WNV--one positive sample in 2000, three in 2002 and seven in 2006.

3.3 Pathogenic Bacteria Assessment

While the Walnut Creek Watershed assessment was being conducted, a separate, but related assessment was also being done. The *E. coli* Task Force was commissioned to study the cause(s) for the unprecedented number of beach closings at Presque Isle State Park during the 2006 summer swimming season. The *E. coli* Task Force was formed of representatives from DEP, DCNR, PAFBC the Erie County Department of Health, the Regional Science Consortium at the Tom Ridge Environmental Center at Presque Isle, Pennsylvania Sea Grant, Erie County Conservation District and the Erie Area Convention and Visitors Bureau. The focus of the task force was to assess factors and potential pollution sources influencing water quality along the Lake Erie shoreline in western Erie County and how it relates to the beach closings at Presque Isle State Park.

The *E. coli* Task Force completed a three-phased assessment to identify potential contamination sources that may be impacting Presque Isle beaches, reference Operation Creek Sweep—Surface Water *E. coli* Assessment, December 19, 2006. The first phase of the assessment involved *Creek Sweep*, a comprehensive sampling event and investigation designed to determine the sources and levels of fecal indicating bacteria (FIB) in the surface waters tributary to Lake Erie. FIB are a bacteria group present in the gastrointestinal tract of warm blooded animals that include, among other groups of bacteria, *Escherichia coli* (*E. coli*), *Bacteroides fragilis* (*Bacteroides*) and *Enterococci sp*. The presence of FIB in surface waters is used as an indicator of the presence of other pathogenic bacteria groups from sewage pollution, which creates potential risk to human health (Francy, 2003).

Phase II of the assessment involved comparing *Creek Sweep* results to historic water quality data from other Pennsylvania streams. Three reference Water Quality Network (WQN) stations within mostly undeveloped watersheds were used as ambient references for comparison to the Lake Erie watershed. The objective of this review was to provide context for evaluating the bacteria levels found during *Creek Sweep*.

Certain sites on Elk Creek and Walnut Creek were sampled a third time for FIB during wet weather, high stream flow conditions as part of Phase III of the assessment. The samples were used for DNA Polymerase Chain Reaction testing (PCR testing) to determine whether the FIB were from animal or human sources.

The assessment provided valuable information on the levels of FIB in Walnut Creek. *Creek Sweep* revealed that FIB appear to be commonly found in surface waters and are released into the environment through point sources and non-point sources. *E. coli* sampling conducted during dry weather, low stream flow conditions established baseline levels for the microorganism. In most cases *E. coli* bacteria levels were relatively low compared to WQN reference stations and public bathing standards. On the contrary, *E. coli* levels are significantly higher during wet weather, high stream flow conditions.

PCR DNA testing results indicate that FIB may be from both animal and human sources. The presence of human specific *Bacteroides* DNA shows that human waste is a contributing source to the bacteria loading in the watershed, possibly from both point sources and non-point sources.

With the interest of public health and safety held first and foremost, a strategy of "the best defense is a good offense" was recommended in the Creek Sweep Report. Specifically, the *E. coli* Task Force was encouraged to:

- Continue its research on FIB sources, monitoring and control programs.
- Partner with local and regional agencies to share resources, gain new knowledge and direct initiatives.
- Continue monitoring and compliance efforts at regulated sewage discharges and Municipal Separate Storm Sewer Systems, as point source discharges remain to be a contributing factor of FIB.
- Continue surveillance within the watershed to identify and eliminate other illegal discharges.
- Employ beach-grooming activities that minimize the proliferation of FIB within beach sands.
- Start collecting data on the beach conditions concurrent with *E. coli* sampling to develop indicators for a predictive model for FIB.

Meanwhile, further study is necessary to identify the predominant sources of FIB within the watershed. Additional FIB sampling coupled with PCR testing is ongoing at specific points within the watershed to identify the source areas and contributing species. These results will then be compared to area land use to identify the actual source of the bacteria loading and drive appropriate corrective action. For example, surface waters identified to be contaminated from human wastes should be directed towards sewage needs surveys and appropriate sewage facilities. Likewise, surface waters found to be contaminated from farm animals can be directed toward agricultural BMPs.

It may be possible to correlate trends of precipitation, wind, stream flow and sediment loading to make a predictive model of FIB levels. Continued monitoring of these parameters, among others, in a portion of the watershed with corresponding FIB sampling could be used as a basis of the model.

From the results of the assessment it is known that tributary streams are one possible source of FIB to Lake Erie, but their fate and transport is unknown. The impacts of FIB on Presque Isle beaches from streams tributary to Lake Erie should be further assessed.

3.4 Giant Hogweed

Giant Hogweed (*Heracleum mantegazzianum*)

Giant Hogweed is a member of the carrot family (Apiaceae) that was introduced into Europe and North America in the early 1900s, originally as a garden and arboretum plant. In the late 1980's it became evident that escapes from cultivation had occurred throughout New York and Pennsylvania, and are now found along ditches, roadsides, stream banks and open wooded areas as well as infesting homeowner flowerbeds and yards.

Giant Hogweed is now considered a public health hazard because of its potential to cause severe skin irritation and possibly blindness. Plant sap can produce painful, burning blisters within 24 to 48 hours after contact, and plant juices can produce painless red blotches that later develop into purplish or brownish scars that may persist for several years.

Giant Hogweed is a long-lived biennial that comes up as a rosette in early spring from roots or seeds. One flower stalk is produced per plant, but a plant may not produce a flower stalk for several years. Plants die after flowering. Plants are most easily identified when blooming in June or July when the stalks are upwards of 6 feet tall or more, and stalks produce numerous small white flowers clustered into a flat-topped umbel up to 2 ½ feet across. The green stems are hollow, ridged, 2-4 inch in diameter with purple blotches and course white hairs. The large diameter leaves are lobed, deeply incised, and are usually at least 12 inches to 3 feet wide. Plants commonly confused with giant hogweed include cow parsnip, angelica, and poison hemlock.

The Pennsylvania Department of Agriculture and USDA/APHIS started the Giant Hogweed Eradication Program in 1998. The program involves early detection efforts and targeted rapid response control measures. Since the program began there have been 520 populations discovered in Pennsylvania. The program is now approaching its final phases as more than half of these populations have been eradicated after 3 or more years of successful treatments. However, riparian infestations are still of high concern, as the rate of spread and distribution of Giant Hogweed is greatest in riparian areas.

A cluster of this noxious weed is known in the vicinity of the Millcreek Mall. A second cluster is located at 42°02' N, 80°06' W near Hershey Road. Finally, there is a known cluster at the mouth of Walnut Creek and Lake Erie. All three of these locations have been treated by the Department of Agriculture since initial discovery and live plants may not exist at these locations. A review of viable sites and controlled sites shows that a large portion of Walnut Creek may have ***undiscovered populations*** of giant hogweed. Particularly, the area from approximately 80°06' W to 80°14' W (42°04' N) is in need of more surveillance for giant hogweed. For more information on the Giant Hogweed Eradication Program, or to report a new discovery, contact the Giant Hogweed Hotline at: 1-877-464-9333 or contact Melissa A. Bravo: Pennsylvania Department of Agriculture Botanist/Weed Scientist in Harrisburg, PA at 717-787-7204.

PART 4—HABITAT AND DIVERSITY

4.1 Stream Assessment

4.1.1 Overview

Four parameters of an aquatic ecosystem interact with one another to shape the overall biological health and diversity of that particular ecosystem. These parameters include the ***aquatic macroinvertebrate community***, ***fish community***, ***habitat composition*** and ***chemistry*** of the surface waters. Separate assessments are conducted to examine the physical condition of each individual parameter. The assessment data from each individual parameter are then combined and analyzed to make inferences regarding the overall health and diversity of the entire ecosystem in question.

Walnut Creek and its major tributaries were evaluated using this approach. Each of these parameters were assessed during 2006 to obtain the biological, physical and chemical data needed in order to make conclusions regarding the overall health and diversity of one of the best steelhead fisheries in the Lake Erie drainage.

To adequately assess the entire Walnut Creek drainage, sampling locations were established throughout the watershed. Sampling locations were situated on the main stem of Walnut Creek and on many of its associated tributaries in order to bracket potential sources of pollution. Three "reference quality" waterways were also assessed for comparative purposes. Sampling locations are described in Table 1.

Walnut Creek sampling location 15UNT

Walnut Creek sampling location 6WC

Walnut Creek sampling location 5UNT

Walnut Creek sampling location 16WC

Walnut Creek sampling location 3UNT

Walnut Creek sampling location 24WC

4.2 Benthic Macroinvertebrate Survey

4.2.1 Introduction

Walnut Creek sampling location 21WC

One method of analyzing the condition of the water quality of a waterway is to survey the aquatic benthic macroinvertebrate community of that particular stream or river. Macroinvertebrates respond differently to the addition of various pollutants, from both point and non-point sources, and can indicate changes within the water quality of the surveyed stream.

Measurements of the macroinvertebrate diversity and abundance, with regard to the waterway's physical habitat, can help define water quality conditions and indicate if pollutants have impacted the waterway. If the macroinvertebrate community is not in balance or is not typical for that particular waterway, determined from historical survey data or when compared to a reference waterway, then the stream may not be attaining its designated aquatic life use. If the designated aquatic life use is not being met, the stream is considered impaired and a specific source and cause for the pollutants are determined. Additional in-depth investigations through stream water sampling and watershed reconnaissance can aid in determining the exact sources and causes of these impairments.

Walnut Creek sampling location 23WC

By examining the benthic macroinvertebrate community throughout an entire watershed, inferences can be made regarding the overall health of all waterways within the watershed.

During April 2006, the benthic macroinvertebrate communities of Walnut Creek and its associated tributaries were surveyed to determine the overall health of the entire watershed. Benthic macroinvertebrate communities from three reference waterways were also surveyed for comparative purposes. The reference waterways included Elk Creek, Goodban Run and Twentymile Creek. The benthic macroinvertebrate sampling was conducted between April 13, 2006 and April 28, 2006. Sampling occurred during the month of April to capture many of the insects in later life stages making identifications easier and allowing the capture of some insects before late spring emergence.

4.2.2 Benthic Macroinvertebrate Sampling Locations

Eighteen aquatic macroinvertebrate sampling locations were established within the Walnut Creek Watershed, including ten stations on the main stem and eight on tributaries (Map 1). Three sampling locations were established on Twenty Mile Creek, Elk Creek and Goodban Run, one on each stream, to serve as reference waterways (Maps 2 & 3).

The main stem of Walnut Creek is protected as a Cold Water Fishery and Migratory Fishery under Chapter 93 Water Quality Standards, Drainage List X. The ten sampling locations on the main stem of Walnut Creek were selected to bracket potential pollutant impacted stream sections. These sections included: highly developed areas, agricultural areas, major transportation routes, a permitted landfill and areas that were currently being developed.

Walnut Creek headwaters sampling location 1WC.

Two major tributaries of Walnut Creek, Thomas Run and Bear Run, were selected because they were bigger in size and could be more easily sampled. Thomas Run is protected as a High Quality - Cold Water Fishery and Migratory Fishery, for its entirety, under Chapter 93 Water Quality Standards, Drainage List X. Three stations were situated on Thomas Run to bracket newly developed areas. Bear Run is protected as a Cold Water Fishery and Migratory Fishery as listed within Chapter 93 Water Quality Standards, Drainage List X. Newly developed areas, with some areas still under construction, and agricultural areas are located in the headwaters of Bear Run. The sampling station was situated near the mouth of Bear Run.

Bear Run sampling location; 22 BR.

Two unnamed tributaries of Walnut Creek were selected because they were previously assessed during State Surface Water Assessment Program Biological Screening Protocol (2001) and found to be impaired due to siltation stemming from urban runoff, storm sewers and residential runoff. Two other unnamed tributaries of Walnut Creek were sampled to bracket newly constructed developments, a cooperative fish hatchery and a stream section that appeared to be nutrient enriched. All stream sections nearby to potential sources of stream impairment were surveyed to attain an overview of the health of the aquatic life within the Walnut Creek Watershed. All of the unnamed tributaries to Walnut Creek are protected as a Cold Water Fishery and Migratory Fishery under Chapter 93 Water Quality Standards, Drainage List X.

Three waterways outside of the Walnut Creek watershed, but still tributaries to Lake Erie, were selected for comparative purposes. These reference streams were selected because they have less development but have the same general stream characteristics and geological features when compared to the Walnut Creek watershed.

Twentymile Creek sampling location 25TM; reference waterway.

Twentymile Creek is similar in drainage area but does not have the amount of development or the number of potential pollution sources as the Walnut Creek watershed. Vineyards and transportation routes are the chief sources of potential pollutants within the Twentymile Creek watershed. Twentymile Creek is protected as a Cold Water Fishery as listed within Chapter 93 Water Quality Standards, Drainage List X.

Elk Creek sampling location 26EC; reference waterway

Elk Creek has a larger drainage area than Walnut Creek. However it was sampled approximately 13.5 miles upstream from the mouth and at a point along its length that would make it comparable in size, or drainage area, to the Walnut Creek Watershed. The Elk Creek watershed has several developed and residential areas but is not as highly developed as the Walnut Creek watershed. Elk Creek is protected as a Warm Water Fishery and Migratory Fishery under Chapter 93 Water Quality Standards, Drainage List X.

Goodban Run sampling location 27GR; reference waterway

Goodban Run is a tributary of Elk Creek and is protected as a Cold Water Fishery and Migratory Fishery as listed within Chapter 93 Water Quality Standards, Drainage List X. The Goodban Run watershed is mostly forested with a low potential for any non-point sources of pollution. The drainage area of Goodban Run is smaller in size and provides an excellent comparison for the tributaries and headwater sampling stations of the Walnut Creek watershed.

4.2.3 Benthic Macroinvertebrate Methods

Semi-quantitative benthic macroinvertebrate samples were collected at all sampling locations using the Pennsylvania Instream Comprehensive Evaluation (ICE) survey methodology. All benthic macroinvertebrate samples were collected from the best available fast and slow riffle habitat at each sampling location. The samples were collected using a D-frame net with 500-micron mesh netting. At each location, six 1-m^2 sections of substrate were thoroughly disturbed during collection and then composited into the same sampling container. The samples were properly preserved in ethanol and transported to the DEP Regional Office for sorting and identification.

The six-kick composite was sorted and all organisms removed for identification. All macroinvertebrates in each sample were identified to the lowest taxanomic level possible. A detailed analysis of the benthic macroinvertebrate community at each sampling location was computed using biometric indices. Using the metric analysis, comparisons were made between the macroinvertebrate communities of the Walnut Creek watershed and reference stream sampling locations.

Habitat conditions were scored at each sampling location according to the protocol described in the Standardized Biological Field Collection and Laboratory Methods. Habitat scoring included eight instream habitat qualities and four riparian zone conditions. Habitat conditions could potentially explain differences in the benthic community composition at sites that differed significantly from others in one or more habitat parameters.

Dissolved oxygen, pH, specific conductance and temperature were measured in the field using a hand-held YSI 556 multi-parameter meter. The meter was calibrated according to manufacturer specifications during each day of use. Total alkalinity was measured using a Hawk Run Total Alkalinity field test kit.

4.2.4 Benthic Macroinvertebrate Analysis and Results

The total numbers of individuals collected by taxonomic group are listed in Table 2. Taxa richness ranged from a low of 4 taxa at station 20UNT to 48 taxa at 1WC. Sample size, or the number of individual organisms collected at each sampling location, ranged from 4122 organisms at 27GR to 84 organisms at 24WC. Chironomidae (midges) were the most abundant taxa collected at all stations except for 22BR, where *Haploperla* (stoneflies) and 27GR, where *Epeorus* (mayflies) were the dominant taxa.

The benthic macroinvertebrate communities from the main stem of Walnut Creek showed a steady decline from the headwaters to the mouth within the following analysis categories: taxa richness, abundance, diversity, the number of intolerant taxa, Hilsenhoff Biotic Index (HBI) and the number and percentage of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa. Significant and noticeable declines within the benthic macroinvertebrate communities of Walnut Creek began near station 7WC. This coincides with the point within the Walnut Creek watershed where the potential for major impacts from non-point source pollution begin. Potential sources of pollution at this point include: previously developed commercial~~ly developed~~ areas, highly traveled transportation routes, residential areas and ongoing major construction activities.

Severe impacts are evident within the benthic macroinvertebrate communities of three unnamed tributaries of Walnut Creek, 9UNT, 12UNT and 20UNT. These three UNT's were very degraded and had low overall analysis scores. The major impacts may be attributed to urban sprawl as these streams have been heavily encroached upon by anthropogenic activities.

Diverse macroinvertebrate communities with balanced trophic structures were found at all three reference sampling locations. Each of these macroinvertebrate communities consisted of a high number of taxa that are generally intolerant of pollution. Therefore, the reference stations provide excellent metric analysis data in which to compare the sampling data from the stations of the Walnut Creek watershed.

4.2.5 Metric Analysis

Five metrics were evaluated to characterize the biological condition of the Walnut Creek watershed. These metrics included: Taxa Richness, Hilsenhoff Biotic Index (modified), EPT Index (modified), Community Loss Index and the Ratio of EPT and Chironomidae Abundances (Table 3).

Taxa Richness is the number of taxa (genera) present within the sample and can characterize the overall health of the macroinvertebrate community. Taxa richness generally increases with healthier water quality.

The Hilsenhoff Biotic Index (HBI) measures organic pollution tolerance and was modified for organisms found in Pennsylvania. The index assigns a value to each taxa. Values range from zero for organisms that are very intolerant of organic pollution to ten for organisms extremely tolerant of pollution. Tolerance values are multiplied by the number of individuals for each taxa within the sample. The results are summed and the total divided by the number of organisms within the sample to calculate the overall HBI score. This produces an index value for the entire sample. The community index values range from zero to ten and can be interpreted according to the following chart from Hilsenhoff (1987):

Hilsenhoff Biotic Index Condition Scoring Criteria

Score	*Narrative Range*	*Degree of Organic Pollution*
0.00 – 3.50	Excellent	No apparent organic pollution
3.51 – 4.50	Very Good	Possible slight organic pollution
4.51 – 5.50	Good	Some organic pollution
5.51 – 6.50	Fair	Fairly significant organic pollution
6.51 – 7.50	Fairly Poor	Significant organic pollution
7.51 – 8.50	Poor	Very significant organic pollution
8.51 – 10.00	Very Poor	Severe organic pollution

The EPT Index is the total number of taxa within the orders Ephemeroptera, Plecoptera and Trichoptera and was modified for organisms found in Pennsylvania. These orders of insects are generally sensitive to environmental stress. This metric value generally increases with healthier water quality.

The Community Loss Index measures the amount of dissimilarity between the macroinvertebrate taxa present at the reference and study sampling locations. The value of the index increases as the reference and study locations become less similar to one another with regard to their community taxa composition.

The Ratio of EPT and Chironomidae Abundances measure the evenness of distribution within these four taxonomic groups. Commonly, an increase in Chironimid abundance and a decrease in EPT abundance are noticed as water quality decreases or environmental stress is placed on the aquatic community. In turn, as the more intolerant EPT taxa are reduced in abundance, the calculated overall metric value is lower.

The functional feeding groups of the collected macroinvertebrate taxa and several other metrics were also reviewed but were not directly used in determining the biological condition of the Walnut Creek watershed. By examining the functional feeding groups of the collected macroinvertebrates, community shifts between sampling stations can be detected. Community shifts within the macroinvertebrate community can be either natural or indicative of environmental stress.

The Shannon Diversity Index depends not only on species richness but also takes relative abundance into account. The index is used to measure the evenness of individual taxa within the diversity of taxa collected. As a general rule, the higher the Index number, the more evenly distributed the taxa are within a sample, indicating better water quality. Benthic communities containing high numbers of only a few taxa with increased numbers of rare taxa generally have lower index values and poorer water quality.

4.2.6 Metric Comparison

Once a numerical value was calculated for each metric and a subsequent overall score computed for each sampling location, comparisons were made between the Walnut Creek watershed and reference waterways. A biological condition category, ranging from non-impaired to severely impaired, was given to each sampling location within the Walnut Creek watershed depending upon the percent comparison to the respective reference waterway. The 1989 EPA Rapid Bioassessment Protocols For Use In Streams And Rivers Manual, Plafkin et.al. (1989), provide scoring for the biological condition categories.

Twentymile Creek was used as a reference waterway in which to compare the main stem sampling locations of Walnut Creek (7WC, 8WC, 11WC, 13WC, 16WC, 21WC, 23WC and 24WC). Elk Creek was also used as a reference waterway in which to compare the main stem sampling locations of Walnut Creek (7WC, 8WC, 11WC, 13WC, 16WC, 21WC, 23WC and 24WC). Goodban Run was used as a reference waterway in which to compare all of the tributaries of Walnut Creek and the two-headwater sampling locations of Walnut Creek (1WC, 2WC, 9UNT, 12UNT, 14UNT, 17TR, 18TRUNT, 19TR, 20UNT and 22BR).

Walnut Creek vs. Twentymile Creek

When compared to Twentymile Creek, all of the sampling locations on the main stem of Walnut Creek were rated as “Moderately Impaired” (Table 4). The “Moderately Impaired” category is given to stations with a percent comparability between 21-50%.

The number and percent of EPT taxa present at all stations within the Walnut Creek watershed are significantly lower than the reference stream. EPT taxa composed 33.3 % of the macroinvertebrate community within Twentymile Creek. The Walnut Creek stations had EPT taxa compositions ranging from 1.5% at stations 13WC and 16WC to 11.6% at station 8WC.

HBI scores range from 5.32 at station 8 WC to 6.02 at station 16WC. These scores, with the exception of station 8WC, indicate “fairly significant organic pollution” present according to the Hilsenhoff Biotic Index Condition Scoring Criteria Chart from Hilsenhoff (1987). The score from station 8 WC indicates the presence of “some degree of organic pollution”. Twentymile Creek, with a HBI score of 4.25, falls into the category of “possible slight organic pollution”.

The Shannon Diversity of Walnut Creek ranges from 0.9 at 24WC to 1.47 at 13WC. Twentymile Creek had a score of 2.26 indicating an evenness of individual taxa within the diversity of taxa collected. The diversity index scores within Walnut Creek show a sharp drop off beginning at station 16WC and extending to the mouth.

Twenty-two intolerant taxa were present at the reference station. The number of intolerant taxa present within Walnut Creek ranged from 6 taxa at 21WC to 17 taxa at 8WC. The sampling stations closest to the mouth of Walnut Creek had the lowest number of intolerant taxa present.

Walnut Creek vs. Elk Creek

When compared to Elk Creek and using the table from Plafkin et.al. (1989), three stations, 21WC, 23WC and 24WC, rated as “Moderately Impaired”. Four stations, 7WC, 11WC, 13WC and 16WC, were rated as “Slightly Impaired” to the reference station by having a percent comparability between 54-79%. Station 8WC rated as “Non-Impaired” by having a percent comparability greater than 83% when compared to Elk Creek (Table 5).

The number and percent of EPT taxa present at all stations within the Walnut Creek watershed were lower than the reference station. The Elk Creek station had an EPT taxa composition of 14.2%. The Walnut Creek stations had EPT taxa compositions ranging from 1.5% at stations 13WC and 16WC to 11.6% at station 8WC. The individual number of EPT taxa begins to drop off at a point downstream of station 8WC.

HBI scores range from 5.32 at station 8WC to 6.02 at station 16WC. These scores, with the exception of station 8WC, indicate “fairly significant organic pollution” present according to the Hilsenhoff Biotic Index Condition Scoring Criteria Chart from Hilsenhoff (1987). The score from station 8 WC along with the HBI score from Elk Creek, 5.37, indicate the presence of “some degree of organic pollution”.

The Shannon Diversity of Walnut Creek ranges from 0.9 at 24WC to 1.47 at 13WC. Elk Creek had a score of 2.11 indicating an evenness of individual taxa within the diversity of taxa collected. The diversity index scores within Walnut Creek show a sharp drop off beginning at station 16WC and extending to the mouth.

Seventeen intolerant taxa were present at the reference station. The number of intolerant taxa present within Walnut Creek ranged from 6 taxa at 21WC to 17 taxa at 8WC. The sampling stations closest to the mouth of Walnut Creek had the lowest number of intolerant taxa present.

Similar taxa richness was noted in the reference stream and the upper stations of Walnut Creek. The macroinvertebrate community of Elk Creek consists of 25 taxa. The taxa richness of Walnut Creek ranged from 10 taxa at 24WC to 26 taxa at 8WC.

Walnut Creek Tributaries vs. Goodban Run

When compared to Goodban Run and using the table from Plafkin et.al. (1989), three stations, 9UNT, 12UNT and 20UNT, rated as “Severely Impaired” by having a percent comparability less than 17% (Table 6). Five stations, 2WC, 14UNT, 17TR, 18TRUNT and 19TR, were rated as “Moderately Impaired” to the reference station by having a percent comparability between 21-50%. Two stations, 1WC and 22BR, were rated as “Slightly Impaired” by having a percent comparability between 54-79%.

The Goodban Run sampling station had an EPT taxa composition of 72.4%. The Walnut Creek tributaries and headwater stations had EPT taxa compositions ranging from 0% at stations 12UNT and 20UNT to 67.4% at station 22BR. The individual number of EPT taxa range from 0 taxa at stations 12UNT and 20UNT to 20 taxa at station 1WC. Goodban Run had 20 individual EPT taxa present.

The mayfly, *Epeorus*, dominated the macroinvertebrate community of Goodban Run. The low overall HBI score for Goodban Run is a reflection of the lower individual HBI score of this mayfly genus. The percent composition of EPT taxa at the reference station is also a reflection of the high number of *Epeorus* taxa present.

HBI scores range from 2.18 at station 22BR to 7.49 at station 20UNT. The HBI score of Goodban Run is 1.74. According to the Hilsenhoff Biotic Index Condition Scoring Criteria Chart from Hilsenhoff (1987), stations 12UNT and 20UNT indicate the presence of "significant organic pollution". Stations 9UNT and 18TRUNT fall into the "fairly significant organic pollution" category. The scores of 2WC, 14UNT, 17TR and 19TR point toward a presence of "some organic pollution". Along with the reference station, 1 WC and 22BR show "no apparent organic pollution" when the Hilsenhoff chart is utilized.

The Shannon Diversity scores range from 0.81 at 20UNT to 2.28 at 2WC. Three tributaries and the two-headwater stations of Walnut Creek had diversity index scores higher than the reference station score of 1.57.

Twenty-five intolerant taxa were present at the reference station. The number of intolerant taxa present within the tributaries and headwater stations of Walnut Creek ranged from a single taxa at 20UNT to 33 taxa at 1WC. Stations 9UNT, 12UNT and 20UNT had the lowest number of intolerant taxa present, 2, 4 and 1, respectively.

Taxa richness varied among all sampling locations. The reference station yielded 36 individual taxa collected. The taxa richness from the Walnut Creek watershed ranged from 4 taxa collected at 20UNT to 48 taxa at 1WC.

4.2.7 Benthic Macroinvertebrate Overview

The aquatic macroinvertebrate health within the Walnut Creek watershed appears to become more depressed as you move downstream towards the mouth. The macroinvertebrate diversity, the number and percentage of EPT taxa and the number of intolerant taxa decrease as you move downstream. The HBI scores are higher near the mouth of Walnut Creek than they are at the headwater sampling stations (Table 7).

When looking at the Walnut Creek watershed, without comparison to a reference waterway, the greatest change within the benthic communities begin between stations 2WC and 7WC.

Walnut Creek sampling location 2WC

Walnut Creek sampling location 7WC

This correlates well with the slight changes within the habitat quality, change in bottom substrate composition and an increase in anthropogenic activities that begin to occur between these sampling stations.

Macroinvertebrate communities are influenced by changes within the bottom substrate and physical habitat composition. Cobble/ gravel sections dominate the headwater sampling locations of Walnut Creek. Bedrock begins to dominate the bottom substrate at sampling locations beginning near station 8WC. Physical habitat scores, which take into account both instream and riparian parameters, also begin to decrease in overall scores between sampling stations 2WC and 7WC. The headwater sections of Walnut Creek are mostly forested/ residential areas. Beginning at a point between sampling stations 2WC and 7WC, anthropogenic activities begin to increase. These activities include major transportation routes, a permitted landfill, highly concentrated commercial areas, residential areas and ongoing major construction activities.

Another distinct change within the macroinvertebrate communities of the Walnut Creek watershed appear between sampling stations 8WC and 11WC.

Walnut Creek sampling location 8WC

Failing silt fence

Stormwater runoff from an active development site along Interchange Road

This change correlates well with the influx of potential non-point source pollutants stemming from the highly developed Peach Street area. The vast amount of impervious areas present along Peach Street raises the potential for non-point source pollutant introduction and an immense increase in stormwater runoff during rain events. Coupled together, they can have detrimental impacts to the aquatic life from the point of entry downstream to the mouth of Walnut Creek and subsequently to the waters of Lake Erie.

The health of the macroinvertebrate community within the Walnut Creek watershed appears to decrease from the headwaters downstream to the confluence with Lake Erie. This decrease can be attributed to the cumulative impacts from the influx of various non-point source pollutants throughout the entire watershed.

4.3 Fish Survey

4.3.1 Introduction

The tributary streams that flow into Lake Erie provide an exceptional potamodromous (freshwater fish migration between lake and stream) fishery for thousands of anglers each year. Because of its popularity, the steelhead (rainbow trout) fishery provides a seasonal boost to the local economy in northwestern Pennsylvania (Murray and Shields 2004). The Lake Erie steelhead fishery is mainly supported by plantings of yearling steelhead, or smolts. Smolt stockings occur in the tributary streams in late winter and spring. These small trout (generally 4-9" in length) typically remain in the tributaries until warmer spring rains trigger their migration into Lake Erie. The majority of steelhead smolts and adults spend their summer in the deeper, colder waters of Lake Erie. Cooler, fall rains in late summer and early fall prompt their migration into area tributaries. Adult steelhead (3-5 year old fish) and jacks (2+ year old fish) can remain in tributary streams from fall until spring.

Natural steelhead spawning does occur in tributary streams and Pennsylvania Fish and Boat Commission Fisheries Biologists have documented some egg hatching. However, survivorship of wild steelhead populations is believed to be low. Possible reasons for the low survivorship of eggs and young-of-year steelhead are related to the lack of suitable spawning and rearing habitat and the high summer temperatures in the Lake Erie tributaries. Therefore, the Lake Erie steelhead fishery has been regarded as a put, grow, and take fishery.

The Pennsylvania Fish and Boat Commission (PFBC) has been planting steelhead into tributary streams since the 1960's. Additional potamodromous fish traditionally stocked and managed by the PFBC since then have included Coho and Chinook salmon. Stockings of brown and brook trout have also occurred. Pink salmon inadvertently run up Pennsylvania's Lake Erie tributaries and are occasionally caught by anglers. Pink salmon have apparently naturalized in Lake Erie from an accidental release in Lake Superior in 1956 (Murray and Shields 2004). In 2005, the PFBC released approximately 1,056,946 yearling steelhead into Lake Erie, tributaries streams to Lake Erie and Presque Isle Bay (http://www.fish.state.pa.us./).

Cooperative nurseries released an additional 126,300 yearling steelhead in 2005. Prior to 2003, the PFBC also conducted annual plantings of yearling Coho and Chinook salmon. However, that program has been discontinued due to poor return rates and concerns over predation from adult salmon on fragile rainbow smelt populations.

Walnut Creek is the second largest and arguably the second most popular tributary for steelhead fishing in the Pennsylvania portion of the Lake Erie drainage (Nagy 2003). In 2005, the PFBC and cooperative nurseries released approximately 219,070 smolts into Section 2 of Walnut Creek. The upstream limit of Section 2 occurs at SR99 near the Millcreek Mall and the downstream limit occurs at the mouth at Lake Erie. Walnut Creek does not receive any adult stockings of brown or rainbow trout so it is not considered an Approved Trout Water. Walnut Creek currently holds two Pennsylvania state fish records. On July 4, 2000, a 19 lb. 10 oz. brown trout was caught at the mouth of Walnut Creek along the area called "The Wall". On April 1, 2001, a 15 lb. 6.25 oz. steelhead has caught in the "Chutes" area of Walnut Creek.

4.3.2 Methods

Fish communities were assessed using a Coffelt backpack electrofishing unit with alternating current (AC). At each station, a 100-meter section of stream was sampled. Starting at a downstream point and maneuvering in a zigzag pattern upstream, a single pass was made. Station locations were chosen to cover a variety of habitats (i.e. riffles, runs, pools, depositional areas) that best characterized the stream reach. Fish species were collected and identified when the electrofishing reach was completed or visually identified immediately and not collected. General abundances were determined in the field for all non-game fish species. Game fish species were collected and additionally weighed, measured and returned to the stream. Abundances were tabulated as follows: rare (< 3 individuals), present (3-9 individuals), common (10-24 individuals), abundant (25-100 individuals) and very abundant (> 100 individuals). General observations were made for habitat complexity and quality and flow. Sampling duration and average stream width was also tabulated at each sampling reach.

A total of 22 stations were examined from June 22, 2006 to July 17, 2006 (Maps 2, 3 & 4). The time of year for sampling was chosen to not coincide with annual fall, winter and spring adult steelhead runs. Additionally, electrofishing during the late spring steelhead smolt stocking by the Pennsylvania Fish and Boat Commission (PFBC) and 3-C-U Cooperative Nurseries were also avoided. Ten sampling locations were chosen on the main stem of Walnut Creek and five stations on unnamed tributaries to Walnut Creek. In addition, two stations were chosen on Thomas Run and one station each on Bear Run and an unnamed tributary to Thomas Run. Reference stations were selected on Twenty-Mile Creek, Elk Creek and Goodban Run to compare fish populations. Fish station locations mimicked the macroinvertebrate stations with the exception of 15UNT, where no benthic insects were collected. Bear Run (22BR) was re-sampled on December 13, 2006 to further examine the brown trout fishery.

4.3.3 Results and Discussion

A total of 24 fish species were collected at the 19 Walnut Creek watershed stations and three reference stations on Elk Creek, Twenty-Mile Creek and Goodban Run (Table 8). Fish diversity ranged from 0 to 20 species per station. Station 24WC at the mouth of Walnut Creek had the highest diversity with 20 species collected while no fish were collected at station 9UNT. In addition, only stocked steelhead smolts were collected at station 20UNT. These individuals probably escaped from a cooperative nursery upstream.

The central stoneroller (*Campostoma anomalum*) was the most common fish collected during the survey. Stonerollers were found at 18 of the 22 fish sampling stations and were at least abundant at 11 stations. This small fish inhabited most of the drainage except in the headwater reaches and a few severely degraded tributaries of Walnut Creek. Central stonerollers consume principally plant material such as periphyton and filamentous algae. The habitat of stonerollers is highly variable but prefer medium sized creeks with pool and riffle habitat that contain sand and gravel bottoms. Because of their herbaceous diet, stonerollers can reach high densities in clean, eutrophic streams (Cooper 1981).

Central Stoneroller (*Campostoma anomalum*)

Blacknose Dace (*Rhinichthyes atratulus*)

Three species of dace were found in the Walnut Creek basin. The blacknose dace, *Rhinichthyes atratulus* was common to abundant at 17 of 19 stations on Walnut Creek and all reference stations. This dace is tolerable of a wide variety of environmental conditions and occur in moderately flowing waters of slower current. Blacknose dace occurred sympatrically in streams with longnose dace, *Rhinichthyes cataractae*. However, the two species occupied different habitats.

Longnose dace were found in 11 of 19 stations and two reference stations, Twenty-Mile Creek and Elk Creek. This species was present to common at most stations where it occurred. Unlike blacknose dace, longnose dace were found in the swifter flowing sections of Walnut Creek over gravelly bottoms.

Longnose Dace (*Rhinichthyes cataractae*)

Redside dace (*Clinostomus elongates)*

The redside dace, *Clinostomus elongatus*, occurred from station 2WC downstream to station 11WC. It was also found at station 7WC and 12UNT. This dace was common at all four stations where it was collected. The habitat of redside dace normally includes small creeks with a variety of pool and riffle areas over sand and gravel substrate.

Rainbow Darter (*Etheostoma caeruleum*)

Five species of darters were found in the Walnut Creek basin, four of which occur in the genus *Etheostoma*. The rainbow darter, *Etheostoma caeruleum*, occurred at 17 stations and was abundant to very abundant at seven stations. This small darter was found in the faster, shallow riffle habitats. Although they occupy different niches, rainbow darters are common associates with fantail and Johnny darters in northwestern Pennsylvania.

The Johnny darter, *Etheostoma nigrum*, was rare to present at only two stations on Walnut Creek, 2WC and 7WC. The species was found in the slower areas in pools or edges of Walnut Creek over fine gravel and sand. The fantail darter, *Etheostoma flabellare*, was collected at 14 stations where it was rare to common.

Johnny Darter (*Etheostoma nigrium*)

Fantail Darter (*Etheostoma flabellare*)

Fantail darters occurred in a variety of habitats during this survey but were most readily found in run areas where cobble or broken bedrock provided cover. The banded darter, *Etheostoma zonale*, was found at only one station, 23WC, where it was present. Banded darters are a widespread and common fish in northwestern Pennsylvania, where they occur in fast, shallow riffles. It is normally a common associate with greenside and variegate darters, neither of which was collected during this survey.

Log perch, *Percina caprodes*, was present at one station, 24WC. This large darter can tolerate silty water and occurs in a variety of habitats. Log perch run up tributary streams to spawn in late spring and early summer and may be locally abundant in the lower reaches of Walnut Creek and probably Twenty-Mile and Elk Creeks during that time period.

Log Perch (*Percina caprodes*)

River Chub (*Nocomis micropogon*)

Creek chubs, *Semotilus atromaculatus*, were collected at 20 stations where they were present to very abundant. This species did not occur at 9UNT and 20UNT. A hardy fish, this species occurred in a variety of habitats but usually were most common in moderate current over bedrock or gravel. Creek chubs are labeled as a transitional species, preferring coolwater conditions as opposed to warmwater or coldwater streams. They often occur sympatrically with blacknose dace and white suckers.

Creek Chub (*Semotilus atromaculatus*)

River chubs were collected at the downstream stations on Walnut Creek and the reference stations on Elk and Twenty-Mile Creeks where they were present to common. River chub habitat includes medium sized streams with cool water in bedrock bottoms and gravelly riffles (Steiner 2002).

Northern hog suckers, *Hypentilium nigricans*, and white suckers, *Catostomus commersoni*, were collected at 13 and 16 stations, respectively. Depending on the station, northern hog sucker abundance was varied while white suckers were present to common. Northern hog suckers usually occur in small to medium size creeks where clean gravel and cobble are common. White suckers are usually tolerable of a variety of different habitats. White suckers migrate into Walnut Creek in large numbers in early spring to spawn in fast flowing riffles. Most white suckers collected during this survey were young-of-year fish.

Northern Hog Sucker (*Hypentilium nigricans*)

Common Shiner (*Notropis cornutus*)

Common shiners, *Notropis cornutus*, were collected at 13 stations where population abundance was varied and ranged from present to abundant. Common shiners prefer medium size creeks with cool water.

Mottled sculpin, *Cottus bairdi*, were collected at 14 stations where they were rare to common. Sculpin usually inhabit small, cold headwaters streams and are normally associated with brook and brown trout. However, this species is

Mottled Sculpin (*Cottus bairdi*)

somewhat variable and does occur in streams where wild, reproducing populations of trout do not exist. During this survey, sculpin were normally found at the headwater areas of the watershed and in tributaries with good water quality and were much less abundant downstream. Mottled sculpin typically have a small home range.

Bluegill, *Lepomis macrochirus*, and pumpkinseed, *Lepomis gibbosus*, were collected at 11 and six stations, respectively. Abundance of these panfish was rare to present at each station. Bluegill and pumpkinseeds were collected from backwater depositional and erosional habitats and deeper pools. Most fish collected were small (< 4 inches in total length). Young-of-year Yellow perch, *Perca flavescens*, were found in low numbers in Elk Creek and Goodban Run.

Stonecat (*Notorus flavus*)

The stonecat, *Notorus flavus*, occurred at five stations and was restricted to the lower reaches of Walnut, Elk and Twenty-Mile Creeks. Stonecats were found in low numbers but population abundance might have been misleading due to the secretive nature of this small member of the catfish family. Stonecats were collected in deeper runs where shelves of bedrock provided ample daytime cover.

Largemouth Bass *(Micropterus salmoides*) (young-of-year)

Young-of-year smallmouth bass, *Micropterus dolomieu*, and largemouth bass, *Micropterus salmoides*, were each collected at three stations. Smallmouth bass were collected at the mouths of Walnut and Twenty-Mile Creeks and at station 26EC on Elk Creek. Good populations of adult smallmouth bass migrate into Walnut Creek in late spring each year to spawn. Young-of-year bass probably use tributary streams of Lake Erie as summer refuge areas.

Smallmouth Bass (*Micropterus dolomieu*) (young-of-year)

The round goby, *Neogobius melanostomus*, was collected at the mouth of Walnut and Twenty-Mile Creeks where they were present to common. An exotic species that was introduced into the Great Lakes around 1990, gobies can be easily identified by their fused pelvic fins, which form a suction disk (Marsden and Jude, 1995). Migration of gobies upstream into the Lake Erie tributaries appears to be limited and may be a result of their inability to traverse natural barriers such as bedrock waterfalls.

Round Goby (*Neogobius melanostomus*)

Fused pelvic fin of Round Goby

Brown trout, *Salmo trutta*, occurred at three stations: 24WC, 25TM, and 22BR. This species was rare to present below the SR5 bridges on Walnut Creek and Twenty-Mile Creek. Individual trout ranged from 10-18 inches in total length. Brown trout collected had a silvery appearance and lacked the red spots normally exhibited in wild-reproducing trout inhabiting mountainous freestone streams and limestone streams in Pennsylvania. We surmise these individuals collected were from a small summer lake run brown trout migration that occurs in the Lake Erie tributaries. As mentioned earlier, the state record brown trout in Pennsylvania was caught in July at the mouth of Walnut Creek.

Lake Run Brown Trout collected from Walnut Creek

A resident wild-reproducing brown trout fishery, however, does exist in Bear Run. Bear Run was sampled at station 22BR on June 23 and December 12, 2006. No brown trout were collected during the June 23rd survey. However, the Pennsylvania Fish and Boat Commission have documented that wild-reproducing brown trout populations traditionally occurred in Bear Run (Johns, personal communications, July 20, 2006). Therefore, a re-survey of the brown trout fishery was conducted on December 12, 2006. A total of seven brown trout were collected in a 300-meter section. Brown trout ranged from 84 to 267 millimeters (3.3-10.5 inches) in length, indicating at least two different age classes and a naturally reproducing population.

Wild-Reproducing Brown Trout collected from Bear Run (267 millimeters).

Naturally reproducing (wild) steelhead trout were collected at six of the 19 Walnut Creek watershed stations and all three-reference stations. Stream-bred steelhead were defined as an individual less than 100-millimeters (4-inches) in length. Stations where naturally occurring populations existed include: 14UNT, 15UNT, 19TR, 22BR, 23WC, 24WC, 25TM, 26EC and 27GR. The number of individuals collected per station reach ranged from two at 15UNT to 138 at 25TM. Wild steelhead ranged in size from 35 to 80 millimeters (1.4-3.1 inches) in length.

Wild-Reproducing Rainbow Trout collected from Thomas Run (51 millimeters).

Steelhead smolts stocked by the PFBC were collected at 12 stations, including all reference stations. Smolts ranged in size from 111 to 282 millimeters (4.4-11.1 inches) in length. A breakdown of the length-frequency distribution of wild steelhead in percentages can be found in Chart 1. Length-weight regressions are tabulated in Chart 2.

Rainbow trout (steelhead) smolt collected from Walnut Creek (158 millimeters).

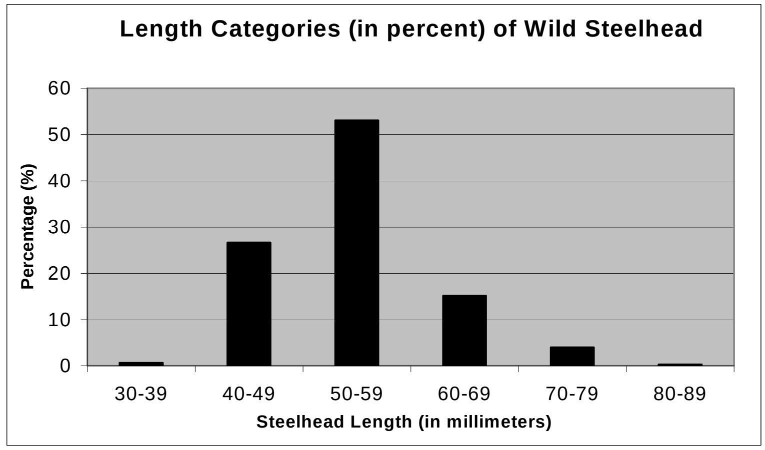


Chart 1. Length categories in percent (%) of wild steelhead collected in the Walnut Creek Watershed in 2006.

From the regression table, it is evident that there are two distinct size classes of fish. Steelhead less than 80 millimeters in length were considered stream bred while those greater than 111 millimeters were considered stocked fish. However, during the re-sampling of Bear Run (22BR) on December 12, 2006, a total of 26 steelhead were collected. The size of these individuals ranged from 85 to 168 millimeters (3.3-6.6 inches) in length. Because of their appearance, size and date of collection, these fish are believed to have occurred from natural reproduction.

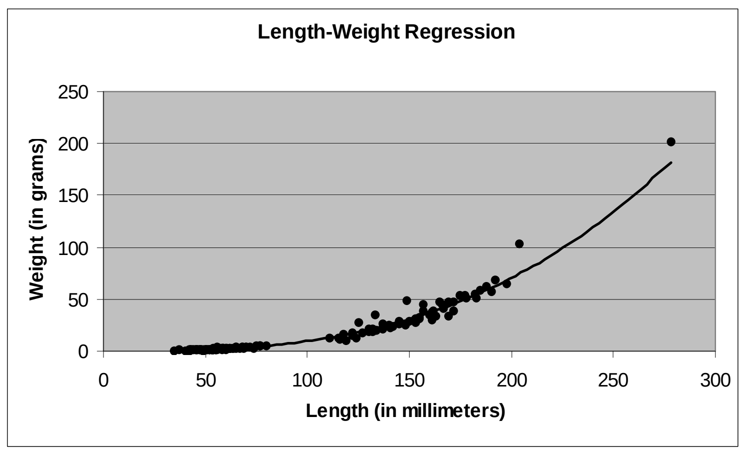


Chart 2. Length-weight regression in wild steelhead and hatchery raised smolts collected in the Walnut Creek Watershed in 2006.

Wild-Reproducing Rainbow Trout (steelhead) collected from Bear Run (130 millimeters).

In general, fish diversity and abundance of Walnut Creek was comparable to Elk and Twenty-Mile Creeks. Some differences exist when comparing Goodban Run to tributary streams of Walnut Creek. Headwater stations contained significantly lower number of fish species than downstream stations. No fish were collected at two stations, 9UNT and 20UNT.

4.4 Physical Habitat Evaluation

4.4.1 Introduction

Physical habitat assessments were conducted at all stations where macroinvertebrate collections were performed. Stations 1WC, 2WC, 7WC, 9UNT, 12UNT, 14UNT, 17TR, 18TRUNT, 19TR, 20UNT and 22BR were compared to the reference station 27GR (Table 9). Stations 8WC, 11WC, 13WC, 16WC, 21WC, 23WC and 24WC were compared to reference stations 25TM and 26EC (Table 10).

The habitat assessment is a visual rating of twelve parameters. Each parameter is scored as excellent (20-16), good (15-11), fair (10-6) or poor (5-0) by receiving a numeric value ranging from 20-0 for a total possible score of 240. Ratings are based on descriptive language of each parameter presented in Barbour et.al. (1999). Total habitat scores were evaluated and compared for each station. Habitat parameters used for riffle/run prevalent streams include: instream cover, epifaunal substrate, embeddedness, velocity/depth regimes, channel alterations, sediment deposits, frequency of riffles, channel flow status, condition of banks, bank vegetative protection, vegetative disruptive pressure, and riparian vegetative zone width.

After all parameters are evaluated, the twelve scores are summed and a total habitat score is derived for each station. Total scores in the "optimal" category range from 240-192, "sub-optimal" 180-132, "marginal" 120-72 and "poor" is 60 or less. The decision gaps between these categories are left to the discretion of the field investigator as to which generic category they would fall into. In addition, a percent comparability evaluation for each station was compared to the appropriate reference station by using the following table taken from Plafkin et.al (1989):

Assessment Category	Percent of Comparability
Comparable to Reference	>90%
Supporting	75-88%
Partially Supporting	60-73%
Non-Supporting	<58%

Substrate type was visually evaluated at each station and percentages of bedrock, boulder, cobble, gravel, sand and silt were tabulated (Table 11).

4.4.2 Physical Habitat Results and Discussion

Overall habitat scores for the three reference stations 27GR, 26EC and 25TM were 175, 164 and 162, respectively. Reference station habitat ratings all scored in the "sub-optimal" category. Total habitat scores in the Walnut Creek watershed ranged from a high of 193 at station 14UNT (optimal rating) to a low of 66 at station 12UNT (poor rating). A total of fourteen stations had overall habitat ratings in the "sub-optimal" category, one station in the "optimal" category, two in the "marginal" category and one in the "poor" category. When compared to the appropriate reference station and using the table from Plafkin et.al. (1989), twelve stations rated "comparable" to the reference station by having a percent comparability of over 90%. Four stations were rated as "supporting" by having a percent comparability between 75-88%. One station each was rated as "partially supporting" and "non-supporting" having a percent comparability between 60-73% and less than 58%, respectively. Four stations, 14UNT, 18TRUNT, 22BR and 16WC, had percent comparability scores greater than 100% and total habitat scores higher than their respective reference station.


Walnut Creek sampling location 14UNT


Walnut Creek sampling location 16WC

Individual habitat parameters show that eleven out of eighteen stations in the Walnut Creek watershed scored in the “marginal” and “poor” categories for condition of banks. Six stations each scored in the “marginal” and “poor” categories for epifaunal substrate and riparian vegetative zone width.

Substrate types in the headwaters of Walnut Creek are dominated by cobble/gravel habitats (45-65%). However, as you move downstream, the stream channel changes and is comprised mainly of bedrock (25-50%) and more characteristic of aquatic systems that drain into Lake Erie. Sand and silt also account for a large percentage of substrate type and ranged from 20-40% of the visual substrate. Lesser amounts of sand and silt were found as you moved downstream and visual observations indicate extensive deposits found among the interstitial spaces of larger particles. This caused a high degree of embeddedness of the available cobble and gravel at many stations. Visual observations also indicate large-scale substrate movement and stream channel alterations during peak flow events. The references stations, 25TM and 27GR, had the lowest amounts of combined sand and silt and were only 15% and 17% of the visible substrate, respectively.

In addition to the physical habitat assessment, the study included a Stream Corridor Assessment, whereby the stream was literally walked and potential environmental problems were documented. Noted were stream encroachments, hydromodifcations, accelerated erosion, sedimentation and lack of riparian buffer. The results of the Stream Corridor Assessment are incorporated in this report as a separate section.

The observations collected during the Stream Corridor Assessment add to, and support, the conclusions of the Physical Habitat Evaluation**.**

4.5 Surface Water Monitoring

4.5.1 Introduction

The quality of surface waters play an important role in defining the types of aquatic life, including bugs and fish, that are present in waterways. Water quality can be affected by both point-source and non-point sources of pollution. Point-sources of pollution can usually be detected through surface water sampling and typically have distinct differences within the water quality above and below the actual discharge point. The origins of non-point sources of pollution are harder to determine and can sometimes be tough to detect through water sampling alone. Surface water sampling, therefore, is used in conjunction with biological surveys to assess the overall health and diversity of a watershed. Water sampling can also aid in identifying the sources and causes of aquatic life use impairment or degradation if they are still unknown after the biological sampling data has been analyzed.

Throughout the entire watershed, many potential non-point sources of pollution are present which pose a threat to its associated aquatic life. In support of the biological surveys conducted within the watershed, surface water sampling locations were established at every macroinvertebrate collection station and various other locations to bracket potential pollution sources.

Twenty-four water sampling locations were established within the Walnut Creek Watershed, including eleven locations on the main stem and thirteen locations on tributaries (Map 5). Three reference waterways, Twenty Mile Creek, Elk Creek and Goodban Run, were sampled for comparative purposes (Maps 2 & 3). Surface water samples were collected during both a warm-water and cold-water time period. Within these respective temperature regimes, samples were collected at a point during a low flow and high flow period. The low flow samples were collected after extended periods of dry weather and the high flow samples were collected shortly after heavy rain events to capture the “first-flush” and/ or while the water levels were rising.

Walnut Creek (24WC) during low-flow period

Walnut Creek (24WC) during high flow period

The low-flow, cold samples were collected on May 2, 2006. The high-flow, cold samples were collected on May 11th and May 18th 2006. Two of the high-flow cold samples were collected on a different day due to time restraints and obtaining the samples while the stream flow was rising. The total rainfall amounts for May 11th and May 18th were 0.74 inches and 1.03 inches, respectively.

The reference low-flow, warm samples were collected on August 14, 2006. The Walnut Creek watershed low-flow, warm samples were collected on September 11th, 2006. High-flow, warm samples, from all waterways, were collected on August 29, 2006. The total rainfall amount for August 29th was 1.23 inches of rain.

4.5.2 Surface Water Monitoring Methods

Surface water samples were collected for laboratory analysis from mid-stream and mid-depth at each sampling location. The samples were collected in accordance with standard sampling protocols, fixed as needed and shipped on ice via overnight courier to the PA DEP Bureau of Laboratories in Harrisburg for analysis. Each sample was analyzed using the Standard Analysis Code (SAC) 035. In addition to the 29 individual parameters specified by SAC 035, the following parameters were also collected for each sample: pH, specific conductance and fecal coliform counts. Oil & grease samples were collected from nine sampling locations.

Water chemistry parameters, pH, dissolved oxygen, temperature, and conductivity, were also evaluated in the field using a YSI 556 multi-parameter meter. The meter was calibrated according to manufacturer specifications before each use. Due to the rising stream flows and inherent hazardous conditions during high flow events, field water chemistry readings were collected during the low-flow sampling events only.

4.5.3 Surface Water Monitoring Results

Low-Flow, Cold Water Sampling

The dissolved oxygen concentrations collected during field chemistry sampling were all within expected ranges. The water clarity at all sampling locations was clear at the time of sample collection. The water samples collected for laboratory analysis during this low-flow, cold-water sampling event indicated the following (Table 12):

- Fecal coliform levels were elevated above 200 colonies/ 100 ml at 14UNT and 17TR;
- pH values were fairly consistent throughout the watershed and ranged from 7.5 units at 27GR to 8.5 units at 17TR, 18TRUNT and 19TR;
- Alkalinity values ranged from 34 mg/L at 27GR to 271 mg/L at 10UNT;
- Sulfate levels were elevated above 90 mg/L at sampling locations 3UNT and 9UNT;
- Total Suspended Solids at sampling locations 4UNT and 6WC were elevated above 25 mg/L;
- Total nitrogen concentrations were elevated above 1 mg/L at 10UNT and 20UNT;
- Specific conductance levels were elevated above 900 umhos/cm at 4UNT, 9UNT, 10UNT, 12UNT and 20UNT;
- Chloride concentrations were above 200 mg/L at 4UNT, 9UNT and 10UNT;
- The turbidity level was above 15 NTU at 6WC;

- Total iron concentrations ranged from 22 ug/L at 25TM to 1413 ug/L at 10UNT;
- Total aluminum concentrations ranged from non-detect levels at 23 stations to 380 ug/L at 10UNT;
- Total manganese concentrations ranged from non-detect levels at 9 stations to 273 ug/L at 10UNT;
- The only measurable total lead readings were collected from 4UNT and 10UNT, 1.1 ug/L and 2.5 ug/L, respectively;
- The only measurable total zinc reading, 29 ug/L, was collected from 10UNT;
- Oil & grease samples, taken at nine sampling locations only, indicated two detectable readings at 9UNT and 11WC, 7.2 and 5.1, respectively

High-Flow, Cold Water Sampling

During the high water sampling event, visual observations of water clarity showed discolored to turbid / muddy water conditions at 20 sampling locations. The water clarity at two sampling locations, 9UNT and 10UNT, was a silver-grayish color. Two locations, 22BR and 25TM, were clear and three locations, 8WC, 17TR and 27GR, were off-color but were not muddy even after heavy rainfall blanketed the Erie County area.

The high flow water sampling data indicate dramatic fluctuations within parameter concentrations when compared to the low flow water sampling data (Table 12): These fluctuations along with other data analysis collected during the high-flow, cold water sampling event are as follows:

- Fecal coliform levels increased at all locations, including the reference locations, and range from 180 colonies/ 100mL at 25TM to 43000 colonies/ 100 mL at 4UNT;
- pH values were still fairly consistent throughout the watershed and ranged from 7.1 units at 10UNT to 8.2 units at 22BR, 24WC and 25TM;
- Sulfate concentrations were elevated at 3UNT;
- Suspended solids increase at all sampling locations except for two of the reference locations, 25TM and 27GR;
- The total nitrogen, total organic carbon and ammonia concentrations increased at all sampling locations, including the reference locations;
- The specific conductance and chloride concentration decrease significantly at 9UNT and 10UNT;
- The biological oxygen demand levels increase at all sampling locations, including the reference locations;
- Turbidity levels increased considerably at all sampling locations except for the reference location 25TM;
- Total iron concentrations increased at all locations and ranged from 48 ug/L at 25TM to 58600 ug/L at 20UNT;
- Total aluminum increased at all locations except for 22BR and 25TM, where the concentrations remained non-detectable. The highest level of total aluminum, 26400 ug/L, was found at 18TRUNT;
- Total manganese increased at all locations except for 25TM where it remained non-detectable and 10UNT where the concentration lowered. The highest concentration of 1059 ug/L was found at 18TRUNT;

- Total lead readings increased at all locations except 22BR, 24WC, 25TM and 27GR where it remained non-detectable. The highest level of 93.2 ug/L was found at 18TRUNT;
- Total zinc readings increased at all locations except 22BR, 23WC, 24WC, 25TM, 26EC and 27GR where it remained at non-detectable levels. The highest level of 186 ug/L was found at 20UNT;
- No detectable Oil & Grease readings were found at any of the nine sampling locations where this parameter was analyzed.

Low-Flow, Warm Water Sampling

The dissolved oxygen concentrations collected during field chemistry sampling were all within expected ranges except for sampling location 5UNT. The dissolved oxygen concentration at 5UNT was 3.59 mg/L or 66.7%. The water clarity at all sampling locations was clear at the time of sample collection. The water samples collected for laboratory analysis during this low-flow, warm water sampling event indicated the following (Table 13):

- Measurable levels of fecal coliforms were detected at all locations except for 25TM where it was non-detectable. Fifteen locations had levels above 200 colonies/100 mL;
- pH values ranged from 7.4 units at 5UNT to 8.7 units at 8WC;
- Alkalinity concentrations ranged from 57 mg/L at 27GR to 251 mg/L at 15UNT;
- Sulfate levels were elevated at 3UNT and 10UNT, 105 mg/L and 155 mg/L, respectively;
- Total suspended solids were slightly elevated at 27GR, 22 mg/L, and relatively low at all other sampling locations;
- Total nitrogen concentrations were elevated above 1 mg/L at 9UNT, 20UNT and 27GR
- Specific conductance levels were elevated above 900 umhos/cm at 9UNT, 10UNT, 12UNT and 20UNT;
- Chloride levels were above 200 mg/L at 9UNT, 10UNT and 12UNT;
- The highest turbidity value, 11.23 NTU, was found at 6WC;
- Total iron concentrations ranged from non-detectable levels at 11WC and 25TM to 2680 ug/L at 4UNT;
- The highest total aluminum concentration was found at 4UNT and had a concentration of 1320 ug/L;
- Total manganese concentrations ranged from non-detectable levels at 11 stations to 505 ug/L at 5UNT;
- The only measurable lead readings, 3 ug/L and 1.2 ug/L, were found at 4UNT and 6WC, respectively;
- Seven measurable zinc readings were noted with the highest concentration of 25 ug/L found at 17TR;
- Nine oil & grease samples were submitted for analysis with no detectable readings found at any sampling location.

High-Flow, Warm Water Sampling

Once again, the high flow water sampling data indicate dramatic fluctuations within parameter concentrations when compared to the low flow water sampling data (Table 13): These fluctuations along with other data analysis collected during the high-flow, warm water sampling event are as follows:

- Fecal coliform levels increased dramatically at all locations and ranged from 500 colonies/ 100 mL at 10UNT to 54000 colonies/ 100 mL at 26EC;
- As with the other sampling events, pH remained fairly consistent throughout all sampling stations;
- Sulfate concentrations were elevated at 3UNT and 10UNT;
- Total suspended solids varied among all sampling locations. Twenty-two sampling locations had an increase in concentration and five sampling locations remained near low-flow sampling concentrations;
- Total nitrogen and total organic carbon levels increased at all sampling locations, except for 4UNT, 9UNT and 20UNT where levels remain constant;
- Specific conductance values decreased at all sampling locations;
- Chloride concentrations decreased at all locations except for 1WC and 26EC, where they increased slightly;
- The biological oxygen demand levels increase at all sampling locations except 15UNT and 16WC;
- Turbidity values increases drastically at all locations except for 10UNT;
- Total iron concentrations increased at all locations and ranged from 230 ug/L at 2WC to 14100 ug/L at 23WC;
- Total aluminum concentrations increased at all locations except for 2WC, 9UNT and 10UNT where it remained at non-detectable levels; The highest concentration, 6912 ug/L, was found at 24WC;
- Four locations, 3UNT, 4UNT, 7WC and 8WC, had detectable total chromium concentrations with levels of 5.2 ug/L, 8.1 ug/L, 4.9 ug/L, and 4.4 ug/L, respectively;
- Total manganese concentrations increased at 19 sampling locations with the highest level, 494 ug/L, found at 23WC;
- Total lead concentrations increased at 21 locations with the highest level of 12.8 ug/L found at 24WC;
- Total zinc concentrations increased at 23 locations with the highest level, 69 ug/L, found at 23WC;
- Nine oil & grease samples were submitted for analysis with no detectable readings found at any sampling location.

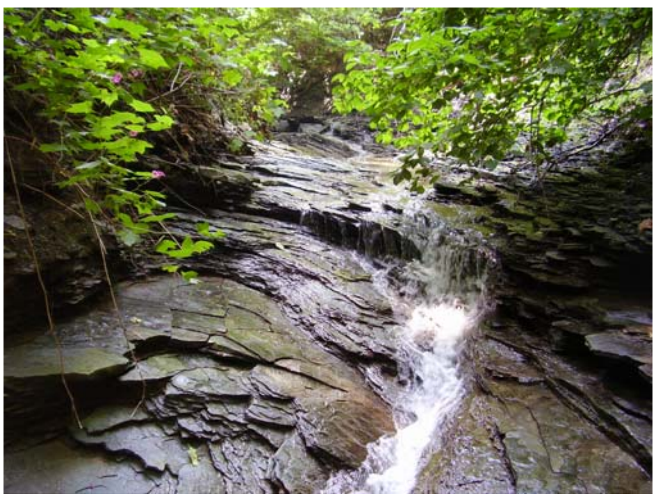
4.5.4 Surface Water Monitoring Discussion

The surface water quality within the Walnut Creek watershed appears to be negatively impacted by stormwater runoff. After rain events and as stream flows begin to increase, the concentration of pollutants entering the surface waters of the Walnut Creek watershed also begin to increase. Metals and fecal coliform concentrations and turbidity values increased significantly after rain events at most water sampling locations. Only two detectable oil & grease concentrations were found during water sampling. These were found during the low-flow, cold sampling event. Impacts stemming from point sources of pollution, however, were not as apparent.

Sampling data from stations 4UNT, 6WC, 9UNT, 10UNT and 20UNT indicate elevated pollutant concentrations during both the low-flow and high-flow sampling events. Possible non-point source contributors of pollutants are encompassed within or adjacent to these sampling locations.

Walnut Creek sampling location 4 UNT

Erosion and Sedimentation / active development upstream of 6WC.



Tributary 9UNT during low flow period

9UNT during high flow period

Potential non-point sources of pollution include, but are not limited to the following: urban and residential runoff, a permitted landfill, transportation routes, agricultural areas and other completed or ongoing commercial development. All of these sources contain enormous amounts of impervious area that create the potential for stormwater runoff, and subsequently, the capacity to impact nearby surface water quality.

The reference water sampling locations experience the same water quality trends and fluctuations as the sampling locations within the Walnut Creek watershed. Because of this, direct comparisons could not be made between the trends within the reference waterways and the Walnut Creek watershed. With this in mind, the chemical sampling within the watershed should be used in conjunction with the biological and physical assessments to make a determination of the overall health and diversity of the watershed.

Due to the cumulative impacts from non-point sources, stream use attainment is in question within numerous sections of the Walnut Creek main stem and several of its associated tributaries. Previous stream assessments conducted during 2001 documented stream use impairments within three tributaries of Walnut Creek, as noted previously in the report. These cursory assessments used a rapid biological assessment procedure and only identified the most severe impairments. These impairments are listed in the 2006 Pennsylvania Integrated Water Quality Monitoring and Assessment Report with the specific cause for impairment as siltation.

Stormwater basin discharge (10UNT)

Because of the more intensive sampling protocols that were used during this particular watershed assessment, it is expected that additional stream use impairments will be documented. Stream use attainment could not be determined because the data analysis / stream use attainment portion of the sampling protocol had not been finalized. Once this portion of the protocol has been finalized, the assessment data will be analyzed and any additional stream use impairments will be documented and included within the next Pennsylvania Integrated Water Quality Monitoring and Assessment Report.

4.6 Stream Assessment Summary

In general, Walnut Creek can be characterized as a medium-sized stream with substrate typically dominated by bedrock. The stream corridor is generally forested and adequately buffered from human encroachment; however, anthropogenic activity throughout the watershed is extensive. Land-use surveys provided by Pennsylvania SeaGrant--Lake Erie Office, based on information from the Erie County Department of Planning, indicates the watershed is approximately 38.04 square miles or 24,352 acres, is 11.28% agricultural, 3.73% commercial, 2.42% industrial, 21.47% low-density residential, 1.18% medium-density residential, 56.69% open-wooded and 3.23% public/institutional. From these percentages, it can be assumed that greater than 10% of the Walnut Creek drainage is currently covered by impervious areas.

Impervious surfaces are mostly impenetrable by water, thereby limiting normal infiltration and retention properties. This creates stormwater run-off during rain events at accelerated rates. Examples of impervious surfaces include roads, parking lots and rooftops. Research has suggested that the amount of impervious surface has been regarded as an important indicator in assessing assumed environmental degradation (Arnold and Gibbons, 1996). The Stormwater Managers Resource Center, or SMRC, (http://www.stormwatercenter.net) reviewed key findings of several studies correlating the relationship of urbanization to aquatic ecosystem impacts. This summary of stream research generally indicates that at small percentages of impervious cover within a watershed, declines in macroinvertebrate diversity start to become significant. In fact, many studies indicate that watersheds with greater than 10% impervious area, stream habitat and macroinvertebrate communities can decline significantly (Booth and Jackson, 1997; Fitzpatrick et.al., 2004). When the amount of imperviousness in a watershed increases to over 25%, stream impacts become severe.

Walnut Creek is currently experiencing many of the hydrologic effects of urbanization. During rain events, stormwater from impervious areas create peak flows that appear to be abnormally accelerated. Peak flows during this “first flush” wash many pollutants, including nitrogen, phosphorus, zinc, lead, aluminum, iron and many others into drains, ditches, tributaries and eventually the main stem of Walnut Creek and Lake Erie. Increased and accelerated peak flows during stormwater events decrease bank stability leading to increased erosion, sedimentation and substrate scouring.

Figure 60. Development – located at the headwaters of 15UNT

Sediment from exposed surfaces during development are also picked up from stormwater and carried downstream, causing an increase in suspended solids and embeddedness of stream substrate. As stream flows subside quickly, silt and clay are deposited into the interstitial spaces in the streambed, decreasing habitat for macroinvertebrates and fish. Lack of stream bank cover from loss of riparian habitat causes an increase in ambient water temperatures Nitrogen and phosphorus inputs accelerated by increased stream temperatures create an increase in algal production.

Active development at the headwaters of 20UNT

Stormwater Runoff from development upstream of 6WC

Sedimentation causing substrate embeddedness (21WC)

Nutrient Enrichment (20UNT)

The Urban Streams Classification Model (www.stormwatercenter.net) divides the percent impervious cover into three categories: sensitive (<10%), impacted (10-25%) and non-supporting (>25%). Currently, the Walnut Creek watershed is assumed to be above the 10% threshold and further future development is projected. During this survey, the aquatic macroinvertebrate community, fish community, habitat composition and chemistry of the surface waters of Walnut Creek and its tributaries were examined extensively. When combined, analyzed as a whole and compared to other watersheds in the Lake Erie drainage, the Walnut Creek drainage did not compare favorably. Walnut Creek has been regarded as having one of the better steelhead runs of any Lake Erie tributary. Future impacts in the watershed, as the percent impervious area inches closer to the 25% threshold, will undoubtedly cause further degradation of the fishery and aquatic macroinvertebrate communities. A serious commitment by county, township and municipal entities in the Walnut Creek basin are needed to better manage further development and provide for control of the quantity and quality of stormwater runoff in the watershed.

4.7 Natural Diversity

A search under the Pennsylvania Natural Diversity Inventory (PNDI) systems reveals that sensitive species under the jurisdictions of the Pennsylvania Department of Conservation and Natural Resources, the Pennsylvania Fish and Boat Commission and the Pennsylvania Game Commission exist within the Walnut Creek watershed. These species may include plants, fish, amphibians, reptiles and/or mammals. There are multiple areas within the watershed where rare, threatened or endangered species exist. Because of the sensitive nature, neither the species names nor the locations are disclosed in this report.

4.8 Wetlands Inventory

The Walnut Creek watershed contains numerous wetlands. Although there is no data source that lists every wetland within the watershed, a review of permitted projects in conjunction with data obtained from the U.S. Fish and Wildlife Service's National Wetland Inventory maps can provide an idea of the acreage and types of wetlands in the watershed.

Wetlands are located throughout the Walnut Creek watershed and are typically one of three types of wetlands. Emergent wetlands, also known as wet meadows, are characterized by grassy vegetation, flowers and ferns. Scrub-shrub wetlands contain smaller woody plants such as dogwood and willow. Forested wetlands are characterized by a majority of trees that may include oaks, maples and willows.

Emergent wetland.
Photo courtesy of USDA Natural Resources Conservation Service

Forested wetland

Wetlands provide important ecological functions. Numerous organisms including many threatened and endangered species utilize wetlands as their habitat. Wetlands also act as filters by removing pollutants and sediments from the watershed. Acting like giant sponges, wetlands retain large amounts of stormwater and help to prevent flooding. They also provide groundwater recharge.
Projects involving wetland (and stream) impacts require state and federal permits. DEP is the issuing agency for state permits under the authority of Chapter 105 Dam Safety and Waterway Management regulations.

Multiple permits have been issued in the Walnut Creek watershed that contain both wetland and stream impacts. A review of the state Chapter 105 permits reveals that approximately 30 acres of wetlands in the Walnut Creek watershed have been impacted by development. Impacts to wetland and streams require mitigation and the typical wetland mitigation plan consists of the creation of replacement wetlands. Of the 30 acres of wetland impacts in the Walnut Creek watershed, 20 acres were replaced within the watershed. One of the largest projects, the Millcreek Mall, was permitted to replace wetlands in another watershed (Conneaut Creek) accounting for a significant loss of wetlands in the Walnut Creek watershed. Some permits also included stream impacts totaling 25,000 linear feet. A summary of the wetland impacts, wetland replacements, stream impacts, and (where known) total wetlands on the project site is as follows:

Great Blue Heron.
Photo by Tim McCabe, USDA Natural Resources Conservation Service.

Permit E25-470 Millcreek Mall and E25-562 Millcreek Mall Pavilion, Millcreek Township

Wetland impacts: 14.49 acres
Wetland replacement: 16.01 acres replaced within Conneaut Creek watershed

Permit E25-517, Lakeview Landfill Expansion, Summit Township

Wetland impacts: 1.39 acres
Wetland replacement: 1.60 acres

Permit E25-527 Bush Industries, Summit Township

Wetland impacts: 2.1 acres
Wetland replacement: 3.8 acres

Permit E25-538 Wegmans, Millcreek Township

Wetland impacts: 0.37 acres
Wetland replacement: 0.4 acres
Total wetlands on site: 3.55 acres
Stream relocation: 1,940 linear feet UNT Walnut Creek
Channel loss: 1,250 linear feet UNT Walnut Creek

Permit E25-544 Niagara Village Subdivision, Millcreek Township

Wetland impacts: 1.22 acres
Wetland replacement: 1.84 acres
Total wetlands on site: 3.19 acres

Permit E25-666 Presque Isle Downs, Summit Township

Wetland impacts: 8.61 acres
Wetland replacement: 10.56 acres
Stream impacts: 11,808 linear feet UNT Walnut Creek
Stream relocation: 1,576 linear feet UNT Walnut Creek

Permit E25-668 Lakeview Landfill, Greene and Summit Townships

Wetland impacts: 2.61 acres
Wetland replacement: 3.47 acres
Stream impacts: 4,941 linear feet UNT Walnut Creek
Stream relocation: 3,390 linear feet UNT Walnut Creek

Permit E25-681 Whispering Woods Estates, Millcreek Township

Wetland impacts: 0.049 acres (deminimus impact, so no replacement required)
Wetland replacement: 0 acres
Total wetlands on site: 8.07 acres
Stream length on site: 32,452 linear feet
Stream impacts: 6,885 linear feet

Permit E25-699: Limited Express Hotel, Summit Township

Wetland impacts: 0.042 acres (deminimus impact, so no replacement required)

It is probable that other wetland impacts have occurred in the Walnut Creek watershed through unpermitted activities, so this summary in no way characterizes all of the wetland impacts in the watershed. General permits, which are usually issued by the Erie County Conservation District, were not reviewed in this summary.

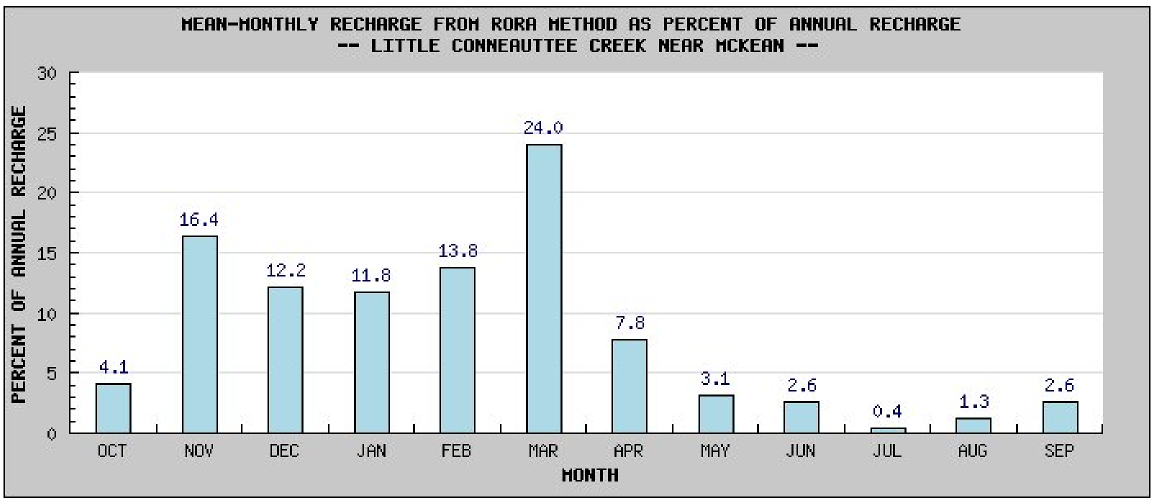
Compliance with 105 permits is typically handled on a complaint basis. Complaint response involves technical advise by the conservation district, any further enforcement is handled by the Department.

The loss of wetlands from the Walnut Creek watershed has most likely had a detrimental impact. In a watershed where stormwater runoff is a significant problem, the loss of wetlands, which function in stormwater retention, only amplifies the problem. Future impacts to wetlands in the watershed should be avoided as much as possible and if impacts are permitted, then it is recommended that mitigation remain within the watershed to prevent any further wetland loss.

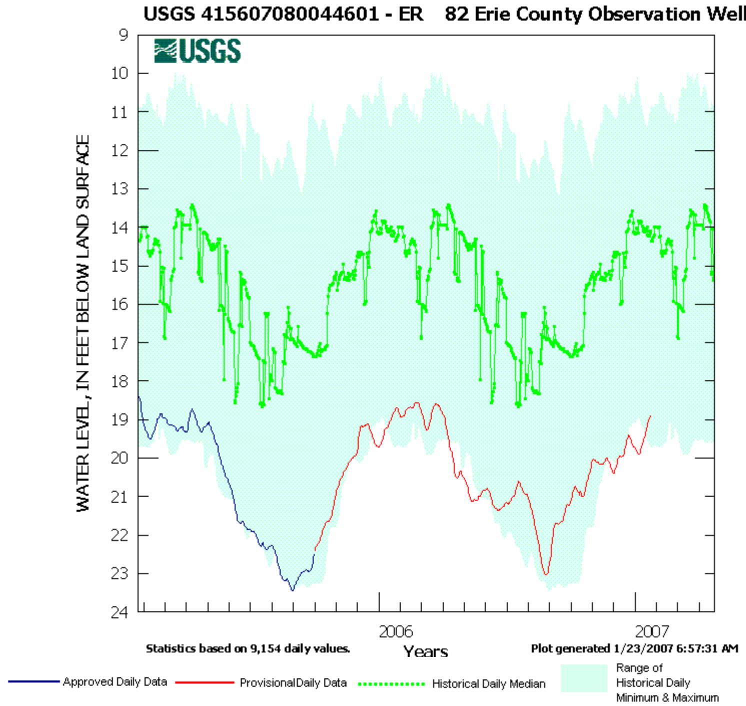
PART 5—WATER USE AND SUSTAINABILTIY

5.1 Groundwater Quantity Assessment

The following U.S. Geological Survey chart shows estimated ground water recharge based on streamflow using hydrograph methods for Little Conneauttee Creek in Erie County. Though some distance from the Walnut Creek watershed, it typifies the seasonal percentage of change in recharge for streams in northwestern Pennsylvania. In short, ground water recharge occurs primarily in the winter months, with a maximum occurring in March. By comparison, recharge is very low in the summer months. This estimate of recharge also corresponds roughly to annual precipitation occurrence, and is most significant in the spring when precipitation and melting snow pack compound the contribution to ground water.



The next two charts represent ground water elevation in the U.S. Geological Survey observation well located in Washington Township, Erie County near Conneauttee Creek. (Latitude 41°56'07", Longitude 80°04'46" NAD27, depth: 82 feet, land surface altitude: 1,419ft ASL, NGVD29, Venango Formation). As with the previous graph, ground water elevation is low in the summer, higher in the winter, and reaches a maximum in February/March.



USGS 415607080044601 - ER 82 Erie County Observation Well
USGS
WATER LEVEL, IN FEET BELOW LAND SURFACE
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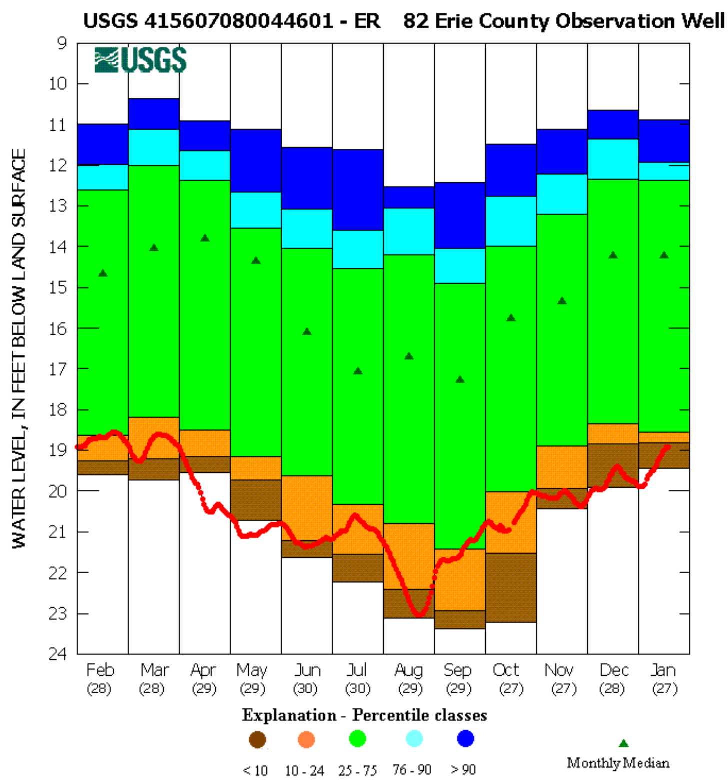
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
2006
2007
Years
Statistics based on 9,154 daily values.
Plot generated 1/23/2007 6:57:31 AM
Approved Daily Data
ProvisionalDaily Data
Historical Daily Median
Range of Historical Daily Minimum & Maximum



USGS 415607080044601 - ER 82 Erie County Observation Well
USGS
WATER LEVEL, IN FEET BELOW LAND SURFACE
9
10
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15
16
17
18
19
20
21
22
23
24
Feb (28)
Mar (28)
Apr (29)
May (29)
Jun (30)
Jul (30)
Aug (29)
Sep (29)
Oct (27)
Nov (27)
Dec (28)
Jan (27)
Explanation - Percentile classes
< 10
10 - 24
25 - 75
76 - 90
> 90
Monthly Median

The previous information is presented to provide an understanding that the watershed receives much less water from precipitation in the summer months. In addition to reduced precipitation in the summer, significantly more precipitation is consumed through evaporation and transpiration. It may be inferred from this information that the maximum runoff contribution to the stream, and recharge to local aquifers, occurs in the late winter and early spring.

5.2 Surface Water Quantity Assessment

The Q7-10 flow is an estimate or actual measurement of the lowest average stream flow for a consecutive 7-day period that would be expected to occur once during a ten-year period. Typically, the Q7-10 would be calculated based on data from an existing gauge station that measures stream level and discharge. There is no gauge station on Walnut Creek; the closest is is on Brandy Run. The Brandy Run gage station is on a small, rural stream in the Elk Creek watershed. It is not representative of the developed Erie area and does not provide meaningful results for the Walnut Creek watershed. The Q7-10 for Walnut Creek cannot be accurately calculated because too many assumptions would have to be made and no significant results would be obtained.

A limited analysis of stream flow was completed as part of the watershed assessment. Stream depth, width, and water velocity measurements were taken on seven separate days in October and November of 2006. These measurements were made at the same location on each day (the downstream end of the U.S. Highway 5 bridge over Walnut Creek). Measurements were made on relatively high and low stream flow days. In consideration of the previous information relating to local precipitation and aquifer recharge, the time of year for this stream flow measurement was selected to coincide, as much as possible, with the expected average precipitation. The analysis of this information is presented in Appendix F. The methodology used to establish stream flows from these measurements is based on the *U.S. Geological Survey Circular 1123 (Wahl, Thomas, and Hirsch, 1995).* This information is available on the Internet at: http://pubs.usgs.gov/circ/circ1123/collection.html. The mean flow in Walnut Creek was calculated at approximately 58 cubic feet/second.

In addition to the measurements discussed above, an analysis of the total watershed area, average annual precipitation, and average annual evapotranspiration was made. Evapotranspiration is the term applied to the combined effects of evaporation and transpiration, or the consumption of water by plants. In short, it is the total amount of water “lost” from the watershed. Precipitation and evapotranspiration estimates were taken from the Pa. Geological *Survey’s Geology of Pennsylvania’s Ground Water* (Fleeger, 1999).

***Chart 4* - Walnut Creek Stream Flow Estimate**

44	Average Annual Rainfall in Walnut Creek Watershed (inches)
22	Average Annual Evapotranspiration in Walnut Creek Watershed (inches)
38.2	Watershed Area (Square Miles)
1.53354E+11	Watershed Area (square inches)
3.37378E+12	Annual Water Volume for Watershed (cubic inches)
9,243,224,821	Average Discharge for Watershed (cubic inches / day)
61.91075	**Average Discharge for Watershed (cubic feet / second)**

These calculations resulted in an average discharge of approximately 62 cubic feet/second. Though both methods involve several significant assumptions, and are inarguably “rough” estimates, the results correlate well to each other (the location of the daily measurements was selected to be near the mouth of the watershed, so as to be comparable to the latter estimate using the total watershed area and precipitation information). This average flow of roughly 60 cubic feet/second also correlates well to other streams in comparably sized watersheds.

DEP has been working cooperatively with the U.S. Geological Survey and other agencies to explore the installation of a permanent gauging station on Walnut Creek. Stream discharge rates would be useful for establishing information needed to more clearly understand local conditions.

5.3 Determination of Groundwater Influences on Surface Water Quality and Quantity

Influence of groundwater quality on stream water quality in Walnut Creek and its tributaries is not well understood. Some general conclusions; however, may be made from knowledge of the watershed features and characteristics and the groundwater quality of the watershed:

- Unconsolidated, glacial materials convey water more rapidly, with less time between infiltration and discharge to the stream, than from the consolidated bedrock aquifers.

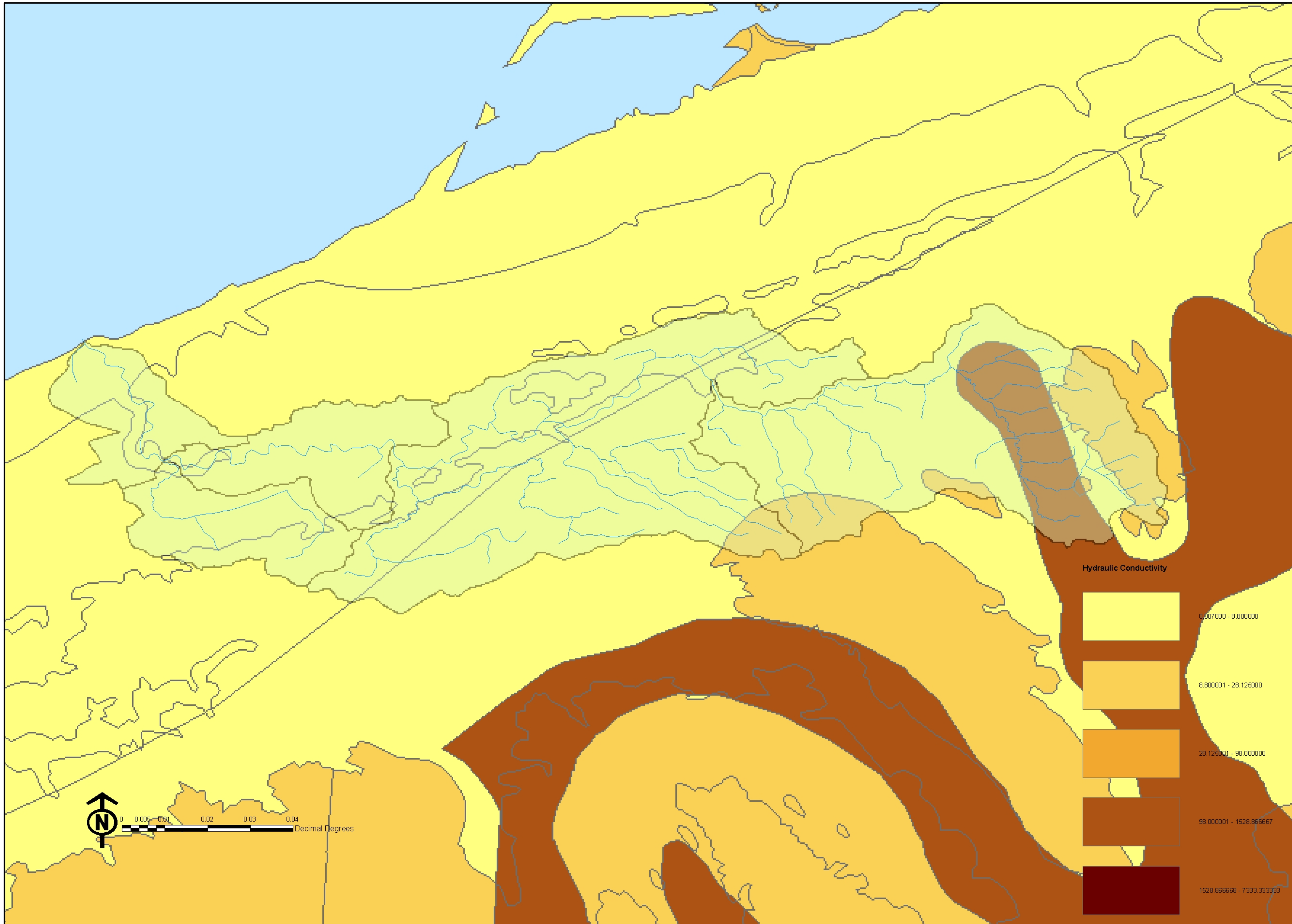
- Consolidated bedrock aquifers provide water to Walnut Creek of lower quality and more slowly than the unconsolidated glacial aquifers.

- The headwaters area of the watershed may be the exception- formations in this area exhibit better water quality and higher hydraulic conductivites.

The following map shows bedrock hydraulic conductivities as noted above. Hydraulic conductivity, in simplest terms, is the capacity for water to move through an aquifer. It is a function of the size of voids in the aquifer material, the degree of interconnectivity of these voids, and the hydraulic gradient. A comprehensive presentation of hydrogeologic science is beyond the scope of this report, suffice to say, that aquifers with higher hydraulic conductivities transmit more water over time. In the Walnut Creek watershed, as depicted in the following map, higher hydraulic conductivities are observed in the southeastern headwaters area. The significance of this observation is that ground water contribution from bedrock to the stream will be greater in this area than further downstream in the watershed, where unconsolidated glacial materials are the dominant contributor. These unconsolidated materials typically exhibit hydraulic conductivities far greater than local bedrock aquifers. This should be considered as part of local ground water use and planning.

This information, coupled with an understanding of the susceptibility analysis of potential sources of contamination presented earlier, demonstrates the susceptibility of the limited, shallow, unconsolidated aquifers that dominate the watershed. Further work in understanding the correlations of local groundwater to surface water within the watershed is warranted.

Hydraulic Conductivity



5.4 Impacts of Surface Water Withdrawals on Watercourses

Known surface water withdrawals within the Walnut Creek watershed include several golf courses, Pennsylvania Fish and Boat Commission facilities, a mobile home park and a landfill. Only one of the golf courses withdraws water directly from Walnut Creek, other withdrawals are taken from ponds, wells, and tributary streams.

Water withdrawal impacts are difficult to quantify. Not all of the facilities with known withdrawals take water year-round. In addition, there are numerous unpermitted or unregistered withdrawals and the effects of these on the Walnut Creek watershed are not clear. However, it is possible that a combination of the withdrawals could have an effect, especially if many of these withdrawals occur during low-flow conditions.

Water withdrawals could have localized impacts on aquatic life. During low flow conditions, Walnut Creek has many isolated pools of water where fish and other aquatic life can become cut off from the main channel. A reduction in the water volume could result in more isolated pools and more trapped organisms. During drought or low-flow conditions, fish mortality in these pools could increase as water temperature rises and the pools begin to evaporate. Although specific data is not available, it can be suggested that during low flow conditions, water withdrawals from Walnut Creek could have localized detrimental impacts to aquatic life.

5.5 Influence of Stormwater Runoff on Stream Quantity and Quality

During precipitation events, Walnut Creek becomes “flashy” and conveys large volumes of water. A stream reach typically several inches in depth can quickly rise to several feet deep. The full range of fluctuations in the stream discharge has not been quantified, but minimum and peak flows calculated during stream measurements were 28 cubic feet/second and 85 cubic feet/second, respectively.

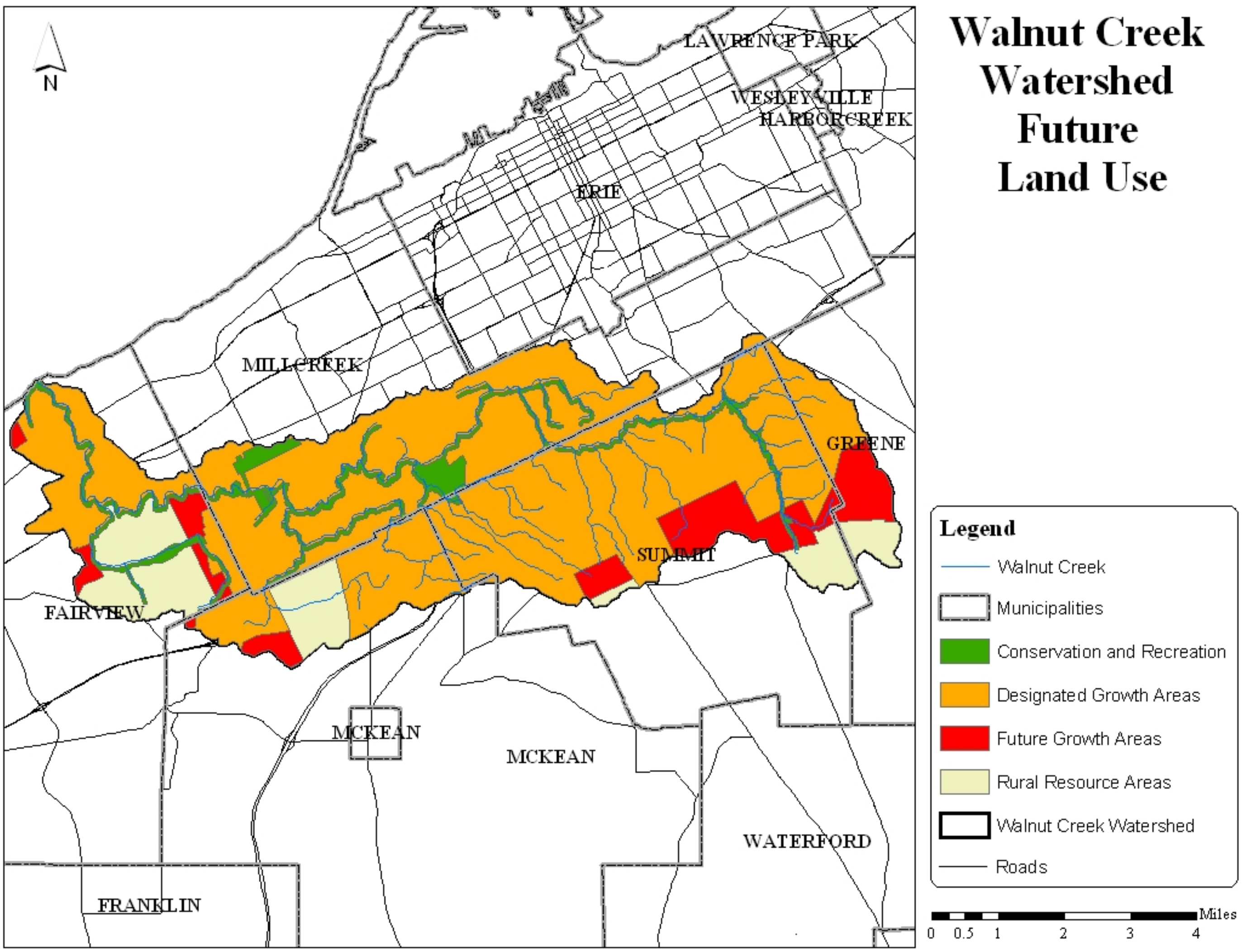
Observations made during the Corridor Assessment revealed areas of accelerated erosion and sedimentation, in part due to stormwater runoff. Sampling during low flow and high flow stream events showed that stormwater runoff is a significant contributor of non-point source pollutants to Walnut Creek and Lake Erie. Creek Sweep results indicated considerably higher *E. coli* loading from stormwater runoff. A comparison of baseline pollutant loads to loading from high stream flow conditions can only be calculated based on limited data. Continuous stream discharge measurement and routine water quality monitoring are necessary to calculate the actual pollutant loading from stormwater runoff to Walnut Creek.

PART 6—COMMUNITY EFFORTS TOWARDS CONSERVATION AND EDUCATION

6.1 Land Use and Planning Activities

6.1.1 Projected Growth Areas in the Walnut Creek Watershed

According to Erie County Department of Planning projections, much of the Walnut Creek watershed is planned for further development in the coming decade. This projection presents a challenge to maintaining the environmental health of the watershed. The figure below identifies areas that are designated for growth in the Walnut Creek watershed (Erie County, 2003). Of important note is the future growth areas located in the headwater sub-basins of the watershed.



Walnut Creek Watershed Land Use/Land Cover

6.*1.2* *Review of County and Municipal Comprehensive Plans*

As part of its Comprehensive Plan, Erie County updated the County Land Use Plan in December 2003. The County Land Use Plan encourages that future land development be managed through local zoning and ordinances to protect public health and, preserve historical, cultural and environmentally sensitive areas. Implementation of the Land Use Plan is accomplished, in part, through State Planning Code and County ordinances. Parts of the plan are nonbinding and left to each municipality to carry out. The full Comprehensive Plan can be found online at: http://www.eriecountyplanning.org/index.php?page=plans-and-controls.

Five Erie County municipalities fall within the Walnut Creek watershed, namely: Millcreek Township, Greene Township, McKean Township, Fairview Township and Summit Township. A summary of each of Township's individual Comprehensive Plan is described below.

6.1.2.a Millcreek Township

Millcreek Township updated its Comprehensive Plan in 2002. The Plan recognizes that much of the land within the township is currently developed, and it is expected that the remaining undeveloped land will be developed before 2010. The township identifies that because so little land is undeveloped, and recognizes that once developed it is difficult to change, the remaining available land should be managed in ways that preserve open space and promote greenways. A new land use designation was utilized in Millcreek Township's Comprehensive Plan called *Rural Residential* that encompasses approximately 3,000 acres in the township. The designation requires that design principals (discussed in the Recreation and Open Space Plan) be employed, which would assure that 50% of the developable land be left as open space in perpetuity. Although low impact design would be used, much of *Rural Residential* lands are located in currently undisturbed areas of the Walnut Creek watershed.

It is encouraging that Millcreek Township has given consideration to the environmental state of the community in its Comprehensive Plan. Methods to sustain development while protecting the environment are described in the plan, such as recommending Conservation Subdivision Design and Conservation Zoning. Also recommended is very little creation of new large-scale commercial retail space and limiting commercial sprawl.

The following descriptions of township Comprehensive Plans are cited from the "Evaluation of Comprehensive Plans" section of the July 2001 *Walnut Creek Watershed Assessment.* Andrew Martin and Associates completed the assessment for Asbury Woods Nature Center and the Millcreek Township School District. The assessment was funded by a DEP Growing Greener grant. The Comprehensive Plans for Greene, McKean, Fairview, and Summit Townships have not been updated since the 2001 assessment.

6.1.2.b Greene Township

Greene Township's Comprehensive Plan, completed in 1981, is out of date. The future of Greene Township cannot accurately be predicted until Greene completes a more current plan for the future. Only a minor portion of the total Walnut Creek watershed is in Greene Township, but the headwaters of the main stream and several tributaries rise there.

6.1.2.c McKean Township

McKean Township's Comprehensive Plan is dated 1997. McKean, primarily a residential community, expresses a concern for maintaining its rural, agriculture-based character. Almost 60% of McKean Township land is vacant, and another 30% is devoted to agriculture. McKean Township's Comprehensive Plan establishes "growth" and "no growth" regions in the township so that uncontrolled growth and development will not alter the "rural flavor" of the area. Unfortunately for the Walnut Creek Watershed, the portion of the watershed that intersects McKean Township lies in the primary area in which McKean plans to encourage growth. The northeast portion of the township through which Walnut Creek passes has already experienced significant subdivision and resultant residential growth, development that McKean wishes to continue and expand. The future zoning of northern McKean Township will be medium-density residential (suburban) with some land remaining rural. Industrial and commercial zones in northwest McKean Township will also increase in size.

6.1.2.d Fairview Township

Fairview Township's Comprehensive Plan was completed in 1997. Development in Fairview will affect the western portion of the Walnut Creek watershed. Most of Fairview Township is presently rural, and the township discounts the perception that this rural character is changing rapidly, maintaining that land use has remained much the same over time. Fairview acknowledges that the Millcreek/Erie Urbanized Area is pressuring expansion into Fairview; the township appears to feel that it is its "turn" to receive the development that has proceeded elsewhere in the past. One way in which Fairview wishes to encourage new development is by extending its public water and sewer lines. Its goal is to provide water for the entire township. Although no major commercial development had occurred at the time of this plan, at least two new industrial parks had been proposed for Fairview, accompanied by plans for new access roads, etc., a mile south of the former borough line. The township acknowledges that Fairview Borough, before it merged with Fairview Township, had reached capacity.

Only a limited amount of land was left available for development, aside from agricultural land owned by Fairview Evergreen Nurseries. However, Fairview

Township contains much open land, which township planners obviously view as a surplus ripe for development. Fairview's plan states that the township has enough of this surplus land to address both economic and environmental concerns: 'the Township contains enough land, absent of protected resources, that can accommodate all anticipated and most unanticipated development for the next twenty years without destroying sensitive environmental features.' The township is projecting new subdivisions already in the works at the time of the plan. Future zoning leaves much land agricultural but establishes big, concentrated centers of commercial and industrial expansion. At the time of this plan, Fairview Township had no comprehensive storm drainage plan, although it had established an ordinance requiring that stormwater be properly managed and controlled in conjunction with new development. Non-residential developments would be required to own and maintain their own stormwater management systems. Fairview Township also had no plan for regulating municipal-type solid waste at the time of this plan which, the township admitted, prompted people to engage in unsafe activities such as burning and/or burying the waste.

6.1.2.e Summit Township

Summit Township completed its Comprehensive Plan in 2000. Summit appears to be trying to establish a delicate balance between the rural nature of the township and what it views as its tremendous potential for growth. Summit is mindful of the topographic features and open space within the township conducive to development; the township places high value on its continued economic growth and development. Therefore, the Comprehensive Plan encourages extensive development in northern Summit, especially the area of the township north of Interstate 90. It also includes plans to build more roads to ease traffic pressure on these new developments. Despite the township's concern for continued economic growth, the plan expresses a concern for environmental preservation within Summit. The township is hoping to preserve large tracts of open land, especially in southern Summit.

These areas set aside for agriculture and conservation may be of limited benefit to the Walnut Creek Watershed; however, as much of this land lies outside the watershed. Even though the northern part of Summit contains many areas of projected development, the township has many plans to make this growth environmentally friendly. Among these plans, several are particularly applicable to the future of Walnut Creek. Summit is concerned with updating its stormwater management guidelines for roadway design. It also is examining new design methods to make runoff less of a problem. The township also plans to incorporate stormwater management into its development plans, limiting huge stretches of parking lots and requiring businesses to provide for open spaces within their developments. Summit plans to periodically evaluate its stormwater management facilities. In addition, it will require appropriate stabilization of all stream banks and waterways so as to enhance stormwater and erosion controls.

Two critical plans by Summit are to 'require the establishment of riparian buffer zones around all streams and tributaries to mitigate the impact of stormwater run-off and to promote infiltration into groundwater' and to 're-establish riparian buffers in developed areas of the township (Section II – Strategies for Action, Page II-7).' Most important for the Walnut Creek Watershed, Summit Township has plans directly related to maintenance and preservation of the watershed's quality. It plans to 'preserve the Walnut Creek corridor as an open space linkage an buffer between single-family residential development to the north and nonresidential uses that may locate to the south (Section II, Strategies for Action, Page II-7).'"

6.2 Conservation Efforts

Due to the diversity of land use in the Walnut Creek Watershed, conservation efforts are not easy to categorize. Undoubtedly, there have been more than a few examples of landowners, large and small, who through their own efforts, have implemented conservation practices to the benefit of the watershed. The ongoing success of the Erie County Conservation District's programs, like the tree seedling and conservation plant sale, attests to the fact that area residents are supportive and cognizant of ways to improve the local environment.

Millcreek Township has a land acquisition program for public green space. It has recently acquired the Cassidy property, which borders Walnut Creek, to be used as public park.

The Erie County Comprehensive Plan identifies the need to preserve agricultural land. It promotes farmland preservation through the Pennsylvania Purchase of Agricultural Conservations Easements (PACE) program.

The PA Fish and Boat Commission created a program to acquire land and offer easements to property owners for stream access for fishermen.

6.3 Environmental Education

Environmental education and outreach within the watershed is a shared effort involving many groups and many partnerships. The Erie Conservation District has developed several programs over the years focusing on watershed education, nutrient management, and erosion control best management practices to protect the county's valuable soil and water resources.

Millcreek Schools, through their Asbury Woods educational facility, promote environmental education and good stewardship to our youth. Mercyhurst, Behrend, and Gannon students and staff support and collaborate with the Conservation District and others in expanding the community environmental knowledge base.

The names mentioned above are some of the many individuals and groups conducting valuable environmental education and conservation programs, all of who deserve recognitions. Overall, local conservation and environmental educational efforts illustrate how the synergy of diverse talents, disciplines, and techniques can converge to create results of maximum effectiveness.

PART 7: SIGNIFICANT FINDINGS AND RECOMMENDATIONS

7.1 Environmental Quality of the Watershed

The Walnut Creek Watershed Environmental Quality Assessment identified activities that both encourage support of, and conflict with, sustaining public health and safety, economic stability and quality of life for Erie County citizens. The watershed resources provide local citizens with good air quality, safe drinking water, and an outstanding sport fishery. There is also available land for farming, public space and private use. The findings of this assessment; however, indicate that the health of the watershed is at risk.

The watershed has experienced significant residential and commercial growth over the past 25 years and further development is projected. This growth has stimulated the local economy and is seen by many as progress. Another important local economic aspect is agriculture. Farming is a mainstay of Pennsylvania's economy and remains a viable sector of Erie County's economy (Erie County Planning Erie County Natural and Historic Resources Plan, December 2003). These activities are critical to the economic stability of the Erie Region. But these same activities, if unmanaged, can conflict with environmental quality.

Land development has reduced the surface area for stormwater infiltration, condensed green space needed for evapotranspiration of stormwater by plants, and diminished the water absorption capacity of the soils. These factors amplify stormwater runoff rates, raise flooding potential, accelerate erosion and increase pollutant loading to the streams. Development also increases the demands of, and threats to, public water supplies. Some of the specific impacts of land development on the Walnut Creek watershed are summarized as follows:

> ***Water Supply***: The City of Erie Water Authority provides reliable, sustainable and good quality water from Lake Erie to most of the residents in the Walnut Creek watershed. Groundwater is used for 16 small public water supplies and numerous private water supplies. Regional groundwater data indicates some areas have elevated levels of nitrates and inorganic chemical concentrations in excess of U.S. Environmental Protection Agency Maximum Contaminant Limits. Groundwater quantity is limited and sources will not likely sustain progressive development. Several areas in Erie County cannot support well construction that meets Safe Drinking Water requirements. Potential sources of contamination have been identified within the watershed, but no documented Source Water Protection strategies are in place to protect groundwater supplies.
>
> ***Pathogenic Bacteria:*** *E. coli* bacteria, an indicator of pathogens, have been found in high levels in Walnut Creek and its tributaries. The source of the bacteria is from both human and animal sources, and primarily associated with non-point source pollutants in stormwater. The in-stream levels of bacteria and the overall load to Lake Erie have not yet been determined.
>
> ***West Nile Virus:*** Although no human cases of West Nile Virus have been reported within the watershed, the threat to public health exists. Since the inception of the West Nile Virus Control Program, there have been eleven positive mosquito samples--one

positive sample in 2000, three in 2002 and seven in 2006.

Giant Hogweed: Giant Hogweed is a public health hazard because of its potential to cause severe skin irritation and blindness. Clusters of the plant have been found in the vicinity of the Millcreek Mall, near Hershey Road and at the mouth of Walnut Creek at Lake Erie. There may also be undiscovered populations in the watershed since the spread of Giant Hogweed is greatest in riparian areas.

Potential Flooding: One of the biggest impacts of land development is an increased rate of stormwater runoff, which raises the potential for localized flooding. Stormwater management is handled by county-wide, watershed based planning focused on preventing problems associated with the quantity and quality of stormwater discharges. Although modern stormwater management practices are now being used in some communities with Municipal Separate Storm Sewer (MS4) permits, previous practices have left inadequate or no stormwater controls.

Loss of Watershed Habitat: Walnut Creek and its tributaries have been notably impacted by stormwater runoff, stream channel modifications, stream encroachments and stream bank erosion. This has contributed to a net wetland loss, stream channel losses, and degraded riparian buffer zones. These conditions have also contributed to water pollution and a loss of habitat for fish, plants and terrestrial species, some of which are protected as threatened and endangered species.

Water Quantity**:** Stream withdrawals can have a negative impact on the biological health of a stream. Water removal during low flow conditions can drain small pools where fish live. Conversely, during storm events Walnut Creek becomes very "flashy" causing accelerated erosion of the stream banks and scouring of the streambed. The actual impact of the rapid variation of flow on the stream structure and habitat is not fully understood. Additional flow and water quality monitoring is needed.

Land Use**:** Land use can be directly correlated to stream health; unmanaged development often yields impaired streams. It is also well recognized that land use planning is necessary for economic stability, and public access to green space is essential to promote quality of life. The 2003 Erie County Comprehensive Plan identifies planning efforts needed to promote future development while preserving environmentally sensitive areas, establishing green space and conserving agricultural lands. While some municipalities have adopted local land use plans, the County Plan is non-binding and not promoted by all watershed municipalities.

There are agricultural operations within the watershed, mostly located in the headwaters of Walnut Creek and near Bear Run. No specific environmental impacts from farming were noted during the assessment, but the potential does exist. Without soil conservation plans fields and stream banks can be badly eroded, riparian buffers can be lost and wetlands filled. Stormwater runoff from agricultural operations can carry pollutants to surface water and groundwater. The conditions can result in a loss of farmable land, a land use worth preserving as noted in the 2003 Erie County Planning Erie County Natural and Historic Resources Plan.

7.2 Moving Forward

Achieving environmental quality that supports public health and safety, economic stability and quality of life cannot be accomplished by one individual organization. Environmental protection and sustainability requires a combined effort of regulatory agencies, county planners, municipal decision makers, private business, volunteer groups, and most importantly, the citizens that live there. The community must support the efforts needed for environmental improvement.

Each party has its individual role, but all parties must work together to accomplish the goal of a healthy environment. To move towards that goal, each party must set an agenda of environmental improvement, take stock of its programs and align resources to forward the agenda. Collectively, the parties need to support mutual initiatives towards environmental improvement, provide checks and balances on mandated programs, and share information on known problems and improvements.

7.3 Drivers for Environmental Improvement

A comprehensive watershed plan is needed for the Walnut Creek watershed. The plan should establish clear benchmarks for surface water quality based on Total Maximum Daily Load design. It should also define the target stream flow discharge during base flow and high flow conditions throughout the watershed. Planning efforts can establish a regional approach to provide for the future water supply needs of the community. It should also clearly identify land use practices that allows for growth while protecting the resources. All those who have a stake in the watershed must support improvement initiatives. Specifically:

- ➢ The Regional DEP office is encouraged to continue directing resources to promote Act 167 Stormwater Management Planning, move Act 537 Sewage Planning forward, and ensure MS4 permit compliance. It should also provide available funding and assistance to promote Source Water Protection strategies and implementation projects that preserve sensitive lands and improve water quality.

- ➢ Municipalities are encouraged to enact and enforce local policies and zoning that effectively address stormwater management, sewage management, preserve green spaces and environmentally sensitive lands, and support Source Water Protection programs.

- ➢ Partnerships should be established between regulatory agencies, municipalities, private enterprise, conservation groups and community members to collectively work towards watershed protection.

- ➢ Education is a key component of environmental improvement. The environmental condition of the watershed should be reported to the community with the challenge of taking individual action.

- ➢ Ongoing monitoring of the environmental quality of the watershed is necessary to identify whether actions towards improvement are effective or not, and be the basis for plan improvement.

7.4 Recommendations

Tables 7.1 through 7.4 identify the specific threats to resources found through the assessment along with recommendations for improvement. The threats have been prioritized as 1 (most significant) to 4 (less significant).

Implementing recommendations can best be accomplished through a partnership of stakeholders. The following is a partial list of partners needed to accomplish the recommendations:

U.S. Environmental Protection Agency (EPA)
U.S. Army Corps of Engineers (USACE)
U.S. Geological Service (USGS)
Department of Environmental Protection (DEP)
Department of Conservation and Natural Resource (DCNR)
Pennsylvania Fish and Boat Commission (F&BC)
Pennsylvania Game Commission (PGC)
Pennsylvania Department of Agriculture (PDA)
Erie County Conservation District (ECCD)
Erie County Planning Office (County Planning)
Erie County Department of Health (ECDH)
Fairview, Millcreek, McKane, Summit and Green Townships (Township)
City of Erie Water Authority (Water Auth.)
Science Consortium at Tom Ridge Environmental Education Center
(Science Consortium)
Pennsylvania Farm Bureau (PFB)
Pennsylvania Rural Water Association (PRWA)
Water Resources Education Network (WREN)
Pennsylvania Sea Grant
Sons of Lake Erie
Local Business (Business)
Conservation groups
School Districts

Table 7.1: Conditions Affecting Public Health and Safety				
Target	***Threat***	***Recommendation***	***Partners***	***Priority***
Public Water Supply	Potential contamination of Lake Erie water resources	Support existing Source Water Protection strategies	Water Auth., EPA, DEP, ECHD, Township PRWA, WREN	**2**
	Potential contamination of groundwater resources	Encourage Source Water Protection strategies for small public water supplies	DEP, ECHD, PRWA, WREN, Township	**2**
	Sustainable Public Water Supply	Regional water resource planning should be implemented for sustaining a good quality and reliable supply source	Water Auth., EPA, DEP, ECHD, Township	**1**
Private Water Supply	Potential contamination of private well resources	Provide outreach and education to residents to protect private wells from contamination	DEP, ECHD, ECCD, PRWA, WREN, Township	**2**
Human Health	West Nile Virus	Continue support of the Erie County Health Department's West Nile Virus surveillance program	DEP & ECHD	**1**
		Continue public outreach and education programs for West Nile Virus prevention	DEP, ECHD, ECCD, Township	**2**
	Pathogenic bacteria	Continue *E. coli* monitoring to identify problems from regulated sources	DEP, DCNR ECHD, Science Consortium, Township	**1**
		Increase sewage treatment plant compliance monitoring during the summer months	DEP & ECHD	**3**

		Increase municipal Sewerage Planning Act 537 compliance, particularly focusing on studying needs areas in Fairview and Summit Townships	DEP, ECHD, Township	**2**
		Increase agricultural outreach activities promoting green riparian buffer zones, barnyard management and Nutrient Management Planning to minimize runoff	DEP, ECCD, PFB, Conservation groups	**3**
		Increase MS4 illicit discharge detection and elimination system compliance	DEP & Township	**2**
	Giant Hogweed	Increase public education efforts on recognizing Giant Hogweed and its hazards	PDA, DEP, ECHD, ECCD, Township, Conservation Groups	**2**
		Increase early detection efforts in the watershed to target rapid response control measures	PDA, DEP, ECHD, ECCD, Township, Conservation Groups	**2**
Public Safety	Potential flooding	Implement the Floodplain Management Program to revise and enforce ordinances that prevent floodplain obstruction and development	DEP, ECCD, Erie County Planning, Township	**2**
		Increase Chapter 105 compliance efforts to minimize stream encroachments	DEP & ECCD	**2**

Table 7.2: Conditions Affecting Habitat And Biological Diversity				
Target	***Threat***	***Recommendation***	***Partners***	***Priority***
Water Quality	Urban stormwater runoff	Update the Erie County, Lake Erie Watershed Act 167 Plan to provide effective stormwater management to address both quality and quality control	DEP, County Planning	**1**
		Adopt and implement the updated Erie County, Lake Erie Watershed Act 167 plan by all watershed municipalities	DEP, Municipality	**1**
		Explore creating a Regional Stormwater Authority to govern ordinances, MS4 permit compliance, and stormwater	DEP, Municipality	**2**
		Expand MS4 public outreach to residential audiences concerning household NPS pollution.	DEP, ECCD, ECDH, Municipality, Conservation groups.	**3**
		Construct new, or retrofit existing, stormwater controls where discharges are contributing to known stream impacts	DEP, ECCD, Municipality, Business, Conservation groups	**1**
		Encourage design of post construction stormwater management structures that go beyond NPDES requirements for controlling the quantity of pollutants and the volume of stormwater runoff	DEP, ECCD, Municipality, Business	**2**
	Stormwater runoff from construction and earthmoving activities	Modify 102 permitting strategies in areas with stream impairments from urban stormwater runoff	DEP, ECCD	**1**
		Increased monitoring and compliance activities at 102 permitted stormwater construction activities	DEP, F&BC, ECCD, Municipality	**1**

		Expand MS4 public outreach to developers of new and redeveloped lands concerning E&S BMPs and PCSM	DEP, ECCD, Municipality, Business	**2**
		Expand outreach to contractors regarding E&S BMP construction and maintenance	DEP, ECCD, Municipality, Business	**2**
	Rural stormwater runoff	Increase public education about non-agricultural NPS pollution, such as fertilizers, household hazardous wastes, and waste disposal.	DEP, ECDH, ECCD, Municipality, Conservation groups	**4**
		Promote septic system inspection and maintenance agreements	DEP, ECDH, Municipality	**4**
	Agricultural stormwater runoff	Increase agricultural outreach activities promoting green riparian buffer zones, barnyard management and Nutrient Management Planning to minimize runoff	DEP, PFB, ECCD, Conservation groups	**3**
		Increase awareness of and promote No-till farming practices	DEP, PFB, ECCD, Conservation groups	**4**
Wetlands	Wetland Loss	Participate in the USACE's Great Lakes Habitat Initiative to inventory and protection of wetland habitats	USACE, DEP, F&BC, ECCD, ECDH	**4**
		Permitted wetland replacement should done at the maximum rate feasible	DEP, ECCD	**1**
		Permitted wetland mitigation should only be done within the watershed	DEP, ECCD	**1**
		Increased enforcement of non-permitted wetland fills	DEP, ECCD	**2**
		Increase public awareness of the functions and values of wetlands	DEP, ECCD, Municipality, Conservation groups	**4**
Stream Channel	Bank erosion	Promote stream bank stabilization projects in areas with severe erosion	DEP, ECCD, Municipality, Conservation groups	**2**

	Channel modification	Encourage natural stream channel design to retrofit existing and in developing new stream mitigation projects	DEP, F&BC, ECCD Municipality, Business	**3**
	Stream encroachment	Increased enforcement of non-permitted stream encroachments	DEP, ECCD	**2**
Riparian Zone	Insufficient buffer area	Establish green riparian buffer zones in new land developments	DEP, PAF&BC, ECCD, Municipality, Business, Conservation groups	**3**
		Protect and re-establish green riparian buffer zones on farmlands through CREP	DEP, PGC, PFB, ECCD	**3**
		Increase public awareness of the functions and values of riparian buffer zones	DEP, PAF&BC, PGC, ECCD, Municipality, Conservation groups	**4**
		Promote urban and suburban reforestation	DEP, F&BC, ECCD, Municipality, Business, Conservation groups	**4**
		Promote conservation easements for riparian areas	DEP, F&BC, ECCD, Municipality, Business, Conservation groups	**3**

Table 7.3: Conditions Water Use and Sustainability				
Target	***Threat***	***Recommendation***	***Partners***	***Priority***
Surface Water Quantity	Surface water withdrawal	Act 220 registration of surface water withdrawals	DEP	**4**
	Decreased base flow	Increase the area of pervious surfaces using stormwater BMPs at new development and redevelopment to allow groundwater recharge and provide for stream base flow	DEP, ECCD, Municipality, Business, Conservation groups	**1**
	Impervious surfaces increasing stormwater discharge rate	Update the Erie County, Lake Erie Watershed Act 167 Plan to provide effective stormwater management to address both quality and quality control, as noted above	DEP, County Planning	**1**
		Adopt and implement the updated Erie County, Lake Erie Watershed Act 167 plan by all watershed municipalities, as noted above	DEP, Municipality	**1**
		Install stream gage station to evaluate impacts of stormwater discharge and pollutant loading	EPA, USACE, USGS, DEP, F&BC, DCNR, ECCD, Municipality, Business, Conservation groups	**1**
Ground-water quantity	Impervious surfaces decreasing groundwater recharge	Update the Erie County, Lake Erie Watershed Act 167 Plan to provide effective stormwater management to address both quality and quality control, as noted above	DEP, County Planning	**1**
		Adopt and implement the updated Erie County, Lake Erie Watershed Act 167 plan by all watershed municipalities, as noted above	DEP, Municipality	**1**

Table 7.4: Conditions Affecting Land Preservation				
Target	***Threat***	***Recommendation***	***Partners***	***Priority***
Public Green Space	Unplanned/unmanaged development	Implementation of 2003 Erie County Land Use Plan and local plans by municipalities to preserve green space	County Planning, municipality	**2**
		Support land acquisition and easements for green space conservation	DEP, ECCD, Municipality, Business, Conservation groups	**2**
		Promote green space in new land development	DEP, ECCD, Municipality, Business, Conservation groups	**3**
		Encourage public access to streams and green spaces	DEP, F&BC, ECCD, Municipality, Business, Conservation groups	**2**
Farmland	Unplanned/managed development	Promote and support farmland preservation through the Pennsylvania Purchase of Agricultural Conservations Easements (PACE)	ECCD, PFB, Municipality, Conservation groups	**2**
		Promote and support farmland preservation through the Pennsylvania Clean and Green Program	ECCD, PFB Municipality, Conservation groups	**2**
Environ-mentally Sensitive Areas	Unplanned/managed development	The Erie County Natural Resource Plan (2003) identifies local natural lands that are critical to community sustainability. The plan should be adopted by municipalities to preserve environmentally sensitive areas	County Planning, Municipality	**2**
		Evaluate Bear Run for protected use reclassification to *High Quality Waters*	DEP	**2**

REFERENCES

Andrew Martin Associates. 2001. Walnut Creek Watershed Assessment. Report of Findings – Section 2: Evaluation of Comprehensive Plans.

Arnold, C. L., and C. J. Gibbons. 1996. Impervious Surface Coverage: The Emergence of a Key Environmental Indicator. *Journal of the American Planning Association*. 62(2): 243-258.

Barbour, M. T., J. Gerritsen, B.,D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Boggs, S. 1987. *Principles of Sedimentology and Stratigraphy* . University of Oregon. Macmillan Publishing; New York, NY; LOC 86-61423.

Booth, D.B. and C.R. Jackson. 1997. Urbanization of Aquatic Systems: Degradation Thresholds, Stormwater Detection, and the Limits of Mitigation. *Journal of the American Water Resources Association*. 35(5): 1077-1090.

Cahill and Associates. 2002. Average Annual Precipitation in Pennsylvania, 1971-1990 from NOAA records.

Commonwealth of Pennsylvania. 2006. *Pennsylvania Code Title 25. Environmental Protection.* Department of Environmental Protection. *Chapter 93. Water Quality Standards.*

Commonwealth of Pennsylvania. 2006. Instream Comprehensive Evaluation Surveys (Draft). Department of Environmental Protection, Bureau of Water Standards and Facility Regulation.

Commonwealth of Pennsylvania. 2003. Standardized Biological Field Collection and Laboratory Methods (Draft). Department of Environmental Protection, Bureau of Water Supply and Wastewater Management.

Commonwealth of Pennsylvania. "2006 Pennsylvania Integrated Water Quality Monitoring and Assessment Report." Department of Environmental Protection. February 7, 2007. <http://www.dep.state.pa.us>.

Commonwealth of Pennsylvania. "Warm/Coolwater Stocking History: Erie County" The Pennsylvania Fish and Boat Commission. February 7, 2006. <http://www.fish.state.pa.us./>.

Cooper, E.L. 1981. Fishes of Pennsylvania and the Northeastern United States. The Pennsylvania State University Press, University Park and London.

Fetter, C.W. 1988. *Applied Hydrogeology, 2nd Edition*. University of Wisconsin, Oshkosh. Merrill Publishing; Columbus, OH; LOC 87-62679.

Fitzpatrick, F.A., M.A. Harris, T.L. Arnold, and K.D. Richards. 2004. Urbanization Influences on Aquatic Communities in Northeastern Illinois Streams. *Journal of the American Water Resources Association.* 40(2): 461-475.

Fleeger. 1999. *Geology of Pennsylvania's Ground Water*. Pennsylvania Department of Conservation and Natural Resources – Bureau of Topographic and Geologic Survey; Harrisburg, Pa.

Francy, D. 2003. *Escherichia coli* at Ohio Bathing Beaches—Distribution, Sources, Wastewater Indicators, and Predictive Modeling. USGS. http://oh.water.usgs.gov/reports/wrir/wrir02-4285.pdf.

Hilsenhoff, W.L. 1987. An improved Biotic Index of Organic Stream Pollution. *Great Lakes Entomologist* 20: 31-39.

Hol, Rinehart, and Winston. 1988. *The Earth Through Time, 3rd Edition.* New York, NY; LOC 87-16512.

Johns, F. Pennsylvania Fish and Boat Commission. Personal phone communication. July 20, 2006.

Klein, R.D. 1979. Urbanization And Stream Water Quality Impairment. *Water Resources Bulletin* 15: 948-963.

Marsden, J.E. and D.J Jude. 1995. *Round Gobies Invade North America*. SeaGrant Publication. The Ohio State University.

Low, D.J.and D.C. Chichester. *Ground Water Quality in Pennsylvania – A compilation of Computerized (Electronic) Databases, 1979 – 2004; Series 150.* U.S. Geological Survey.

Murray, C. and M. Shields. 2004. "Creel Analysis and Economic Impact of Pennsylvania's Lake Erie Tributary Fisheries in Erie County, Pennsylvania with Special Emphasis on Landlocked Steelhead Trout (*Oncorhynchus mykiss*)." The Pennsylvania Fish and Boat Commission. December 5, 2006. *http://www.fish.state.pa.us/images/fisheries/research/erietribs2004/000index.htm*

Nagy, John. 2003. Steelhead Guide 3rd Edition. Great Lakes Publishing, Pittsburgh, PA.

PA Sea Grant – Lake Erie Office. Sean Rafferty compiled GIS data provided from Erie County Department of Planning.

Paul, M.J. and J.L. Meyer. 2001. Streams in the Urban Landscape. *Annual Review of Ecology and Systematics* 32: 333-365.

Plafkin, J. L. and M. T. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. EPA/444/4-89-001. U.S. Environmental Protection Agency; Office of Water (WH-553); Washington, D.C.

Richards, D. B. and H. McCoy, J. T. Gallaher. 1987. *Water Resources Report 62 – Ground Water Resources of Erie County*. U.S. Geological Survey. Pennsylvania Department of Conservation and Natural Resources – Bureau of Topographic and Geologic Survey; Harrisburg, Pa.; ISBN 0-8182-0085-5.

Roy, A.H., A.D. Rosemond, M.J. Paul, D.S. Leigh, and J.B. Wallace. 2003. Stream Macroinvertebrate Response To Catchment Urbanisation (Georgia, U.S.A.). *Freshwater Biology* 48: 329-346.

Sevon, W.D. and G. Fleeger. 1999. *Educational series 6 - Pennsylvania and the Ice Age.* Pennsylvania Geological Survey; Fourth Series.

Steiner, L. 2000. Pennsylvania Fishes. Pennsylvania Fish and Boat Commission Publication.

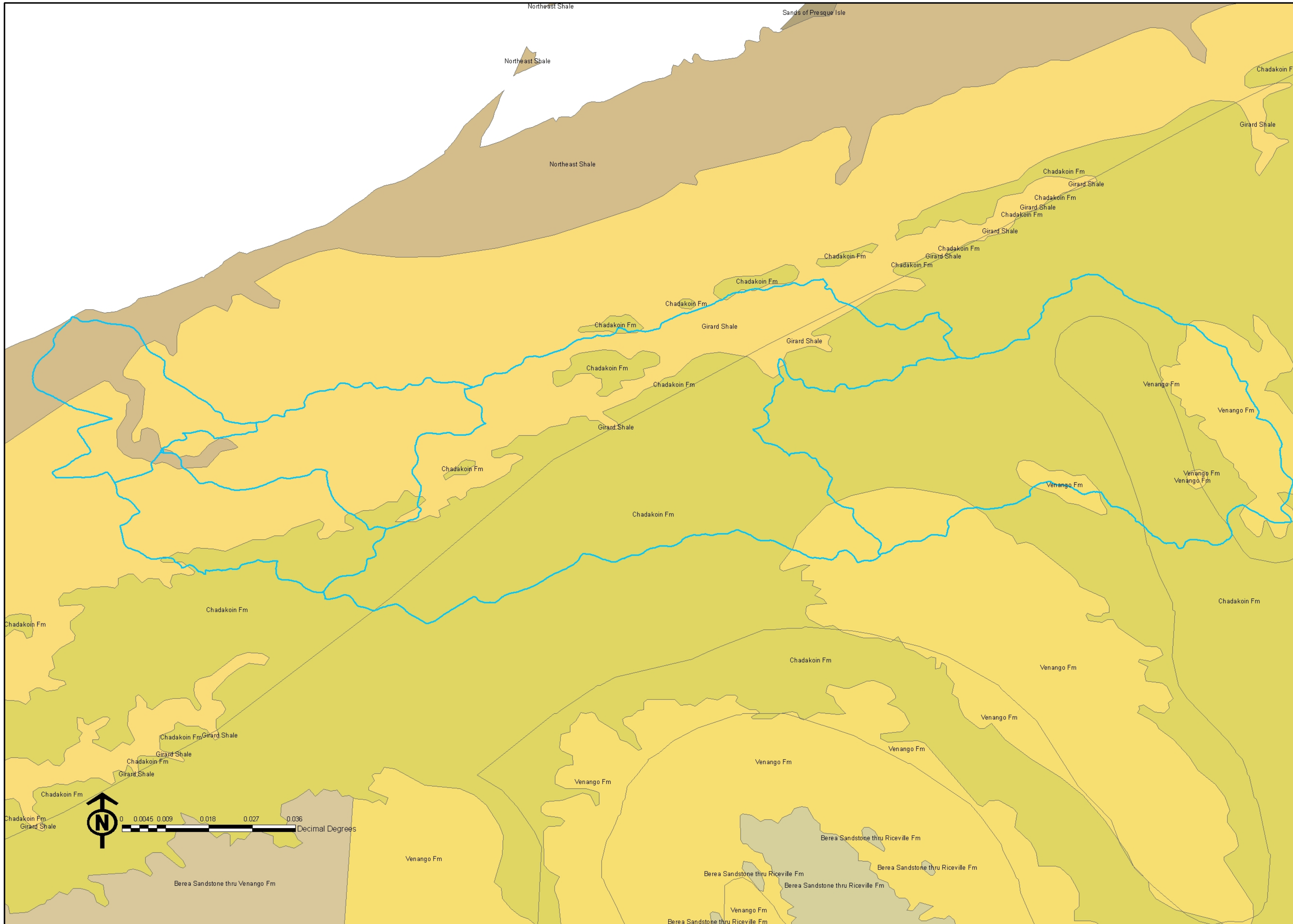
Stormwater Managers Resource Center (SMRC). The Impervious Cover Model (Table 1 review). February 7, 2007. <http://www.stormwatercenter.net/>.

Taylor, D. C. 1991. *Soil Survey of Erie County, 1957 Series.* U.S. Department of Agriculture, Pa. State University.

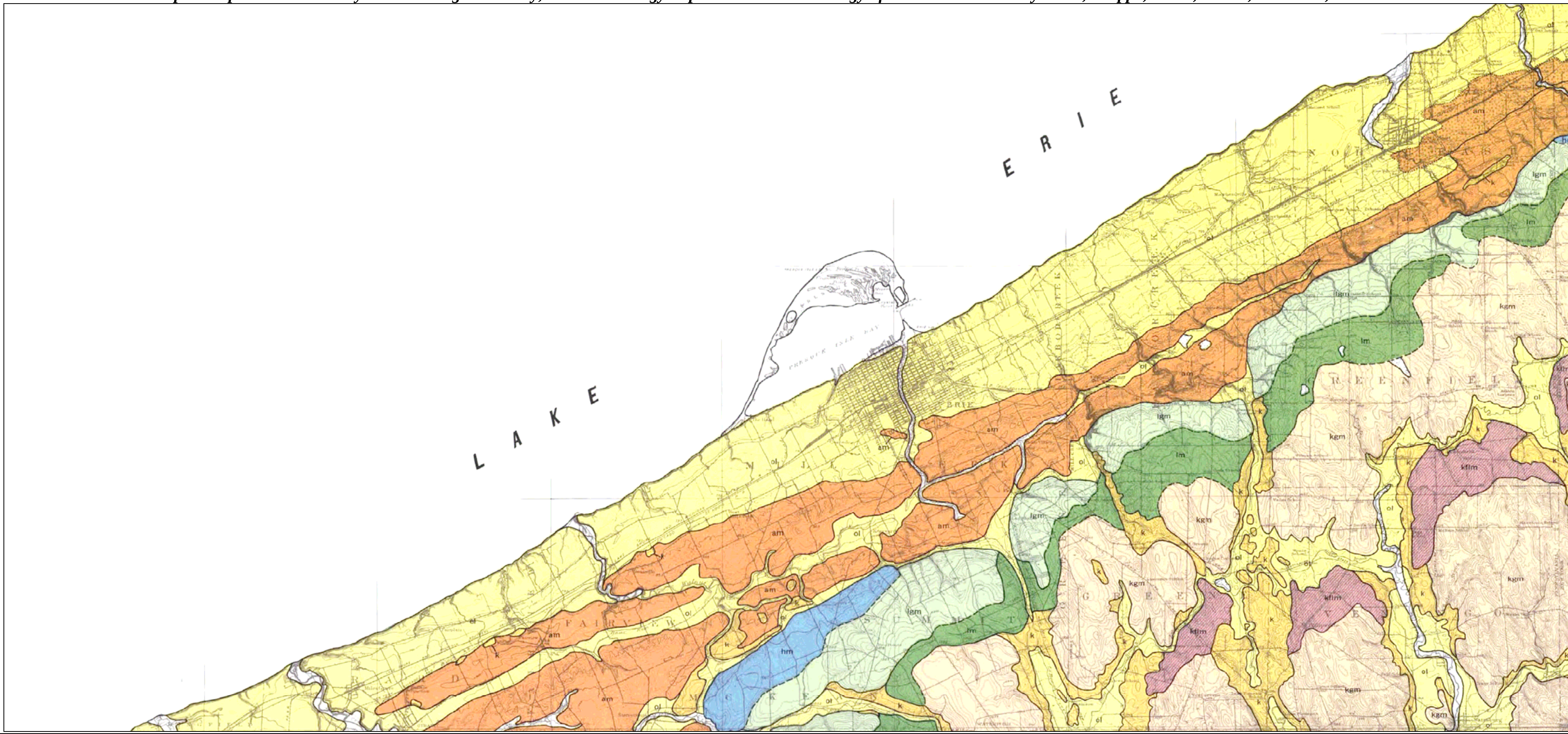
Trautman, M. B. 1981. The Fishes of Ohio, Revised Edition. Ohio State University Press.

Wahl, T. and Hirsch. 1995. *Circular 1123.* U.S. Geological Survey.

Surficial Bedrock Geology



Map Excerpted From: Pennsylvania Geological Survey, General Geology Report 32 - Glacial Geology of Northwestern Pennsylvania, Sheppa, White, Droste, and Sitler, 1959

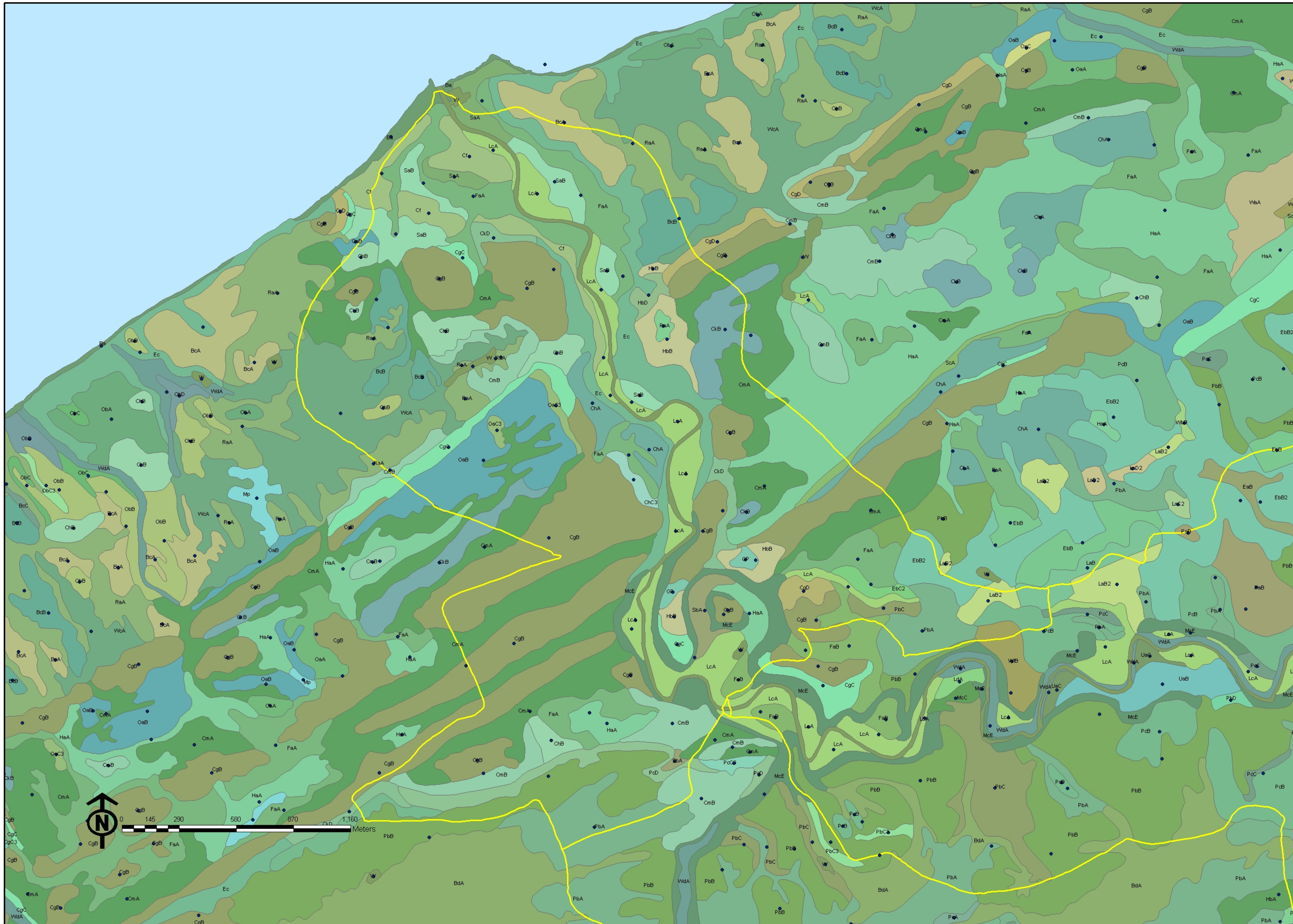


EXPLANATION

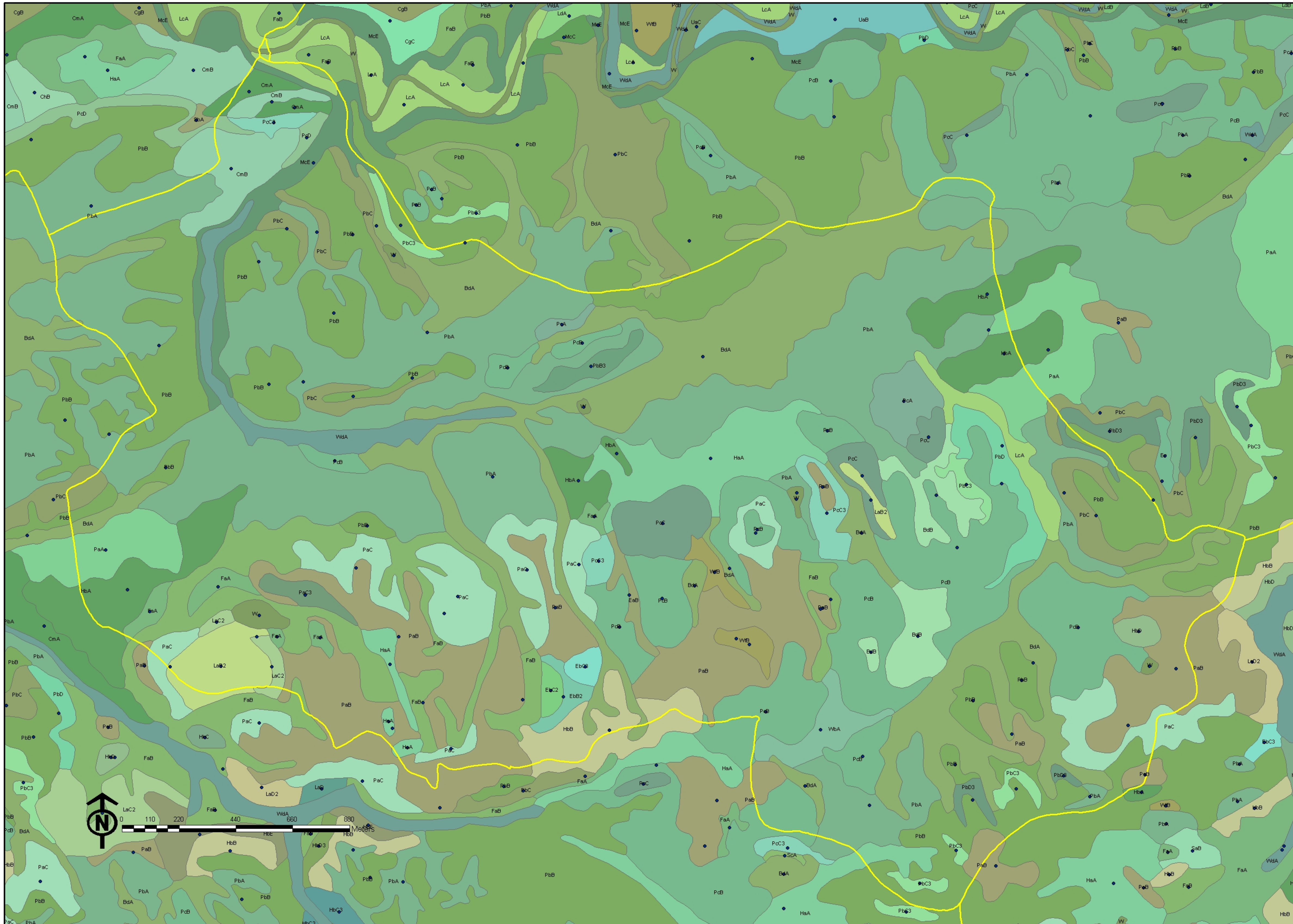
Epoch	Stage	Substage	Unit	Symbol	Topographic Features	Character of Material	Topography
PLEISTOCENE	WISCONSIN	CARY	Ashtabula Till	am	Ashtabula morainic system (end moraines)	Till (silt)	Strongly constructional; knob and kettle topography; numerous undrained depressions
				am	Ashtabula moraine under thin beach sands		
			Hiram Till	hm	Defiance end moraine	Till (silty clay to clay)	Undulating; locally constructional; scattered undrained depressions; very weak at places
				hgm	ground moraine	Till (silty clay)	Flat to gently undulating; local poorly drained areas
			Lavery Till	lm	Lavery end moraine	Till (silt)	Somewhat undulating; locally constructional; undrained areas rare
				lgm	ground moraine	Till (silt)	Level to gently undulating
			Kent Till	km	Kent end moraine	Till (sandy loam)	Strongly constructional; knob and kettle topography; numerous undrained depressions
				kflm	Findley Lake recessional moraine	Till (loam)	
				kcm	Clymer recessional moraine	Till (loam)	
				kgm	ground moraine	Till (loam becoming sandy loam toward the east and southeast)	Smooth to gently undulating; undrained areas very rare
	ILLINOIAN		Inner phase	il	ground (?) moraine	Thin, discontinuous, weathered till blanket	Erosional; similar to non-glaciated area, but less "rugged", rare slightly constructional patches
			Outer phase	io	ground moraine (?)	Rare patches of thin weathered till over bedrock; scattered erratics	Erosional; similar to non-glaciated area, but slightly less "rugged"
	ILLINOIAN OR WISCONSIN		Undifferentiated members of units above	k	kames, kame terraces, kame moraines, and eskers	Sand and gravel	Distinctly constructional except in Illinoian areas. Knobby; commonly in the form of ridges, terraces, or isolated mounds; kame moraines intimately mixed with end moraines
			Undifferentiated members of units above	ol	outwash (valley trains), river terraces, lake deposits including beaches of former high levels of Lake Erie	Bedded sand, silt, and clay; sand and gravel	Generally smooth to gently undulating; commonly nearly level or gently sloping downstream
RECENT OR PRE-PLEISTOCENE			Undifferentiated		stream alluvium and bedrock		

NOTE — The symbols above are normally prefixed by the letter "Q" for Quaternary. The letter has been omitted since all units having symbols are of Quaternary age.
Glaciofluvial deposits outside the glacial border are only partially mapped.

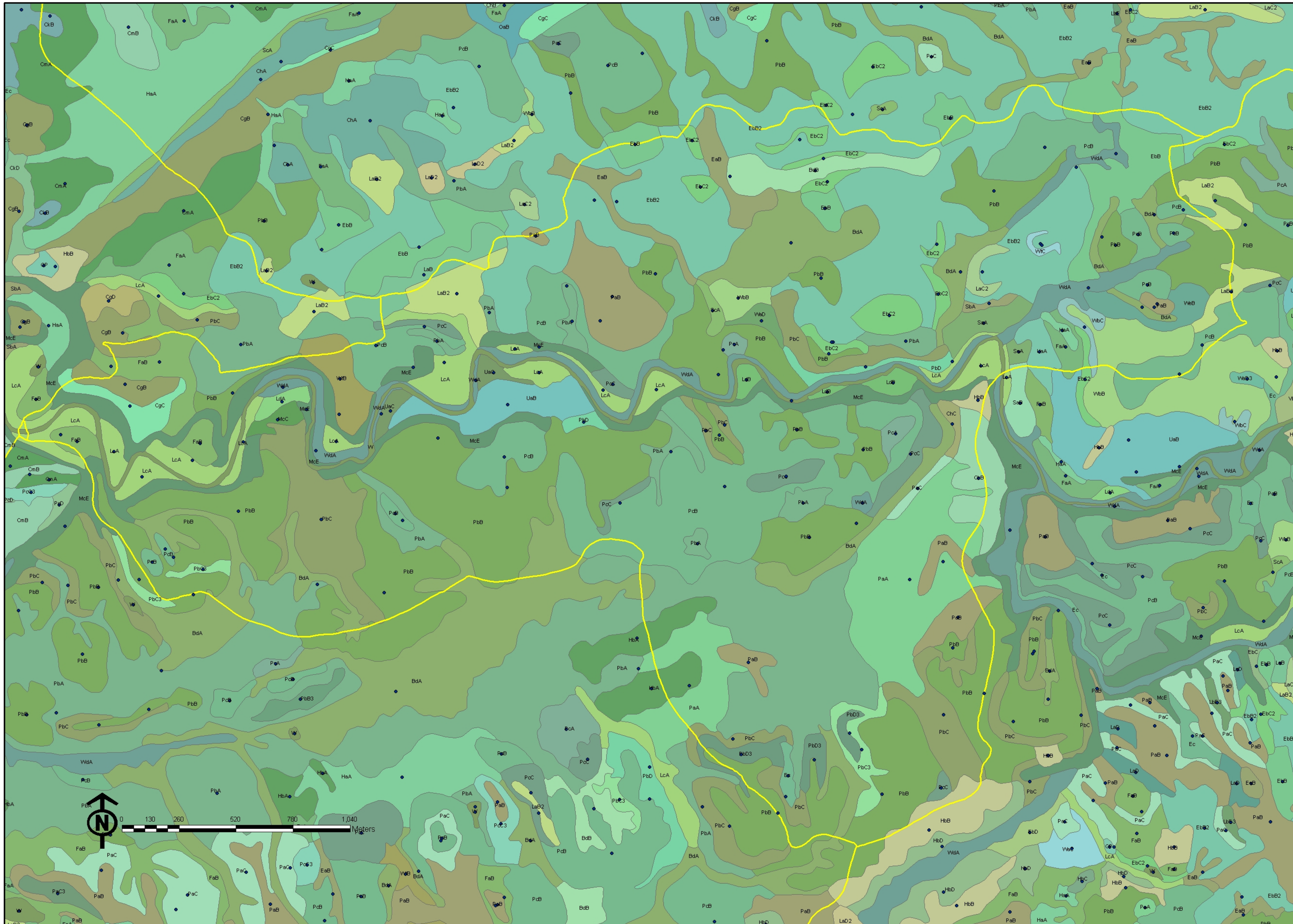
Sub-Watershed Soils Map 1



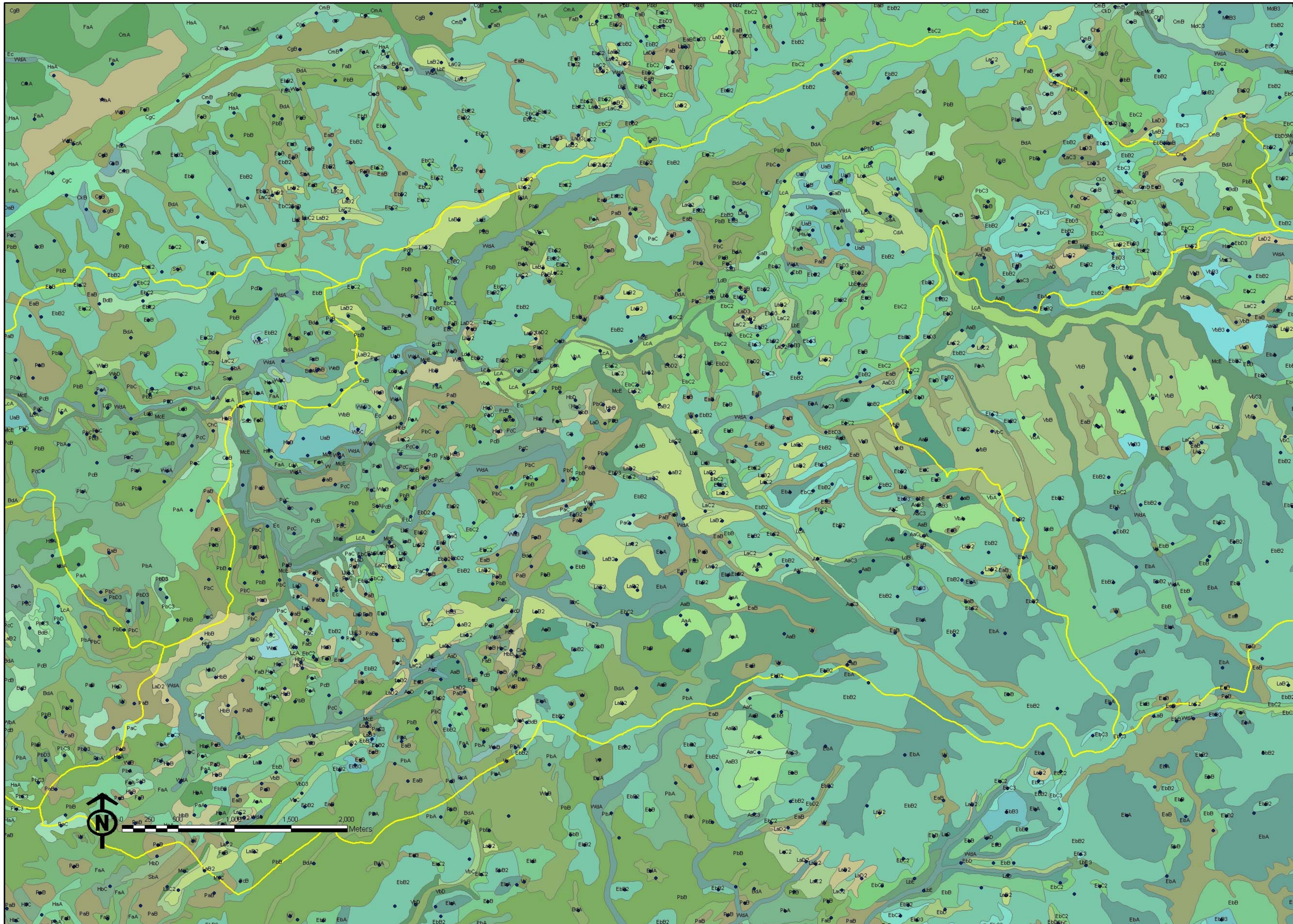
Sub-Watershed Soils Map 2



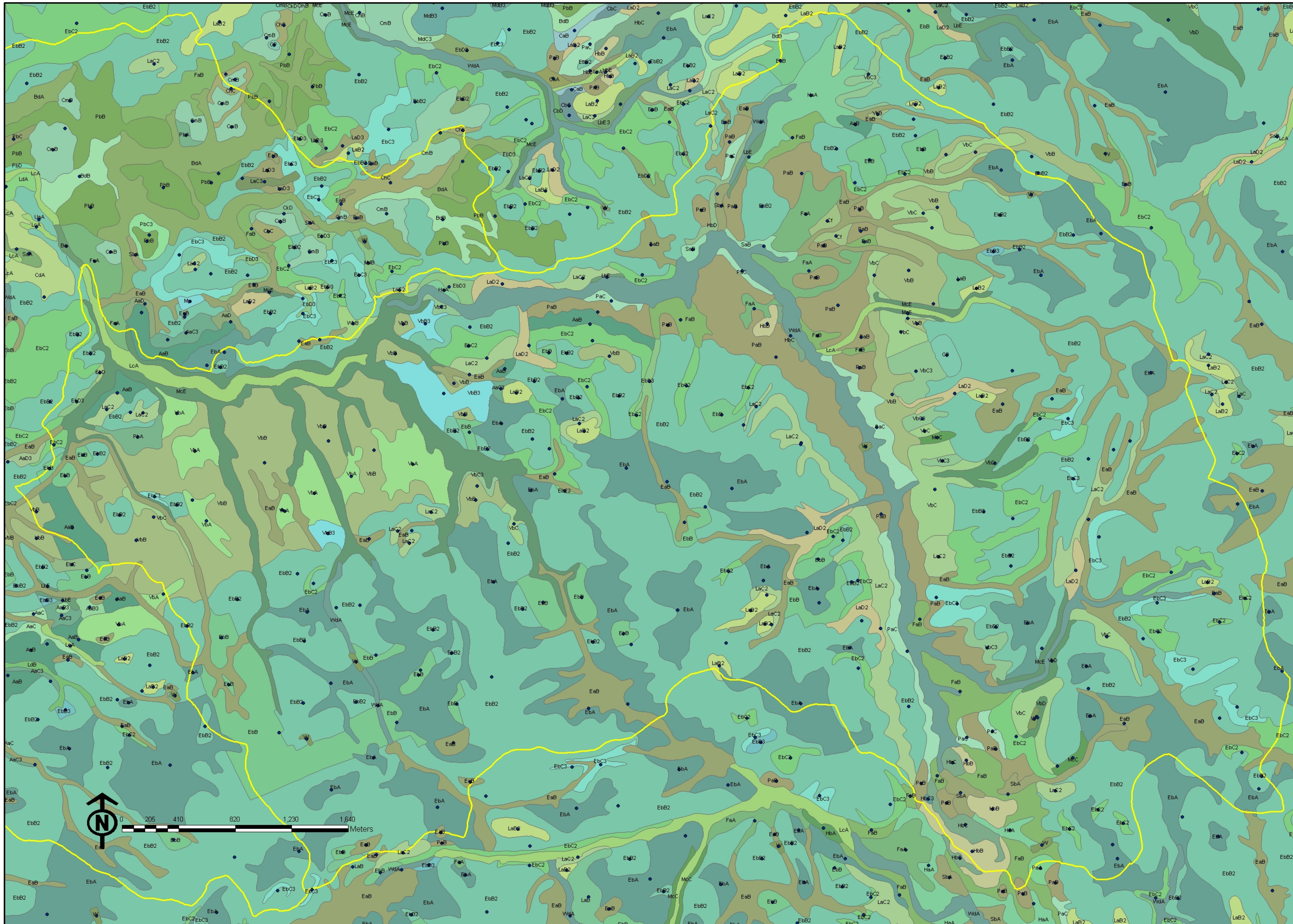
Sub-Watershed Soils Map 3



Sub-Watershed Soils Map 4



Sub-Watershed Soils Map 5



Water Resource Report 62

1987

GROUNDWATER RESOURCES OF ERIE COUNTY, PENNSYLVANIA

David B. Richards
H. Jack McCoy
John T. Gallaher
U.S. Geological Survey

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
OFFICE OF RESOURCES MANAGEMENT
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY
Donald M. Hoskins, State Geologist

PREPARED IN COOPERATION WITH
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CONTENTS

ILLUSTRATIONS

FIGURES

PLATES

(in envelope)

TABLES

GROUNDWATER RESOURCES OF ERIE COUNTY, PENNSYLVANIA

by
David B. Richards, H. Jack McCoy,
and John T. Gallaher

ABSTRACT

In Erie County, potable groundwater is available from unconsolidated glacial deposits and from fractured bedrock aquifers. The groundwater is generally of good chemical quality. Locally, however, groundwater ranges from moderately hard to very hard and is high in iron. Water from a few wells exceeds recommended drinking water limits of the U.S. Environmental Protection Agency for iron, chloride, and total dissolved solids. In bedrock wells, the high concentrations of chloride may be caused by connate water at shallow depths in the valleys and locally by brine disposal associated with petroleum exploration and production.

The best aquifers are glacial-outwash and glacial-beach deposits, based upon reported well yields and specific capacities. The outwash deposits are restricted to the major stream (buried) valleys of the central and southern parts of the county. The beach deposits are restricted to the vicinity of the Lake Erie shoreline. Nearly one fourth of all of the wells completed in outwash deposits have reported well yields of more than 20 gallons per minute. The largest reported well yield was 1,000 gallons per minute, from outwash deposits at Waterford. Wells completed in lacustrine and beach deposits are reported to yield as much as 500 to 800 gallons per minute.

The buried-valley deposits consist of stratified sand, gravel, silt, and clay. These deposits have saturated thicknesses commonly exceeding 100 feet and locally exceeding 400 feet, and are favorable locations for high-yield (400 to 500 gallons per minute) wells. The saturated parts of these deposits can be located, prior to the final well-site selection, by seismic-refraction and gravity surveys.

Glacial-till and bedrock aquifers are widespread in the county. However, the availability of groundwater from these units is significantly less than the availability of groundwater from the glacial-outwash and glacial-beach deposits. The till and bedrock aquifers locally do not provide sufficient groundwater for most domestic uses due to low permeability. The yields of bedrock wells vary according to geologic unit. The median yield for wells located in till and bedrock, for all types of topography, is about 5 gallons per minute. The range of yields for wells in glacial till and bedrock is from 0.1 to about 60 gallons per minute.

INTRODUCTION

PURPOSE AND SCOPE

From January 1975 through March 1980, hydrologic data were collected in Erie County, Pennsylvania, as part of a program to appraise the groundwater resources of the state. These data have been compiled and interpreted, and the results are presented in this report.

The purpose of the report is to provide water managers and planners with sufficient data to enable them to provide for the prudent use and protection of an invaluable natural resource. The report is also intended to supply homeowners with understandable facts and figures that will help them provide for their own water needs.

In this report, the authors describe the occurrence, availability, and quality of groundwater in Erie County, the geology, the water-bearing characteristics of aquifers, and the thickness of unconsolidated deposits. Data are included on the depths, yields, and quality of water from more than 1,700 wells.

DESCRIPTION OF THE STUDY AREA

Erie County covers 812 square miles in the northwesternmost corner of Pennsylvania (Figure 1). It is bordered on the west by Ohio, on the east by New York and Warren County, on the north by Lake Erie, and on the south by Crawford County. The city of Erie is the county seat, the industrial and cultural center of the area, and Pennsylvania's only freshwater port. About 47 percent of the land in the county is used for agriculture. Orchards and vineyards predominate in the north on the lake plain and escarpment slope. On the upland plateau in the south, cattle raising and agriculture are important activities.

TOPOGRAPHY AND DRAINAGE

There are three physiographic divisions in the county (Figure 1): the *lake plain* bordering Lake Erie, the *upland plateau* covering the southeastern two thirds of the area, and the *escarpment slope,* which separates the other two (Tomikel and Shepps, 1967). The lake plain begins at the lake level, approximately 572 feet above sea level, and extends inland to an altitude of about 800 feet. The plain is about 2 miles wide in the eastern part of the county and widens to about 5 miles in the west. The surface of the lake plain is flat to very gently sloping except where cut by streams or interrupted by glacial beach ridges. The upland plateau borders the escarpment slope and rises to an altitude of about 1,900 feet above sea level in the Corry area. The surface is generally smooth and rolling except where cut by broad valleys that have relatively steep walls and flat bottoms. In the Edinboro-Waterford area, much of the land surface consists of long, parallel ridges separated by intervening valleys, which are oriented about N35°W.

Topographic relief differs widely within the county. In the western part, the difference in altitude between the high and low points is on the order of 100 feet or less. The difference increases to the east and southeast, reaching a maximum of about 600 feet in the Corry area.

Two separate drainage systems transport water from the area (Figure 1). North-flowing streams empty into Lake Erie, which is part of the St. Lawrence River drainage system. With the exception of Conneaut Creek, these streams have steep gradients, and flow on, or have cut deeply into, bedrock. The south-flowing streams are part of the French Creek-Allegheny River drainage system. They are much slower moving and flow on the glacial sediments that fill broad valleys.

Also shown in Figure 1 are the stream-gaging stations in the county. Some low-flow data associated with these stations are listed in Table 1. During periods of little or no precipitation, streamflow is maintained by groundwater discharge from the aquifers (base flow). In areas of relatively impermeable bedrock and till, the base flow is very small or zero. In areas of permeable materials, base flow may be sufficient for municipal and industrial supplies, and for maintenance of conditions necessary for aquatic life. The stream characteristic commonly used in planning for low-flow utilization is the 7-day, 10-year low flow, which is defined as the lowest average rate of flow for 7 consecutive days that is likely to occur in 10 years. The maximum 7-day, 10-year low flow per square mile from Table 1 is 0.09 ft^3/s (cubic foot per second).

POPULATION AND WATER USE

The population of Erie County in 1980 was 279,780 (U.S. Department of Commerce, 1980). More than half of the people live in the Erie metropolitan area and use water pumped from Lake Erie. The remainder use groundwater, ex-

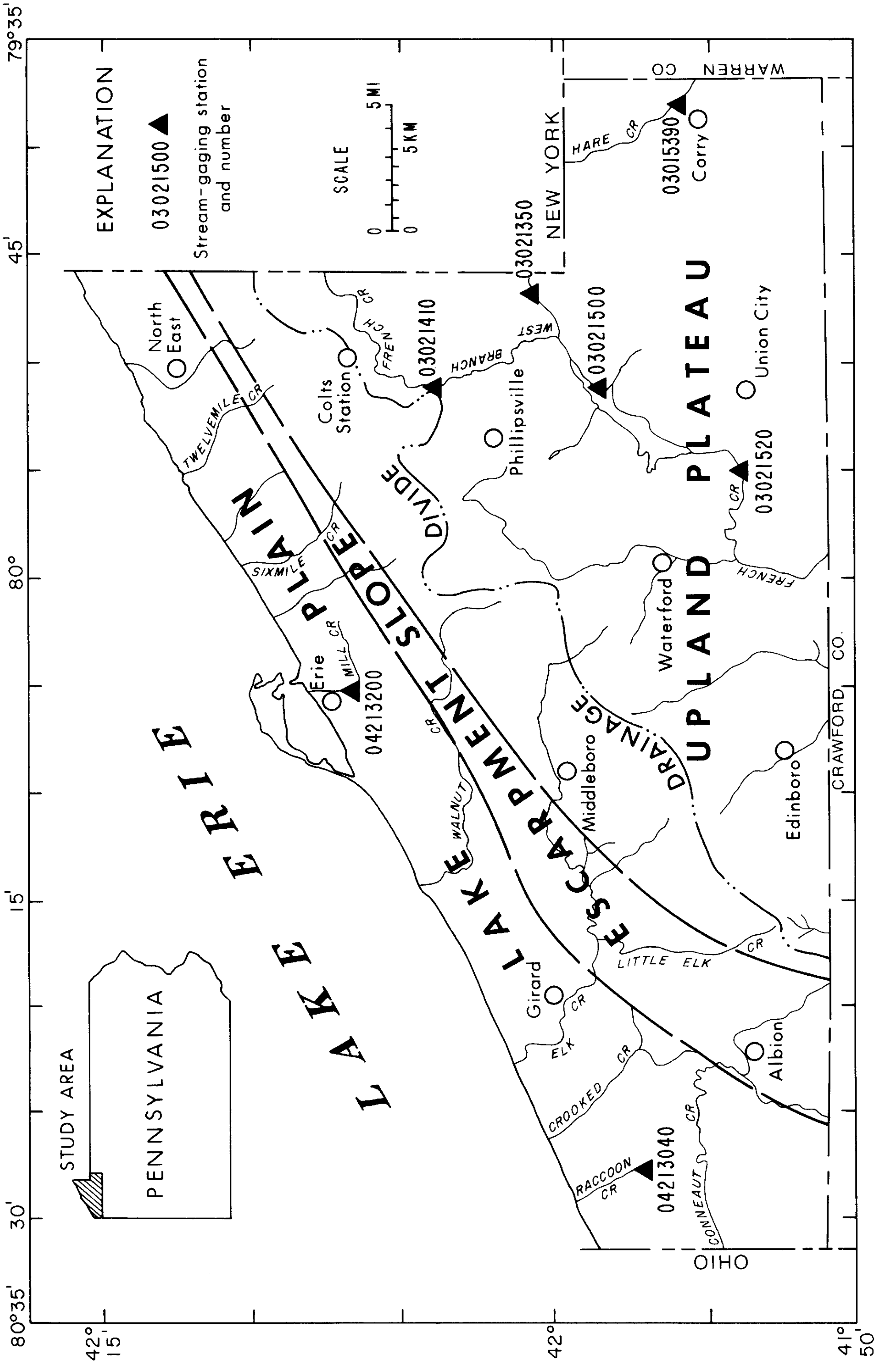

Figure 1. Location, physiographic divisions, principal streams, and stream-gaging stations of the study area.

Table 1. *Summary of Streamflow Data from Seven Gaging Stations*

Surface-water gaging station number and name/location		Drainage area (mi^2)	Length of record	7-day, 10-year low flow (ft^3/s) and	[$(ft^3/s)/mi^2$]	Remarks
03015390	Hare Creek near Corry	12.3	1964–80	[1]0.7	0.06	Partial record station
03021350	French Creek near Wattsburg	92	1974 to current year	[2]4	.04	Minimum flow for period of record = 6.0 ft^3/s
03021410	West Branch French Creek near Lowville	52.3	1974 to current year	1 estimated	.02	Minimum flow for period of record = 3.2 ft^3/s
03021500	French Creek at Carters Corners	208	1910–71	9.6	.05	Minimum low flow for 62 years of record = 3.9 ft^3/s
03021520	French Creek near Union City	221	1909 to current year	NA[3]	NA	Regulated flow since 1971
04213040	Raccoon Creek near West Springfield	2.53	1962–68 1968 to current year	NA	NA	No flow on many days
04213200	Mill Creek at Erie	9.16	1964–80	[1].8	.09	Partial record station

[1]From Page and Shaw (1977).
[2]Calculated from Flippo (1982, Table 11, p. 18).
[3]NA, not applicable.

cept in the boroughs of North East and Union City, where reservoirs are used. Seventeen municipalities and water companies pump an average daily total of about 4 Mgal/d (million gallons per day), mostly from glacial-outwash and glacial-beach deposits. Approximately 57,000 people obtain their water supplies from domestic wells. The estimated consumption rate is about 90 gallons per day per person, which totals more than 5 Mgal/d (Table 2).

Water supplied for cattle and for irrigation is not shown in Table 2 because these data were not available. The dairy industry uses an estimated 1 Mgal/d for watering, milk processing, and sanitary purposes. The total irrigated land area ranges from 400 to 600 acres, depending upon climatological conditions. Irrigation water use ranges from about 50 million to 200 million gallons per year.

PREVIOUS STUDIES

The groundwater resources of Erie County were described by Leggette (1936) and Mangan and others (1952). The geology and hydrology of western Crawford County, bordering much of Erie County on the south, were discussed by Schiner and Gallaher (1979). Poth (1962) described the occurrence of saline waters (brines) in western Pennsylvania. White (1881), Leggette (1936), and Tomikel and Shepps (1967) presented information on the bedrock, glacial deposits, and groundwater in the area. The stratigraphy of the Lower Mississippian rocks was described by de Witt (1946, 1951), Pepper and others (1954), and Schiner and Kimmel (1972). The glacial geology of Erie County was presented by Leverett (1902), Shepps and others (1959), and White and others (1969).

Table 2. *Water Use in Erie County*

(From Pennsylvania Department of Environmental Resources, Office of Resources Management, Bureau of Resources Planning, written communication, 1980)

Water supplier	Total gallons per capita used per day in 1970	Total use in 1970 (Mgal/d)	Water source
	Surface water		
City of Erie, Bureau of Water	262	44.44	Lake Erie
North East Borough Water Department	380	1.799	3 reservoirs; 1 spring
Union City Borough	146	.539	Reservoir
	Ground water		
Albion Borough	69	.182	3 wells; 3 springs
Corry Water Supply Co.	162	1.229	21 wells
Borough of Edinboro Water Department	94	.458	3 wells
Fairview Borough	57	.097	3 wells
Girard Borough	67	.174	3 wells
Lake City Borough	139	.264	3 wells
Lake Shore Maintenance Association	77	.057	2 wells
Palmer Shores	45	.006	1 well
Pennsylvania Water Co. (Erie Suburban Water Co.)	87	.614	17 wells
Ridgeville Water Co.	66	.021	3 wells
Waterford Borough	73	.110	1 well

ACKNOWLEDGEMENTS

The following water-well contractors contributed valuable data on water wells: Alfred Burch, Michael Burch, Max Hickernell, and Moody Drilling Company, Inc. Further acknowledgement is given to other drillers who also submitted clear, accurate well records.

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For information on the application of gravity technique to the indirect definition of buried alluvial channels in the county, the authors acknowledge John A. Rhodes, graduate student at Pennsylvania State University, Department of Geosciences, and Dr. Peter M. Lavin (his advisor), and Mark Anthony Ruof, student at Allegheny College, Department of Geology, and Dr. Walter F. Ebaugh (his advisor).

GROUNDWATER SYSTEM

OCCURRENCE AND MOVEMENT

The source of potable groundwater supplies in Erie County is precipitation that infiltrates from the land surface. Most of the water of precipitation either flows overland to streams or is returned to the atmosphere by evaporation or transpiration. The remainder moves downward through the soil and rock until it reaches the zone of saturation, within which all pores and fractures are filled with water. The water within this zone of saturation is called groundwater.

Groundwater moves downward and laterally through the soil and rock by gravity, traveling slowly from the areas of intake, at topographic highs, to areas of discharge at lower altitudes. The direction of flow is controlled by the composition and structure of the subsurface materials, but generally is in the direction of the slope of the topography. Groundwater discharges in places as seeps, swamps, and springs along stream valleys and maintains minimal streamflows (base flow) during periods of drought. This groundwater, en route to discharge areas, is available for use when intercepted and tapped by water wells.

The movement of water in unconsolidated materials, such as sand and gravel, is through intergranular openings (primary openings); in bedrock, the movement is mainly through interconnected fractures (secondary openings). The capability of these geologic units to transmit water is referred to as permeability or hydraulic conductivity. Saturated permeable geologic units that yield significant quantities of water to wells and springs are called aquifers (Lohman, 1972, p. 2). In Erie County, the aquifers consist of unconsolidated glacial and alluvial deposits overlying sedimentary bedrock—mainly sandstones, siltstones, and shales of Devonian and Mississippian ages. Groundwater availability is highly variable in both the unconsolidated deposits and the bedrock. Water is stored in and transmitted through the primary and secondary openings. The distribution, interconnection, and number of these openings have a direct relationship to the yields of the wells penetrating the aquifers. Groundwater may occur under either water-table (unconfined) or artesian (confined under pressure) conditions, as shown in Figure 2. Under water-table conditions, the water surface is at atmospheric pressure, and the water level rises in response to recharge and falls in response to discharge. To a lesser extent, the water level also fluctuates in response to changes in barometric pressure. The water level in a well in an unconfined aquifer is at the top of the zone of saturation and is referred to as the water table. The areal configuration of the water table generally parallels the land surface. Water-table conditions are present in the unconsolidated deposits and in the bedrock units of the upland plateau.

Artesian conditions are a common groundwater occurrence in the county. Under artesian conditions, the water-bearing unit is overlain and underlain by relatively impermeable beds, such as the sandstone between the shales shown in Figure 2; thus, the aquifer is confined. The water level in a well in a confined aquifer rises to the level of hydrostatic pressure in the aquifer, which is above the top of the aquifer. Flowing wells, which represent a special type of artesian well, are also common. These occur when the level of hydrostatic pressure is higher than the land surface (Figure 2). The areal configuration of the water surface for artesian aquifers is known as the potentiometric surface. Within wells tapping artesian aquifers, the water levels fluctuate in

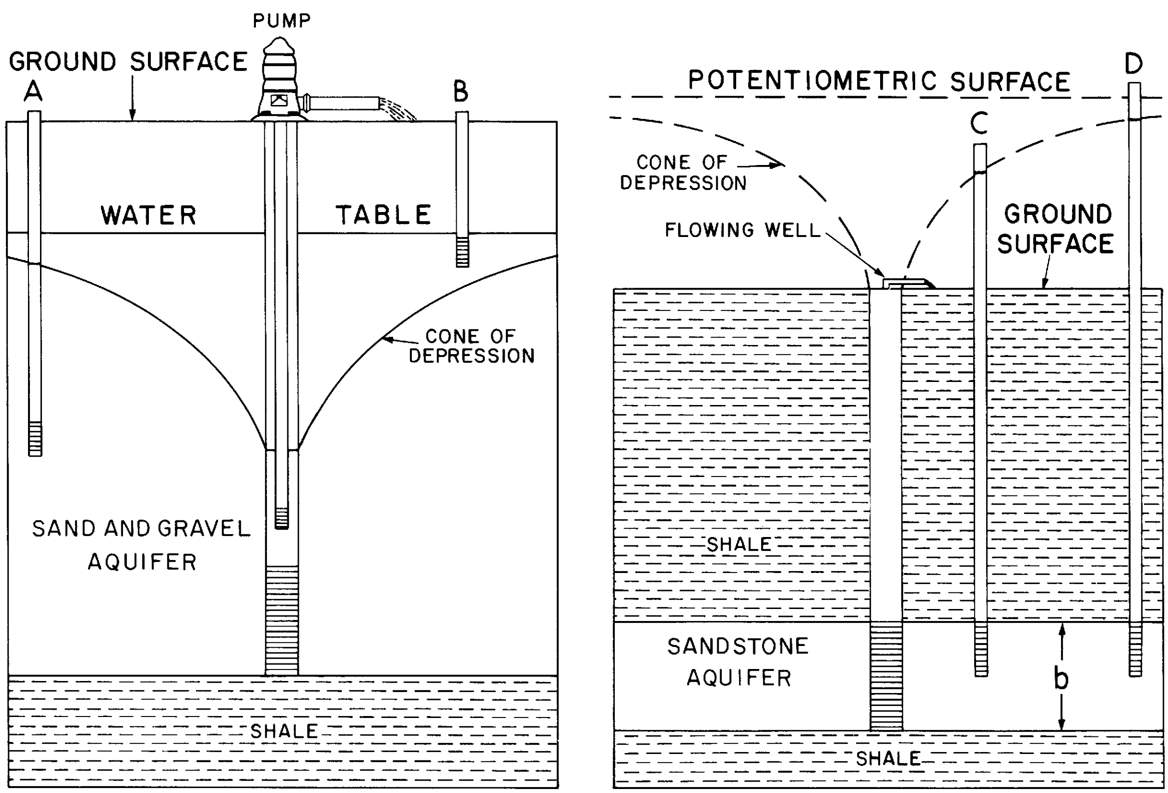


Figure 2. The effect of discharging wells in an unconfined aquifer (left) and a confined aquifer (right) (modified from Lohman, 1972, Figure 8, p. 8). The water level in the deep well A has declined due to the pumping well. The shallow well B is dry due to the pumping well. The hydrostatic pressure in well C has declined more than in well D due to the proximity of the flowing well. (The "b" represents the thickness of the confined aquifer.)

response to changes in barometric pressure. Artesian conditions are present in the unconsolidated deposits and in the interbedded sandstones and shales of the bedrock units in the county.

WATER LEVELS

Water levels in wells rise and fall according to the relative amounts of recharge (additions to the aquifer) and discharge (losses to springs, streams, and wells). Water levels are generally highest (shallowest) in March and April, and are generally lowest (deepest) in September and October. During the summer months, little infiltrated precipitation recharges the saturated zone due to the high rate of plant water use (evapotranspiration). However, patterns of water-level fluctuations can vary from the normal due to winter thaws, prolonged droughts, and sustained rainfall.

The water levels of wells shown in Tables 3 and 12 were reported by well drillers at the time of completion of the wells. In general, water levels fluctuate less in wells tapping unconfined aquifers than in wells tapping confined aquifers because the unconfined aquifers have a greater capacity to store water. Water levels in both types of aquifers fluctuate less in the discharge areas (valley bottoms and lake plain) than in the recharge areas (uplands).

The summary of well data (Table 3) indicates that the median water levels in wells tapping the different aquifers are quite similar in magnitude. However, water levels in wells in each aquifer range from near or above land surface (flowing) to depths of several tens of feet. The variables that cause this range in water levels include topography, well depths, the number of water-bearing zones penetrated, the depth of hole cased, well construction, the degree of fracturing, the presence of artesian conditions, and the seasonal water-level conditions at the time of drilling. In most instances, the complexity of the hydrologic conditions created by combinations of these variables makes it difficult to predict the water level at any given well site.

Most of the wells tap groundwater that exhibits artesian tendencies to a small degree; therefore, water levels in the wells commonly rise above the water-bearing zones. Water levels commonly are (1) deepest in wells drilled in hilltops, (2) shallowest in wells drilled in and near valley bottoms and on the lake plain, and (3) intermediate in wells drilled in other topographic sites.

Water levels in wells tapping unconfined aquifers are affected by local precipitation, whereas water levels in wells tapping artesian aquifers may respond to both local and regional precipitation or to only regional precipitation.

The average precipitation in Erie County ranges from 38 inches (at Erie) to 46 inches (at Corry). Long-term data from the Union City Filtration Plant precipitation station (U.S. Department of Commerce, 1950–82) indicate an average annual precipitation of 43.45 inches. The precipitation is fairly evenly distributed throughout the year.

In well Er–82, which is located north of Edinboro and is part of the statewide observation-well network, the artesian water conditions of the fractured shale of the Venango Formation have been monitored continuously since July 1966. The hydrograph record of this well is shown in Figure 3. The monthly precipitation of the Union City station is also synchronously plotted with the water levels of well Er–82. The deepest water levels generally coincide with periods of below normal precipitation, such as in 1968 and 1978. Conversely, the shallowest water levels coincide with periods of above normal precipitation, such as in 1969–70, 1972, and 1977.

More detailed information on basic hydrologic and geologic relationships is given in *Ground Water in Pennsylvania* by Becher (1970), *A Primer on Ground Water,* by Baldwin and McGuinness (1963), and *Ground Water Manual,* by U.S. Department of the Interior (1981).

AVAILABILITY

The availability of groundwater resources is determined by means of collection and analysis of hydrologic data. These data are both collected in the field and compiled from records of well drillers, well owners, consulting firms, and state, federal, and other government agencies. Other sources of information include water-, gas-, and

Table 3. *Summary of Well Data*

Geologic unit	Well depth (feet)			Reported yield (gal/min)			Specific capacity [(gal/min)/ft]			Water level (feet below land surface)		
	Number of wells	Median	Range	Number of wells	Median	Range	Number of wells	Median	Range	Number of wells	Median	Range
Domestic wells												
Sands of Presque Isle	1	26	—	1	30	—	1	—	—	1	3	—
Glacial-beach deposits	93	35	9–105	59	7	0.1–30	24	0.8	0.05–10	62	12	1–71
Glacial-outwash deposits	441	62	15–402	395	15	.1–360	170	1.2	.04–30	370	20	[1]F–150
Glacial-till deposits	282	55	17–220	252	5	.1–50	125	.26	.009–30	237	15	F–87
Total for glacial drift	816	56	9–402	696	10	.1–360	319	.7	.009–30	669	18	F–150
Cuyahoga Group	9	69	38–102	8	13.5	5–62	7	.5	.18–62	9	12	1–30
Berea Sandstone through Riceville Formation	28	71	40–130	27	15	2–40	20	.52	.12–10	27	22	1–78
Corry Sandstone through Riceville Formation	25	72	35–150	24	15	2–50	15	.75	.02–20	23	20	6–52
Berea Sandstone through Venango Formation	80	52	31–112	72	7	.1–46	42	.21	.02–20	72	8	1–20
Venango Formation	170	65	36–250	166	8	.5–50	71	.2	.01–30	151	10	F–95
Chadakoin Formation	311	60	33–160	283	4	.1–50	115	.14	.01–45	268	10	1–90
Girard Shale	41	60	30–140	33	2	.1–50	10	.06	.01–4	29	15	5–78
Northeast Shale	53	40	12–250	21	4	.1–25	7	.36	.006–25	23	12	1–60
Total for bedrock	717	60	12–250	634	5	.1–62	287	.2	.006–62	602	15	F–95
Nondomestic wells												
Glacial-beach deposits	55	32	10–96	47	75	1–850	20	17	.03–270	31	8	F–38
Glacial-outwash deposits	50	59	13–405	39	60	1–1,000	20	9	.1–140	40	11	F–78
Glacial-till deposits	13	60	33–195	8	11.5	.1–50	3	1.5	.47–3.3	9	8	0–56
Total for glacial drift, combined	118	45	10–405	94	56.5	.1–1,000	43	10	.03–270	80	8	F–78
Total for bedrock, combined	25	63	26–185	18	6	1–55	6	.17	.02–.4	22	11	F–73

[1]F, flowing.

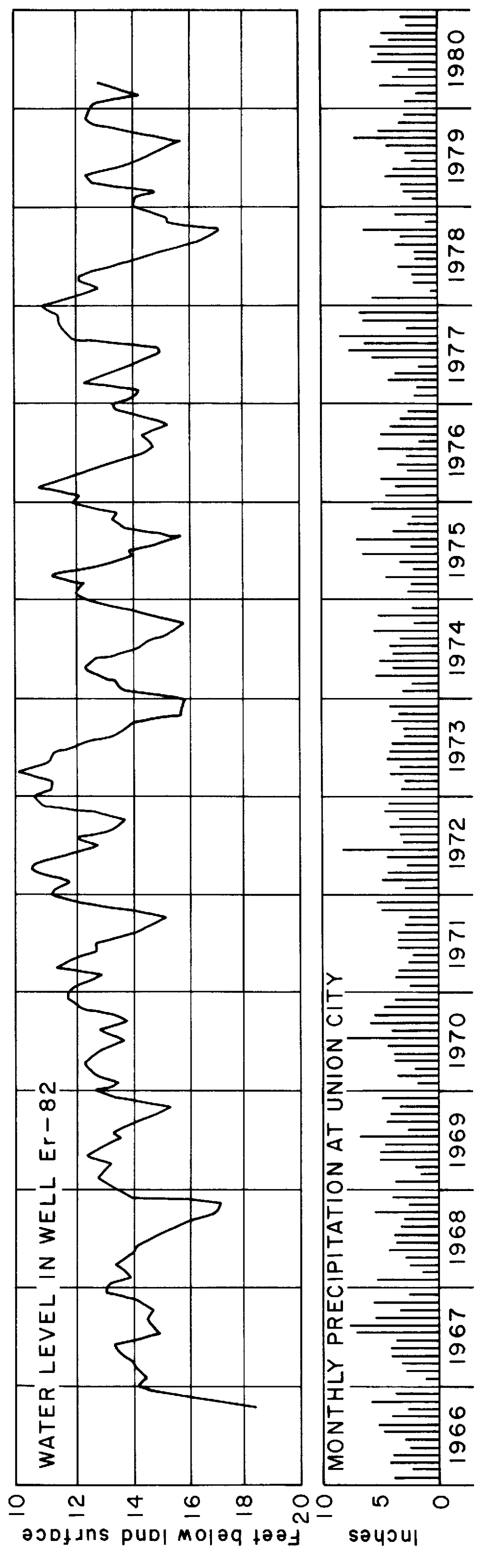


Figure 3. The water level in well Er-82 and the monthly precipitation at Union City, 1966–80.

oil-well records, test wells, highway borings, rock outcrops, and geophysical surveys.

Hydrologic data collected from inventoried wells include static water level below land surface, well depth, depth to water-bearing zones, aquifer definition, well yield, specific capacity, characteristics of well construction (casing and perforations), and chemical quality. Water-well data for more than 1,700 inventoried wells are tabulated in Table 12. The summarization and analysis of selected data from wells, tabulated by geologic unit, are shown in Table 3. The selected data include well depth, reported yield, specific capacity, and water level. Well locations are shown on Plates 1 and 2.

Well Yield and Specific Capacity

The amount of water available to a well is commonly expressed as the well yield in gallons per minute (gal/min). The yield data given in Tables 3 and 12 are from information provided by well drillers. These yield values are from short-term pumping periods, generally minutes and not hours. Long-term well yields (weeks and months) are significantly lower.

A more reliable index of water availability is specific capacity, which is the well yield divided by the drawdown of water level (in feet) within the well during pumping. Drawdown is the drop in water level from the static level to the pumping level. In poor aquifers, specific capacity decreases with increased pumping rates and time. A well pumped at 10 gal/min, with 5 feet of drawdown (specific capacity = 2 (gal/min)/ft [gallons per minute per foot]) will not necessarily discharge 20 gal/min with 10 feet of drawdown. Ideally, the yield and specific capacity are based on pumping or bailing rates, which lower the water in the well to a level at which the water level is stabilized. That is, the rate of withdrawal equals the flow of water from the aquifer into the borehole. In many instances, especially in wells of low to moderate yield, the rate of withdrawal during the drillers' tests exceeds the rate of flow into the well, and equilibrium is not established. Therefore, the specific-capacity values shown should be considered as maximum and valid only for short-term pumpage.

Water-Bearing Properties

Wells sited in glacial unconsolidated deposits have higher reported yields and specific capacities than wells sited in bedrock units, as indicated in Table 3. The thickness distribution of these unconsolidated deposits is presented on Plate 2. The areas of greatest saturated thickness have the best potential for groundwater availability. However, in the area of the lake plain and escarpment slope, salty water commonly occurs at shallow depths (see Table 8).

The well yields and specific capacities depend upon the ease of movement of water through the subsurface materials, and upon the amount of water the materials can release from storage. The ability of soil and rock material to transmit water is known as hydraulic conductivity (K) and is related to the size, amount, and degree of interconnection of openings in the material. The product of hydraulic conductivity (K) and the saturated thickness (b) is called transmissivity (T); that is, $T = K \cdot b$. The larger the value of transmissivity, the greater the availability of groundwater for supply. For example, a large thickness of saturated sand and gravel is an excellent well site. The volume of water released from storage in subsurface materials is called storage coefficient (S) for confined aquifers and specific yield for unconfined aquifers and is related to the amount of water-filled openings for a given volume of saturated material. Specific yield may range from 0.02 for clay to 0.22 for coarse gravel (Johnson, 1967, p. D70).

Long-term well yield and the effect of pumpage on the aquifer system can be determined by knowing the water-bearing properties K, T, and S. Figure 4 shows the range in values of hydraulic conductivity for both rock material and unconsolidated deposits. Table 4 also shows the average hydraulic conductivities for materials of various grain sizes in unconsolidated deposits. For example, the hydraulic conductivity for sand and gravel ranges from about 100 to 10,000 ft/d (feet per day), and about 1×10^{-8} to 1×10^{-3} ft/d for shale.

The hydraulic properties of unconfined and confined aquifers are determined by aquifer tests. These tests are controlled field experiments

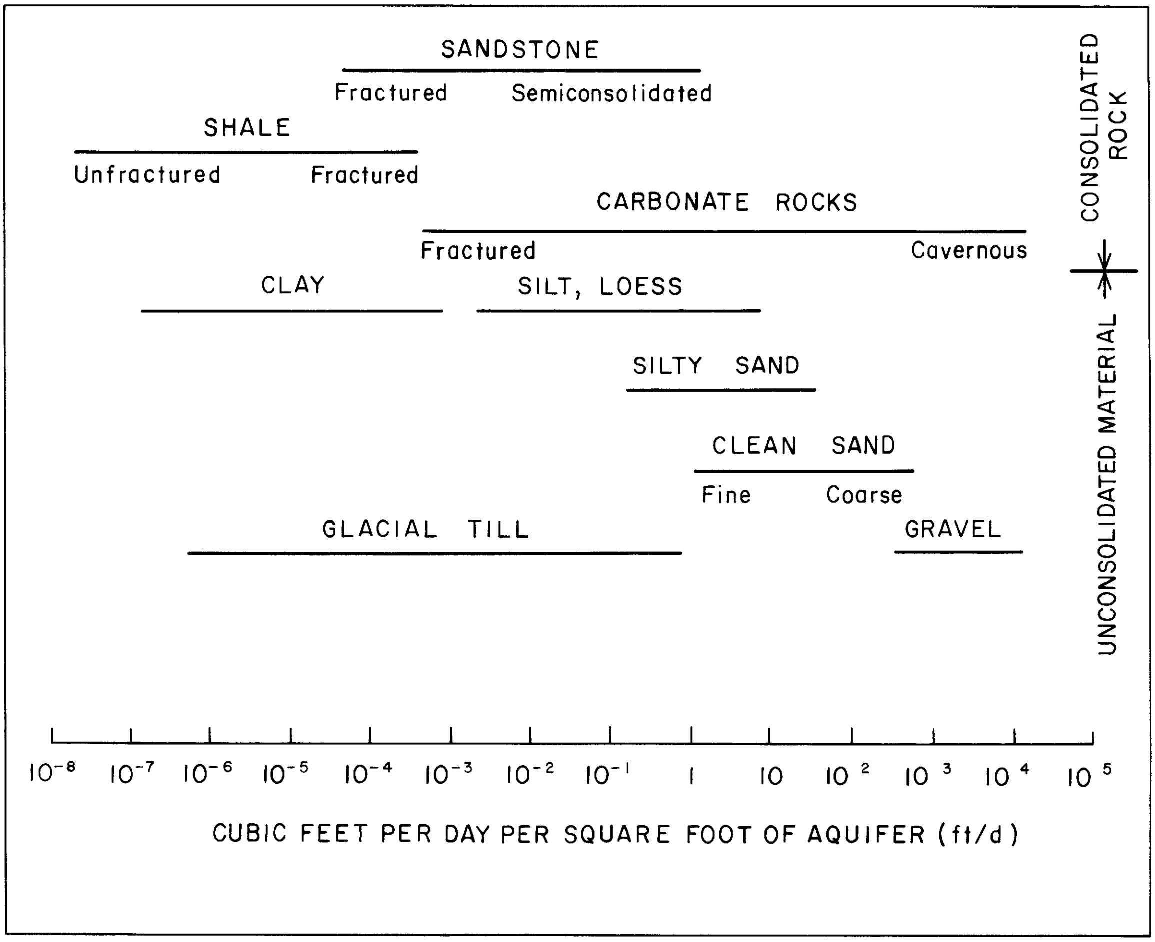


Figure 4. Range of hydraulic-conductivity values for selected geologic materials (modified from Heath, 1983, p. 13).

in which a known quantity of water is withdrawn from (or recharged to) an aquifer by means of a well. Aquifer tests are not discussed in this report. More detailed information on aquifer testing can be found in *Ground-Water Hydraulics* by Lohman (1972), *Applied Hydrogeology* by Fetter (1980), *Theory of Aquifer Tests* by Ferris and others (1962), *Ground Water Manual* by U.S. Department of the Interior (1981), and *Groundwater and Wells* by Driscoll (1986).

An aquifer test was made in Summit Township in the saturated fractured shale of the Venango Formation. Details of the test are included in Appendix 1. The calculated hydraulic properties were 1,100 (gal/d)/ft (gallons per day per foot) for K, 147 ft^2/d for T, and 6 x 10^{-4} for S.

The greatest potential for groundwater resource development in Erie County is from the saturated, highly permeable unconsolidated deposits. Field aquifer testing is the most accurate and reliable, as well as the most expensive and time consuming, means of determining hydraulic properties. Table 4 and Figure 4, however, can provide some assistance in evaluating and comparing the water-supply potentials of various

Table 4. *Hydraulic Conductivities for Estimating Transmissivity for Unconfined Alluvial Aquifers*

(From Lohman, 1972, Table 17, p. 53)

Material	Hydraulic conductivity (ft/d)
GRAVEL	
Coarse	1,000
Medium	950
Fine	900
SAND	
Gravel to very coarse	800
Very coarse	700
Very coarse to coarse	500
Coarse	250
Coarse to medium	100
Medium	50
Medium to fine	30
Fine	15
Fine to very fine	5
Very fine	3
CLAY	1

aquifer sites. Inasmuch as $T = K{\cdot}b$, the T at a potential well site is the sum of the $K{\cdot}b$ values for all of the layers, or

$$T = K_1{\cdot}b_1 + K_2{\cdot}b_2 + \ldots + K_n{\cdot}b_n.$$

Thus, the transmissivity of soil and rock material recorded on drillers' logs or on geologic sections can be estimated by use of this equation. An application of this method is applied to the driller's log of well Er–808, as illustrated in Table 5. At this site, the transmissivity of the glacial-outwash aquifer is estimated to be 7,000 ft^2/d.

Fracture Traces

In bedrock terrain, groundwater availability (well yield) is generally greatest along fracture traces (Siddiqui and Parizek, 1971). Fracture traces are natural linear features on the land surface that appear as topographic, vegetal, or soil-tonal alignments visible on aerial photographs.

Table 5. *Transmissivity Estimation for the Driller's Log of Well Er–808*

(Reported water level was at 3 feet below land surface; however, the reported water-bearing zones were 12 to 16 feet and 90 to 100 feet. The well construction is disregarded in the estimation.)

Material	Thickness (feet)	Estimated hydraulic conductivity[1] (ft/d)	Estimated transmissivity (ft^2/d)
Clay and gravel	12	—	—
Gravel and sand, containing clay	4	800	3,200
Clay	74	1	74
Sand, fine-grained	6	15	90
Gravel and sand, coarse	4	1,000	4,000
			Total 7,364

[1]Estimated from Table 4.

Because most water obtained from bedrock aquifers is from fractures, a well located on a fracture trace should have the optimum yield for a given area. Even greater yields would be expected from a well at the intersection of two fracture traces. Locating a well on a fracture trace is more likely to increase yield where the well is drilled in dense and well-cemented rocks such as siltstone and sandstone. According to Lattman (written communication, 1974), locating a well on a fracture trace in shale probably does not increase yield because the plastic quality of the shale allows the fracture to close up and seal itself off.

WATER QUALITY

As groundwater slowly moves through the aquifer(s), it dissolves chemical constituents from the rock material and carries them in solution. The natural chemical quality of groundwater is determined by the concentrations of the dissolved constituents. These concentrations are determined largely by the type and solubility of the minerals in the rock and by the length of time that the water is in contact with the rock. The measurements of water quality include specific conductance, dissolved solids, hardness, major anions, and major cations. The major anions include bicarbonate, sulfate, nitrate, and chloride. The major cations include calcium, magnesium, sodium, potassium, manganese, and iron.

The majority of natural groundwater problems are the result of high concentrations of dissolved solids, hardness (compounds of calcium and magnesium), iron, sulfate, nitrate, and chloride. The severity of a groundwater-quality problem is defined by comparing the concentration of a given constituent to the U.S. Environmental Protection Agency (1977) recommended drinking water limit for that constituent.

The chemical type of water is defined from the dominant anion and cation in the water. According to Durfor and Anderson (1963, p. W10), the principal type of low-flow surface water in Erie County is calcium bicarbonate. The chemical analyses published by Mangan and others (1952) for the Lake Erie shore region also indicate that the principal type of most of the low-flow surface water (base flow) and groundwater is calcium bicarbonate. However, water in Twelvemile Creek and Sixteenmile Creek is a calcium sulfate type.

The evaluation of groundwater quality is based on 402 analyses from 371 wells, and on analyses from low-flow stream sites. The results of these analyses, which were made by the U.S. Geological Survey, Pennsylvania state agencies, and private analysts, are shown in Tables 9, 10, and 11. In Table 6, the quality characteristics that generally are important to groundwater users in the area are summarized. Only the principal aquifer is listed in the tables, although in many instances the water entering a well is a mixture from several aquifers. Some wells were sampled several times to determine seasonal or long-term quality changes. Well Er-1481 was sampled at progressively greater depths during drilling to relate changes in water quality to depth.

The chemical analyses of groundwater in Tables 9, 10, and 11 indicate that the principal chemical types are calcium bicarbonate and sodium chloride. Groundwater, especially from the unconsolidated deposits, is commonly hard to very hard (median concentration of 160 mg/L (milligrams per liter) to a maximum concentration of 720 mg/L) and in places has high iron concentrations (from 0.01 to 30 mg/L). During prolonged periods of no precipitation, the base flow of streams reflects the chemical type of areal groundwater, but the chemical-analyses base in Table 11 is insufficient to define the principal chemical types of base flow. The important water-quality characteristics of base flow are summarized in Table 7. For groundwater and for base flow, chloride concentrations, specific conductance, and hardness are higher in the lake plain and escarpment slope than in the upland plateau.

Computer-generated maps show the distribution of specific-conductance values and the concentrations of chloride, hardness, and iron (Figures 5, 6, 7, and 8). The data used are those from groundwater samples, and the interpretation is intended only as a generalization of water-quality conditions in the county.

Chloride concentration and overall water quality may be estimated by measuring specific conductance, which is the measure of the capacity of water to conduct an electric current. Specific conductance varies directly with the concentration of dissolved solids and the degree of ionization of the aquifer material. Figures 9 and 10 show, respectively, the relationship between specific conductance and chloride concentration and between specific conductance and dissolved-solids concentration. Data from northwestern Pennsylvania and nearby areas were used to determine the slopes in the lines representing these relationships. In water containing low dissolved solids, chloride is not a major element and specific conductance is related to other constituents. As shown in Figure 9, the change in slope below a chloride concentration of about 800 mg/L indicates a change in the ratio of specific conductance to chloride concentration.

In Figure 10, the terminology of Krieger and others (1957) has been modified by placing the division between "fresh" and "slightly saline" water at 500 mg/L dissolved solids, rather than at the 1,000 mg/L generally used by the U.S. Geological Survey. This modification was made to conform with local usage. The maximum recommended limit of total dissolved solids for

Table 6. *Summary of Selected Groundwater-Quality Characteristics*

Geologic unit	Iron (Fe) (mg/L)			Chloride (Cl) (mg/L)			Hardness as $CaCO_3$ (mg/L)			Specific conductance (μmho/cm at 25 °C)		
	Number of analyses	Median	Range	Number of analyses	Median	Range	Number of analyses	Median	Range	Number of determinations	Median	Range
Glacial-beach deposits	46	0.39	0.03-30	76	24	4-1,000	77	220	92-610	41	460	281-3,500
Glacial-outwash deposits	83	.15	.01-2.6	120	10	1.5-1,200	117	140	5-720	97	422	146-4,800
Glacial-till deposits	46	.19	.01-2.8	54	27	2.5-1,110	51	120	5-570	89	547	251-3,840
Unconsolidated deposits, combined	175	.2	.01-30	250	15	1.5-1,200	245	160	5-720	187	442	146-4,800
Berea Sandstone through Riceville Formation	5	.05	.02-.7	5	3	2.5-6.2	5	158	120-210	4	400	300-480
Corry Sandstone through Riceville Formation	7	.09	.05-2.5	7	10	2-22	6	110	6-120	6	260	190-320
Berea Sandstone through Venango Formation	9	.15	.05-.52	11	42	3.8-716	8	122	35-180	7	520	300-2,800
Venango Formation	25	.13	.01-.43	25	18	2.5-600	25	120	50-230	25	400	280-2,800
Chadakoin Formation	37	.08	.01-3.2	59	18	3-5,200	52	122	5-310	47	401	220-2,400
Girard Shale	6	1.7	.21-66	12	48	12-3,000	14	190	13-600	12	778	369-9,870
Northeast Shale	8	.08	.025-5.5	32	135	3-9,500	33	132	26-2,500	32	695	239-25,800
Bedrock, combined	97	.11	.01-66	151	23	2-9,500	143	130	5-2,500	133	430	190-25,800

Table 7. Summary of Selected Low-Flow Water-Quality Characteristics for the Period 1970–78

(Data collected by Pennsylvania Department of Environmental Resources)

Physiographic division	Iron (mg/L)			Chloride (mg/L)		
	Number of analyses	Range	Median	Number of analyses	Range	Median
Escarpment slope and lake plain[1]	12	0.05–1.97	0.19	13	23–79	47
Upland plateau	4	.30–1.18	.70	7	4–11	8.0

Physiographic division	Hardness as $CaCO_3$ (mg/L)			Specific conductance (μmho/cm at 25 °C)		
	Number of analyses	Range	Median	Number of analyses	Range	Median
Escarpment slope and lake plain[1]	13	124–212	192	13	260–600	460
Upland plateau	6	82–130	108	7	182–290	218

[1]Gaging station data period from 1976 to 1978 only.

drinking water is 500 mg/L (U.S. Environmental Protection Agency, 1977, p. 17146). An approximation of the straight line in Figure 10 may be used for the conversion of specific conductance (SC) to dissolved solids (DS); that is, dissolved solids can be estimated by multiplying specific conductance by 0.6, or, DS = 0.6 x SC. From the data listed in Table 10, the calculated coefficient value is 0.61. According to Hem (1985, p. 67), the coefficient can range from 0.55 to 0.75.

Figure 5 is a computer-generated map showing the general distribution of specific conductance in the county, based on 320 specific-conductance determinations of water from all of the major aquifers. All of the median specific conductances shown for the various aquifers in Table 6 are comparable in magnitude. The higher specific-conductance values were measured from wells that had excessive chloride concentrations. Most of the areas of high specific conductance are in the lake plain and escarpment slope (Figure 5). The specific conductance of water from wells in the upland plateau generally is lower. An exception is in the upland area west and northwest of the borough of Waterford. This lower conductivity of water in the uplands is generally attributed to the circulation of recharge water from precipitation. The lowlands is the discharge area of the more mineralized groundwater.

Chloride

In many locations in Erie County, the chloride concentration of groundwater exceeds 250 mg/L and increases with depth. This is especially true of the bedrock aquifers where the groundwater containing high chloride concentration is considered to be connate or native water—that is, trapped in the interstices of the sedimentary rocks at the time of deposition. However, some unconsolidated aquifers contain groundwater that has high chloride concentrations. The presence of high chloride concentrations in the

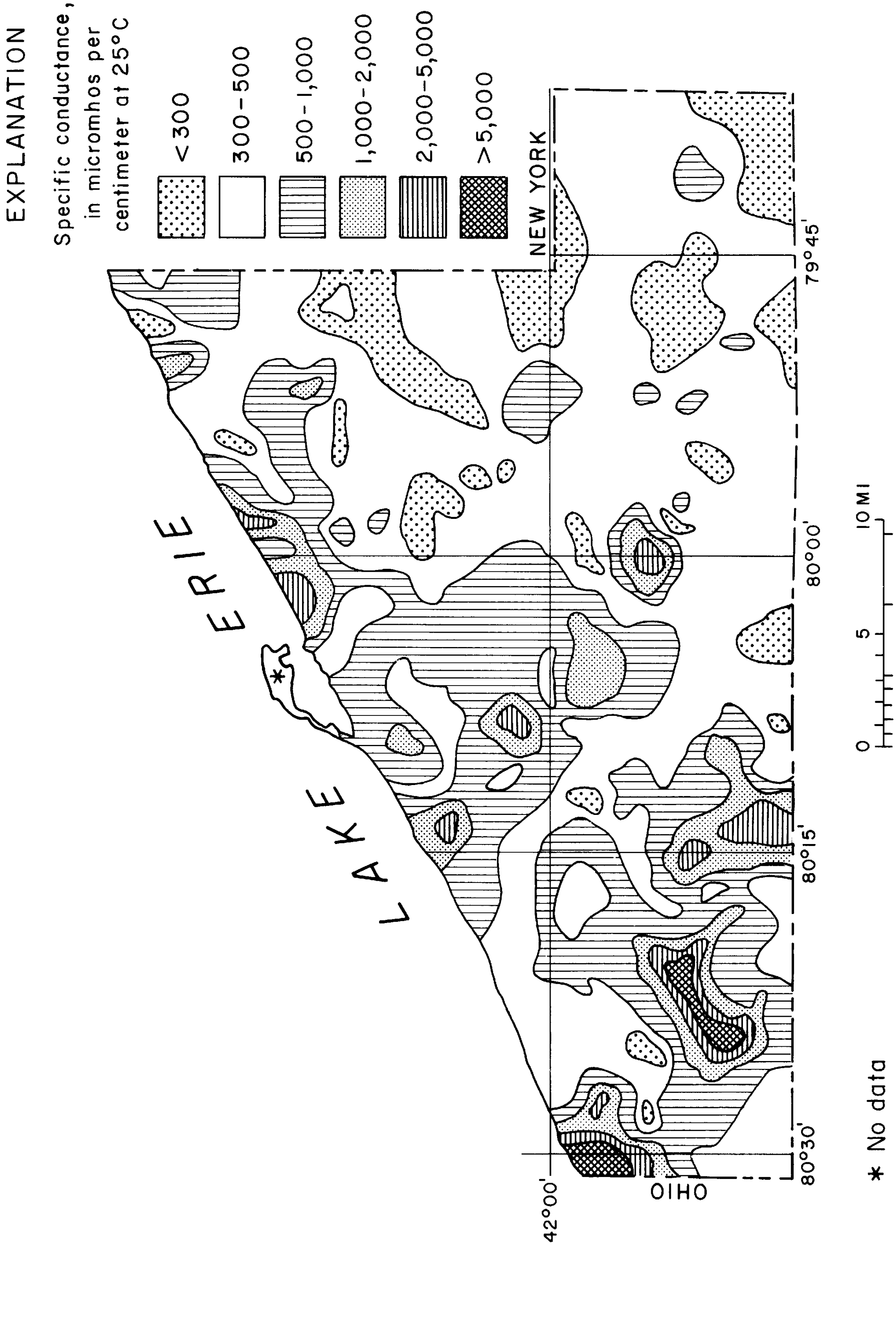


Figure 5. Distribution of specific-conductance values in the wells sampled.

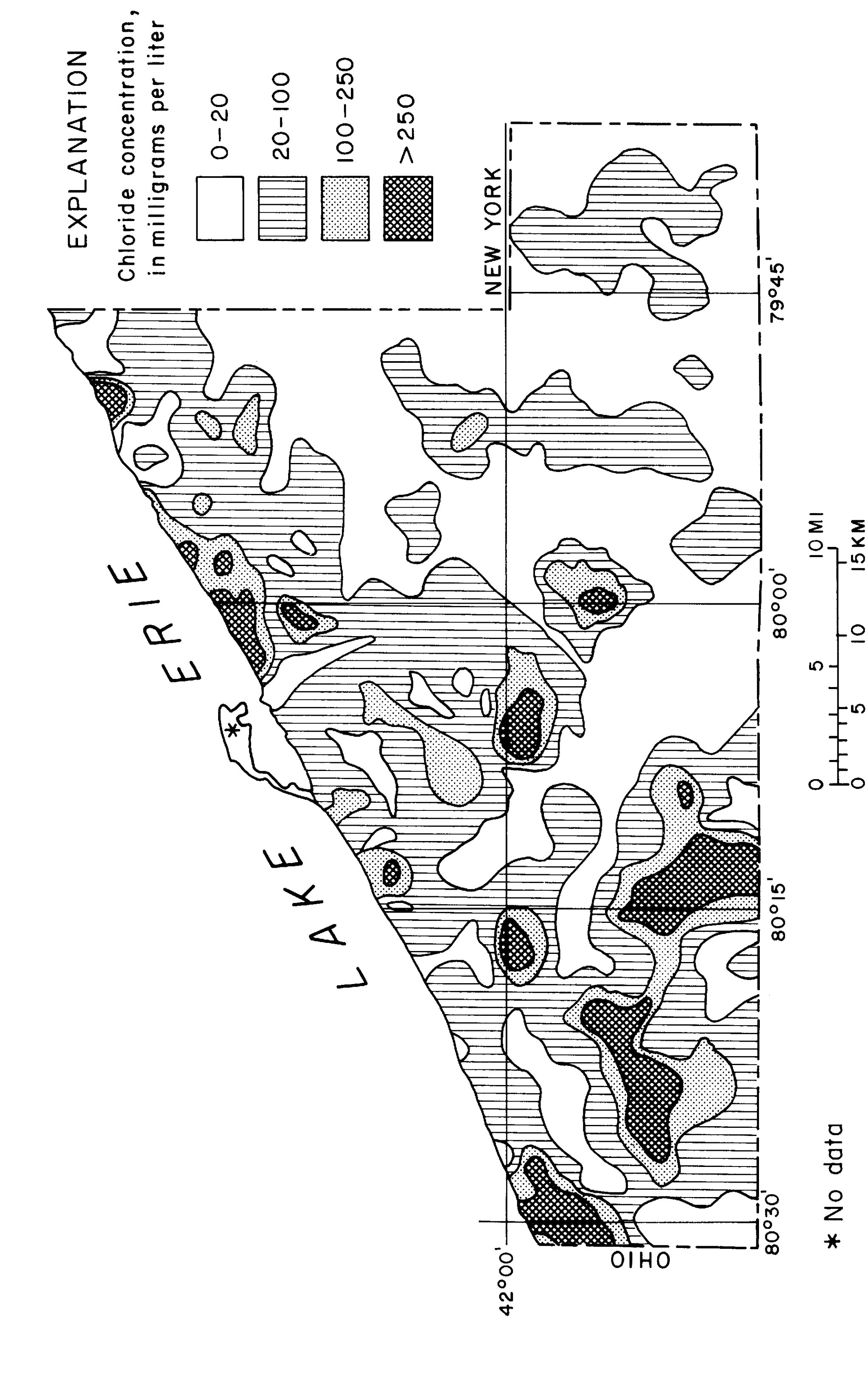


Figure 6. Distribution of chloride concentrations in the wells sampled.

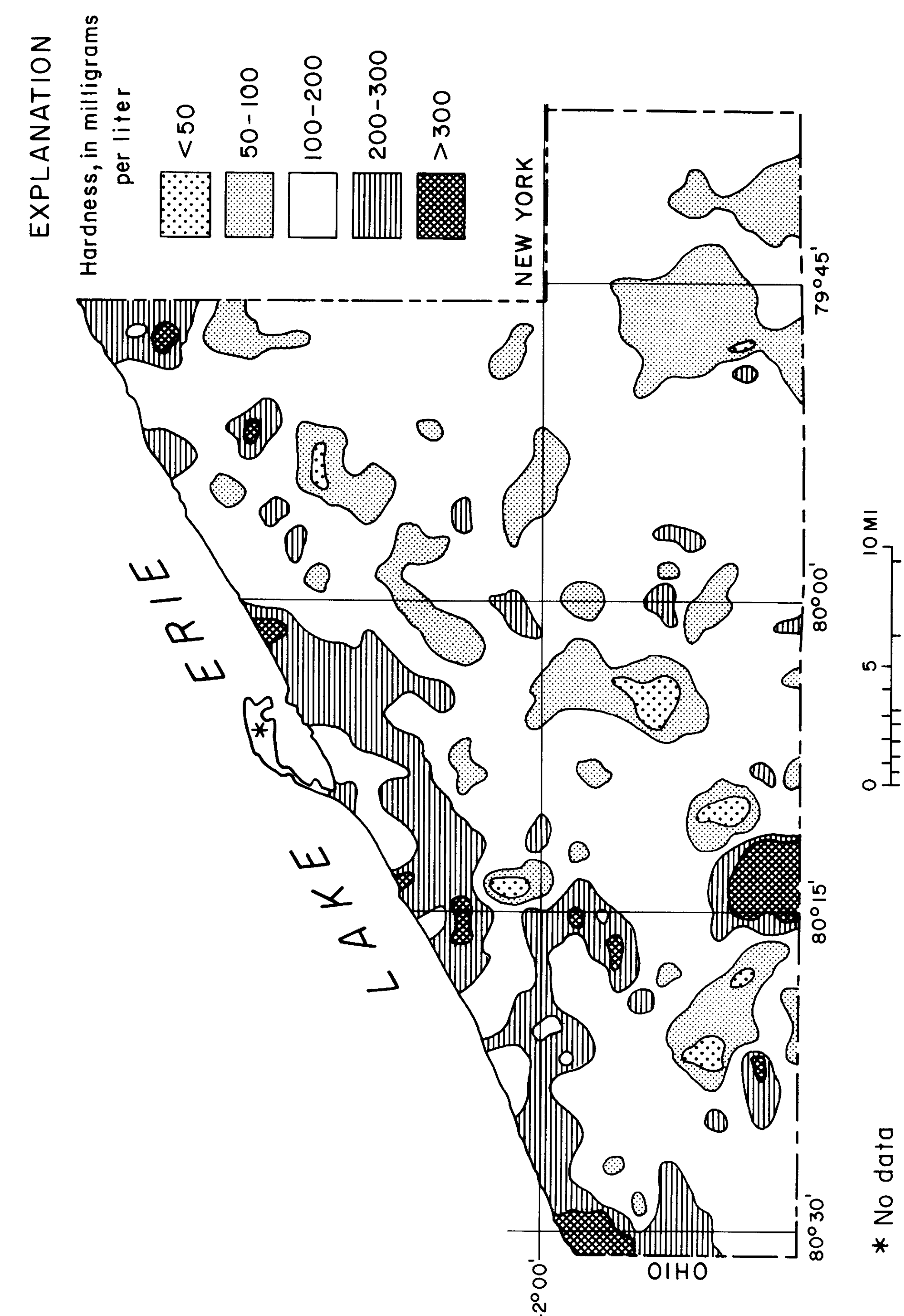


Figure 7. Distribution of total-hardness concentrations in the wells sampled.

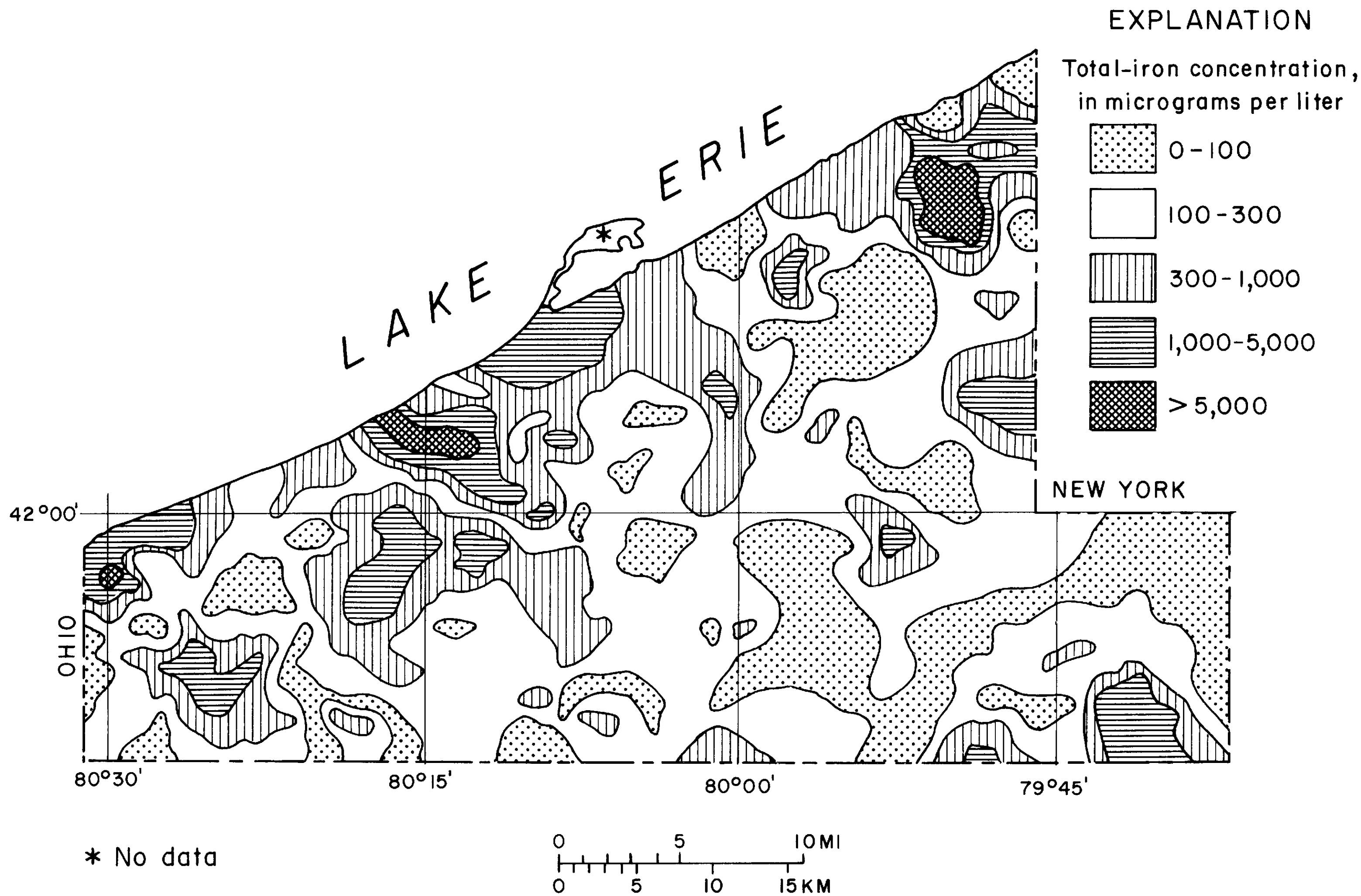


Figure 8. Distribution of total-iron concentrations in the wells sampled.

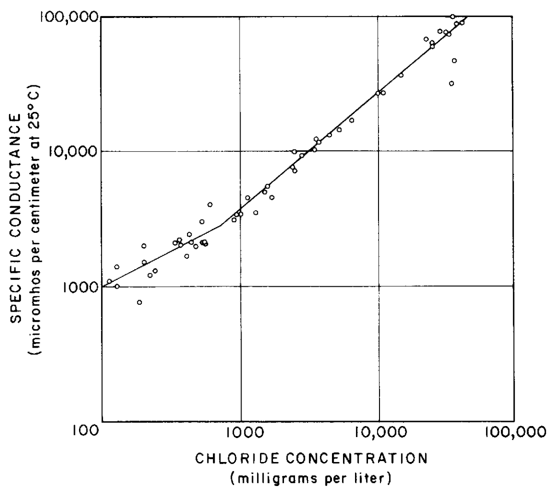


Figure 9. Relationship between specific conductance and chloride concentration (from Schiner and Gallaher, 1979, Figure 2, p. 31).

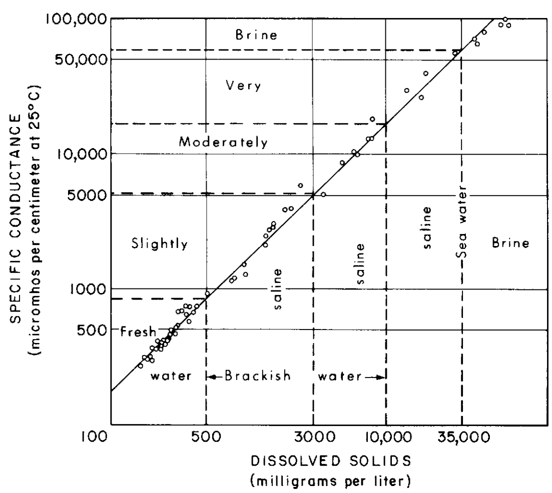


Figure 10. Relationship between specific conductance and dissolved solids, and the classification of salinity of water (from Schiner and Gallaher, 1979, Figure 3, p. 32).

county is probably due to restricted flushing by percolating fresh groundwater.

In the upland plateau, glacial and preglacial valleys have divided much of the upland area into hydrologically isolated "islands" (Poth, 1962). Before the valleys were filled with glacial drift, these "islands" stood as much as from 400 to 800 feet above the valley floor, creating a hydraulic gradient that permitted the draining and flushing of the units standing above the drainage level. Also, the upland area of the county is capped by sediments that are higher in the stratigraphic column and are generally more permeable than the lower, tighter units. For these reasons, the problem of salinity in bedrock wells in this area is much less common than in similar wells in the lake plain and escarpment slope. Wells Er-1122 and Er-1123, in the upland area about 3 miles east of Edinboro, penetrated more than 400 feet of bedrock, and salt water was not reported by the driller. The bottoms of these wells, at about 1,000 feet above sea level, are probably 300 feet or more above the bedrock floor underlying nearby Conneauttee Creek valley. Wells of such depth, drilled beneath the flushing zone, would normally yield water similar to that of sea water. Some exceptions exist in the upland area. A few wells drilled near the centers of some of the areally larger and topographically lower upland "islands" reportedly yield saline water. Wells drilled near the edges of the same upland "islands" generally yield fresh water.

In the lake plain especially, and to some degree in the western end of the escarpment slope, topographic relief is minimal and the connate water has drained from only the uppermost part of the bedrock. In much of the eastern half of the lake plain, the drift overlying the bedrock is very thin and impermeable, and does not yield water to wells. Attempts to obtain adequate household water supplies by drilling into the bedrock often result in saltwater wells, with accompanying natural gas in some places (see Table 9).

In most of the area west and south of Elk Creek, in the western part of the county, the conditions are similar. The drift there is relatively thick, but it generally is composed of clayey, impervious till that commonly yields quantities of water that are inadequate even for domestic supplies. The underlying bedrock consists of shaly units that contain brine at shallow depths (about 100 feet). In the deep, buried valleys of this area, the brines are still slowly draining from the bedrock into the valley-fill drift, but the movement of water through the drift is too slow to permit complete flushing. Deep wells in the valley-fill drift of preglacial Conneaut Creek yield saline water even in the more permeable outwash deposits near Lake Erie. Well Er–1481, about 3 miles north of Albion, was drilled to determine the thickness and composition of the drift in this buried valley. As recorded in Table 9, the chloride concentration increased gradually to about 100 mg/L at the 120-foot depth, and to about 400 mg/L at the 141-foot depth (top of bedrock).

Tolerance to chloride varies among individuals. The maximum recommended limit for chloride concentration is 250 mg/L (U.S. Environmental Protection Agency, 1977).

Figure 6 is a map showing the distribution of chloride (saline) concentrations in wells sampled and inventoried in the county. Wells that yield excessively saline water normally are destroyed and not reported or are plugged from the bottom of the well to above the salty zone and used, but not recorded as failures. Also, well drillers have learned by experience and word of mouth not to exceed depths at which salt water is known or suspected to be present. Whenever saline water is encountered during drilling, it is pointless to drill deeper. The salinity increases rapidly with depth, and there is no fresh water below the saline zone. Table 8 is a compilation of relevant data on the occurrence of saline water (chloride in excess of 250 mg/L), aquifer, and well depth for the wells inventoried and sampled in the county. This table, together with Tables 9, 10, 11, and 12 and Plates 1 and 2, can provide information to well drillers and potential well owners about the approximate depth to the saline zone.

In areas of shallow salt water, some procedures are available to help minimize the problem. Critical factors include well depth and the occurrence and amount of overlying fresh water available for dilution. During routine well construction, the well depth could be increased a few feet into bedrock to create additional storage. Large-diameter dug wells could be used to provide more area for freshwater entry and more storage volume. Slotted well casing set loosely at the top of the bedrock would allow the entry of water from the drift into the borehole.

Table 8. *Aquifer, Well Depth, and Chloride Concentrations Greater than 250 mg/L*

(In part from Koester and Miller, 1980)

Aquifer	Well number	Township location	Well depth (feet)	Chloride concentration (mg/L)
Glacial-beach deposits	Er– 377	Fairview	53	RS[1]
	556	do.	73	1,000
	1220	Millcreek	38	300
	1415	Harborcreek	17	320
	1523	Millcreek	34	710
Glacial-outwash deposits	71	Girard	77	RS
	99	Waterford	144	RS
	503	Elk Creek	40	720
	1061	Waterford	165	1,220
	1206	Millcreek	48	490
	1254	Conneaut	120	380
	1423	Waterford	227	RS
Glacial-till deposits	957	Millcreek	70	280
	1481	Girard	141	425
	1496	McKean	55	RS
	1651	Conneaut	50	250
	1686	Springfield	60	410
	1687	do.	55	480
Berea Sandstone through Venango Formation	67	Elk Creek	36	RS
	68	do.	54	716
	69	do.	50	RS
	1280	Franklin	70	550
Venango Formation	562	do.	70	250
	1495	McKean	61	600
Chadakoin Formation	70	Franklin	72	RS
	72	Girard	100	RS
	306	Conneaut	46	616
	414	McKean	64	450
	649	North East	35	RS
	863	Summit	50	310
	872	do.	50	RS
Girard Shale	1222	Girard	84	540
	1683	Springfield	63	1,400
	1685	do.	150	3,000
Northeast Shale	15	Harborcreek	36	655
	16	do.	40	RS
	18	do.	40	490
	19	do.	34	1,170
	29	do.	82	470
	34	do.	41	1,540
	35	do.	40	305
	36	do.	35	280
	41	do.	30	255
	42	do.	30	255
	50	North East	60	1,110
	103	Harborcreek	159	RS
	104	North East	250	RS
	106	do.	128	RS
	1646	Springfield	50	RS
	1684	do.	185	9,500

[1]RS, driller reported salty groundwater.

Hardness

Hardness is a property of water indicating the concentrations of calcium and magnesium ions. Hardness affects the lathering properties of soap, causes scale to form in pipes, in boilers, and on cooking utensils, and may leave a curd on bathtubs and wash basins.

Hardness may be expressed either in milligrams per liter (mg/L) or in grains per gallon (gr/gal) of $CaCO_3$ (calcium carbonate). According to the U.S. Environmental Protection Agency (1976, p. 75), a concentration of 0 to 75 mg/L (0 to 4.4 gr/gal) is considered soft, 75 to 150 mg/L (4.4 to 8.8 gr/gal) is moderately hard, 150 to 300 mg/L (8.8 to 17.5 gr/gal) is hard, and more than 300 mg/L (17.5 gr/gal) is very hard.

The range of groundwater hardness in Erie County is from soft to very hard, but the median hardness of all aquifers is hard to very hard. As seen in Table 6, the water from glacial-beach deposits is considerably harder than that from the other aquifers. Also, the water from bedrock wells generally is not as hard as that from alluvium. Water moving through shale units may be partially modified from a calcium bicarbonate type to a sodium bicarbonate type by a natural ion-exchange process not unlike that which takes place in home water-softening units.

The areal distribution of hardness is based on 388 determinations and is shown in Figure 7. As indicated on this map and from the medians in Table 6, the water in most of the area has a hardness ranging from 100 to 200 mg/L as $CaCO_3$. Most of the samples containing the highest hardness concentrations were taken from wells in the western parts of the lake plain and escarpment slope areas.

Hardness in water can be removed with treatment by such processes as lime-soda softening and zeolite or ion-exchange systems.

Iron

Iron is dissolved from many soil and rock components. Upon exposure to air, the dissolved iron is oxidized and redeposited as a reddish to dark-brown stain. The U.S. Environmental Protection Agency (1977) recommends that iron concentrations not exceed 0.3 mg/L. In the quantities usually found in groundwater, iron is objectionable because it may impart an unpleasant taste to the water and stain clothing, utensils, and plumbing fixtures.

Under conditions of high concentration, the iron problem may be complicated by the presence of ferrian (iron) bacteria. This bacterial growth forms a slimy, rust-colored mass, which builds up on plumbing fixtures and may clog water pipes. Chlorine bleach introduced into the water system will temporarily control this growth. Iron concentrations can be reduced by aeration followed by sedimentation and filtration processes.

Iron concentrations in the groundwater of Erie County differ widely, as shown in Figure 8. The aquifers of the upland plateau supply water of lower iron concentration, generally, than those in the lake plain. The summary of water-quality characteristics (Table 6) indicates that water from glacial-beach deposits and the Girard Shale generally has the highest iron concentrations, and water from the glacial-outwash deposits and other bedrock units has the least.

Gases

Hydrogen sulfide (H_2S) and natural gas are present in some wells in the county. Hydrogen sulfide is formed by the decomposition of sulfide minerals, and has an odor similar to that of rotten eggs. Heavy concentrations may cause black staining of fixtures and utensils. The odor may be dispelled by allowing the water to sit in an open container at room temperature, or, if the concentration is not too high, it may be eliminated by running the water through an iron-removal filter. The gas can also be released from the water before use by venting the gas to the atmosphere at the well. A hydrogen sulfide odor was observed or reported in water from wells Er–99, 115, 210, 296, 520, 609, 706, 940, 1356, and 1357 (Table 9). These wells tap a variety of bedrock and alluvial aquifers.

Natural or "shale" gas, often accompanied by saline water, was noted in wells Er–67, 70, 71, 103, 104, 107, 109, 210, 218, 272, 317, 365, 377, 608, 609, 668, 683, 694, 702, 744, 863, 919, 1132, 1179, 1232, 1318, 1368, 1397, 1495, 1496, 1578, 1644, and 1646 (Table 9). Most of the gas was in bedrock wells having depths of less than 70 feet, but some was reported in wells drilled in alluvium. In general, these wells were in the lake plain area of the county. The source of the gas may be the thin sandstones in the Northeast Shale that may have been tapped for domestic gas supplies, or, in a few local instances, leaking or abandoned gas wells. To avoid possible excess gas accumulation with resulting explosion hazard, it is recommended that water wells in this area be vented to allow escape of the gas.

DESCRIPTION AND WATER-BEARING CHARACTERISTICS OF CONSOLIDATED DEPOSITS

The bedrock exposed in the county (Plate 1) is the result of the compaction and cementation of sediments that were deposited in ancient seas. The age of these sedimentary rocks ranges from Late Devonian to Early Mississippian. The outcrops are progressively younger toward the south. The regional dip of the rock units is generally toward the south at a slope of about 15 to 20 feet per mile. In the southern and southeastern parts of the county, contacts between many of the Mississippian and Devonian units are indistinguishable or questionable. For this reason, many of the units have been combined on the map.

In the county, names assigned to many rock units, or combinations of units, have differed greatly since geologic studies began. The nomenclature of Berg and others (1980), which is the nomenclature of the 1980 Pennsylvania state geologic map, is used in this report. The stratigraphic nomenclature for the rocks of Devonian age does not follow the usage of the U.S. Geological Survey.

Generally, the rocks become more coarse grained in the upper units of the stratigraphic sequence. Also, the coarseness of many of the younger aquifer units increases towards the east and southeast.

The drillers' logs of many wells in the upland plateau area indicate that much of the uppermost bedrock surface consists of "broken, soft, or fractured" rock material. The maximum thickness of the fractured zone is about 10 feet.

The description and water-bearing characteristics of the geologic units in the county follow the format below:

Description—Includes the composition, geographic occurrence and extent, and general thickness of the geologic unit.

Water-Bearing Characteristics—Includes a description of the availability of groundwater from the geologic unit in terms of well yield, specific capacity, and well depth, based on the well inventory. The range of values and the median value for these characteristics, summarized in Table 3, are assumed to be representative of all wells tapping the aquifer.

Water-Quality Characteristics—Provides an indication of the chemical quality of groundwater from the geologic unit in terms of concentrations of chloride and iron ions, hardness, and specific conductance. The range of analytical results, and the median value, for these characteristics are summarized for each aquifer in Table 6.

Evaluation of the Aquifer—Contains a summary of the significant hydrogeologic characteristics of the geologic unit, including water quantity and quality. The quantity characteristics primarily include well yield and specific capacity. The characteristics for nondomestic wells are assumed to represent maximum aquifer capability. The water-quality characteristics include chloride concentration, hardness, and dissolved-solids concentration.

DEVONIAN

Northeast Shale

Description

The Northeast Shale lies in a band along Lake Erie and is the oldest bedrock exposed in Erie

County. Near the borough of North East, the outcrop area is more than 3 miles wide and the unit is 400 feet thick. The unit thins and narrows toward the west and is not exposed at the Ohio state line. The formation is a gray shale containing layers of fine-grained sandstone which are generally less than 1 foot thick. Locally, shallow wells penetrating the sandstone layers may yield enough natural gas for domestic use. Most of the wells inventoried and sampled were in Harborcreek and North East Townships in the lake plain physiographic division.

Water-Bearing Characteristics

As shown in Table 3, the median reported yield for 21 inventoried domestic wells sited in the Northeast Shale was 4 gal/min, and the range was 0.1 to 25 gal/min. The median specific capacity for seven inventoried domestic wells in this aquifer was 0.36 (gal/min)/ft, and the range was 0.006 to 25 (gal/min)/ft. The median reported well depth for 53 inventoried wells in this aquifer was 40 feet, and the range was 12 to 250 feet.

Water-Quality Characteristics

Chemical-quality data from the shale aquifer indicate high concentrations of dissolved solids and chloride at shallow depths. As shown in Table 6, the chloride concentration ranged from 3 to 9,500 mg/L, and the median was 135 mg/L. The hardness ranged from 26 to 2,500 mg/L as $CaCO_3$ (soft to very hard); the median hardness was 132 mg/L (moderately hard). For eight samples analyzed for iron concentrations, the range was from 0.025 to 5.5 mg/L, and the median was 0.08 mg/L, which does not indicate a serious problem. Specific conductance ranged from 239 to 25,800 μmho/cm (micromhos per centimeter at 25 °C), and the median was 695 μmho/cm. Values of dissolved solids, estimated from Figure 10, were about 150 to 15,000 mg/L, and the median was about 400 mg/L.

Evaluation of the Aquifer

The Northeast Shale does not have the potential for a good potable water supply due to generally poor water-bearing characteristics and poor water quality.

The chloride concentrations sampled from this aquifer are the highest in the county (up to 9,500 mg/L), possibly because of the presence of connate water in the aquifer, brine disposal associated with natural gas exploration and production from the sandstone layers of this unit, or the upward movement of saline water from the underlying Upper Devonian shales.

Because this aquifer is in contact with Lake Erie, there is some speculation regarding the infiltration of lake water into the aquifer. However, due to the general impermeable nature of the shale and glacial-drift deposits locally overlying the shale, infiltration is believed to be insignificant. Many water wells drilled along the lake shore were completely dry, even though the depths of some wells were far below the lake level.

Girard Shale

Description

The Girard Shale overlies the Northeast Shale and ranges from 50 to 200 feet in thickness. It forms a band roughly paralleling the Lake Erie shore, and it widens and thickens toward the west. The Girard Shale is very fine grained, uniform in texture, and light gray in color.

Water-Bearing Characteristics

As shown in Table 3, the median reported yield for 33 inventoried domestic wells sited in the Girard Shale was 2 gal/min, and the range was 0.1 to 50 gal/min. The median specific capacity for 10 inventoried domestic wells was 0.06 (gal/min)/ft, and the range was 0.01 to 4 (gal/min)/ft. The median reported well depth for 41 wells was 60 feet, and the range was 30 to 140 feet.

Water-Quality Characteristics

Chemical-quality data indicate excessive dissolved-solids and iron concentrations in some places. As shown in Table 6, the iron concentrations ranged from 0.21 to 66 mg/L, and the median was 1.7 mg/L; five of the six analyses exceeded the drinking water limit of the U.S. Environmental Protection Agency (1977). The chloride concentrations ranged from 12 to 3,000 mg/L, and the median value was 48 mg/L. The hardness ranged from 13 to 600 mg/L as $CaCO_3$ (soft to very hard); the median hardness was 190 mg/L (hard). Specific conductance ranged from 369 to 9,870 μmho/cm, and the median was 778 μmho/cm. The range of dissolved solids as estimated from Figure 10 was about 200 to 6,000 mg/L; the estimated median was about 470 mg/L.

Evaluation of the Aquifer

The Girard Shale is the poorest aquifer in Erie County, as measured by reported well yields and specific capacity.

Chadakoin Formation

Description

The Chadakoin Formation is a shale and sandstone unit overlying the Girard Shale, and is about 300 feet thick. This formation is the most common bedrock unit in the county. It underlies most of the valleys of the southward-flowing streams, and, to the north, it is incised by streams tributary to Lake Erie. The Chadakoin Formation is noticeably more coarse grained than the underlying units and contains thicker sandstone beds.

Water-Bearing Characteristics

As shown in Table 3, the median of reported yields for 283 inventoried domestic wells was 4 gal/min, and the range was 0.1 to 50 gal/min. The median specific capacity for 115 inventoried domestic wells was 0.14 (gal/min)/ft, and the range was 0.01 to 45 (gal/min)/ft. The median of reported well depths for 311 inventoried wells was 60 feet, and the range was 33 to 160 feet.

Water-Quality Characteristics

As shown in Table 6, the chloride concentration ranged from 3 to 5,200 mg/L, and the median was 18 mg/L. The hardness ranged from 5 to 310 mg/L as $CaCO_3$ (soft to very hard); the median hardness was 122 mg/L (moderately hard). The range of iron concentrations was from 0.01 to 3.2 mg/L, and the median was 0.08 mg/L. The specific conductance ranged from 220 to 2,400 μmho/cm, and the median was 401 μmho/cm. The estimated range of dissolved solids was about 130 to 1,400 mg/L, and the median was about 240 mg/L.

Evaluation of the Aquifer

The Chadakoin Formation is an extensive aquifer which is marginally acceptable for water supply. The water quality is better than the quality of the underlying aquifer. The elevated chloride concentrations are a local problem and are considered by some (Harrison, 1983) to be related to the groundwater discharge of the connate water from the underlying aquifers or to brines associated with natural gas exploration and production.

Venango Formation

Description

The Venango Formation is nearly 250 feet thick and consists of three coarse-grained sandstones separated by two shales. The shales average 100 feet in thickness and the sandstones average 30 feet. The three sandstone members—the Woodcock, Salamanca, and LeBoeuf—are known to oil-well drillers as the First, Second, and Third Venango oil sands. The lowest of the three, the LeBoeuf Sandstone Member, has been extensively quarried in the southern part of the county. The Venango Formation underlies much of the flat upland surface in the southeastern part of the county.

Water-Bearing Characteristics

As shown in Table 3, the median of reported yields for 166 domestic wells was 8 gal/min, and the range was 0.5 to 50 gal/min. The median specific capacity for 71 domestic wells was 0.2 (gal/min)/ft, and the range was 0.01 to 30 (gal/min)/ft. The median of reported well depths for 170 inventoried wells was 65 feet, and the range was 36 to 250 feet.

Water-Quality Characteristics

The chloride concentration ranged from 2.5 to 600 mg/L, and the median was 18 mg/L. The hardness ranged from 50 to 230 mg/L as $CaCO_3$ (soft to hard); the median hardness was 120 mg/L (moderately hard). The range of iron concentration was from 0.01 to 0.43 mg/L; the median was 0.13 mg/L. Specific conductance ranged from 280 to 2,800 μmho/cm, and the median was 400 μmho/cm. The estimated range of dissolved solids was about 170 to 1,700 mg/L, and the median was about 240 mg/L.

Evaluation of the Aquifer

The Venango Formation is a good aquifer for water supply. The water quantity and quality are generally better than those of the underlying aquifers. As with the Chadakoin Formation, high chloride concentrations are a local problem, and probably indicate restricted natural flushing of the aquifer by fresh water.

DEVONIAN AND MISSISSIPPIAN

Riceville Shale, Berea Sandstone, and Corry Sandstone

Description

The Riceville Shale overlies the Venango Formation and is the uppermost Devonian unit. It is about 80 feet thick, consists primarily of light-gray shales separated by thin layers of siltstone and fine-grained sandstone, and forms much of the upland area in the extreme southern part of the county. The Mississippian Cussewago Sandstone and Bedford Shale, both present in Crawford County to the south, are unidentifiable in Erie County; the Riceville Shale is capped by the Berea Sandstone in western Erie County and the Corry Sandstone in eastern Erie County. On Plate 1, the Mississippian Berea and Corry Sandstones are included with the Devonian Riceville Shale as combined units. In the Albion area, where the combined Berea and Riceville sequence is indefinite because of the lack of exposures, the mappable unit is the sequence from the Venango upward through the Berea.

The Berea Sandstone is a finer grained facies of the sandstone found at the type locality in Berea, Ohio. The Berea consists primarily of hard siltstone containing interbedded shales and very fine grained sandstones. It is about 15 feet thick in the southwestern part of the county and thins toward the east and north.

The Corry Sandstone is the eastern equivalent of the Berea. It thickens from west to east and is about 20 feet thick at the type locality near Corry. It is a light-buff fine-grained sandstone, locally conglomeratic near its base. The combined Corry and Riceville sequence forms much of the uplands in the southeastern part of Erie County.

Water-Bearing Characteristics

As summarized in Table 3 for the inventoried wells sited in the Berea Sandstone through the Riceville Shale, the median reported yield for 27 domestic wells was 15 gal/min, and the range was 2 to 40 gal/min. The median specific capacity for 20 domestic wells was 0.52 (gal/min)/ft, and the range was 0.12 to 10 (gal/min)/ft. The median reported well depth was 71 feet, and the range was 40 to 130 feet.

For the inventoried wells sited in the Corry Sandstone through the Riceville Shale, the median yield for 24 domestic wells was 15 gal/min, and the range was 2 to 50 gal/min. The median specific capacity for 15 domestic wells was 0.75 (gal/min)/ft, and the range was 0.02 to 20 (gal/min)/ft. The median reported well depth was 72 feet, and the range was 35 to 150 feet.

Water-Quality Characteristics

As shown in Table 6, for the analyzed samples from the Berea Sandstone through the Riceville Shale, the chloride concentration ranged from 2.5 to 6.2 mg/L; the median was 3 mg/L. The hardness ranged from 120 to 210 mg/L as $CaCO_3$ (moderately hard to hard); the median hardness was 158 mg/L (hard). The iron concentration ranged from 0.02 to 0.7 mg/L, and the median was 0.05 mg/L. Specific conductance ranged from 300 to 480 μmho/cm, and the median was 400 μmho/cm. The estimated range of dissolved solids was about 180 to 290 mg/L, and the median was about 240 mg/L.

For the analyzed samples from the Corry Sandstone through the Riceville Shale, the chloride concentration ranged from 2 to 22 mg/L, and the median was 10 mg/L. The hardness ranged from 6 to 120 mg/L (soft to moderately hard); the median hardness was 110 mg/L (moderately hard). The iron concentration ranged from 0.05 to 2.5 mg/L; the median was 0.09 mg/L. Specific conductance ranged from 190 to 320 μmho/cm, and the median was 260 μmho/cm. The estimated range of dissolved solids was about 110 to 190 mg/L, and the median was about 160 mg/L.

Evaluation of the Aquifer

The Riceville Shale, including the overlying Berea and Corry Sandstones, is the best bedrock aquifer in Erie County, as measured by reported well yields and specific-capacity values. Considering the limited water-quality sampling, the groundwater quality is not significantly different from that of the underlying Venango Formation, as measured by hardness and dissolved solids (specific conductance). However, iron and chloride concentrations are the lowest of all aquifers in the county. This is related to the upland position of the aquifer and the natural flushing of the unit by percolating fresh groundwater.

MISSISSIPPIAN

The Mississippian-age rocks conformably overlie the Devonian-age rocks in southern Erie County. As previously discussed, the Cussewago Sandstone and Bedford Shale, both found in Crawford County to the south, are unidentifiable in Erie County. Therefore, the lowest recognizable Mississippian units are the Corry and Berea Sandstones, which are discussed in the previous section.

Cuyahoga Group

Description

The Cuyahoga Group caps the uplands and lies above the Berea and Corry Sandstones. Where well developed, the group consists of the Orangeville Shale, the Sharpsville Sandstone, and the Meadville Shale, in ascending order. The Orangeville Shale is relatively soft and easily eroded. The Sharpsville Sandstone is composed mostly of sandstone but includes interbedded layers of shale and siltstone. The Meadville Shale is composed mostly of silty shale, thin beds of siltstone, and some sandstone lenses. Erosion has removed much of the Cuyahoga Group and made identification of the individual units difficult. In Erie County, the maximum thickness of the group is about 100 feet.

Water-Bearing Characteristics

As shown in Table 3, the median reported yield of eight domestic wells was 13.5 gal/min, and the range was 5 to 62 gal/min. The median specific capacity for seven domestic wells was 0.5 (gal/min)/ft; the range was 0.18 to 62 (gal/min)/ft. The median reported well depth was 69 feet, and the range was 38 to 102 feet.

Water-Quality Characteristics

Samples for chemical analysis were not collected from this aquifer.

Evaluation of the Aquifer

The areal extent of the Cuyahoga Group is limited to the southern boundary of the county. The presence of the sandstone units near the land surface makes both water-bearing characteristics and water-quality characteristics favorable for groundwater development.

Shenango Formation

The Shenango Formation overlies the Cuyahoga Group in some of the uplands in the southeastern part of Erie County. The shaly upper member has been removed by erosion, and only a few feet of the sandstone and siltstone of the lower member remain. No wells were inventoried or sampled in the Shenango Formation because of its limited areal extent.

DESCRIPTION AND WATER-BEARING CHARACTERISTICS OF UNCONSOLIDATED DEPOSITS

Nearly all bedrock in the county is covered by unconsolidated deposits of glacial origin known as drift. Collectively, the groundwater is more readily available in these deposits than in the underlying bedrock units. Figure 11 shows the general distribution of the unconsolidated deposits in the county. Plate 2 shows the thickness distribution. Although as thick as 450 feet, the deposits differ widely in texture, composition, and degree of particle size sorting. The selected drillers' logs in Appendix 2 illustrate this variable composition.

As described by Shepps and others (1959), Tomikel and Shepps (1967), and White and others (1969), Pleistocene glaciation formed Lake Erie, the lake plain, the present stream-drainage system, inland lakes, swamps, and the various types of unconsolidated deposits—namely till, outwash, and beach sands.

Presque Isle and the mainland extension are known as a sand spit and are postglacial in age. These areas of fine-grained lake sediments were built up by the action of lake currents. The maximum thickness of the lake sediments is about 150 feet.

The topics of discussion for the unconsolidated deposits parallel the topics for the bedrock aquifer units—that is, description, water-bearing characteristics, water-quality characteristics, and evaluation of the aquifer for water supply.

In the discussion of water-bearing characteristics, the analyses for nondomestic wells (industrial and public-supply wells) are separate from the analyses of the domestic wells. The well yields and specific capacities for the domestic wells are significantly less than for the nondomestic wells constructed as part of subsurface exploratory programs using sophisticated well-construction and completion techniques. The domestic-well owner generally does not use these techniques. The exploratory programs include test drilling and seismic refraction. The objective of these programs is to locate sites where the water-bearing units have the greatest transmissivity. The well-construction and completion techniques include (1) use of large-diameter casing; (2) selection of well screens and gravel packs to maximize infiltration surface; and (3) use of wells that are open to the full saturated thickness of the aquifer. Domestic-well owners generally drill wells to depths only necessary to supply household needs.

THICKNESS OF DEPOSITS

The general location of outwash channels in northwestern Pennsylvania and the associated thickness of unconsolidated deposits were initially presented by Leggette (1936, Plate 4). Plate 2 shows the thickness of unconsolidated deposits in the county and supports Leggette's original concept of the buried drainage channels. The outwash deposits in these buried channels are very favorable locations for high-yield wells. The thickness data used in contouring Plate 2 were obtained from water-, oil-, and gas-well records, highway test borings, test wells, rock outcrops, and seismic exploration.

The seismic-refraction method was used to define the depth and shape of the major buried river valleys in Erie County. The cross sections resulting from the application of this method are shown on Plate 2. In Erie County, the density of geologic materials increases with depth, and there is a sharp density contrast between unconsolidated saturated deposits and the underlying bedrock, both necessary conditions for the successful application of this method (Eaton and Watkins, 1970).

For example, past seismic surveys north of Corry, near well Er–1536, showed the following seismic velocities of various materials: unsaturated soils, 2,000 ft/s (feet per second); saturated sand and gravel, 5,000 ft/s; dense glacial till, 6,000 ft/s; and bedrock, about 14,000 ft/s. The composition of subsurface material was determined from nearby drill holes in the evaluation of relative seismic velocities. The drill holes that have known material logs are termed drill-hole controls.

The following eight seismic lines, totaling about 30,000 feet, were run:

(1) *North of Albion (Conneaut Creek valley and vicinity), 16,000 feet of line (sections A-A', B-B', and C-C' on Plate 2)*—The interpreted maximum thickness of 280 feet of unconsolidated deposits may represent the location of the preglacial buried channel for Conneaut Creek (Carll, 1880; Leverett, 1902); drill-hole control for the line was well Er-1481.

(2) *South of Waterford (French Creek valley), 6,000 feet of line (sections F-F' and G-G' on Plate 2)*—The interpreted maximum thickness of unconsolidated deposits was 240 feet; drill-hole control consisted of wells Er-1041 and 1081.

(3) *North of Lowville (valley of West Branch of French Creek), 4,500 feet of line (section H-H' on Plate 2)*—The interpreted maximum thickness of unconsolidated deposits was 190 feet; drill-hole control was well Er-808.

(4) *West of Corry (valley of South Branch of French Creek), 3,000 feet of line (sections D-D' and E-E' on Plate 2)*—The interpreted maximum thickness of unconsolidated deposits was 480 feet; drill-hole control was well Er-971.

Drillers' logs for the numbered wells are in Appendix 2.

The seismic-refraction method and the associated equipment are explained in several reports and texts: Bonini and Hickok (1959), Eaton and Watkins (1970), Zohdy and others (1974), Birch (1976), and Dobrin (1976).

Another indirect method of thickness determination of subsurface deposits is the gravity method. This has also been used with some success in glaciated terrain and was applied in Erie County. In addition to the previous references cited, reports that contain an explanation of this method include the following: Spangler and Libby (1968), Rankin and Lavin (1970), Ibrahim and Hinze (1972), Calkin and others (1974), and Carmichael and Henry (1977).

The gravity method is commonly used as a reconnaissance tool because it is comparatively quick and inexpensive, provided that equipment is rented or already available, and it does not disrupt the environment.

In conjunction with the geohydrologic investigation of Erie County, two college theses were also undertaken to demonstrate the applicability of the gravity method to the definition of the buried valleys. The unpublished theses were by J. A. Rhodes of Pennsylvania State University (1980) and M. A. Ruof of Allegheny College (1980).

GLACIAL-TILL DEPOSITS

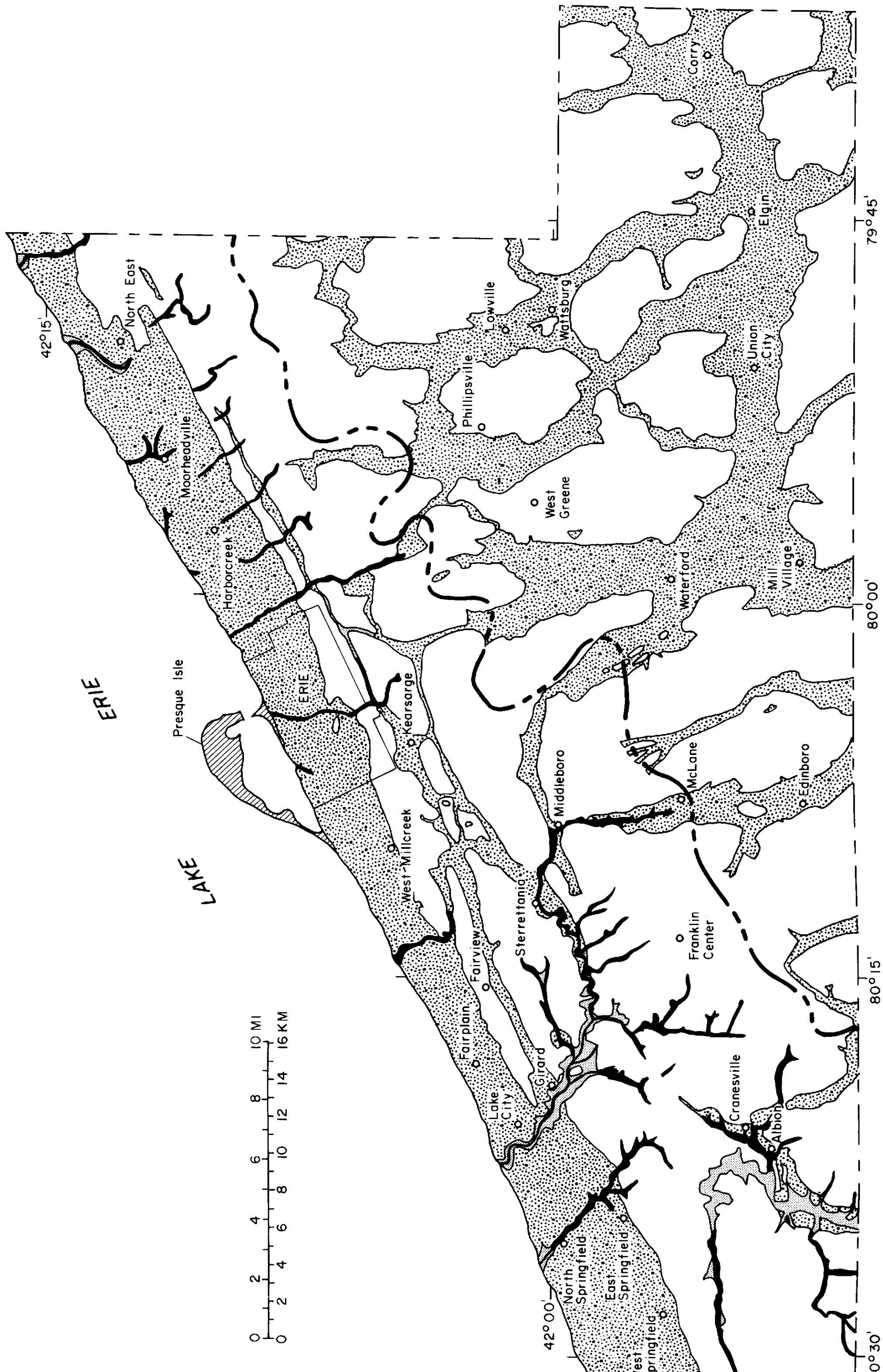
Description

Glacial till, which covers the greater part of Erie County, was deposited as ground moraine beneath the main ice mass and as end moraines at the limits of the ice advances. Ground moraines are generally irregular in shape and have little topographic expression. End moraine remnants in the area display some sinuous linearity and a knobby surface.

Glacial till consists of a relatively unstratified, unsorted mixture of clay, silt, sand, gravel, and boulders. Till deposits, especially in the upland areas, almost always overlie either bedrock or the till of an earlier glacial-ice advance. The thickness of the till over most of the county is less than 50 feet; however, well depths in till have exceeded 200 feet.

Water-Bearing Characteristics

As shown in Table 3, the median reported yield for 252 domestic wells was 5 gal/min, and for eight nondomestic wells was 11.5 gal/min. The range of reported yields for all wells was 0.1 to 50 gal/min. The median specific capacity for 125 domestic wells was 0.26 (gal/min)/ft. The median specific capacity for three nondomestic


LAKE
ERIE
Presque Isle
North East
Moorheadville
Harborcreek
ERIE
Kearsarge
West Millcreek
Fairview
Fairplain
Sterrettania
Lake City
Girard
North Springfield
East Springfield
West Springfield
Cranesville
Albion
Franklin Center
Middleboro
McLane
Edinboro
Waterford
Mill Village
West Greene
Phillipsville
Lowville
Wattsburg
Union City
Elgin
Corry
42°15'
42°00'
79°45'
80°00'
80°15'
80°30'
0 2 4 6 8 10 MI
0 2 4 6 8 10 12 14 16 KM

EXPLANATION

MAP FEATURE	CHARACTER AND DISTRIBUTION	WATER-BEARING CHARACTERISTICS
Presque Isle	Fine-grained sand deposited by lake currents.	A good aquifer (limited aquifer information).
Bedrock and alluvium	Bedrock (black) covered with recent stream alluvium (stipple pattern) of varying thickness.	A good aquifer where fractured and in hydraulic connection with the stream (limited aquifer information).
Undifferentiated unconsolidated deposits	Stratified deposits of sand, gravel, silt, and clay. Includes glacial-beach, glacial-outwash, kame, and lacustrine deposits, and recent stream alluvium in the French Creek watershed.	A good aquifer; yields range from 0.1 to 1,000 gal/min.
Ground moraine and end moraine	Till consisting of relatively unstratified, unsorted mixture of silt, loam, and silty clay to clay.	A good aquifer; yields range from 0.1 to 50 gal/min, and the median is 5 gal/min.
Drainage divide		

Figure 11. Map showing the distribution of unconsolidated deposits in Erie County (modified from Shepps and others, 1959, Plate 1).

wells was 1.5 (gal/min)/ft. The range of specific capacity for all wells was 0.009 to 30 (gal/min)/ft. The median well depth for 282 domestic wells was 55 feet, and the median depth for 13 nondomestic wells was 60 feet. The range of well depths for all wells was 17 to 220 feet.

Water-Quality Characteristics

As shown in Table 6, the chloride concentration of groundwater from till ranged from 2.5 to 1,110 mg/L, and the median was 27 mg/L. The iron concentration ranged from 0.01 to 2.8 mg/L; the median was 0.19 mg/L. The hardness ranged from 5 to 570 mg/L as $CaCO_3$ (soft to very hard), and the median was 120 mg/L (moderately hard). The specific conductance ranged from 251 to 3,840 μmho/cm, and the median was 547 μmho/cm. The estimated range for dissolved solids was about 150 to 2,300 mg/L, and the median was about 330 mg/L.

Evaluation of the Aquifer

Glacial till is a marginally acceptable aquifer but is areally extensive. Considering well yields and water quality, till is the poorest aquifer of the unconsolidated deposits. As indicated in Table 8, chloride concentrations may locally exceed the 250 mg/L recommended limit in wells that are 50 to 141 feet deep. The quality of groundwater from till is generally comparable to that of the underlying bedrock aquifers. Locally, the groundwater in till may be of poorer quality.

GLACIAL-OUTWASH DEPOSITS

Description

Glacial outwash is a drift deposit that is transported and deposited by, or in, water. These deposits were carried from the glacial ice by meltwater streams originating below, within, and from the face and sides of the ice sheets of the past glacial epoch. These deposits are known as eskers, kames, kame terraces, kame moraines, valley trains, and lake-type sediments.

Glacial outwash consists of relatively well sorted, stratified deposits of sand, gravel, silt, and clay. The lake-type sediments (silt and clay) generally are found in the lake plain. The other outwash deposits occur in the major stream valleys, as illustrated by Leggette (1936, Plate 4). The composition of these deposits generally remains the same with depth and commonly extends to bedrock, but on the slopes of valley walls, isolated remnants of glacial till are locally present. The thickness of the outwash generally is more than 100 feet and is more than 400 feet in some areas in the French Creek buried valley (see Plate 2). The ponded outwash deposits in much of French Creek valley are uniform in grain size, but generally are so fine that well yields are very small or nonexistent.

Water-Bearing Characteristics

As shown in Table 3, the median reported yield for 395 domestic wells was 15 gal/min, and for 39 nondomestic wells was 60 gal/min. The range of reported yields for all wells was 0.1 to 1,000 gal/min. The median specific capacity for 170 domestic wells was 1.2 (gal/min)/ft and for 20 nondomestic wells was 9 (gal/min)/ft. The range of specific capacity for all wells was 0.04 to 140 (gal/min)/ft. The median well depth for domestic wells was 62 feet and for nondomestic wells was 59 feet. The range of well depth for all wells was 13 to 405 feet.

Water-Quality Characteristics

As shown in Table 6, the chloride concentration for groundwater ranged from 1.5 to 1,200 mg/L, and the median was 10 mg/L. The iron concentration ranged from 0.01 to 2.6 mg/L, and the median was 0.15 mg/L. The hardness ranged from 5 to 720 mg/L as $CaCO_3$ (soft to very hard); the median was 140 mg/L (moderately hard). The specific conductance ranged from 146 to 4,800 μmho/cm, and the median was 422 μmho/cm. The estimated dissolved-solids concentration ranged from about 90 to 2,900 mg/L, and the median was about 250 mg/L.

Evaluation of the Aquifer

Glacial-outwash deposits are a very good aquifer; however, they are restricted to the major stream valleys and near the shoreline of Lake Erie. Also, the lateral extent of the layers may be limited and unpredictable because of the nature of deposition, erosion, and redeposition related to the multiple advances and retreats of the glaciers.

The greatest saturated thicknesses of outwash deposits can be accurately located through an exploration program that consists of test drilling, supplemented with seismic refraction when possible. The seismic-refraction geophysical technique was demonstrated in four areas of Erie County—near Albion, Waterford, Lowville, and Corry. The seismic lines and thicknesses of deposits are shown on Plate 2. The well sites that have the greatest saturated thickness of sand and gravel will provide the best sustained well yield and the highest specific capacity. Also, those wells that are located near, and hydraulically connected to, streams will sustain the best long-term well discharge.

Groundwater quality in the outwash deposits is the best of any of the unconsolidated aquifers. However, as indicated in Table 8, chloride concentrations may locally exceed the 250 mg/L recommended limit in wells from 40 to 227 feet deep.

GLACIAL-BEACH DEPOSITS

Description

Overlying the outwash deposits of the lake plain are remnants of former beach ridges. These were deposited during the various higher stages of ancestral Lake Erie and are similar in texture and composition to modern lake bottoms and ridges. These beach deposits range in composition from sand to gravelly sand.

Water-Bearing Characteristics

As shown in Table 3, the median reported well yield for 59 inventoried domestic wells was 7 gal/min and for 47 inventoried nondomestic wells was 75 gal/min. The range of reported yields for all wells was 0.1 to 850 gal/min. The median specific capacity for 24 domestic wells was 0.8 (gal/min)/ft, and the median for 20 nondomestic wells was 17 (gal/min)/ft. The range of specific capacity for all wells was 0.03 to 270 (gal/min)/ft. The median depth was 35 feet for 93 domestic wells and 32 feet for 55 nondomestic wells. The range of depths for all wells was 9 to 105 feet.

Water-Quality Characteristics

As shown in Table 6, the iron concentration of groundwater ranged from 0.03 to 30 mg/L, and the median was 0.39 mg/L. The chloride concentration ranged from 4 to 1,000 mg/L; the median was 24 mg/L. The hardness ranged from 92 to 610 mg/L as $CaCO_3$ (moderately hard to very hard), and the median was 220 mg/L (hard). The specific conductance ranged from 281 to 3,500 μmho/cm, and the median was 460 μmho/cm. The estimated dissolved-solids concentration ranged from about 170 to 2,100 mg/L, and the median was about 280 mg/L.

Evaluation of the Aquifer

The glacial-beach deposits constitute the best aquifer in Erie County as measured by the median well yield and the median specific capacity for nondomestic wells. However, these deposits are restricted in areal extent. Careful well-site selection, assisted by a test-drilling program and a seismic exploratory program, can result in a better well than one sited in a bedrock aquifer.

Water quality is about the same as the water quality from the other glacial-drift aquifers. However, groundwater from the beach deposits is notably higher in dissolved iron; more than half of the results exceed the recommended limit of the U.S. Environmental Protection Agency of 0.3 mg/L. The groundwater is also characteristically hard. As indicated in Table 8, the chloride concentration may locally exceed the 250 mg/L recommended limit in wells from 17 to 73 feet deep.

SOURCES OF ADDITIONAL INFORMATION

In addition to this report, other information on obtaining water for domestic supplies is available from governmental agencies.

The Bureau of Topographic and Geologic Survey, of the Pennsylvania Department of Environmental Resources, systematically maps, describes, and evaluates the geology, mineral resources, physiography, and groundwater resources of the Commonwealth, and the results of these investigations are published for use by the public. The bureau also has reports on recently drilled wells.

The Bureau of Water Quality Management, Pennsylvania Department of Environmental Resources, directs efforts to provide clean water for a variety of uses for the Commonwealth. The bureau, through regional offices, tests domestic water samples (for a fee) for contamination and provides advice on necessary corrective measures. The bureau also supplies information on public water supplies—that is, proper well construction requirements, biological reports, and chemical quality.

The Bureau of Community Environmental Control, Pennsylvania Department of Environmental Resources, administers programs relating to individual sewage and water systems.

The Water Resources Division of the U.S. Geological Survey has the principal responsibility within the federal government for providing water-resources information. The division obtains this information by investigating the occurrence, quantity, quality, distribution, and movement of surface water and groundwater, in cooperation with other federal and state governmental agencies. After collection, the data are analyzed and interpreted and the results are reported in various publications. The Pennsylvania District (P. O. Box 1107, Harrisburg, PA 17108) of the Water Resources Division is responsible for the federal effort in water-resources studies in the Commonwealth.

Basic information on groundwater quantity and quality may be obtained from the pamphlets by Baldwin and McGuinness (1963) and Swenson and Baldwin (1965), which are available from the Superintendent of Documents, Government Printing Office, Washington, D. C. 20402. Pennsylvania geological publications, such as *Ground Water in Pennsylvania* by Becher (1970), are available from the Pennsylvania Geological Survey, Department of Environmental Resources, P. O. Box 2357, Harrisburg, PA 17120.

GUIDELINES FOR DEVELOPING DOMESTIC WATER SUPPLIES

The homeowner generally has little choice in the selection of a well site. Usually, wells are drilled close to the residence, and the only consideration given to well location is for the prevention of possible contamination. However, an understanding of the geologic and hydrologic information given in this report, combined with proper well construction, increases the chances of obtaining a successful well. The following facts should be kept in mind when planning a domestic well system.

1. The depth, yield, water quality, and type of construction of nearby wells commonly indicate what may be expected of a similar well.
2. The drilling and testing of wells during dry periods, when water levels and yields are lowest, permits the optimum setting of pumps. Also, water quality at that time commonly is at its worst.
3. In areas where well yields are marginal, as much reservoir capacity as possible is desirable, either within the well itself or in a reservoir tank at the surface. Underground storage commonly is increased by use of larger diameter well casing and by extending the borehole below the water-bearing zone. Each foot of water in a 6-inch-diameter well represents about 1.5 gallons. In the more commonly used 8-inch-diameter well casing, each foot of water equals about 2.5 gallons. The cost of drilling wells greater than 8 inches in diameter may be prohibitive in deep wells, and the

cost of well storage should be compared with that of ground-level storage.

4. Where water supplies must be developed in relatively thin, poorly permeable drift, consideration should be given to the construction of very large diameter dug or bored wells. Each foot of water in a well 3 feet in diameter represents about 53 gallons. Additionally, the greater circumference adds considerably to the area of entry for water moving into the well. Randall and others (1966) report that a dug well in glacial till can provide enough water for an average family of three. In the construction of dug wells extreme care must be taken to avoid pollution.
5. Where yields from the bedrock are small and water is to be obtained from drilled wells in drift, the well casing should be slotted at the bottom and seated loosely into the top of the rock. This allows inflow of the water, which commonly lies at the drift-bedrock contact.
6. The use of screened wells should be considered in areas where the drift is thick but only fine or very fine sand deposits can be tapped.

A good reference for general information on the construction and development of small well-supply systems is the U.S. Environmental Protection Agency (1975) publication *Manual of Individual Water Supply Systems*. This may be obtained for a nominal fee from the Superintendent of Documents, Washington, D. C. 20402.

SUMMARY AND CONCLUSIONS

Potable groundwater resources in Erie County are available from unconsolidated deposits and from fractured bedrock aquifers. The aquifers that have the highest well yields and specific capacities are glacial-outwash and glacial-beach deposits. However, these deposits are limited in areal extent, being restricted to the major stream (buried) valleys and near the Lake Erie shoreline. The maximum saturated thickness in these valleys can be effectively defined prior to final well-site selection by seismic-refraction and gravity techniques. The highest well yields from these deposits are about 1,000 gal/min.

Glacial-till and bedrock aquifers are widespread in the county. However, their groundwater availabilities are significantly less than the availabilities of the glacial-outwash and glacial-beach deposits. Low permeability is responsible for these low well yields, which are suitable only for domestic needs.

The yields of bedrock wells differ according to geologic unit. Yields are lowest in the Northeast and Girard Shales in the lake plain and highest in the coarser, stratigraphically higher units in the upland plateau. There is little difference in yield between domestic bedrock wells and those drilled for public or industrial supplies. There is little variation in yield on the basis of topographic location of the bedrock well sites. The medians of all bedrock wells in all types of topography range from 5 to 6 gal/min. The range of well yields for bedrock wells was 0.1 to 62 gal/min.

Most wells in the area tap more than one water-bearing zone, and the water is usually under artesian conditions. Medians of water levels in bedrock wells average about 10 feet below land surface; those in drift wells are about twice as deep. Water levels are generally deepest at hilltop sites and shallowest (commonly flowing) in wells drilled in the valleys of southward-flowing streams.

Potential sites for high-yielding wells include the kame deposits in the Corry-Union City area, the southward-flowing valleys tributary to French Creek, and the relatively thick northeast-southwest-trending outwash deposits south of Harborcreek. Some of these areas may contain extensive lenses of coarse, permeable drift capable of supplying the water needs of industry and small communities. Problems of low yield exist where the drift is thin or highly impermeable and overlies low-yielding bedrock containing saline water. In parts of the eastern lake plain and in much of the county west of the Albion-East Springfield areas, suitable supplies of potable water may be difficult to find.

The overall quality of groundwater in Erie County is generally satisfactory. However, the water is hard to very hard, and iron and chloride concentrations differ widely. On the basis of median values, only water from the glacial-beach deposits and the Girard Shale exceeds the maximum recommended limits of iron concentration. The major potential water-quality problem is chloride concentrations in excess of the recommended limit. The presence of connate brines is associated directly with topographic relief. Bedrock within the shallow groundwater-flow system has mostly been flushed of its original marine brines. Bedrock at or below the shallow groundwater-flow system, such as the shaly units in the lake plain, contains high chloride concentrations at relatively shallow depths (30 to 100 feet). Saline water is also found in deep impermeable drift below drainage, as in the buried preglacial valley of Conneaut Creek. Generally, salinity in the bedrock decreases upward in the stratigraphic column. The uppermost bedrock units yield water that is very low in chloride. Median chloride concentrations in water from glacial drift range from 10 to 27 mg/L, which approximates the chloride concentrations of surface water during base flow.

REFERENCES

Baldwin, H. L., and McGuinness, C. L. (1963), *A primer on ground water,* U.S. Geological Survey, 26 p.

Becher, A. E. (1970), *Ground water in Pennsylvania,* Pennsylvania Geological Survey, 4th ser., Educational Series 3, 42 p.

Berg, T. M., Edmunds, W. E., Geyer, A. R., and others, compilers (1980), *Geologic map of Pennsylvania,* Pennsylvania Geological Survey, 4th ser., Map 1, scale 1:250,000, 3 sheets.

Birch, F. S. (1976), *A seismic ground-water survey in New Hampshire,* Ground Water, v. 14, no. 2, p. 94–100.

Bonini, W. E., and Hickok, E. A. (1959), *Seismic-refraction method in ground-water exploration,* American Institute of Mining, Metallurgical, and Petroleum Engineers Transactions 1958, v. 211, p. 485–488.

Calkin, P. E., Hodge, D. S., Champion, D. E., and others (1974), *Gravity delineation of the preglacial Cazenovia River valley, western New York State, U.S.A.,* Zeitschrift fuer Geomorphologie, v. 18, no. 3., p. 247–259.

Carll, J. F. (1880), *The geology of the oil regions of Warren, Venango, Clarion, and Butler Counties,* Pennsylvania Geological Survey, 2nd ser., Report III, 482 p.

Carmichael, R. S., and Henry, G., Jr. (1977), *Gravity exploration for groundwater and bedrock topography in glaciated areas,* Geophysics, v. 42, no. 4, p. 850–859.

de Witt, Wallace, Jr. (1946), *The stratigraphic relationship of the Berea, Corry, and Cussewago sandstones in northeastern Ohio and northwestern Pennsylvania,* U.S. Geological Survey Oil and Gas Investigations Preliminary Chart 21.

________ (1951), *Stratigraphy of the Berea Sandstone and associated rocks in northeastern Ohio and northwestern Pennsylvania,* Geological Society of America Bulletin, v. 62, p. 1347–1369.

Dobrin, M. B. (1976), *Introduction to geophysical prospecting,* 3rd ed., New York, McGraw-Hill, 630 p.

Driscoll, F. G. (1986), *Groundwater and wells,* St. Paul, Minn., Johnson Division, 1089 p.

Durfor, C. N., and Anderson, P. W. (1963), *Chemical quality of surface waters in Pennsylvania,* U.S. Geological Survey Water-Supply Paper 1619–W, 50 p.

Eaton, G. P., and Watkins, J. S. (1970), *The use of seismic refraction and gravity methods in hydrogeological investigations,* in Morley, L. W., ed., *Mining and groundwater geophysics, 1967,* Geological Survey of Canada Economic Geology Report 26, p. 544–568.

Ferris, J. G., Knowles, D. B., Brown, R. H., and Stallman, R. W. (1962), *Theory of aquifer tests,* U.S. Geological Survey Water-Supply Paper 1536–E, p. 69–174.

Fetter, C. W., Jr. (1980), *Applied hydrogeology,* Columbus, Ohio, Charles E. Merrill, 488 p.

Flippo, H. N., Jr. (1982), *Technical manual for estimating low-flow characteristics of Pennsylvania streams,* Pennsylvania Department of Environmental Resources, Office of Resources Management, Water Resources Bulletin 15, 86 p.

Harrison, S. S. (1983), *Evaluating system for ground-water contamination hazards due to gas-well drilling on the glaciated Appalachian Plateau,* Ground Water, v. 21, p. 689–700.

Heath, R. C. (1983), *Basic ground-water hydrology,* U.S. Geological Survey Water-Supply Paper 2220, 84 p.

Hem, J. D. (1985), *Study and interpretation of the chemical characteristics of natural water,* 3rd ed., U.S. Geological Survey Water-Supply Paper 2254, 264 p.

Ibrahim, Abdelwahid, and Hinze, W. J. (1972), *Mapping buried bedrock topography with gravity,* Ground Water, v. 10, no. 3, p. 18–23.

Johnson, A. I. (1967), *Specific yield—Compilation of specific yields for various materials,* U.S. Geological Survey Water-Supply Paper 1662–D, 74 p.

Koester, H. E., and Miller, D. R. (1980), *Ground-water quality and data on wells and springs in Pennsylvania—Volume 1, Ohio and St. Lawrence River basins,* U.S. Geological Survey Open-File Report 80–1119, 95 p.

Krieger, R. A., Hatchett, J. L., and Poole, J. L. (1957), *Preliminary survey of the saline-water resources of the United States,* U.S. Geological Survey Water-Supply Paper 1374, 172 p.

Leggette, R. M. (1936), *Ground water in northwestern Pennsylvania,* Pennsylvania Geological Survey, 4th ser., Water Resource Report 3, 215 p.

Leverett, Frank (1902), *Glacial formations and drainage features of the Erie and Ohio basins,* U.S. Geological Survey Monograph 41, 802 p.

Lohman, S. W. (1972), *Ground-water hydraulics,* U.S. Geological Survey Professional Paper 708, 70 p.

Mangan, J. W., Van Tuyl, D. W., and White, W. F., Jr. (1952), *Water resources of the Lake Erie shore region in Pennsylvania,* U.S. Geological Survey Circular 174, 36 p.

Page, L. V., and Shaw, L. C. (1977), *Low-flow characteristics of Pennsylvania streams,* Pennsylvania Department of Environmental Resources, Office of Resources Management, Water Resources Bulletin 12, 441 p.

Pepper, J. F., de Witt, Wallace, Jr., and Demarest, D. F. (1954), *Geology of the Bedford Shale and Berea Sandstone in the Appalachian basin,* U.S. Geological Survey Professional Paper 259, 111 p.

Poth, C. W. (1962), *The occurrence of brine in western Pennsylvania,* Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 47, 53 p.

Randall, A. D., Thomas, M. P., Thomas, C. E., Jr., and Baker, J. A. (1966), *Water resources inventory of Connecticut—Part 1, Quinebaug River basin,* Connecticut Water Resources Bulletin 8, 102 p.

Rankin, W. E., and Lavin, P. M. (1970), *Analysis of a reconnaissance gravity survey for drift-filled valleys in the Mercer quadrangle, Pennsylvania,* Journal of Hydrology, v. 10, p. 418–435.

Rhodes, J. A. (1980), *The depth interpretation of gravity data for drift-filled valleys in Erie County, Pennsylvania,* University Park, Pennsylvania State University, M. S. thesis, 67 p.

Ruof, M. A. (1980), *Mapping of a buried drainage basin in the quadrangles of Albion, East Springfield, Fairview, and Fairview, S. W., Erie County, Pennsylvania,* Meadville, Pa., Allegheny College, B. S. thesis, 13 p.

Schiner, G. R., and Gallaher, J. T. (1979), *Geology and groundwater resources of western Crawford County, Pennsylvania,* Pennsylvania Geological Survey, 4th ser., Water Resource Report 46, 103 p.

Schiner, G. R., and Kimmel, G. E. (1972), *Mississippian stratigraphy of northwestern Pennsylvania,* U.S. Geological Survey Bulletin 1331-A, 27 p.

Shepps, V. C., White, G. W., Droste, J. B., and Sitler, R. F. (1959), *Glacial geology of northwestern Pennsylvania,* Pennsylvania Geological Survey, 4th ser., General Geology Report 32, 59 p.

Siddiqui, S. H., and Parizek, R. R. (1971), *Hydrogeologic factors influencing well yields in folded and faulted carbonate rocks in central Pennsylvania,* Water Resources Research, v. 7, no. 5, p. 1295–1312.

Spangler, D. P., and Libby, F. J. (1968), *Application of the gravity survey method to watershed hydrology,* Ground Water, v. 6, no. 6, p. 21–26.

Swenson, H. A., and Baldwin, H. L. (1965), *A primer on water quality,* U.S. Geological Survey, 27 p.

Tomikel, J. C., and Shepps, V. C. (1967), *The geography and geology of Erie County, Pennsylvania,* Pennsylvania Geological Survey, 4th ser., Information Circular 56, 64 p.

U.S. Department of Commerce, Bureau of the Census (1980), *Statistical abstract of the United States,* 1059 p.

U.S. Department of Commerce, Environmental Data Service (published annually, 1950–82), *Climatological data, Pennsylvania.*

U.S. Department of the Interior, Water and Power Resources Service (1981), *Ground water manual,* 2nd ed., U.S. Government Printing Office, 480 p.

U.S. Environmental Protection Agency (1975), *Manual of individual water supply systems,* Report EPA-430/9-74-007, 155 p.

__________ (1976), *Quality criteria for water,* U.S. Government Printing Office, 256 p.

__________ (1977), *National secondary drinking water regulations,* Federal Register, v. 42, no. 62, Thursday, March 31, 1977, Part I, p. 17143–17147.

__________ (1983), *National interim primary drinking water regulations,* Title 40, Chapter I, Pt. 141, Code of Federal Regulations, p. 230–236.

U.S. Geological Survey (1971), *1970 water resources data for Pennsylvania—Part 1, Surface water records,* U.S. Geological Survey, Water Resources Division, Harrisburg, Pa., 332 p.

__________ (1972a), *1970 water resources data for Pennsylvania—Part 2, Water quality records,* U.S. Geological Survey, Water Resources Division, Harrisburg, Pa., 293 p.

__________ (1972b), *1971 water resources data for Pennsylvania—Part 1, Surface water records,* U.S. Geological Survey, Water Resources Division, Harrisburg, Pa., 308 p.

__________ (1974), *1971 water resources data for Pennsylvania—Part 2, Water quality records,* U.S. Geological Survey, Water Resources Division, Harrisburg, Pa., 330 p.

__________ (1975a), *1974 water resources data for Pennsylvania—Part 1, Surface water records,* U.S. Geological Survey, Water Resources Division, Harrisburg, Pa., 331 p.

__________ (1975b), *1974 water resources data for Pennsylvania—Part 2, Water quality records,* U.S. Geological Survey, Water Resources Division, Harrisburg, Pa., 464 p.

__________ (1976), *Water resources data for Pennsylvania—Water year 1975—Volume 3, Ohio River and St.*

Lawrence River basins, U.S. Geological Survey Water-Data Report PA-75-3, 196 p.

———— (1977), *Water resources data for Pennsylvania—Water year 1976—Volume 3, Ohio River and St. Lawrence River basins,* U.S. Geological Survey Water-Data Report PA-76-3, 262 p.

———— (1978), *Water resources data for Pennsylvania—Water year 1977—Volume 3, Ohio River and St. Lawrence River basins,* U.S. Geological Survey Water-Data Report PA-77-3, 272 p.

———— (1979), *Water resources data for Pennsylvania [water year 1978]—Volume 3, Ohio River and St. Lawrence River basins,* U.S. Geological Survey Water-Data Report PA-78-3, 310 p.

White, G. W., Totten, S. M., and Gross, D. L. (1969), *Pleistocene stratigraphy of northwestern Pennsylvania,* Pennsylvania Geological Survey, 4th ser., General Geology Report 55, 88 p.

White, I. C. (1881), *The geology of Erie and Crawford Counties,* Pennsylvania Geological Survey, 2nd ser., Report Q4, 406 p.

Zohdy, A. A., Eaton, G. P., and Mabey, D. R. (1974), *Application of surface geophysics to ground-water investigations,* U.S. Geological Survey Techniques of Water-Resources Investigations, Book 2, Chapter D1, 116 p.

FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM UNITS (SI)

Multiply inch-pound units	*By*	*To obtain SI units*
inch (in.)	2.540	centimeter (cm)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square foot (ft^2)	.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
foot per second (ft/s)	3.281	meter per second (m/s)
foot per mile (ft/mi)	.1895	meter per kilometer (m/km)
cubic foot (ft^3)	.02832	cubic meter (m^3)
gallon (gal)	3.785	liter (L)
gallon per minute (gal/min)	.06309	liter per second (L/s)
gallon per day per foot [(gal/d)/ft]	12.42	liter per day per meter [(L/d)/m]
million gallons per day (Mgal/d)	.0438	cubic meter per second (m^3/s)
grains per gallon (gr/gal)	17.12	milligram per liter (mg/L)
micromhos (μmho)	1.0	microsiemens (μS)
degree Fahrenheit (°F)	$°C = 5/9(°F-32)$	degree Celsius (°C)

APPENDICES

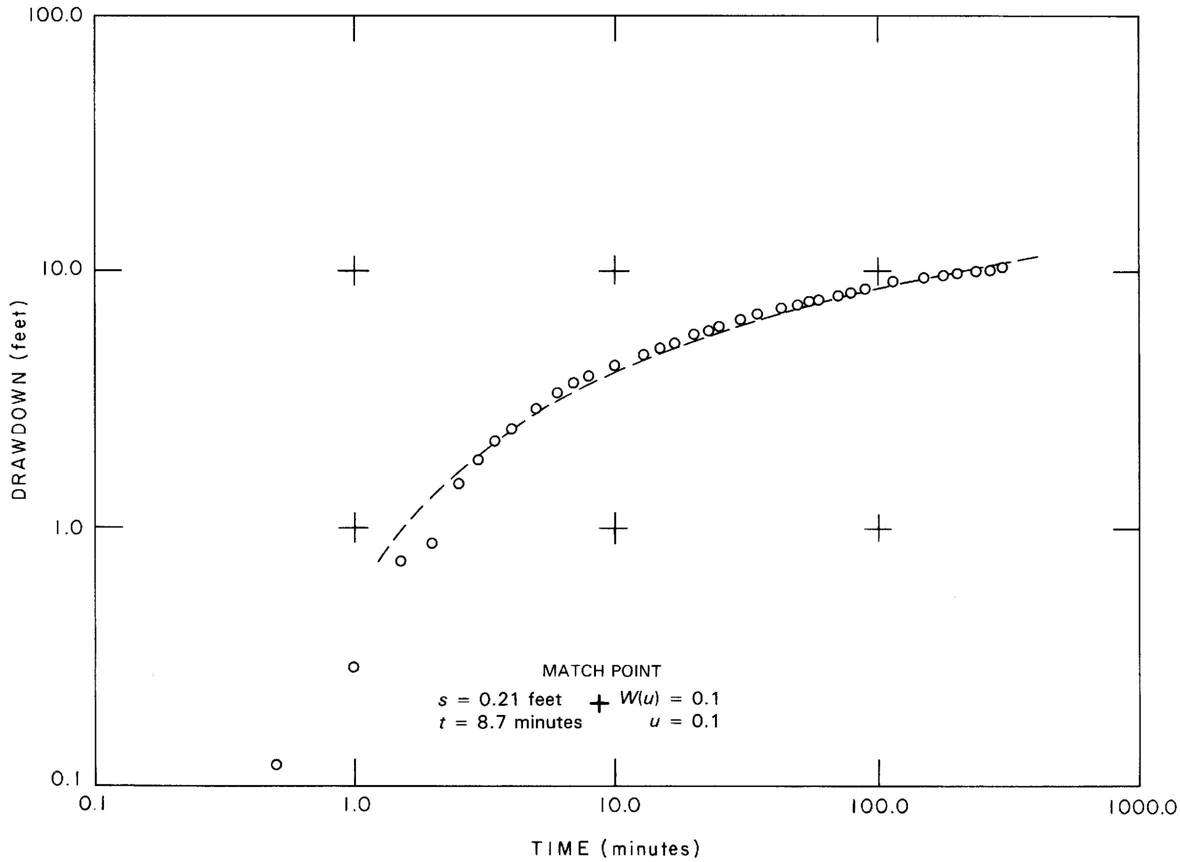
APPENDIX 1. AQUIFER TEST IN SUMMIT TOWNSHIP

An aquifer test in Summit Township was made by personnel of the U.S. Geological Survey. Well Er-80 was pumped and water levels were measured in an observation well 24 feet to the east. Both wells tapped the saturated fractured shale of the Venango Formation. Well Er-80 was pumped continuously for 5 hours at 21 gal/min (see table below). The water level in well Er-80 had declined from a static level of 6 feet below land surface to 37 feet below land surface, and only 1 foot of water remained above the pump intake. The base of the saturated fractured shale was at a depth of 44 feet, and the saturated thickness was 38 feet. The specific capacity for this test was 0.68 (gal/min)/ft. A plotting of the drawdown versus time is shown on the following graph. Using the Theis curve-fitting method,

Aquifer Test in Summit Township

Date: October 5, 1965
Location: Summit Township, Erie County
Proposed State Police barracks
Hydrologist-in-Charge: Harold Meisler, U.S. Geological Survey, Water Resources Division
East well observation: 24 feet from pumping well
Pumping-well discharge: Q = 21 gallons per minute

Elapsed time (minutes)	Water level (feet)	Drawdown (feet)	Elapsed time (minutes)	Water level (feet)	Drawdown (feet)
0	6.86	0	30	13.40	6.54
.25	6.87	.01	35	13.70	6.84
.50	6.98	.12	43	14.08	7.22
1	7.15	.29	50	14.33	7.47
1.5	7.60	.74	55	14.50	7.64
2	7.98	.88	60	14.62	7.76
2.5	8.35	1.49	71	14.895	8.035
3	8.70	1.84	80	15.145	8.285
3.5	9.03	2.17	90	15.45	8.59
4	9.31	2.45	115	16.065	9.20
5	9.81	2.95	120	16.14	9.28
6	10.19	3.33	140	16.33	9.47
7	10.51	3.65	150	16.41	9.55
8	10.76	3.90	165	16.53	9.67
10	11.17	4.31	180	16.62	9.76
13	11.64	4.78	202	16.75	9.89
15	11.93	5.07	211	16.81	9.95
17	12.18	5.32	240	16.95	10.09
20	12.52	5.66	273	17.21	10.35
23	12.85	5.99	300	17.46	10.60
25	13.04	6.18			



the hydraulic properties T and S are determined to be as follows:

$$T = 114.6\ \frac{QW(u)}{s} \qquad S = \frac{Tut}{2{,}693r^2}$$

$$T = 114.6 \times 21 \times \frac{0.1}{0.21} \qquad S = \frac{1{,}146 \times 0.1 \times 8.7}{2{,}693 \times (24)^2}$$

$$= 1{,}146\ [(\text{gal/d})/\text{ft}] \qquad = 0.0006427$$

where

s = drawdown in an observation well located at a given radius from the pumping well at a specific time since pumping began [in feet];

Q = uniform discharge from the pumping well [in gallons per minute];

T = transmissivity of the aquifer at the test site [in gallons per day per foot];

r = distance from the pumping well to the observation well [in feet];

S = coefficient of storage [no units];

t = time since pumping began [in days];

u = $\frac{r^2S}{4Tt}$; and

$W(u)$ = well function of u (table of values can be found in Ferris and others, 1962; Lohman, 1972; Fetter, 1980; Heath, 1983; and Driscoll, 1986).

The hydraulic conductivity for the fractured shale at this site would be about 4 ft/d [from $K = T/b = 1{,}100/(38 \times 7.48)$] (7.48 is the conversion factor for the number of gallons per cubic foot).

APPENDIX 2. REPRESENTATIVE DRILLERS' LOGS

Well Er-80
(Summit Township)

Latitude: 42°01′56″N
Longitude: 80°03′29″W
Aquifer: Venango Formation
Date drilled: August 20, 1965
Well depth: 53 feet
Land-surface altitude (LSD): 1,370 feet
Depth to water below LSD and date of measurement: 5 feet (October 4, 1965)

Lithologic description	Thickness (feet)	Depth (feet)
Clay, brown	8	8
Shale, black	5	13
Shale, black (broken)	31	44
Shale, black	9	53

Well construction: Hole drilled with cable-tool rig; 6-inch casing to depth of 46 feet, 7 inches, and perforated from 12 feet, 7 inches to 46 feet, 7 inches.

Well Er-82
(Washington Township)

Latitude: 41°56′07″N
Longitude: 80°04′46″W
Aquifer: Venango Formation
Date drilled: June 15, 1966
Well depth: 82 feet
Land-surface altitude (LSD): 1,419 feet
Depth to water below LSD and date of measurement: 17.0 feet (June 21, 1966)

Lithologic description	Thickness (feet)	Depth (feet)
Soil	1	1
Till, brown, with gravel and sand	12	13
Till, light-gray, with gravel and sand	42	55
Shale, dark-gray	27	82

Well construction: Hole drilled with air-rotary rig; 6-inch steel casing to 56 feet and then open hole to depth of well.

Well Er-120
(Union Township)

Latitude: 41°53′49″N
Longitude: 79°51′34″W
Aquifer: Glacial-outwash deposits
Date drilled: Unknown
Well depth: 160 feet
Land-surface altitude (LSD): 1,272 feet
Depth to water below LSD and date of measurement: Flowed in October 1928

Lithologic description	Thickness (feet)	Depth (feet)
Clay and gravel	110	110
Shale	50	160

Well construction: Cased to 110 feet and then open hole.

Well Er-126
(Union Township)

Latitude: 41°53′49″N
Longitude: 79°45′51″W
Aquifer: Glacial-outwash deposits
Date drilled: 1905
Well depth: 315 feet
Land-surface altitude (LSD): 1,355 feet
Depth to water below LSD and date of measurement: 5 feet (1905)

Lithologic description	Thickness (feet)	Depth (feet)
Gravel and "quicksand"	310	310
Sand, gray	5	315

Well construction: Hole drilled with cable-tool rig; cased the full depth of hole and open ended.

Well Er-137
(City of Corry)

Latitude: 41°55′41″N
Longitude: 79°38′28″W
Aquifer: Glacial-outwash deposits
Date drilled: 1926
Well depth: 402 feet
Land-surface altitude (LSD): 1,410 feet
Depth to water below LSD and date of measurement: 5 feet (1926)

Lithologic description	Thickness (feet)	Depth (feet)
Soil	2	2
Gravel	20	22
"Quicksand"	80	102
Clay, blue	280	382
Hardpan, gravelly	10	392
Shale	10	402

Well construction: Hole drilled with cable-tool rig; cased to 392 feet and then open hole; cased with 6-inch casing.

Well Er-370
(Girard Township)

Latitude: 42°00′37″N
Longitude: 80°17′51″W
Aquifer: Glacial-beach deposits
Date drilled: June 1972
Well depth: 61 feet
Land-surface altitude (LSD): 785 feet
Depth to water below LSD and date of measurement: 2.2 feet (June 19, 1972)

Lithologic description	Thickness (feet)	Depth (feet)
Clay and sand, blue, stratified	10	10
Silt, gray, and sand, fine	15	25
Sand, gray, fine, and silt	15	40
Sand, medium, and gravel	20	60
Till, compact	1	61

Well construction: Hole drilled with air-rotary rig; 12-inch and 8-inch steel casing to 49 feet, 8 inches, and then 10 feet of screen.

Well Er-323
(Springfield Township)

Latitude: 41°58′53″N
Longitude: 80°24′26″W
Aquifer: Glacial-beach deposits
Date drilled: August 17, 1970
Well depth: 96 feet
Land-surface altitude (LSD): 722 feet
Depth to water below LSD and date of measurement: 18 feet (August 17, 1970)

Lithologic description	Thickness (feet)	Depth (feet)
Sand, brown	11	11
Clay and gravel, brown	2	13
Clay and gravel, blue	72	85
Sand, fine, silty	.5	85.5
Clay, blue	5.5	91
Sand, coarse, with silt	1	92
Clay and gravel, hard-packed	8	100
Shale(?)	1	101

Well construction: Hole drilled with cable-tool rig; cased the full depth of hole with 8-inch steel casing and open ended.

Well Er-403
(Fairview Township)

Latitude: 42°00′51″N
Longitude: 80°13′02″W
Aquifer: Glacial-till deposits
Date drilled: April 1974
Well depth: 152 feet
Land-surface altitude (LSD): 952 feet
Depth to water below LSD and date of measurement: 83 feet (April 15, 1974)

Lithologic description	Thickness (feet)	Depth (feet)
Topsoil	1	1
Clay	49	50
Sand and gravel, cemented	3	53
Clay, "gummy," blue	76	129
Shale	33	152

Well construction: Hole drilled with cable-tool rig; 8-inch steel casing to 130 feet and then open hole.

Well Er-497
(Millcreek Township)

Latitude: 42°03′57″N
Longitude: 80°10′36″W
Aquifer: Glacial-outwash deposits
Date drilled: July 1969
Well depth: 44 feet
Land-surface altitude (LSD): 804 feet
Depth to water below LSD and date of measurement: 5 feet (July 18, 1969)

Lithologic description	Thickness (feet)	Depth (feet)
Clay and gravel, brown	12	12
Clay and gravel, blue	6	18
Clay and gravel, coarse, and sand	1	19
Clay and gravel, blue	17	36
Gravel, coarse, and sand	9	45
Clay, blue	5	50
Shale	5	55

Well construction: Hole drilled with cable-tool rig; 10-inch steel casing to 39 feet and then 5 feet of screen.

Well Er-556
(Fairview Township)

Latitude: 42°04′06″N
Longitude: 80°13′38″W
Aquifer: Glacial-beach deposits
Date drilled: January 15, 1969
Well depth: 73 feet
Land-surface altitude (LSD): 690 feet
Depth to water below LSD and date of measurement: 4 feet (January 15, 1969)

Lithologic description	Thickness (feet)	Depth (feet)
Gravel and sand, brown	28	28
Clay and gravel, blue	17	45
Sand, fine, and silt (water-bearing)	3	48
Clay and gravel, blue	5	53
Shale, blue	20	73

Well construction: No casing.

Well Er-711
(Harborcreek Township)

Latitude: 42°11′32″N
Longitude: 79°57′13″W
Aquifer: Glacial-till deposits
Date drilled: April 6, 1968
Well depth: 82 feet
Land-surface altitude (LSD): 660 feet
Depth to water below LSD and date of measurement: 50 feet (April 1968)

Lithologic description	Thickness (feet)	Depth (feet)
Clay, brown, sandy	14	14
Clay and gravel, blue	10	24
Sand, blue, fine (water-bearing)	1	25
Clay and gravel, hard-packed	43	68
Shale, blue	14	82

Well construction: Hole drilled with cable-tool rig; 8-inch steel casing to 72 feet and then open hole.

Well Er-808
(Venango Township)

Latitude: 42°04′15″N
Longitude: 79°50′31″W
Aquifer: Glacial-outwash deposits
Date drilled: July 20, 1964
Well depth: 100 feet
Land-surface altitude (LSD): 1,320 feet
Depth to water below LSD and date of measurement: 3 feet (July 20, 1964)

Lithologic description	Thickness (feet)	Depth (feet)
Clay and gravel, yellow	12	12
Gravel and sand, brown (water-bearing)	4	16
Clay, blue	74	90
Sand, blue, fine	6	96
Gravel and sand, coarse (water-bearing)	4	100

Well construction: Hole drilled with cable-tool rig; cased to 95 feet and then 4 feet of perforated casing; cased with 6-inch casing.

Well Er-947
(Millcreek Township)

Latitude: 42°05′17″N
Longitude: 80°02′01″W
Aquifer: Glacial-outwash deposits
Date drilled: March 21, 1963
Well depth: 119 feet
Land-surface altitude (LSD): 1,089 feet
Depth to water below LSD and date of measurement: 90 feet (March 21, 1963)

Lithologic description	Thickness (feet)	Depth (feet)
Clay and gravel, brown	19	19
Clay and gravel, blue	9	28
Sand and gravel, brown, cemented	18	46
"Quicksand"	26	72
Clay and gravel, blue	45	117
Gravel, blue, hard	1	118
Shale, blue	1	119

Well construction: Hole drilled with cable-tool rig; 6-inch steel casing to 115 feet and then 4 feet of perforated casing.

Well Er-971
(Concord Township)

Latitude: 41°55′08″N
Longitude: 79°40′11″W
Aquifer: Glacial-outwash deposits
Date drilled: March 5, 1971
Well depth: 220 feet
Land-surface altitude (LSD): 1,392 feet
Depth to water below LSD and date of measurement: 0 feet (March 1971)

Lithologic description	Thickness (feet)	Depth (feet)
Clay and gravel	10	10
Clay, blue	30	40
Clay and gravel	20	60
Sand	100	160
Clay and gravel	20	180
"Quicksand"	10	190
Clay and gravel	24	214
Rock	6	220

Well construction: Hole drilled with cable-tool rig; 6-inch steel casing to 214 feet and then open hole.

Well Er-1041
(Le Boeuf Township)

Latitude: 41°54′29″N
Longitude: 79°55′05″W
Aquifer: Glacial-outwash deposits
Date drilled: October 30, 1969
Well depth: 70 feet
Land-surface altitude (LSD): 1,214 feet
Depth to water below LSD and date of measurement: 35 feet (October 30, 1969)

Lithologic description	Thickness (feet)	Depth (feet)
Gravel, brown, coarse	12	12
Clay and gravel, brown	3	15
Clay and gravel, blue	15	30
Gravel and clay, hard	18	48
Sand, fine	1	49
Sand and gravel, cemented	21	70

Well construction: Hole drilled with cable-tool rig; 8-inch steel casing down to 70 feet and then open end.

Well Er-1081
(Le Boeuf Township)

Latitude: 41°54′33″N
Longitude: 79°58′40″W
Aquifer: Glacial-outwash deposits
Date drilled: October 1966
Well depth: 34 feet
Land-surface altitude (LSD): 1,175 feet
Depth to water below LSD and date of measurement: 10 feet (October 1966)

Lithologic description	Thickness (feet)	Depth (feet)
Clay and gravel, brown	10	10
Gravel, brown	2	12
Clay and gravel, blue	22	34

Well construction: Hole drilled with cable-tool rig; 8-inch steel casing to 34 feet and then open end.

Well Er-1172
(McKean Township)

Latitude: 41°59′03″N
Longitude: 80°03′55″W
Aquifer: Venango Formation
Date drilled: May 1975
Well depth: 160 feet
Land-surface altitude (LSD): 1,325 feet
Depth to water below LSD and date of measurement: 62 feet (May 2, 1975)

Lithologic description	Thickness (feet)	Depth (feet)
Clay and gravel, brown	8	8
Gravel and clay, blue	7	15
Clay, blue	8	23
Gravel, blue	7	30
Sand, blue	1	31
Clay and gravel, blue	94	125
Sand and gravel, cemented	1	126
Shale, rock	34	160

Well construction: Hole drilled with cable-tool rig; 8-inch casing down to 130 feet and then open hole.

Well Er-1331
(Greene Township)

Latitude: 42°04′27″N
Longitude: 79°58′06″W
Aquifer: Glacial-outwash deposits
Date drilled: November 1977
Well depth: 108 feet
Land-surface altitude (LSD): 1,210 feet
Depth to water below LSD and date of measurement: 2 feet above LSD (November 1977)

Lithologic description	Thickness (feet)	Depth (feet)
Clay and gravel, brown	12	12
Gravel and clay, blue	12	24
Sand and gravel, blue	12	36
Clay, gravel, and sand, pink	8	44
Sand and gravel, blue	5	49
Gravel and clay, blue	2	51
Clay, blue	24	75
Clay and gravel, blue	17	92
Shale	16	108

Well construction: Hole drilled with cable-tool rig; 8-inch casing down to 94 feet and then open hole.

Well Er-1285
(McKean Township)

Latitude: 42°01′15″N
Longitude: 80°11′10″W
Aquifer: Glacial-outwash deposits
Date drilled: April 4, 1977
Well depth: 145 feet
Land-surface altitude (LSD): 1,100 feet
Depth to water below LSD and date of measurement: 78 feet (April 1, 1977)

Lithologic description	Thickness (feet)	Depth (feet)
Clay, brown	8	8
Clay and gravel	67	75
Sand	1	76
Clay and cobbles, blue	58	134
Sand and gravel	3	137
Shale	8	145

Well construction: Hole drilled with cable-tool rig; 8-inch casing down to 140 feet and then open hole.

Well Er-1423
(Waterford Township)

Latitude: 41°56′03″N
Longitude: 79°58′46″W
Aquifer: Glacial-outwash deposits
Date drilled: August 13, 1956
Well depth: 227 feet
Land-surface altitude (LSD): 1,180 feet
Depth to water below LSD and date of measurement: 80 feet (no date)

Lithologic description	Thickness (feet)	Depth (feet)
Sand and gravel, and clay and gravel, blue	20	20
"Quicksand"	70	90
Clay and gravel, blue, sandy	35	125
Sand and gravel, cemented	10	135
Clay and gravel, blue	20	155
Shale, black(?)	72	227

Well construction: Hole drilled with cable-tool rig; 7-inch casing down to 155 feet and then open hole.

Well Er-1481
(Conneaut Township)

Latitude: 41°56′24″N
Longitude: 80°21′49″W
Aquifer: Glacial-till deposits
Date drilled: October 5, 1978
Well depth: 141 feet
Land-surface altitude (LSD): 850 feet
Depth to water below LSD and date of measurement: 35 feet (October 5, 1978)

Lithologic description	Thickness (feet)	Depth (feet)
Clay, blue	89	89
Sand, brown, very fine	2	91
Clay, gray	13	104
Clay, blue, gray	33	137
Shale	3	140

Well construction: Hole drilled with cable-tool rig; 8-inch steel casing down to 111 feet and then open hole.

Well Er-1536
(Wayne Township)

Latitude: 41°56′23″N
Longitude: 79°38′28″W
Aquifer: Glacial-outwash deposits
Date drilled: August 1974
Well depth: 209 feet
Land-surface altitude (LSD): 1,415 feet
Depth to water below LSD and date of measurement: No data

Lithologic description	Thickness (feet)	Depth (feet)
Topsoil	2	2
Gravel	2	4
Sand and gravel	4	8
Clay and gravel, brown	7	15
Clay, brown; some gravel, fine	10	25
Gravel, fine	4	29
Clay and gravel, gray	8	37
Clay, blue	162	199
Shale, gray, sandy	10	209

Well construction: Hole drilled with air-rotary rig; 8-inch steel casing down to 200 feet and then open hole.

Well Er-1484
(Conneaut Township)

Latitude: 41°54′18″N
Longitude: 80°21′37″W
Aquifer: Glacial-outwash deposits
Date drilled: August 1960
Well depth: 111 feet
Land-surface altitude (LSD): 892 feet
Depth to water below LSD and date of measurement: No data

Lithologic description	Thickness (feet)	Depth (feet)
Clay and gravel, yellow, mixed	15	15
Clay and gravel, blue, mixed	7	22
Gravel, coarse	2	24
Clay and gravel, blue	1	25
Gravel, coarse	2	27
Clay, blue	22	49
Gravel, coarse	4	53
Clay, blue	1	54
Sand, blue, fine	20	74
Clay, blue	36	110
Shale	1	111

Well construction: Hole drilled with cable-tool rig; steel casing down to 110 feet and then open end.

Well Er-1648
(Concord Township)

Latitude: 41°55′04″N
Longitude: 79°43′29″W
Aquifer: Glacial-outwash deposits
Date drilled: June 26, 1964
Well depth: 138 feet
Land-surface altitude (LSD): 1,404 feet
Depth to water below LSD and date of measurement: Flowed on June 26, 1964

Lithologic description	Thickness (feet)	Depth (feet)
Clay and gravel, yellow	12	12
"Quicksand," brown	14	26
Clay, blue	10	36
"Quicksand"	14	50
Clay, blue	40	90
Sand, fine, with trace gravel, coarse	2	92
Clay, blue	38	130
Gravel	2	132
Clay, blue	4	136
Shale, blue	2	138

Well construction: Hole drilled with cable-tool rig; 6-inch steel casing down to 134 feet and then 4 feet of perforated casing.

Well Er-1661
(Wayne Township)

Latitude: 41°56'32"N
Longitude: 79°38'39"W
Aquifer: Glacial-outwash deposits
Date drilled: August 1974
Well depth: 71 feet
Land-surface altitude (LSD): 1,420 feet
Depth to water below LSD and date of measurement: 16.3 feet (August 1974)

Lithologic description	Thickness (feet)	Depth (feet)
Gravel, fine	22	22
Sand and gravel	15	37
Sand and gravel; some clay	15	52
Sand and gravel; some silty clay	19	71

Well construction: Hole drilled with air-rotary rig; 12-inch steel casing down to 59 feet and then screen to bottom of hole.

Well Er-1680
(Wayne Township)

Latitude: 41°55'50"N
Longitude: 79°40'10"W
Aquifer: Glacial-outwash deposits
Date drilled: February 1968
Well depth: 405 feet
Land-surface altitude (LSD): 1,420 feet
Depth to water below LSD and date of measurement: 12.2 feet (February 1968)

Lithologic description	Thickness (feet)	Depth (feet)
Topsoil	1	1
Clay and gravel	6	7
Gravel and sand	8	15
Clay and gravel	13	28
Gravel with streaks of clay	16	44
Clay and gravel	12	56
Clay	4	60
Sand	11	71
Clay	4	75
"Quicksand"	15	90
Clay and gravel	15	105
Clay	293	398
Clay and gravel	4	402
Rock	3	405

Well construction: Hole drilled with air-rotary rig; 8-inch casing.

Well Er-1719
(North East Township)

Latitude: 42°12'51"N
Longitude: 79°46'19"W
Aquifer: Girard Shale
Date drilled: June 21, 1968
Well depth: 95 feet
Land-surface altitude (LSD): 1,108 feet
Depth to water below LSD and date of measurement: 34 feet (June 21, 1968)

Lithologic description	Thickness (feet)	Depth (feet)
Clay and gravel, yellow	8	8
Gravel, coarse, and clay	9	17
Clay and gravel, blue	6	23
Clay and gravel, brown	5	28
Clay and gravel, blue	1	29
Shale, rock, blue	66	95

Well construction: Hole drilled with cable-tool rig; 8-inch steel casing down to 32 feet and then open hole.

Well Er-1723
(Amity Township)

Latitude: 41°59'02"N
Longitude: 79°50'14"W
Aquifer: Glacial-outwash deposits
Date drilled: July 1974
Well depth: 85 feet
Land-surface altitude (LSD): 1,284 feet
Depth to water below LSD and date of measurement: No data

Lithologic description	Thickness (feet)	Depth (feet)
Gravel, brown	11	11
Clay, brown-gray	17	28
Sand and gravel, cemented	13	41
Clay and gravel, blue	13	54
Clay and gravel, brown	1	55
Clay and gravel, blue	1	56
Clay, blue	13	69
Hardpan	4	73
Clay, blue	9	82
Shale, blue	3	85

Well construction: Hole drilled with cable-tool rig; 8-inch steel casing down to 52 feet and then open hole.

Table 9. *Field Analyses of Groundwater*

Aquifer: Qb, glacial-beach deposits; Qo, glacial-outwash deposits; Qt, glacial-till deposits; MDbr, Berea Sandstone through Riceville Formation, undivided; MDcr, Corry Sandstone through Riceville Formation, undivided; MDbv, Berea Sandstone through Venango Formation, undivided; Dv, Venango Formation; Dch, Chadakoin Formation; Dg, Girard Shale; Dne, Northeast Shale.

Well number	Aquifer	Date of analysis or comment	Iron (mg/L)	Chloride (mg/L)	Hardness (mg/L as $CaCO_3$)	Specific conductance (µmho/cm at 25°C)	Remarks (*indicates driller's comments)
Er- 45	Qb	6/22/79	0.28	20	190	460	---
67	MDbv	7/26/28	---	---	---	---	*Salty; gas.
68	MDbv	6/11/29	---	---	---	---	*Very salty.
69	MDbv	6/11/29	---	---	---	---	*Very salty.
71	Qo	7/26/28	---	---	---	---	*Gas from gravel; salty.
72	Dch	7/26/28	---	---	---	---	*Salty.
91	Qo	9/13/78	.01	32	120	420	---
99	Qo	6/30/28	---	---	---	---	*Slightly salty; sulfur odor.
103	Dne	7/ 2/28	---	---	---	---	*Slightly salty; gas.
104	Dne	7/ 2/28	---	---	---	---	*Salty; gas.
106	Dne	7/ 2/28	---	---	---	---	*Salty.
107	Qt	7/ 2/28	---	---	---	---	*Some gas.
109	Dne	7/ 2/28	---	---	---	---	*Gas.
114	Qo	9/13/78	.01	2	75	220	---
115	Qo	7/ 3/28	---	---	---	---	*Sulfur odor.
128	Qo	6/20/79	.09	50	30	560	---
148	MDbv	7/12/79	.05	120	35	1,100	---
164	Qt	7/16/79	.44	22	220	530	---
185	Dch	6/22/79	.75	5	90	330	---
189	Qo	5/10/71	---	---	---	---	*Very hard; very high iron.
210	Dg	7/28/70	---	---	---	---	*Gas; sulfur odor.
218	Qo	12/ 7/66	---	---	---	---	*Gas at 61 feet.
241	Qo	7/16/79	.05	28	190	640	---
272	Qo	7/ 8/64	---	---	---	---	*Gas at bottom.
289	Dch	6/ 6/79	.11	30	160	430	---
292	Qo	6/13/79	.12	10	130	500	---
296	Qo	7/ 9/75	---	---	---	---	*Strong sulfur odor.
310	Qt	7/ 6/79	.28	32	160	640	---
314	Qo	7/ 6/79	.05	8	260	610	---
317	Qo	9/20/68	---	---	---	---	*Gas at 80 feet.
332	Qt	7/ 6/79	.59	190	310	1,050	---
339	Dch	9/15/70	---	---	---	---	*Iron bacteria.
344	Dch	10/19/73	---	---	---	---	*Very high iron.
345	Dch	7/ 6/79	.039	22	100	310	---
347	Qt	7/ 6/79	.08	28	70	300	---
365	Qt	6/28/75	---	---	---	---	*Gas at 74 feet.
375	Qb	7/ 6/79	.08	15	160	330	---
377	Qb	8/ 1/72	---	---	---	---	*Gas and salt water at 50 feet.
378	Qb	7/ 6/79	.20	42	180	550	---
404	Qt	7/ 6/79	.14	2	20	390	---
414	Dch	7/ 6/79	.17	450	140	2,400	---
427	Qo	7/ 6/79	2.6	20	150	580	---
429	Qo	7/ 6/79	.09	15	5	500	---
455	Qo	7/ 6/79	.03	60	200	720	---
503	Qo	7/ 6/79	.20	550	720	2,700	---
520	Qo	12/ 8/67	---	---	---	---	*Sulfur odor.
536	Qo	7/ 6/79	.28	20	190	460	---
555	Qb	4/ 6/72	---	---	---	---	*Very hard.
556	Qb	7/ 6/79	.05	1,000	310	3,500	Well abandoned.
562	Dv	7/ 6/79	.32	250	25	1,500	---
591	MDbv	7/ 6/79	.15	22	125	490	---
596	Qo	7/ 6/79	.60	18	105	430	---
608	MDbv	6/23/76	---	---	---	---	*Gassy, oily water.
609	MDbv	11/30/68	---	---	---	---	*Gas and sulfur odor at 70 feet.
620	MDcr	6/28/79	1.25	5	60	190	---
622	MDcr	6/28/79	.05	5	110	305	---
624	MDcr	6/28/79	.05	20	115	320	---
637	Dv	6/25/79	.04	5	105	280	---

Table 9. *(Continued)*

Well number	Aquifer	Date of analysis or comment	Iron (mg/L)	Chloride (mg/L)	Hardness (mg/L as $CaCO_3$)	Specific conductance (μmho/cm at 25°C)	Remarks (*indicates driller's comments)
Er- 643	Qt	6/25/79	.08	200	90	1,200	---
649	Dch	10/12/73	---	---	---	---	*Salty.
650	Dch	6/25/79	.05	15	170	410	---
654	Dch	6/25/79	.04	25	75	330	---
658	Dch	6/25/79	.02	110	310	840	---
660	Qt	6/25/79	.90	72	85	590	---
663	Qt	6/25/79	.08	35	60	525	---
664	Dg	6/25/79	1.19	12	160	500	---
666	Dne	6/25/79	.03	25	150	400	---
668	Dne	6/18/73	--	---	---	---	*Gas at 60 feet.
675	Qo	6/25/79	.05	15	70	330	---
677	Qt	6/25/79	.09	70	170	600	---
680	Dch	6/25/79	.06	8	5	220	---
690	Dch	6/25/79	.02	30	170	460	---
694	Dne	9/24/72	---	---	---	---	*Gas at 48 feet; plugged back.
702	Dg	12/17/75	---	---	---	---	*Gas at 56 feet.
704	Dg	6/25/79	2.2	62	240	700	---
706	Dne	8/26/67	---	---	---	---	*Sulfur odor.
707	Dne	6/25/79	.45	50	140	560	---
713	Qo	6/25/79	.52	28	200	530	---
714	Dne	6/25/79	.04	40	200	600	---
726	Qt	6/28/79	.41	5	100	260	---
744	Dch	9/25/72	---	---	---	---	*Some natural gas.
756	Dch	6/21/79	.29	8	95	230	---
766	Dch	6/21/79	.08	22	140	380	---
777	Dv	6/21/79	.01	25	140	400	---
806	Qo	6/21/79	.08	3	120	290	---
810	Qt	4/23/74	---	---	---	---	*High iron.
822	Qo	6/21/79	.25	58	110	550	---
829	Dv	6/21/79	.20	15	115	620	---
852	Qt	6/21/79	.16	22	160	600	---
863	Dch	6/ 3/76	---	---	---	---	*Natural gas at 50 feet.
872	Dch	7/20/71	---	---	---	---	*Salty at 60 feet.
879	Qo	6/21/79	.06	18	240	625	---
893	Qo	6/21/79	.22	35	120	565	---
919	Qt	2/10/73	---	---	---	---	*Some natural gas.
940	Qo	12/28/76	---	---	---	---	*Strong sulfur odor.
957	Qt	7/ 9/79	.18	28	140	540	---
967	Qo	7/ 9/79	.02	18	140	370	---
968	MDcr	7/ 9/79	.09	10	120	280	---
969	Qo	7/ 9/79	.25	2	95	300	---
971	Qo	7/ 9/79	.18	68	90	700	---
1015	Dch	7/ 9/79	2.0	5	110	265	---
1026	Dch	7/ 9/79	.05	10	200	500	---
1029	Qo	7/ 9/79	.02	180	400	1,000	---
1032	Dv	7/ 9/79	.10	20	120	420	---
1041	Qo	7/ 9/79	.05	5	120	270	---
1042	Dch	7/ 9/79	.03	15	85	370	---
1048	Dv	7/ 9/79	.05	8	120	300	---
1061	Qo	6/14/79	.23	1,220	510	4,800	---
1064	Qo	8/22/79	.12	5	90	245	---
1073	Dch	6/18/79	.08	8	85	245	---
1077	Qo	6/18/79	.01	8	140	320	---
1085	Dv	6/18/79	.04	5	50	300	---
1086	Qo	6/18/79	.08	5	120	300	---
1087	Dv	6/18/79	.10	40	230	600	---
1091	Dv	6/18/79	.17	80	180	530	---
1092	Qt	6/18/79	.02	8	180	420	---
1094	Qo	6/18/79	.08	8	90	290	---
1096	MDcr	6/18/79	.05	10	85	240	---
1100	Dv	6/18/79	.15	45	160	500	---
1101	Dv	6/18/79	.25	8	150	375	---
1110	MDbr	8/ 8/79	.70	2	210	480	---
1113	Qo	8/10/79	.11	5	90	225	---
1115	Dv	8/22/79	.43	6	160	360	---
1120	Qo	8/23/79	.15	9	100	220	---

Table 9. *(Continued)*

Well number	Aquifer	Date of analysis or comment	Iron (mg/L)	Chloride (mg/L)	Hardness (mg/L as $CaCO_3$)	Specific conductance (μmho/cm at 25°C)	Remarks (*indicates driller's comments)
Er-1121	Qt	8/15/79	.05	2	110	300	---
1129	Dv	8/28/79	.26	2	120	380	---
1131	MDbr	8/24/79	.02	2	120	300	---
1132	MDbr	7/23/68	---	---	---	---	*Natural gas at 75 feet.
1135	Dv	8/22/79	.19	5	120	310	---
1141	Dv	8/ 9/79	.18	8	85	340	---
1143	Dv	7/31/79	.02	8	180	410	---
1146	Dv	8/10/79	.15	15	20	580	---
1153	Dv	8/ 9/79	.18	18	150	650	---
1172	Dv	8/ 7/79	.02	150	60	1,200	---
1175	Qo	8/ 8/79	.02	180	95	1,700	---
1179	Dv	7/29/66	---	---	---	---	*Shale gas at 32 feet.
1180	MDbv	7/30/79	.23	32	120	560	---
1185	Qo	7/24/79	.07	8	140	340	---
1230	Dch	6/15/79	3.2	8	190	700	---
1232	Dv	---	---	---	---	---	*Natural gas at 83 feet.
1237	MDbv	6/15/79	.05	42	80	520	---
1239	Dch	6/15/79	.03	5	50	275	---
1245	Qt	6/15/79	.01	15	5	650	---
1254	Qo	6/28/79	1.1	380	120	1,850	---
1256	Qo	6/15/79	.03	8	100	275	---
1259	Qt	6/15/79	.02	5	10	525	---
1267	Qt	6/15/79	3.0	18	230	800	---
1279	MDbv	6/28/79	.19	5	110	300	---
1280	MDbv	6/28/79	.15	550	180	2,800	---
1283	Dch	6/28/79	.17	18	200	520	---
1291	Qo	6/28/79	.1	10	90	380	---
1311	Dch	6/28/79	.12	5	110	275	---
1313	Qt	6/28/79	.28	5	100	270	---
1316	Dch	6/28/79	.02	78	120	610	---
1318	Qb	5/21/76	---	---	---	---	*Natural gas at 35 feet.
1319	Dne	6/28/79	.08	40	120	420	---
1321	Dg	6/28/79	.21	68	220	650	---
1325	Dch	8/ 9/79	1.6	30	75	305	---
1330	Dch	6/28/79	.03	48	55	490	---
1334	Dch	6/28/79	.05	5	80	260	---
1343	Qt	6/28/79	.02	5	140	350	---
1354	Dch	7/11/79	.05	20	150	600	---
1356	Qt	5/31/77	---	---	---	---	*Sulfur odor.
1357	Qo	5/27/77	---	---	---	---	*Sulfur odor.
1368	Dv	6/11/64	---	---	---	---	*Gas at 60 feet.
1372	Dch	7/11/79	.15	65	55	745	---
1394	Qo	8/19/79	.05	50	110	320	---
1396	MDbr	7/19/79	.04	6	200	440	---
1397	Dv	7/19/79	.13	80	55	780	---
1397	Dv	9/--/51	---	---	---	---	*Gas at 63 feet.
1408	Dch	7/19/79	.06	12	35	420	---
1411	Qo	7/19/79	.14	12	100	300	---
1413	Dch	7/11/79	.10	18	85	240	---
1415	Qb	7/19/79	.37	320	160	1,450	---
1417	Dne	7/11/79	.09	38	120	400	---
1423	Qo	8/13/56	---	---	---	---	*Salty water.
1424	Qo	7/19/79	.18	10	100	270	---
1425	Qb	---	---	---	---	---	*Very hard.
1431	Qt	---	---	---	---	---	*Very hard.
1440	Qt	7/11/79	.38	45	240	830	---
1443	Qo	7/11/79	1.1	75	---	750	---
1445	Dch	7/11/79	.02	10	80	405	---
1448	Dch	7/19/79	.03	8	100	340	---
1452	Qo	7/11/79	.5	8	210	450	---
1458	Dch	7/19/79	.07	6	120	300	---
1460	Qo	9/ 6/78	.22	2	75	200	---
1469	Qo	7/19/79	.3	6	95	260	---
1474	Dch	7/11/79	.1	12	140	370	---
1477	Qo	7/11/79	.08	18	120	310	---

Table 9. *(Continued)*

Well number	Aquifer	Date of analysis or comment	Iron (mg/L)	Chloride (mg/L)	Hardness (mg/L as $CaCO_3$)	Specific conductance (µmho/cm at 25°C)	Remarks (*indicates driller's comments)
Er-1481	Qt	10/ 1/78	.03	10	85	450	At 89-foot depth.
1481	Qt	10/ 3/78	.07	75	150	720	At 100-foot depth.
1481	Qt	10/ 5/78	.1	400	185	2,300	At 141-foot depth.
1481	Qt	7/19/79	.1	425	95	2,500	---
1482	Qt	7/19/79	.55	18	120	600	---
1488	Qo	9/13/78	.05	2	125	340	---
1488	Qo	7/19/79	.09	5	140	340	---
1490	Dv	9/13/79	.02	2	145	390	---
1495	Dv	4/22/76	---	---	---	---	*Salt and gas at 70 feet.
1495	Dv	7/19/79	.13	600	160	2,800	Cemented back to 61 feet.
1496	Qt	7/31/76	---	---	---	---	*Salt and gas at 59 feet; plugged back to 55 feet.
1512	Qb	7/23/79	.10	58	200	600	---
1544	Qo	7/27/79	.18	10	120	320	---
1561	Dch	7/16/79	.57	55	210	635	---
1564	Dch	7/24/79	.60	12	100	395	---
1567	Qo	7/24/79	.03	25	150	440	---
1569	Dv	8/29/79	.12	5	120	310	---
1574	MDbr	7/24/79	.05	4	140	360	---
1575	Qb	7/16/79	.08	22	190	480	---
1578	Qo	12/--/51	---	---	---	---	*Gas from bedrock.
1579	Qb	7/16/79	.20	22	140	430	---
1581	Qb	---	---	---	---	---	*Hard; very low iron.
1583	Qo	7/24/79	.23	72	240	560	---
1587	Dch	7/24/79	.11	5	100	325	---
1593	MDcr	11/19/70	---	---	---	---	*Hard; high iron.
1599	Qt	7/16/79	3.3	28	570	1,400	---
1605	Dv	7/27/79	.05	32	140	360	---
1609	Qt	8/21/79	.20	2	80	240	---
1612	Dch	7/27/79	.10	4	110	280	---
1614	Dv	7/27/79	.05	120	120	950	---
1616	Qt	7/24/79	.08	32	180	470	---
1618	Qt	7/16/79	.25	25	110	400	---
1619	Dch	7/16/79	.05	22	110	400	---
1622	Qo	7/16/79	.15	5	140	360	---
1623	Dv	10/ 2/72	---	---	---	---	*Hard; very high iron.
1626	Dch	7/16/79	.02	20	240	560	---
1630	Qt	7/16/79	.07	5	150	380	---
1642	Qt	7/27/79	.03	12	120	440	---
1643	Qo	7/24/79	.01	18	170	420	---
1644	Qb	1/23/67	---	---	---	---	*Gas at 25 feet.
1644	Qb	7/24/79	3.3	32	320	800	---
1646	Dne	12/24/66	---	---	---	--	*Some gas; very salty.
1647	MDbv	7/27/79	.52	4	170	510	---
1649	Dv	7/16/79	.09	30	120	350	---
1650	MDcr	7/16/79	2.5	22	85	230	---
1651	Qt	7/24/79	.43	250	200	1,700	---
1652	Qo	7/24/79	.03	5	110	280	---
1666	Dch	7/24/79	.16	5	130	320	---
1668	Qt	6/28/77	---	---	---	---	*Very high iron.
1693	Qo	9/13/78	.20	8	100	260	---
1694	Qt	8/20/79	.32	2	110	300	---
1696	Qt	9/ 9/79	1.4	15	180	380	---
1708	Qo	8/19/79	.10	10	125	320	---
1722	Qo	9/ 6/78	.01	15	120	320	---

Table 10. *Chemical Analyses of Groundwater from Selected Wells*[1]

(Results are in milligrams per liter unless otherwise indicated)

Aquifer: Qb, glacial-beach deposits; Qo, glacial-outwash deposits; Qt, glacial-till deposits; MDbv, Berea Sandstone through Venango Formation, undivided; Dch, Chadakoin Formation; Dg, Girard Shale; Dne, Northeast Shale.

Well number	Aquifer	Date of sampling	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Dissolved solids	Hardness (as $CaCO_3$)	Specific conductance (µmho/cm at 25°C)
Er- 2	Qo	5/23/51	0.67	61	14	11	1.9	217	37	9.0	259	210	428
3	Dch	5/24/51	1.3	32	12	132	4.4	144	17	206	491	130	949
4	Qo	5/25/51	.42	61	15	5.4	1.8	227	30	4.0	247	210	416
5	Qo	5/24/51	.96	41	20	159	5.2	386	46	110	587	190	1,020
6	Qb	5/24/51	1.3	68	12	4.2	1.4	182	69	7.0	268	220	434
7	Dg	5/24/51	66	48	14	7.8	2.1	104	80	18	241	180	395
8	Qo	5/23/51	.29	85	20	4.5	1.9	230	88	14	348	300	559
67	MDbv	9/27/28	.42	32	14	160	6.3	406	3.2	115	[2]544	140	---
73	Qb	7/22/29	.12	58	12	3.4	4.0	171	41	6.0	[2]239	190	---
91	Qo	9/25/28	.39	27	7.8	26	1.6	168	14	3.2	[2]179	100	---
98	Qo	10/ 1/28	.30	25	8.3	37	2.2	162	5.1	28	[2]204	97	---
102	Dne	9/27/28	.38	28	6.4	4.4	1.6	48	48	10	[2]133	96	---
116	Qo	10/ 2/28	.08	30	9.6	9.1	1.1	148	6.4	2.8	[2]147	110	---
132	Qo	9/26/28	.19	27	7.7	7.7	1.4	121	18	1.8	[2]137	99	---
132	Qo	9/30/64	.22	28	7.8	16	.7	132	19	3.8	144	100	252
136	Qo	7/20/29	.05	36	6.4	3.0	3.5	130	19	3.6	158	120	---
141	Qo	10/ 5/64	.49	35	11	27	1.1	168	25	15	207	130	340
1523	Qb	11/16/73	.18	68	17	144	6.4	228	133	165	792	240	1,200
1523	Qb	5/19/77	---	125	25	403	5.8	---	---	710	1,620	420	2,400
1683	Dg	4/28/77	.32	190	31	710	10	380	86	1,400	---	600	5,110
1684	Dne	4/27/77	5.5	660	210	2,900	42	130	3.0	9,500	---	2,500	25,800
1685	Dg	4/14/77	5.6	140	48	1,700	18	540	6.0	3,000	---	550	9,870
1686	Qt	4/27/77	.04	68	6.8	310	4.7	87	230	410	---	200	2,090
1687	Qt	4/27/77	.01	39	6.2	390	3.5	270	11	480	---	120	2,110
1688	Qt	4/27/77	.33	33	8.5	48	4.6	120	75	170	---	120	941
1689	Qt	4/27/77	.40	30	5.5	14	2.0	160	60	53	---	98	613

[1]From Koester and Miller (1980), p. 12-18.
[2]Sum of constituents.

Table 11. *Selected Chemical Analyses of Low-Flow Surface Water in Erie County*[1]

(Results are in milligrams per liter unless otherwise indicated)

Low-flow stream site[2]	Date of sampling	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Dissolved solids	Hardness (as $CaCO_3$)	Specific conductance (μmho/cm at 25°C)	Discharge (ft^3/s)
03021400 West Branch of French Creek near Hornby (DA = 43.7 mi^2)	5/21/70	---	25	4.6	---	---	105	12	4.0	---	82	182	16
	8/31/71	---	40	7.2	---	---	98	46	8.7	---	130	290	5.3
	9/26/74	---	---	---	---	---	110	20	8.0	---	---	218	9.7
	9/16/75	0.30	32	4.4	---	---	---	12	7.0	---	100	200	29
03021500 French Creek at Carters Corners (DA = 208 mi^2)	5/17/77	1.18	33	7.7	---	---	---	12	10	176	116	250	---
	8/22/78	.79	37	8.3	---	---	---	20	11	196	126	225	---
03021520 French Creek at Union City (DA = 211 mi^2)	8/18/76	.62	30	5.8	---	---	---	8.0	8.0	124	100	210	---
04213150 Walnut Creek near Erie (DA = 26.9 mi^2)	8/17/76	---	55	13	---	---	---	40	79	378	194	530	---
	5/18/77	1.97	54	12	---	---	---	44	71	402	188	550	---
	8/16/78	.27	55	18	---	---	---	62	67	392	212	540	
04213160 Lake Erie at Erie Waterworks intake	8/19/76	.15	24	35	---	---	---	16	26	184	204	320	NA[3]
	5/11/77	.50	34	9.2	---	---	---	16	23	204	124	300	NA
	8/31/78	.05	35	12	---	---	---	---	24	200	136	260	NA
04213294 Sixteenmile Creek near North East (DA = 9.83 mi^2)	10/23/75	3.48	52	15	---	---	---	50	48	360	192	490	---
	8/18/76	.19	56	6.2	---	---	---	34	41	320	166	420	---
	5/19/77	.16	64	9.7	---	---	---	43	47	366	200	380	---
	8/22/78	.16	---	---	---	---	---	110	56	442	206	600	---
04233085 Elk Creek at Lake City	8/17/76	.19	51	11	---	---	---	42	47	314	176	460	---
	5/16/77	.14	44	12	---	---	---	42	35	294	160	420	---
	8/15/78	.48	56	14	---	---	---	66	51	362	200	490	---

[1] From U.S. Geological Survey (1971, 1972a, 1972b, 1974, 1975a, 1975b, 1976, 1977, 1978, 1979). Data collected and analyzed by Pennsylvania Department of Environmental Resources.
[2] DA, drainage area.
[3] NA, not applicable.

Table 12. *Record of Wells*

Well location: The number that is assigned to identify the well. It is prefixed by a two-letter abbreviation of the county. The lat-long is the coordinates, in degrees and minutes, of the southeast corner of a 1-minute quadrangle within which the well is located.

Use: C, commercial; D, dewater; F, fire; H, domestic; I, irrigation; N, industrial; P, public supply; R, recreation; S, stock; T, test; U, unused; Z, other.

Topographic setting: C, stream channel; F, flat; H, hilltop; L, swamp; S, hillside; T, terrace; U, undulating; V, valley flat.

Aquifer: Qs, sands of Presque Isle; Qb, glacial-beach deposits; Qo, glacial-outwash deposits; Qt, glacial-till deposits; Mc, Cuyahoga Group; MDbr, Berea Sandstone through Riceville Formation, undivided; MDcr, Corry Sandstone through Riceville Formation, undivided; MDbv, Berea Sandstone through Venango Formation, undivided; Dv, Venango Formation; Dch, Chadakoin Formation; Dg, Girard Shale; Dne, Northeast Shale.

Lithology: c, clay; clgr, clayey gravel; fsed, fractured sedimentary rock, unclassified; fsh, fractured shale; fss, fractured sandstone; fst, fractured siltstone; gr, gravel; sd, sand; sdgr, sand and gravel; sed, sedimentary rock, unclassified; sh, shale; ss, sandstone; ssh, soft shale; st, siltstone; t, till; u, unconsolidated sediments, unclassified.

Static water level: Depth--F, flows but head is not known.
Date--month/last two digits of year.

Reported yield: gal/min, gallons per minute.

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

Hardness: mg/L, milligrams per liter.

Specific conductance: µmho/cm at 25°C, micromhos per centimeter at 25 degrees Celsius.

Table 12.

Well location		Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/lithology
Number	Lat-Long							
Er- 1	4157-7952	G. P. Estes	---	1936	U	1,440	S	Qt/gr
2	4204-8010	Kenneth Kallenbach	Vernon Reed	1948	H	790	S	Qo/gr
3	4205-8001	C. H. Lyons	do.	1950	H	1,030	S	Dch/sh
4	4206-8001	H. W. Zillman	Oakes and Bennett	1949	H	980	H	Qo/sdgr
5	4211-7957	C. A. Masso	Vircle L. Griffin	1947	H	650	F	Qo/gr
6	4212-7951	L. L. Parmenter	Ralph C. Parmenter	1947	H	790	F	Qb/gr
7	4211-7950	H. S. Orton	do.	1943	H	990	S	Dg/sh
8	4200-8020	Lake City Borough	Vernon Reed	1949	P	730	F	Qo/gr
9	4206-8001	Frank Schrimper	do.	1900	N	1,005	T	Dch/sh
10	4206-8000	R. E. Guckes	Oakes and Bennett	1946	H	1,025	S	Dch/sh
11	4205-8000	Joseph Holdsworth, Jr.	Ralph Freeman	1951	H	1,120	S	Dch/sh
12	4206-8000	W. E. Brightman	Vernon Reed	1950	H	1,105	H	Dch/sh
13	4207-8000	Clara Black	Oakes and Bennett	1947	H	805	S	Dne/sh
14	4208-8000	Carl Hayward	do.	1949	H	778	F	Dne/sh
15	4209-8000	William Bendig	---	---	H	652	T	Qb/u
16	4208-7959	Ralph Freeman	Ralph Freeman	1945	H	721	F	Dne/sh
17	4208-7959	Glenn Freeman	do.	1946	H	718	F	Dne/sh
18	4208-7959	Robert Hesch	---	1948	H	720	F	Dne/sh
19	4208-7959	Eugene Beliveau	Oakes and Bennett	1948	H	728	F	Dne/sh
20	4206-7958	A. C. Kellogg	---	1938	H	1,190	S	Dch/sh
21	4206-7957	Seth Tuttle	Oakes and Bennett	1947	H	1,255	S	Dch/sh
22	4206-7956	Fred Akerly	do.	---	H	1,220	S	Dch/sh
23	4209-7959	Raymond Fenell	Ralph Freeman	1946	H	650	F	Dne/sh
24	4209-7959	Kenneth Bird	do.	1947	H	685	F	Dne/sh
25	4209-7959	Clifford Bash	---	1949	H	685	F	Dne/sh
26	4209-7959	do.	---	1951	H	685	F	Dne/sh
27	4210-7956	M. Richards	---	---	H	725	F	Dne/sh
28	4210-7956	D. A. Parker	---	---	H	730	F	Dne/sh
29	4210-7958	C. G. Carlson	---	1949	H	640	U	Dne/sh
30	4215-7947	G. H. Hartman	Ralph C. Parmenter	1947	H	590	F	Dne/sh
31	4214-7946	John McGaughey	do.	1950	H	790	F	Dne/sh
32	4214-7949	Howard Post	Vircle L. Griffin	1945	H	705	---	Qo/sdgr
33	4212-7952	F. W. Allen	---	1930	H	780	F	Qo/u
34	4209-7958	Robert Wood	Ralph Freeman	1949	H	730	F	Dne/sh
35	4208-7959	Lawrence Schroll	do.	---	N	722	F	Dne/sh
36	4208-7958	Bernie Rice	do.	1949	H	745	F	Dne/sh
37	4210-7955	L. N. Field	---	1941	H	730	F	Dne/sh
38	4211-7953	Tacoma Pneumatic Foundry	Oakes and Bennett	1947	H	760	F	Dne/sh
39	4213-7948	P. R. Thompson	Vircle L. Griffin	1931	H	820	F	Dne/sh
40	4209-7959	Glenn Kauffman	Oakes and Bennett	1944	H	720	F	Dne/sh
41	4208-7959	Fred Edwards	do.	1943	H	730	F	Dne/sh
42	4208-7959	W. L. Speigelhalter	---	---	H	730	F	Dne/sh
43	4209-7959	E. Lachesky	Oakes and Bennett	1948	H	715	F	Dne/sh
44	4204-8012	Leo Garris	Vernon Reed	1950	C	720	F	Qb/gr
45	4203-8011	Colly Shilliff	Bernard P. Kuntz	1946	C	728	S	Qb/u
46	4207-7958	Donald Shepard	Oakes and Bennett	1950	H	983	S	Qo/gr
47	4212-7953	John Archer	Vircle L. Griffin	1947	C	750	F	Qo/gr
48	4212-7953	do.	do.	1947	C	750	F	Qo/gr
49	4212-7953	Gerald Bemis	do.	1951	H	750	F	Qo/gr
50	4214-7949	Paul Luke	do.	1947	H	605	U	Qt/u
52	4208-7959	Lawrence Schroll	---	---	H	735	F	Qb/gr
54	4212-7951	Cramer Motors Inc.	Vircle L. Griffin	1949	C	780	F	Qt/u
55	4214-7946	A. J. Reiman	---	1920	H	790	F	Qb/gr
56	4214-7946	David Worster	---	---	H	765	F	Qb/u
57	4214-7947	Mrs. Carl Hood	---	1920	H	700	S	Qb/u
58	4209-7959	Willard Harman	Oakes and Bennett	1946	H	732	F	Qt/u
60	4154-8024	G. Hagebone	J. M. Cole	1918	H	900	S	Dch/fst
61	4154-8022	Elmer Thompson	do.	---	H	860	V	Qt/gr
62	4153-8021	Bessemer and Lake Erie Railroad	---	---	H	910	V	Qo/sdgr
63	4152-8019	John Zeblecabage	J. M. Cole	1929	H	1,010	S	Qt/t
64	4151-8017	Albion Borough	---	1913	P	1,090	T	Qo/gr
65	4151-8017	do.	---	1913	P	1,090	T	Qo/gr
66	4152-8018	William Revak	J. M. Cole	1920	H	1,110	S	MDbv/sh
67	4154-8017	F. R. Warner	do.	1916	H	1,126	U	MDbv/st
68	4154-8016	Andy Sabol	---	1914	U	1,160	F	MDbv/sh
69	4154-8016	do.	J. M. Cole	1914	U	1,160	F	MDbv/st
70	4154-8014	Redlis Inc.	do.	1913	H	1,248	S	MDbv/fst
71	4157-8019	Charles Langdon	do.	1918	H	860	S	Qo/sdgr
72	4257-8017	Joseph Buren	do.	1915	H	930	F	Dch/fst
73	4201-8018	Girard Borough	---	1900	P	740	S	Qb/sdgr
74	4201-8015	J. T. Raine	Vernon Reed	1928	P	820	F	Qb/gr
75	4201-8015	do.	do.	1928	P	820	F	Qb/gr
79	4201-8003	Summit Township	Moody Drilling Co., Inc.	1965	U	1,370	S	Dv/fsh

(Continued)

Total depth below land surface (feet)	Casing Depth (feet)	Casing Diameter (inches)	Depth(s) to water-bearing zone(s) (feet)	Static water level Depth below land surface (feet)	Static water level Date measured (mo/yr)	Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (μmho/cm at 25°C)	pH (units)	Well number
19	---	48	---	19	8/36	---	---	---	---	---	Er- 1
18	---	8	---	F	5/51	15	---	210	428	8.0	2
72	---	6	---	28	1950	---	---	130	949	7.4	3
82	82	5	---	64	5/50	---	---	210	416	8.0	4
72	70	6	30	5	1947	---	---	190	1,020	8.0	5
52	---	4	---	---	---	---	---	220	434	8.0	6
49	---	6	---	5	7/51	---	---	180	395	7.3	7
36	36	8	---	8	5/51	110	---	300	559	7.8	8
32	---	---	---	---	---	---	---	256	618	7.8	9
45	---	---	---	---	---	---	---	168	354	7.8	10
46	---	---	---	---	---	---	---	98	348	8.0	11
75	65	---	---	---	---	---	---	156	455	7.9	12
40	---	---	---	---	---	---	---	178	554	7.8	13
40	---	---	---	---	---	---	---	126	533	7.8	14
36	---	---	---	---	---	---	---	312	2,310	7.5	15
40	---	---	---	---	---	---	---	96	295	6.6	16
32	---	---	---	---	---	---	---	98	563	7.8	17
40	---	---	---	---	---	---	---	132	1,790	7.6	18
34	---	---	---	---	---	---	---	258	3,560	7.2	19
65	9	---	---	9	---	---	---	124	654	7.6	20
80	8	---	---	---	---	---	---	190	505	7.7	21
45	---	---	---	---	---	---	---	118	359	7.7	22
26	---	---	---	---	---	---	---	98	262	6.7	23
35	---	---	---	---	---	---	---	346	1,000	7.4	24
39	---	---	---	---	---	---	---	192	1,170	7.6	25
12	12	24	---	---	---	---	---	238	1,160	7.7	26
30	22	---	---	---	---	---	---	94	275	6.5	27
25	---	---	---	---	---	---	---	26	797	8.4	28
82	32	6	42	20	---	---	---	184	2,010	7.6	29
53	---	---	---	---	---	---	---	364	750	7.3	30
51	---	---	---	---	---	---	---	176	347	7.5	31
60	---	---	---	---	---	---	---	120	279	7.7	32
64	---	---	---	27	---	---	---	146	321	6.6	33
41	6	---	---	---	---	---	---	444	5,060	6.9	34
40	---	---	35	---	---	---	---	236	1,240	7.2	35
35	---	---	---	---	---	---	---	158	1,230	7.2	36
24	---	---	---	---	---	---	---	124	566	6.9	37
39	---	---	---	---	---	---	---	76	195	6.5	38
45	---	---	---	---	---	---	---	178	360	7.6	39
40	15	---	---	---	---	---	---	38	641	7.8	40
30	---	---	---	---	---	---	---	116	1,140	7.8	41
30	---	---	---	---	---	---	---	91	1,170	7.6	42
48	---	---	---	---	---	---	---	68	239	6.3	43
60	60	---	---	---	---	---	---	120	417	8.0	44
38	38	---	---	F	---	---	---	190	460	7.6	45
35	---	---	22	---	---	---	---	82	206	6.8	46
78	78	---	---	---	---	---	---	252	494	7.8	47
50	---	---	---	---	---	---	---	258	497	7.7	48
79	79	---	---	12	7/51	---	---	238	459	7.7	49
60	---	---	---	---	---	---	---	190	3,840	7.3	50
15	15	---	---	8	7/51	---	---	100	318	6.3	52
65	65	---	---	---	---	---	---	122	251	7.1	54
28	28	---	---	---	---	---	---	310	568	7.3	55
20	---	5	---	---	---	---	---	144	420	7.5	56
28	28	---	---	---	---	---	---	136	315	7.4	57
30	---	---	22	---	---	---	---	88	303	6.4	58
103	83	4	---	30	7/28	---	---	---	---	---	60
113	80	4	---	6	---	---	---	---	---	---	61
30	30	3	---	---	---	---	---	---	---	7.4	62
51	14	4	---	15	---	---	---	---	---	---	63
29	29	8	---	F	---	---	---	---	---	7.6	64
20	20	10	---	3	---	---	---	---	---	---	65
72	43	4	---	4	9/20	---	---	---	---	---	66
36	17	4	---	6	---	---	---	140	---	8.1	67
54	---	4	---	6	---	---	---	---	---	---	68
50	---	4	---	6	---	---	---	---	---	---	69
72	19	4	---	16	---	---	---	---	---	---	70
77	77	4	55	40	---	---	---	---	---	---	71
100	43	4	---	---	---	---	---	---	---	---	72
12	12	20	---	8	---	---	---	190	---	7.6	73
52	52	8	40	24	---	15	---	---	---	8.0	74
51	51	8	41	24	---	15	15	---	---	8.0	75
46	46	6	13	5	10/65	4	.25	---	---	---	79

Table 12.

Well location		Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Number	Lat-Long							
Er- 80	4201-8003	Summit Township	Moody Drilling Co., Inc.	1965	U	1,370	S	Dv/fsh
82	4156-8004	U.S. Geological Survey	do.	1966	U	1,419	H	Dv/sh
88	4151-8009	J. T. Young	J. M. Cole	1923	H	1,535	H	Mc/fst
90	4151-8012	Raymond Hotchkiss	do.	1929	H	1,260	S	MDbv/fst
91	4152-8000	Charles Pollock	---	---	H	1,200	S	Qo/u
93	4155-7959	T. B. Matchett	McCray Bros.	1923	H	1,190	V	Qo/gr
97	4156-7959	Waterford Water Supply Co.	---	1928	P	1,173	V	Qo/gr
98	4156-7959	do.	---	1924	P	1,173	V	Qo/gr
99	4156-7959	do.	---	1927	P	1,173	S	Qo/gr
102	4210-7957	New York Central Railroad	Vircle L. Griffin	1927	H	730	F	Dne/sh
103	4212-7953	R. C. Bard	Adgate Marshall	1911	H	750	F	Dne/ss
104	4212-7953	Louise Trejchel	do.	1911	H	750	F	Dne/ss
105	4210-7952	Roger Marshall	do.	1911	H	990	S	Qt/gr
106	4212-7950	Ross Jones	do.	1911	H	800	S	Dne/ss
107	4212-7950	North East Borough	do.	1911	H	800	F	Qt/u
108	4214-7950	May MacLachlan	do.	1911	H	640	S	Dne/ss
109	4213-7948	Margaret Pero	do.	1911	H	830	F	Dne/ss
110	4210-7948	Nora Morse	do.	1911	H	1,240	S	Dch/ss
111	4210-7946	W. R. Desin	do.	1911	H	1,480	S	Dch/ss
112	4207-7949	Josephine Lang	do.	1911	S	1,440	S	Dch/ss
113	4207-7949	do.	do.	1911	H	1,440	S	Dch/ss
114	4201-7949	Art Conrad	---	1930	C	1,297	V	Qo/u
115	4201-7948	A. T. Gilmore	---	---	H	1,290	V	Qo/u
116	4201-7946	L. J. Jensen	---	1913	H	1,340	V	Qo/gr
117	4156-7946	Amity Township School	McCray Bros.	1913	H	1,540	S	Qt/gr
118	4156-7946	Garry Prebble	do.	1917	H	1,480	T	Qo/gr
119	4155-7945	H. Dunn	do.	1913	H	1,420	V	Qo/gr
120	4153-7951	Merril Soul Milk Co.	---	---	N	1,272	V	Qo/gr
121	4154-7951	Will Gross	McCray Bros.	1915	H	1,250	V	Qo/sdgr
122	4154-7951	---	---	---	U	1,260	V	Dv/sh
123	4154-7948	Union City Borough	---	1920	P	1,380	S	Dv/sh
126	4153-7945	Crowley	McCray Bros.	1905	H	1,355	V	Qo/sd
127	4154-7944	Harrington	---	---	H	1,385	V	Qo/gr
128	4154-7944	Dave Lyons	---	---	H	1,380	V	Qo/gr
129	4152-7944	Lilley	---	---	H	1,390	S	Dv/fss
130	4154-7942	Charles Gates	McCray Bros.	1916	H	1,380	V	Qo/gr
131	4151-7943	Charles Drake	do.	1913	H	1,460	S	Qt/gr
132	4155-7940	State Fish Hatchery	do.	1921	Z	1,400	T	Qo/gr
136	4156-7938	Corry Water Supply Co.	---	1927	Z	1,420	V	Qo/gr
137	4155-7938	Ed Marsh	---	1926	H	1,410	V	Qo/u
138	4155-7938	A. A. Williams	---	1926	H	1,420	S	Dv/fss
139	4155-7938	Sweet	---	1903	H	1,435	F	Dv/sh
140	4154-7938	Corry Water Supply Co.	---	---	N	1,680	S	Dv/fss
141	4156-7959	Waterford Borough	Moody Drilling Co., Inc.	1962	P	1,175	V	Qo/sdgr
142	4152-8018	F. L. Kitcey	Alfred L. Burch	1970	H	1,112	S	Qt/sdgr
143	4152-8018	Ronald Mayer	Richard L. Ticknor	1975	H	1,162	H	MDbv/fsh
144	4152-8018	Daniel Donch	do.	1975	H	1,130	S	MDbv/fsh
145	4153-8015	John Surovick	B. W. Bateman and Son	1966	H	1,250	S	Qt/u
146	4153-8015	Jack Baker	Donald L. Hermann	1972	H	1,220	S	Qt/u
147	4153-8015	Francis Surovick	Moody Drilling Co., Inc.	1956	H	1,220	U	MDbv/fsh
148	4153-8018	R. T. Hallstead	do.	1957	H	1,150	U	MDbv/ss
149	4153-8018	Bliss Miller	B. W. Bateman and Son	1967	H	1,125	S	MDbv/fsh
150	4153-8018	Larry Valentine	Boyd Lee Hall	1971	H	1,135	S	MDbv/fsh
151	4153-8018	Stanley Rosecky	Alfred L. Burch	1967	H	1,142	S	MDbv/fsh
152	4153-8019	Dalton Hammett	do.	1974	H	1,076	T	MDbv/fsh
153	4153-8019	Glenn Hanas	Michael W. Burch	1976	H	1,088	S	MDbv/fss
154	4153-8019	W. L. Nelson	do.	1975	H	1,080	S	MDbv/fsh
155	4153-8019	David Timko	Alfred L. Burch	1970	H	1,050	S	MDbv/fsh
156	4153-8019	Edwin Sherman	Moody Drilling Co., Inc.	1964	H	1,080	S	MDbv/fsh
157	4153-8020	Lawrence Steinhoff	John E. Gage, Jr.	1971	H	985	T	Dch/fsh
158	4153-8020	Keith Merchants	Max E. Hickernell	1961	H	957	V	Dch/fsh
159	4153-8020	Lundy's Lane Church	Moody Drilling Co., Inc.	1959	H	938	V	Dch/fsh
160	4153-8020	John Dziak	B. W. Bateman and Son	1967	H	942	V	Dch/fsh
161	4153-8020	Archie Dodge	do.	1967	H	955	T	Qt/t
162	4153-8020	Milton Viard	do.	1967	H	942	T	Qt/t
163	4153-8021	Joseph Bayus	Richard L. Ticknor	1975	H	900	T	Dch/fsh
164	4154-8015	J. M. Semple	Boyd Lee Hall	1971	H	1,202	S	Qt/t
165	4154-8015	D. A. Soltis	B. W. Bateman and Son	1969	H	1,230	S	Qt/t
166	4154-8016	J. J. Schanz	Donald L. Hermann	1972	H	1,169	U	MDbv/ssh
167	4154-8016	A. P. Sabol	John E. Gage, Jr.	1974	H	1,172	U	MDbv/ssh
168	4154-8017	N. D. Martin	Alfred L. Burch	1972	H	1,132	U	MDbv/ssh
169	4154-8017	P. R. Crane	Moody Drilling Co., Inc.	1957	H	1,110	U	Dch/fsh
170	4154-8017	do.	Alfred L. Burch	1971	H	1,110	U	MDbv/fsh
171	4154-8018	Vergil Taylor	John E. Gage, Jr.	1972	H	1,100	U	Qt/gr

(Continued)

Total depth below land surface (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Depth(s) to water-bearing zone(s) (feet)	Static water level: Depth below land surface (feet)	Static water level: Date measured (mo/yr)	Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (μmho/cm at 25°C)	pH (units)	Well number
53	46	6	---	5	10/65	21	.06	---	---	---	Er- 80
82	56	6	---	17	6/66	---	---	---	---	---	82
38	18	4	---	6	---	---	---	---	---	---	88
60	60	4	---	15	---	---	---	---	---	---	90
104	80	6	40	24	---	---	---	120	420	---	91
200	200	3	198	1	---	---	---	---	---	---	93
52	52	8	42	F	---	53	---	---	---	---	97
100	100	6	97	F	---	20	---	97	---	---	98
114	114	6	38	F	---	90	---	---	---	---	99
40	22	6	---	20	---	---	---	96	---	---	102
159	110	6	---	60	---	---	---	---	---	---	103
250	150	6	---	---	---	---	---	---	---	---	104
75	20	6	---	---	---	---	---	---	---	---	105
128	14	6	---	60	---	---	---	---	---	---	106
99	30	6	---	---	---	---	---	---	---	---	107
90	69	6	---	60	---	---	---	---	---	---	108
52	33	6	---	15	---	---	---	---	---	---	109
85	19	6	---	3	---	---	---	---	---	---	110
77	52	6	---	20	---	---	---	---	---	---	111
104	52	6	---	---	---	---	---	---	---	---	112
108	24	6	---	---	---	---	---	---	---	---	113
305	300	3	---	---	---	---	---	75	220	8.2	114
260	260	4	---	6	---	---	---	---	---	---	115
120	120	4	---	F	---	---	---	110	---	---	116
44	20	---	---	20	---	---	---	---	---	---	117
110	110	---	---	20	---	---	---	---	---	---	118
111	111	---	---	20	---	---	---	---	---	---	119
160	110	---	---	F	---	---	---	---	---	---	120
75	75	---	---	20	---	---	---	---	---	---	121
---	---	---	225	F	---	---	---	---	---	---	122
100	20	6	---	16	---	---	---	---	---	---	123
315	315	---	310	5	---	---	---	---	---	---	126
160	160	---	---	F	---	---	---	---	---	---	127
250	250	---	---	F	---	---	---	30	560	---	128
250	---	4	123	F	---	---	---	---	---	---	129
315	315	4	314	F	---	---	---	---	---	---	130
61	25	---	19	30	---	---	---	---	---	---	131
65	65	4	---	F	10/28	15	---	100	252	8.0	132
50	50	---	---	F	---	---	---	120	---	---	136
402	392	6	392	5	---	---	---	---	---	---	137
120	22	6	80;110	5	---	---	---	---	---	---	138
120	100	---	---	F	---	---	---	---	---	---	139
140	20	6	---	40	---	---	---	---	---	---	140
96	80	12	86	76	---	360	---	130	340	7.6	141
32	32	8	24	4	8/70	12	---	---	---	---	142
50	27	8	12;22	5	6/75	5	.23	---	---	---	143
50	17	8	14;16	5	6/75	7	.33	---	---	---	144
50	40	6	41	15	10/66	6	.24	---	---	---	145
52	21	12	21	10	11/72	15	.36	---	---	---	146
42	25	8	---	10	6/56	18	---	---	---	---	147
70	---	8	---	---	---	.1	---	35	1,100	---	148
53	20	6	34	10	6/67	3	.08	---	---	---	149
39	29	12	28;39	---	---	---	---	---	---	---	150
49	27	8	24	10	7/67	1	---	---	---	---	151
50	15	12	15;20;30	8	8/74	5	---	---	---	---	152
50	20	8	19;42	---	---	1	---	---	---	---	153
50	14	8	10;28	7	8/75	9	.22	---	---	---	154
40	21	8	16;20	---	---	10	---	---	---	---	155
55	47	8	45	14	4/64	12	.39	---	---	---	156
47	23	8	12;27	6	3/71	2	.05	---	---	---	157
75	26	12	60	24	6/61	5	---	---	---	---	158
83	30	8	---	20	9/59	2	---	---	---	---	159
50	27	6	18;30	12	8/67	3	.09	---	---	---	160
45	20	6	24	18	4/67	4	.18	---	---	---	161
50	23	6	16;25	6	11/67	8	.24	---	---	---	162
70	19	8	16	13	7/75	2	---	---	---	---	163
50	28	12	28;43	8	7/71	---	.30	220	530	---	164
45	24	6	28	4	10/69	5	.14	---	---	---	165
70	29	8	26	3	8/72	25	---	---	---	---	166
45	26	8	22	10	7/74	3	.20	---	---	---	167
50	27	8	23;48	5	4/72	5	.11	---	---	---	168
72	31	8	---	20	11/57	.5	---	---	---	---	169
60	31	8	10;14;40	4	7/71	5	---	---	---	---	170
34	24	---	12;23	7	6/72	7	.88	---	---	---	171

Table 12.

Well location								
Number	Lat-Long	Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Er- 172	4154-8018	Jerry Pender	John E. Gage, Jr.	1974	H	1,116	H	MDbv/sh
173	4154-8018	do.	do.	1974	H	1,116	H	MDbv/sh
174	4154-8019	R. L. Jones	Moody Drilling Co., Inc.	1958	H	1,041	S	Dch/sh
175	4154-8019	James Klobusnik	Alfred L. Burch	1970	H	1,064	S	Qt/sdgr
176	4154-8021	C. W. Summerville	---	---	H	895	V	Qt/t
177	4155-8015	Erwin Koestel	B. W. Bateman and Son	1967	H	1,146	S	Qt/t
178	4155-8017	Roy Lydic	John E. Gage, Jr.	1972	H	1,078	T	Dch/fsh
179	4155-8018	Daniel Longstreth	Michael W. Burch	1975	H	1,100	S	Dch/sh
180	4155-8019	M. J. Pietrowski	Robert Anderson	1975	H	1,020	S	Qt/c
181	4155-8019	William Reiser	John E. Gage, Jr.	1975	H	958	S	Qt/c
182	4155-8019	Edith Margetta	do.	1973	H	1,040	S	Qt/sd
183	4155-8019	Lawrence Orr	B. W. Bateman and Son	1968	H	1,026	S	Dch/sh
184	4155-8017	John Morrison	John E. Gage, Jr.	1973	H	1,085	U	Dch/fsh
185	4155-8018	Donna Burger	Michael W. Burch	1975	H	1,089	S	Dch/sh
186	4155-8018	Edward Fletcher	John E. Gage, Jr.	1972	H	1,112	F	MDbv/fsh
187	4155-8019	Phillip Garlick	Richard L. Ticknor	1975	H	1,030	S	Dch/sh
188	4155-8019	R. J. Thoms	John E. Gage, Jr.	1973	H	960	S	Qo/sd
189	4155-8019	Paul Panko	Alfred L. Burch	1971	H	930	H	Qo/sdgr
190	4155-8020	Albert Kuzma	do.	1974	H	930	S	Qo/gr
191	4155-8020	E. J. Angellotti	John E. Gage, Jr.	1972	H	930	S	Qo/sd
192	4155-8022	W. H. Keith	do.	1970	H	860	H	Qt/gr
193	4153-8020	Elk Creek Township	Jack Young	1976	H	972	S	Qt/t
194	4156-8017	Dale Starr	do.	1976	H	1,068	S	Dch/fsh
195	4156-8018	D. L. Platz	John E. Gage, Jr.	1972	H	965	T	Qo/gr
196	4156-8018	R. M. Halm	do.	1972	H	920	U	Qo/gr
197	4156-8019	Richard Otteni	do.	1971	H	940	H	Qo/gr
198	4156-8019	Walter Youngs	George H. Ackerman	1972	H	942	H	Qt/t
199	4156-8019	T. V. Hunt	B. W. Bateman and Son	1969	H	875	S	Qt/t
200	4156-8019	William Hunt	do.	1969	H	872	S	Qt/t
201	4156-8020	Dennis Clendenning	John E. Gage, Jr.	1974	H	873	U	Dch/sh
202	4156-8020	Carl Pedano	do.	1970	H	875	S	Qt/sd
203	4156-8020	John Struchen	B. W. Bateman and Son	1969	H	875	S	Dch/sh
204	4156-8021	J. B. Shope	Lowell Halstead	1973	H	840	H	Qo/sd
205	4157-8015	O. R. Tome	Alfred L. Burch	1972	H	1,142	U	MDbv/sh
206	4157-8015	George Bucho	do.	1975	H	1,071	S	Dch/sh
207	4157-8015	Thomas Steinmiller	do.	1975	H	1,075	S	Dch/sh
208	4157-8017	R. P. Krahe	do.	1973	H	930	S	Dch/fsh
209	4157-8017	A. J. Silva	do.	1974	H	950	T	Dch/fsh
210	4157-8017	J. B. Cook	do.	1970	H	880	S	Dg/sh
211	4157-8017	J. A. Olack	George H. Ackerman	1974	H	932	H	Qo/u
212	4157-8017	William Felege	Lowell Halstead	1973	H	920	S	Qo/gr
213	4157-8018	William Soudan	Alfred L. Burch	1975	H	880	S	Qo/sdgr
214	4157-8019	J. L. Borland	do.	1974	H	860	F	Qo/u
215	4157-8019	Muriel Hollenbeck	do.	1973	H	873	H	Qo/sd
216	4157-8019	E. S. Rakowski	do.	1972	H	882	H	Qo/sd
217	4157-8019	Gordon Beers	B. W. Bateman and Son	1968	H	878	H	Qo/sd
218	4157-8019	John Shaffer	Alfred L. Burch	1966	H	862	T	Qo/gr
219	4157-8019	David Struchen	Lowell Halstead	1973	H	868	H	Qo/gr
220	4157-8019	Robert Shepherd	Alfred L. Burch	1975	H	890	H	Qo/sdgr
221	4157-8019	G. L. Strobel	John E. Gage, Jr.	1974	H	880	H	Qo/gr
222	4157-8020	T. D. Sterrett	Donald L. Hermann	1972	H	880	F	Qo/sdgr
223	4158-8016	William Bushelman	Alfred L. Burch	1969	U	755	H	Dg/sh
224	4158-8017	Lewis McDonald	Lowell Halstead	1973	H	870	F	Qo/gr
225	4158-8018	P. R. Hokanson	Michael W. Burch	1975	H	785	S	Dg/sh
226	4158-8021	H. C. Klein	B. W. Bateman and Son	1969	H	815	H	Qo/gr
227	4158-8021	Carol Feasler	do.	1969	H	816	F	Qo/gr
228	4158-8021	John Vancise	John E. Gage, Jr.	1974	H	817	H	Qo/gr
229	4158-8021	S. F. Gnacinski	Charles J. Richardson III	1973	H	830	F	Qo/sdgr
230	4158-8022	Anshelm Sundberg	McCray Bros.	1972	H	790	S	Qt/t
231	4159-8016	R. C. Herhold	Felix J. Waible	1974	H	890	H	Qo/sdgr
232	4159-8015	John Eckels	John E. Gage, Jr.	1975	H	945	H	Qo/sdgr
233	4159-8016	B. B. Gilmore	Alfred L. Burch	---	U	875	H	Qo/u
234	4159-8016	John Spaulding	Robert Anderson	1977	H	880	H	Qo/gr
235	4159-8016	B. B. Gilmore	Alfred L. Burch	1969	H	875	H	Qo/gr
236	4159-8017	Gerard Schellang	Michael W. Burch	1976	H	864	H	Dg/sh
237	4159-8017	Gunnison Bros. Tannery	Moody Drilling Co., Inc.	1958	H	750	S	Dg/sh
238	4157-8019	John Mitrison	Alfred L. Burch	1973	H	888	S	Qo/sd
239	4159-8019	Dennis Bills	do.	1975	H	828	S	Qo/sdgr
240	4159-8019	D. A. Graham	do.	1975	H	800	S	Qo/sdgr
241	4159-8019	Milton Baldwin	do.	1971	H	790	S	Qo/gr
242	4159-8019	Stephen Sorgen	do.	1974	H	795	S	Qo/sdgr
243	4159-8019	Joseh Michalski	do.	1973	H	826	S	Qo/sdgr
244	4159-8020	E. E. Cook	do.	1975	H	795	S	Qo/sdgr
245	4159-8020	Jack Baudau	do.	1972	H	738	V	Qo/gr

(Continued)

Total depth below land surface (feet)	Casing Depth (feet)	Casing Diameter (inches)	Depth(s) to water-bearing zone(s) (feet)	Static water level: Depth below land surface (feet)	Static water level: Date measured (mo/yr)	Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (μmho/cm at 25°C)	pH (units)	Well number
38	28	8	13;22	5	8/74	8	.53	---	---	---	Er- 172
38	25	8	15;25	10	7/74	8	.40	---	---	---	173
75	19	10	---	15	6/58	.1	---	---	---	---	174
27	27	8	18	10	8/70	30	---	---	---	---	175
30	30	6	29	20	8/76	3	.43	---	---	---	176
45	31	6	33	12	6/67	6	.24	---	---	---	177
40	24	8	12;24	4	3/72	8	.57	---	---	---	178
50	13	8	---	8	9/75	4	.10	---	---	---	179
65	13	8	12;25;30	10	8/75	6	.12	---	---	---	180
50	18	8	18	---	---	4	---	---	---	---	181
31	21	8	10;21	3	5/73	18	1.5	---	---	---	182
45	19	6	20	10	8/68	2	.06	---	---	---	183
52	32	8	32	5	---	12	.67	---	---	---	184
50	13	8	9;28	2	---	4	.09	90	330	---	185
38	34	8	11;28	3	6/72	15	.68	---	---	---	186
50	19	8	16	6	7/75	6	---	---	---	---	187
46	29	8	9;15;29	2	5/73	18	1.4	---	---	---	188
30	30	8	12;20	---	---	20	.8	---	---	---	189
40	39	8	33	8	10/74	18	---	---	---	---	190
26	26	8	16;22	10	6/72	15	1.5	---	---	---	191
62	62	6	59	20	9/70	3	.10	---	---	---	192
50	30	8	19;24	15	9/76	8	.27	---	---	---	193
50	17	8	14;28;42	10	9/76	12	.34	---	---	---	194
30	24	---	19	15	6/72	7	.7	---	---	---	195
35	26	8	19	10	6/72	7	7	---	---	---	196
43	43	8	43	28	7/71	12	12	---	---	---	197
100	100	8	96	---	---	2	---	---	---	---	198
80	25	6	30	15	3/69	1	.02	---	---	---	199
85	30	6	32	20	2/69	2	.03	---	---	---	200
61	60	8	7;54	30	6/74	3	.3	---	---	---	201
127	127	8	121	61	6/70	3	.08	---	---	---	202
65	60	6	61	15	9/69	8	.23	---	---	---	203
98	98	8	90	---	---	60	---	---	---	---	204
60	10	8	11;25;50	10	9/72	8	---	---	---	---	205
45	16	8	15;20	14	10/75	.5	---	---	---	---	206
60	13	8	13;30	9	10/75	1	---	---	---	---	207
55	25	8	20;25;43	12	8/73	15	---	---	---	---	208
60	18	8	---	1	5/74	10	---	---	---	---	209
60	10	8	32	25	7/70	10	---	---	---	---	210
135	121	8	114	102	8/74	35	---	---	---	---	211
79	76	8	75	40	8/73	15	---	---	---	---	212
65	57	8	52	22	5/75	8	---	---	---	---	213
89	89	6	89	72	10/74	10	---	---	---	---	214
112	112	8	106	80	---	18	---	---	---	---	215
119	119	8	114	89	10/72	20	---	---	---	---	216
100	100	6	100	50	4/68	8	.19	---	---	---	217
85	73	8	69	---	---	10	---	---	---	---	218
82	82	8	25;78	20	8/73	30	---	---	---	---	219
111	111	8	105	86	5/75	20	2.0	---	---	---	220
118	118	8	112	60	5/74	12	.3	---	---	---	221
212	212	8	22;207	150	8/72	30	1.5	---	---	---	222
50	---	---	14	10	5/69	.3	.06	---	---	---	223
65	65	8	65	---	8/73	50	---	---	---	---	224
90	45	5	47	40	8/75	3	---	---	---	---	225
63	63	5	63	18	11/69	3	.08	---	---	---	226
68	68	5	68	33	10/69	4	.13	---	---	---	227
66	66	8	64	30	10/74	23	23	---	---	---	228
38	38	24	38	18	6/73	6	.5	---	---	---	229
53	53	---	10;20;50	20	3/72	1	.03	---	---	---	230
88	88	8	84	63	6/74	10	---	---	---	---	231
44	44	8	26;38	30	5/75	10	10	---	---	---	232
60	60	8	---	---	---	---	---	---	---	---	233
36	36	8	32	18	2/77	15	2.1	---	---	---	234
32	32	8	27	17	5/69	5	---	---	---	---	235
117	90	8	95	70	4/76	.3	.01	---	---	---	236
60	21	10	---	---	---	3	---	---	---	---	237
60	44	8	37;46	22	8/73	9	---	---	---	---	238
68	68	8	40;60	34	7/75	20	2.0	---	---	---	239
74	74	8	41;50;65	25	1/75	18	.46	---	---	---	240
42	42	8	38	14	4/71	50	---	190	640	---	241
60	60	8	55	20	8/74	30	1.5	---	---	---	242
88	88	8	41;44	45	8/73	30	---	---	---	---	243
60	60	8	30;56	15	11/75	20	1	---	---	---	244
20	20	8	15	8	4/72	10	---	---	---	---	245

Table 12.

Well location		Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Number	Lat-Long							
Er- 246	4159-8020	J. W. Pustelak	Alfred L. Burch	1972	H	736	V	Qo/gr
247	4159-8021	D. L. Lance	do.	1972	H	745	S	Qo/sdgr
248	4159-8021	Neil Anderson	do.	1970	H	742	S	Qo/sd
249	4159-8021	D. S. Carey	do.	1974	H	755	H	Qo/sd
250	4158-8022	L. V. Komisarski	Max E. Hickernell	1971	H	754	V	Qo/gr
251	4154-8023	Fred Kiedaisch	Jack Young	1976	H	859	S	Qo/sdgr
252	4151-8024	W. J. Lawrence	Alfred L. Burch	1971	H	870	V	Dch/sh
253	4152-8023	D. C. Byerley	do.	1971	H	890	S	Dch/sh
254	4152-8027	C. M. English	Richard L. Ticknor	1975	H	954	T	Dch/sh
255	4151-8024	Kenneth Adams	Boyd Lee Hall	1973	H	850	V	Qo/sd
256	4152-8028	Paul Valinsky	Lorenze Lee Hall	1976	H	955	T	Dch/ssh
257	4151-8024	William Knapp	B. W. Bateman and Son	1969	H	930	S	Dch/ssh
258	4151-8023	Napoleon Lockhart	do.	1968	H	965	H	Dch/sh
259	4151-8025	William Hale	Lorenze Lee Hall	1976	H	952	S	Dch/fsh
260	4152-8025	J. A. Harrington	Alfred L. Burch	1973	H	880	S	Qo/sd
261	4152-8028	J. J. Frey	Richard L. Ticknor	1975	H	952	F	Qo/gr
262	4152-8029	J. A. Lloyd	do.	1975	H	960	U	Qo/gr
263	4152-8031	Roy Huston	Lowell Halstead	1973	H	955	F	Dch/sh
264	4152-8031	Barbara Fawcett	John E. Gage, Jr.	1972	H	910	U	Qt/sd
265	4154-8031	R. R. Hammer	Max E. Hickernell	1970	H	850	H	Qo/gr
266	4156-8030	Richard Reinke	do.	1968	H	680	F	Qt/gr
267	4152-8024	Stanley Loomis	Moody Drilling Co., Inc.	1963	H	861	T	Qo/gr
268	4152-8026	A. B. Nearhoof	John E. Gage, Jr.	1970	H	940	U	Qo/gr
269	4152-8026	D. P. Blood	Alfred L. Burch	1972	H	950	F	Qo/sd
270	4152-8028	George Fronce	Lorenze Lee Hall	1975	H	952	F	Dch/sh
271	4153-8023	John Kulyk	Moody Drilling Co, Inc.	1954	H	892	U	Qo/sdgr
272	4153-8023	Arturs Eigners	Alfred L. Burch	1964	H	860	V	Qo/gr
273	4153-8023	William Greenlee	Max E. Hickernell	1966	H	860	V	Qo/gr
274	4153-8024	W. J. Simlick	Boyd Lee Hall	1973	H	856	H	Qt/c
275	4153-8024	Thomas Roan	do.	1970	H	868	S	Qt/u
276	4153-8024	Charles English	Max E. Hickernell	1972	H	850	S	Qt/gr
277	4153-8024	E. L. Simlick	John E. Gage, Jr.	1974	H	850	H	Qt/c
278	4153-8025	William Van Genewitt	Max E. Hickernell	1965	H	900	H	Dch/fsh
279	4153-8025	Pearl Moyer	Moody Drilling Co., Inc.	1961	H	902	F	Dch/fsh
280	4153-8026	Rex Jackson	John E. Gage, Jr.	1972	H	924	S	Qt/c
281	4153-8026	Pearl Callahan	Boyd Lee Hall	1970	H	901	H	Qt/c
282	4153-8026	Harry Minch	B. W. Bateman and Son	1969	H	910	H	Dch/fsh
283	4153-8026	Frank Czulewicz	Max E. Hickernell	1967	H	920	H	Dch/fsh
284	4153-8028	Clarence Bricker	Jack Young	1976	H	925	U	Dch/fsh
285	4153-8028	A. F. Hemstreet	John E. Gage, Jr.	1974	H	905	V	Qo/gr
286	4153-8029	Gordon Hill	Berkley D. Bossard	1967	H	910	U	Dch/sh
287	4153-8029	Arnold Hill	do.	1967	H	918	U	Dch/fsh
288	4153-8026	Peter Loepp	do.	1967	H	935	U	Dch/sh
289	4153-8026	John Gable	do.	1967	H	935	U	Dch/sh
290	4153-8026	John Avey	do.	1967	H	922	U	Dch/sh
291	4153-8027	Elmer Randall	B. W. Bateman and Son	1967	H	925	U	Dch/fsh
292	4153-8029	Harold Isiminger	Lowell Halstead	1973	H	920	H	Qo/gr
293	4153-8025	Bernard Kinney	B. W. Bateman and Son	1966	H	898	S	Dch/sh
294	4154-8026	Roy Beckman	Berkley D. Bossard	1967	H	910	S	Qo/gr
295	4154-8024	Rodney Klemm	B. W. Bateman and Son	1968	H	915	S	Qo/gr
296	4154-8023	D. K. Braddock	Michael W. Burch	1975	H	850	S	Qo/sdgr
297	4154-8023	Carl White	Max E. Hickernell	1971	H	890	S	Qo/gr
298	4154-8023	Carl Hahn	Alfred L. Burch	1967	H	892	H	Qt/c
299	4154-8023	Carlyle Krieg	John E. Gage, Jr.	1974	H	912	U	Qt/sd
300	4154-8024	Dale Fobes	Max E. Hickernell	1970	H	920	S	Qt/clgr
301	4154-8024	David Carnes	U. S. Dean	1973	H	905	S	Qt/gr
302	4154-8025	T. M. Ryan	Alfred L. Burch	1970	H	908	S	Qt/clgr
303	4154-8025	R. L. Bomboy	John E. Gage, Jr.	1974	H	890	V	Qt/t
304	4154-8025	Merle Sterling	Max E. Hickernell	1969	H	900	S	Qt/clgr
305	4154-8025	Michael Rastetter	Ralph Wayne Grant	1974	H	900	S	Qt/c
306	4154-8026	Walter Henderson	Lowell Halstead	1973	H	910	V	Dch/fsh
307	4154-8026	E. B. Brennan	Berkley D. Bossard	1970	H	910	V	Qt/c
308	4154-8026	Roland Zuschlag	Lowell Halstead	1973	H	905	S	Qt/gr
309	4154-8027	R. H. White	Max E. Hickernell	1971	H	910	S	Qt/gr
310	4154-8027	D. L. Robson	John E. Gage, Jr.	1974	H	910	U	Qt/gr
311	4154-8025	Robert Dorchester	do.	1974	H	904	S	Qt/sd
312	4155-8022	Joseph Iesue	Lorenze Lee Hall	1975	H	862	H	Qo/sdgr
313	4155-8027	Anson Thornton	Max E. Hickernell	1969	H	882	H	Qo/gr
314	4155-8027	R. H. Henck	Charles J. Richardson III	1973	H	867	H	Qo/sdgr
315	4155-8028	W. J. Elliott	John E. Gage, Jr.	1974	H	855	S	Qo/sd
316	4156-8024	Earl Born	do.	1975	H	826	S	Qo/gr
317	4156-8027	G. W. Hills	Alfred L. Burch	1968	H	784	S	Qo/sdgr
318	4157-8024	Donald Adams	Max E. Hickernell	1970	H	790	S	Qt/sd
319	4157-8025	William Marino	John E. Gage, Jr.	1970	H	735	F	Qb/sd

(Continued)

Total depth below land surface (feet)	Casing Depth (feet)	Casing Diameter (inches)	Depth(s) to water-bearing zone(s) (feet)	Static water level Depth below land surface (feet)	Static water level Date measured (mo/yr)	Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (μmho/cm at 25°C)	pH (units)	Well number
22	22	8	16	7	7/72	20	---	---	---	---	Er- 246
34	34	8	21	19	11/72	20	---	---	---	---	247
40	40	8	---	21	12/70	6	6	---	---	---	248
26	26	8	18;21	14	8/74	15	---	---	---	---	249
38	38	8	34	24	11/71	10	---	---	---	---	250
60	60	8	12;58	10	7/76	10	.33	---	---	---	251
60	23	8	21;33	10	10/71	8	---	---	---	---	252
50	25	8	13;20;37	10	4/71	2	---	---	---	---	253
45	24	8	14;20	4	7/75	11	.48	---	---	---	254
124	124	8	95;110	14	10/73	25	1.8	---	---	---	255
49	24	8	20;30	3	6/76	6	.14	---	---	---	256
45	12	6	14	8	3/69	3	.09	---	---	---	257
50	12	6	16	8	10/68	2	.05	---	---	---	258
64	21	8	25	---	---	5	---	---	---	---	259
37	37	8	10;30	19	10/73	30	5	---	---	---	260
40	22	8	12;18	5	5/75	4	---	---	---	---	261
50	24	8	20	6	6/75	7	.2	---	---	---	262
55	25	8	25	---	---	5	---	---	---	---	263
48	24	8	12;17	15	10/72	7	7	---	---	---	264
76	57	8	53;68	48	8/70	12	---	---	---	---	265
65	54	8	56	20	11/68	1	---	---	---	---	266
108	104	8	65	35	10/63	8	8	---	---	---	267
38	38	6	34	10	9/70	3	.14	---	---	---	268
50	38	8	30	13	6/72	8	---	---	---	---	269
50	29	8	26;43	---	---	---	---	---	---	---	270
48	45	12	---	35	3/54	15	---	---	---	---	271
128	105	6	100;102	---	---	2	---	---	---	---	272
130	101	6	103	80	9/66	.5	---	---	---	---	273
52	50	8	50	5	10/73	3	.06	---	---	---	274
36	36	5	36	16	10/70	5	5	---	---	---	275
80	69	8	74	60	6/72	2	---	---	---	---	276
51	40	8	43	15	9/74	5	.2	---	---	---	277
42	21	8	36;41	20	7/65	5	---	---	---	---	278
50	---	8	---	12	12/61	15	---	---	---	---	279
40	22	8	12;22	10	9/72	12	12	---	---	---	280
44	23	8	39	15	10/70	5	.62	---	---	---	281
40	21	5	25	2	8/69	10	.36	---	---	---	282
60	23	8	25;39	2	10/67	3	---	---	---	---	283
35	22	8	9;20	5	7/76	7	.28	---	---	---	284
35	35	8	31	15	10/74	8	---	---	---	---	285
50	23	8	17	9	7/67	2	.05	---	---	---	286
50	20	8	14;20	1	9/67	15	1.1	---	---	---	287
47	24	8	18	8	6/67	4	.45	---	---	---	288
44	---	6	12;18	4	6/67	2	.18	160	430	---	289
44	27	6	22	6	7/67	.5	---	---	---	---	290
40	13	6	14;22	1	8/67	8	.3	---	---	---	291
88	88	8	80	58	6/73	6	---	130	500	---	292
40	24	6	26	10	9/66	3	.12	---	---	---	293
65	61	6	56;65	14	7/67	12	.33	---	---	---	294
80	78	6	80	15	6/68	3	.05	---	---	---	295
105	105	8	11;83;103	50	7/75	15	.50	---	---	---	296
81	81	6	77	40	1971	7	---	---	---	---	297
110	99	8	21	---	---	---	---	---	---	---	298
113	113	8	113	40	8/74	4	.20	---	---	---	299
80	68	8	---	20	8/70	15	---	---	---	---	300
71	71	8	68	---	---	20	---	---	---	---	301
75	44	8	40;52	---	---	4	---	---	---	---	302
34	34	8	19;21	15	10/74	7	---	---	---	---	303
40	27	8	31	12	7/69	20	---	---	---	---	304
55	35	8	---	---	---	---	---	---	---	---	305
46	40	8	35;42	---	---	5	---	---	---	8.3	306
53	43	6	38	7	9/70	16	.47	---	---	---	307
57	57	8	57	35	9/73	5	---	---	---	---	308
70	70	8	67	50	11/71	15	---	---	---	---	309
72	72	8	68	30	10/74	5	---	160	640	---	310
48	48	8	18;41	18	4/74	7	7	---	---	---	311
97	95	6	97	32	6/75	18	---	---	---	---	312
55	55	8	51	39	10/69	20	---	---	---	---	313
36	36	30	24	24	6/73	5	.50	255	610	---	314
93	93	8	29;86	53	4/74	22	22	---	---	---	315
50	50	8	44	14	2/75	2	---	---	---	---	316
80	64	8	60	55	9/68	.5	---	---	---	---	317
86	86	8	78	55	7/70	10	---	---	---	---	318
39	39	6	33	10	9/70	2	.2	---	---	---	319

Table 12.

Well location: Number	Well location: Lat-Long	Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Er- 320	4157-8026	C. E. Ryen	John E. Gage, Jr.	1971	H	711	F	Qb/gr
321	4157-8023	Charles Schmidt	Max E. Hickernell	1968	H	812	S	Qt/sd
322	4157-8025	Steven Lascak	B. W. Bateman and Son	1967	H	735	F	Qb/sd
323	4158-8024	H. L. Althouse	Alfred L. Burch	1970	P	722	F	Qb/sd
324	4157-8023	Merle English	B. W. Bateman and Son	1967	H	830	F	Qt/u
325	4156-8027	Leonard Coleman	do.	1966	H	750	H	Qb/sd
326	4152-8023	Earl Davis	do.	1968	H	890	S	Dch/sh
327	4152-8023	Esther Brooks	do.	1968	H	912	S	Dch/sh
328	4153-8022	Alex Bennett	Max E. Hickernell	1973	H	875	S	Dch/sh
329	4155-8028	Timothy Kupetz	Michael W. Burch	1976	H	850	H	Dg/sh
330	4154-8021	Lynn Drury	B. W. Bateman and Son	1967	H	890	S	Qo/gr
331	4154-8022	John Gage	do.	1968	H	890	H	Qo/sd
332	4152-8022	Alex Pankion	do.	1969	H	1,010	V	Qt/t
333	4151-8019	Norman Stevens	do.	1968	H	1,088	S	Qt/t
334	4152-8019	Sylvester Graczyk	Boyd Lee Hall	1973	H	985	S	Qt/t
335	4152-8019	Gerald Ulan	Max E. Hickernell	1968	H	1,021	S	Dch/st
336	4151-8016	Ronald Kimmy	Alfred L. Burch	1968	H	1,245	S	MDbv/fsh
337	4151-8016	James Loughner	do.	1966	H	1,245	S	MDbv/fsh
338	4151-8018	Paul Uram	Max E. Hickernell	1973	H	1,090	S	Dch/st
339	4152-8022	Stephen Duda	Alfred L. Burch	1970	H	1,008	F	Dch/fsh
340	4151-8021	A. B. McAdoo	Max E. Hickernell	1970	H	1,083	H	MDbv/st
341	4152-8022	George Rendulic	Alfred L. Burch	1967	H	987	U	Dch/fsh
342	4151-8019	R. F. Main	Max E. Hickernell	1975	H	1,080	U	Qo/gr
343	4151-8018	Violet Rath	do.	1970	H	1,088	U	Qt/gr
344	4152-8022	George Watral	Alfred L. Burch	1973	H	1,005	V	Dch/sh
345	4152-8020	D. E. Terry	John E. Gage, Jr.	1975	H	1,030	S	Dch/fsh
346	4151-8018	Gordon Neal	Boyd Lee Hall	1971	H	1,095	U	Dch/sh
347	4151-8007	Ward Hambry	Alfred L. Burch	1966	H	1,200	V	Qt/clgr
349	4151-8008	Ronald Larson	Boyd Lee Hall	1969	H	1,340	S	MDbr/sh
350	4151-8008	S. W. Bowne	Alfred L. Burch	1966	H	1,325	S	MDbr/fsh
351	4151-8009	J. C. Snyder	Boyd Lee Hall	---	H	1,485	S	Mc/fsh
352	4151-8009	Casimer Yeast	Moody Drilling Co., Inc.	1965	H	1,525	S	Mc/sh
353	4151-8009	R. A. Davis	Boyd Lee Hall	1967	H	1,525	S	Mc/sh
354	4151-8009	L. K. Harned	Max E. Hickernell	1966	H	1,455	S	MDbr/fsh
355	4151-8009	Gordon Flood	Boyd Lee Hall	1971	H	1,515	S	Mc/fsh
356	4151-8012	H. G. Hardman	do.	1973	S	1,378	S	MDbv/fsh
357	4151-8013	Robert Ward	do.	1975	H	1,225	S	MDbv/fsh
358	4152-8008	Bruce Hackensmith	Max E. Hickernell	1967	H	1,250	S	Dv/sed
359	4152-8009	T. K. Rowland	John E. Gage, Jr.	1973	H	1,450	S	Qt/u
360	4152-8011	Boyd Nelson	Alfred L. Burch	1969	H	1,445	V	Qt/sdgr
361	4152-8013	Steve Watrol	Max E. Hickernell	1971	H	1,243	V	Qo/gr
362	4152-8013	Steve Panko, Jr.	Lorenze Lee Hall	1973	H	1,250	S	Qo/sdgr
363	4200-8015	R. S. Pustelak	Lowell Halstead	1973	H	885	S	Qo/sd
364	4200-8015	Richard Gill	George H. Ackerman	1968	H	910	T	Qo/gr
365	4200-8015	Joseph Lamberton	Alfred L. Burch	1975	U	880	V	Qt/t
366	4200-8015	do.	do.	1975	H	870	V	Qo/sdgr
367	4200-8016	Louis Kolarick	Max E. Hickernell	1963	H	845	U	Qo/gr
368	4200-8016	---	Donald L. Hermann	1972	H	880	U	Qo/t
369	4200-8016	Patrick Filutze	Felix J. Waible	1977	H	840	S	Qo/gr
370	4200-8017	Lucman Land Corp.	Moody Drilling Co., Inc.	1972	P	785	F	Qb/gr
371	4200-8017	do.	do.	1972	P	790	F	Qb/gr
372	4200-8021	L. H. Laborde	B. W. Bateman and Son	1969	H	660	S	Dne/sh
373	4201-8015	Fairview Borough	Alfred L. Burch	1974	P	815	T	Qb/gr
374	4201-8016	George Wiser	Michael W. Burch	1975	H	760	S	Qb/gr
375	4201-8021	P. A. Burger	Charles J. Richardson III	1974	H	640	F	Qb/sdgr
376	4203-8016	W. H. Neason	do.	1973	H	660	F	Qb/sdgr
377	4203-8016	A. E. Narducci	Alfred L. Burch	1972	H	640	F	Qb/clgr
378	4203-8016	do.	Charles J. Richardson III	1973	H	600	S	Qb/sdgr
379	4203-8015	E. J. Seppala	Alfred L. Burch	1976	H	655	F	Qb/sd
380	4200-8015	G. W. Kunz	Donald L. Hermann	1972	H	900	F	Qo/sdgr
381	4200-8015	W. H. Williams, Jr.	George H. Ackerman	1974	H	840	S	Qo/sd
382	4200-8015	W. H. Williams	do.	1973	H	840	S	Qo/sd
383	4200-8015	R. J. Carter	do.	1972	H	862	H	Qo/u
384	4200-8016	R. C. Weed, Jr.	Charles J. Richardson III	1973	H	852	S	Qo/sdgr
385	4200-8017	A. A. Bartfai	Lowell Halstead	1973	H	860	H	Qo/gr
386	4200-8017	D. P. Cassell	do.	1973	H	880	H	Qo/gr
387	4200-8020	Frederick Leffingwell	Alfred L. Burch	1972	H	640	V	Qo/u
388	4201-8015	Fairview Borough Water Authority	do.	1970	P	815	T	Qo/gr
389	4201-8019	Michael Sakuta	Charles J. Richardson III	1973	H	723	F	Qb/sdgr
390	4202-8015	D. C. Schaper	George H. Ackerman	1972	H	676	F	Qb/u
391	4202-8015	V. G. Rice	Donald L. Hermann	1973	H	690	F	Qb/sdgr
392	4202-8015	Richard Wheeler	Charles J. Richardson III	1973	H	688	T	Qb/sdgr
393	4202-8018	J. O. Evans	Robert Anderson	1974	H	615	S	Qb/c

(Continued)

Total depth below land surface (feet)	Casing		Depth(s) to water-bearing zone(s) (feet)	Static water level		Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (µmho/cm at 25°C)	pH (units)	Well number
	Depth (feet)	Diameter (inches)		Depth below land surface (feet)	Date measured (mo/yr)						
38	38	8	32;35	25	6/71	5	5	---	---	---	Er- 320
91	91	8	85	50	5/68	10	---	---	---	---	321
50	50	6	23;50	15	3/67	3	.09	---	---	---	322
96	96	8	11;85;91	18	8/70	10	---	---	---	---	323
65	65	6	65	25	7/67	2	.06	---	---	---	324
46	46	6	32	2	9/66	2	.05	---	---	---	325
40	18	6	20	10	8/68	2	.07	---	---	---	326
45	11	6	12	6	7/68	2	.06	---	---	---	327
75	43	8	48	14	2/73	1	---	---	---	---	328
55	17	8	21	11	6/76	2	.05	---	---	---	329
22	21	6	20	12	4/67	3	.38	---	---	---	330
102	102	6	46;102	40	11/68	4	.09	---	---	---	331
40	15	6	16	3	5/69	10	.59	310	1,050	---	332
85	35	6	45;75	25	1/68	2	.08	---	---	---	333
40	29	8	18	10	7/73	5	.36	---	---	---	334
80	32	6	60	25	7/68	2	---	---	---	---	335
50	31	8	31;40	20	8/68	20	1	---	---	---	336
50	25	8	22;33;42	8	7/66	30	2.5	---	---	---	337
68	37	8	42	12	3/73	5	---	---	---	---	338
47	32	8	12;13;17;32	8	9/70	9	---	---	---	---	339
62	62	8	41;58	10	8/70	2	---	---	---	---	340
40	21	8	8;15;30	2	3/67	15	---	---	---	---	341
60	52	6	45;55	45	10/75	30	30	---	---	---	342
70	41	6	---	34	5/70	---	---	---	---	---	343
50	28	8	14;18;29	10	10/73	3	---	---	---	---	344
47	8	8	12;14;17	---	---	7	---	100	310	---	345
71	31	8	35	12	8/71	2	.04	---	---	---	346
50	30	8	15;25;40	8	7/66	15	---	70	300	---	347
101	---	8	69;97	50	5/69	11	.9	---	---	---	349
45	39	8	35;40	27	9/66	30	10	---	---	---	350
69	38	8	44;64	8	---	12	.3	---	---	---	351
102	20	7	28;91	30	9/65	7	---	---	---	---	352
41	27	8	---	1	---	20	1.4	---	---	---	353
130	34	6	60;85;110	30	9/66	2	---	---	---	---	354
69	38	12	44;66	20	7/71	62	62	---	---	---	355
40	20	8	15;35	10	1973	20	1	---	---	---	356
74	21	10	20;65	11	5/75	10	.17	---	---	---	357
52	25	6	29;39;45	---	---	20	---	---	---	---	358
36	28	8	16;24	8	8/73	15	15	---	---	---	359
60	45	8	14;30;41	7	3/69	8	---	---	---	---	360
40	26	8	19	7	9/71	15	---	---	---	---	361
40	38	8	35	8	7/63	40	3.3	---	---	---	362
84	84	8	38;81	---	---	30	---	---	---	---	363
38	38	6	38	6	5/68	20	---	---	---	---	364
74	62	8	8;58	---	---	---	---	---	---	---	365
17	17	8	7	4	6/75	20	---	---	---	---	366
41	41	7	---	10	3/63	20	---	---	---	---	367
96	92	8	22;92	18	7/72	5	.07	---	---	---	368
49	49	8	45	7	3/77	40	---	---	---	---	369
61	61	8	40	2	6/72	600	25	---	---	---	370
51	32	8	30	F	6/72	490	22	---	---	---	371
40	26	6	12;26	6	6/69	6	.23	---	---	---	372
40	35	12	---	24	5/74	100	7.7	---	---	---	373
45	45	8	38	35	8/75	13	1.6	---	---	---	374
34	34	30	20	20	6/74	6	.5	160	330	---	375
20	20	24	8	8	10/73	7	.7	---	---	---	376
53	---	8	15;53	---	---	---	---	---	---	---	377
34	34	30	24	16	9/73	5	.4	180	550	---	378
70	64	8	28;59	15	5/76	1	---	---	---	---	379
113	113	8	105;110	83	8/72	16	2.3	---	---	---	380
70	60	8	---	---	---	---	---	---	---	---	381
110	60	8	100	---	---	0	---	---	---	---	382
66	---	8	62	---	---	10	---	---	---	---	383
23	23	24	10	8	8/73	6	.43	---	---	---	384
78	78	8	70	---	---	6	---	---	---	---	385
74	74	8	74	19	9/73	80	---	---	---	---	386
40	13	8	7	8	10/72	1	---	---	---	---	387
50	37	8	19;30;42	24	3/70	30	---	---	---	---	388
16	16	30	7	7	7/73	12	4	---	---	---	389
50	16	8	16	5	6/72	10	---	---	---	---	390
32	32	8	29	13	1/73	20	2.2	---	---	---	391
18	18	30	7	8	11/73	7	.9	---	---	---	392
20	10	12	2	1	6/74	6	.35	---	---	---	393

Table 12.

Well location: Number	Well location: Lat-Long	Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Er- 394	4203-8016	Hugh McClelland	Charles J. Richardson III	1973	H	662	F	Qb/gr
395	4200-8007	Stanley Tecza	Donald L. Hermann	1973	H	1,080	H	Dch/ssh
396	4200-8008	A. J. Hoehn	Lowell Halstead	1973	H	1,082	H	Qt/gr
397	4200-8009	R. A. Jaworowicz	Robert Anderson	1975	H	1,060	S	Qt/t
398	4200-8009	F. E. Hammer	Donald L. Hermann	1972	H	1,032	S	Qt/clgr
399	4200-8010	Ronald Waisley	do.	1976	H	1,018	S	Dch/sh
400	4200-8010	J. A. Spaulding	Robert Anderson	1974	H	1,005	S	Dch/fsh
401	4200-8010	James Toner	do.	1974	H	1,022	S	Dch/fst
402	4200-8011	Spartan Inns of America Inc.	Felix J. Waible	1975	P	1,000	H	Qo/sdgr
403	4200-8013	Paul Bacik, Jr.	Robert Anderson	1974	H	952	H	Qt/t
404	4200-8013	Thomas Terella	---	---	H	950	H	Qt/u
405	4200-8013	David Pollock	Alfred L. Burch	1966	H	950	T	Qo/sd
406	4200-8014	W. R. Meyer	do.	1964	H	920	H	Qo/sdgr
407	4200-8014	J. M. Walsh	---	---	H	920	S	Qo/u
408	4200-8014	J. D. Baker	Alfred L. Burch	1971	H	930	S	Qt/sd
409	4201-8007	J. A. Bernet	do.	1969	H	1,076	F	Dch/fsh
410	4201-8007	Allan Otteni	do.	1970	H	1,082	F	Dch/fsh
411	4201-8007	W. H. Heath	Robert Anderson	1972	H	1,080	S	Dch/fsh
412	4201-8007	Robert Broussard	Michael W. Burch	1976	H	1,075	F	Dch/fsh
413	4201-8008	P. J. Zukowski	Harlan and Fenical	1974	H	1,062	F	Qo/u
414	4201-8008	H. D. Taylor	Lorenze Lee Hall	1973	H	1,063	S	Dch/fsh
415	4201-8008	Ross Wyman	John A. Quarno, Jr.	1976	H	1,055	S	Qo/sdgr
416	4201-8008	Happy Homes Enterprises Inc.	Michael W. Burch	1975	P	1,080	F	Dch/fsh
417	4201-8010	Paul Malinchak	Alfred L. Burch	1975	H	970	H	Qo/sdgr
418	4201-8010	Lloyd Hickey	George H. Ackerman	1976	H	990	T	Qo/sdgr
419	4201-8010	Lucien Lawson	Robert Anderson	1976	H	1,000	S	Dch/fsh
420	4201-8010	D. E. Nash	Bernard P. Kuntz	1945	H	975	H	Qo/gr
421	4201-8011	J. R. Rinderle	Robert Anderson	1974	H	890	S	Qo/gr
422	4201-8011	F. R. Chernek	do.	1974	H	1,002	H	Qo/gr
424	4201-8012	Steve Hetz	Alfred L. Burch	1973	H	930	S	Qo/sdgr
425	4201-8012	Donald Bartosik	Donald L. Hermann	1973	H	900	S	Qo/sdgr
426	4201-8012	Steve Gurak	John E. Gage, Jr.	1974	H	945	S	Qo/gr
427	4201-8012	E. S. Lindenberger	George H. Ackerman	1973	H	948	S	Qo/sd
428	4201-8013	J. T. Heinlein	Alfred L. Burch	1972	H	826	V	Qo/sdgr
429	4201-8013	Donald Vogt	Boyd Lee Hall	1968	H	848	S	Qo/u
430	4201-8014	J. A. Spaulding	Robert Anderson	1974	H	822	S	Qo/sdgr
431	4201-8014	James Benson	Alfred L. Burch	1973	H	855	S	Qo/sd
432	4201-8014	G. A. Shallenberger	do.	1971	H	832	S	Qo/sdgr
433	4202-8007	R. D. Bliley	Max E. Hickernell	1975	H	1,087	H	Dch/sh
434	4202-8007	W. H. Bachmann	Alfred L. Burch	1974	H	1,020	T	Qo/u
435	4202-8007	Ray Yosten	Michael W. Burch	1976	H	1,010	T	Dch/fsh
436	4202-8008	W. C. Dunlavey	Alfred L. Burch	1974	H	1,015	S	Dch/fsh
437	4202-8008	T. R. Brown	George H. Ackerman	1973	H	1,030	T	Qt/u
438	4202-8008	K. J. Sauers	Robert Anderson	1974	H	1,020	T	Qt/u
439	4202-8008	M. D. Dunlavey	do.	1975	H	1,010	S	Qo/gr
440	4202-8008	Roy Korrell	George H. Ackerman	1974	H	1,022	T	Qo/u
441	4202-8008	Keith Holland	Alfred L. Burch	1972	H	1,025	T	Qo/sdgr
442	4202-8008	P. M. Mead	do.	1973	H	1,010	T	Qo/sdgr
443	4202-8008	A. J. Hartleb	Donald L. Hermann	1972	H	945	S	Dch/ssh
444	4202-8008	J. E. Zietler	do.	1973	H	975	S	Dch/ssh
445	4202-8008	J. J. Grimaldi	do.	1972	H	955	S	Dch/fsh
446	4202-8008	A. L. Massey	do.	1972	H	940	S	Qo/sdgr
447	4202-8010	Harrison Putnam	Alfred L. Burch	1972	H	846	V	Qo/gr
448	4202-8010	Ernest Barber	do.	1971	H	840	V	Qo/gr
449	4202-8011	J. E. Nelsen	George H. Ackerman	1975	H	875	S	Qo/gr
450	4202-8010	Darcy Whitman	Michael W. Burch	1976	I	902	F	Qo/gr
451	4202-8011	G. G. Ellsworth	George H. Ackerman	1973	H	814	S	Qo/u
452	4202-8011	H. K. Bierer	Alfred L. Burch	1973	H	832	S	Qo/sdgr
453	4202-8011	J. P. Lantzy	do.	1973	H	852	U	Qo/gr
454	4202-8011	G. E. Beck	Donald L. Hermann	1972	H	844	U	Qo/sdgr
455	4202-8011	Methodist Church	Alfred L. Burch	1968	H	854	F	Qo/sdgr
456	4202-8011	Ronald Till	Michael W. Burch	1977	H	860	S	Qo/sdgr
457	4202-8011	Peter Czernyicky	Alfred L. Burch	1967	H	853	F	Qo/sdgr
458	4202-8011	Lillian Berarducci	George H. Ackerman	1975	H	852	F	Qo/sdgr
459	4202-8012	Thomas Gleason	Felix J. Waible	1976	H	820	U	Qo/gr
460	4202-8012	Richard Carson	Alfred L. Burch	1967	H	825	F	Qo/sdgr
461	4202-8013	W. F. Hafner	George H. Ackerman	1975	H	750	F	Qb/clgr
462	4202-8013	Gerald Allender	Felix J. Waible	1976	H	810	U	Qo/gr
463	4202-8013	Edwin Sopp	George H. Ackerman	1974	H	800	T	Qo/gr
464	4202-8014	Jarecki Industries, Ltd.	Alfred L. Burch	1973	N	800	T	Qb/clgr
465	4202-8014	Leslie Shafer	George H. Ackerman	1974	H	810	T	Qb/gr
466	4202-8014	David Keck	Alfred L. Burch	1975	H	820	H	Qb/sdgr

(Continued)

Total depth below land surface (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Depth(s) to water-bearing zone(s) (feet)	Static water level: Depth below land surface (feet)	Static water level: Date measured (mo/yr)	Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (µmho/cm at 25°C)	pH (units)	Well number
14	14	24	4	4	6/73	6	.67	---	---	---	Er- 394
60	20	12	20	16	6/73	2	---	---	---	---	395
60	50	12	50	---	---	3	---	---	---	---	396
49	27	8	26;31	16	---	5	.17	---	---	---	397
72	42	12	37	---	---	2	---	---	---	---	398
50	23	8	10;18	3	4/76	4	---	---	---	---	399
47	16	8	16;36	10	3/74	7	.2	---	---	---	400
75	16	8	16;25	11	7/74	2	.03	---	---	---	401
113	113	8	109	47	8/75	10	---	---	---	---	402
152	130	8	130	83	4/74	1	.02	---	---	---	403
105	105	6	106	38	3/76	18	---	20	390	---	404
96	96	8	59;96	---	---	20	---	---	---	---	405
127	127	6	44;70;115;123	85	11/64	15	---	---	---	---	406
105	90	5	90	58	9/76	15	---	---	---	---	407
115	---	8	72;103	---	---	---	---	---	---	---	408
60	19	8	8;20;43	1	7/69	2	---	---	---	---	409
60	18	8	16;18	8	4/70	5	---	---	---	---	410
50	17	12	22;28	11	8/72	1	.03	---	---	---	411
60	21	8	17;45	9	8/76	2	.04	---	---	---	412
67	---	8	16;42	---	---	25	---	---	---	---	413
64	---	12	23;40	8	7/73	9	.2	140	2,400	---	414
60	40	8	34	21	11/76	10	---	---	---	---	415
50	13	8	14;18	3	10/75	6	.14	---	---	---	416
73	73	8	62;68	58	2/75	24	12	---	---	---	417
65	65	8	61	42	6/76	18	---	---	---	---	418
72	12	8	35;45	24	10/76	2	---	---	---	---	419
122	122	---	---	---	---	---	---	150	430	7.7	420
42	42	8	28;40	8	8/74	15	.5	---	---	---	421
49	49	8	47	36	3/74	15	3.7	---	---	---	422
68	68	8	18;62	56	8/73	30	---	---	---	---	424
75	75	8	52;72	---	---	10	---	---	---	---	425
58	58	8	51	36	7/74	28	28	---	---	---	426
82	82	8	58;80	58	10/73	8	---	150	580	---	427
41	41	8	38	23	9/72	18	1	---	---	---	428
70	70	8	---	40	9/68	20	3.3	5	500	---	429
41	41	8	29;41	26	11/74	15	1.5	---	---	---	430
103	103	8	24;98	35	9/73	30	---	---	---	---	431
62	62	8	57	29	7/71	18	---	---	---	---	432
48	14	16	18	8	8/75	---	---	---	---	---	433
78	50	5	46	40	12/74	5	---	---	---	---	434
40	13	8	11;30	7	10/76	5	.16	---	---	---	435
60	26	8	24;48	28	4/74	6	---	---	---	---	436
75	---	8	54	20	4/73	2	---	---	---	---	437
67	46	8	45	35	7/74	3	.1	---	---	---	438
57	57	8	56	43	---	14	1.4	---	---	---	439
62	---	8	---	---	---	22	---	---	---	---	440
61	61	8	55;61	46	8/72	20	---	---	---	---	441
60	55	8	38;47;55	34	9/73	8	---	---	---	---	442
82	73	8	73	36	6/72	4	.08	---	---	---	443
60	53	8	40;46	21	1/73	10	.3	---	---	---	444
65	52	8	48	23	9/72	8	.25	---	---	---	445
55	40	8	37;42	18	12/72	15	.75	---	---	---	446
28	28	8	12	12	6/72	50	---	---	---	---	447
28	28	8	14	8	10/71	50	---	---	---	---	448
58	58	8	53	18	9/75	20	---	---	---	---	449
29	29	8	24	22	9/76	10	3.3	---	---	---	450
90	---	8	34	16	5/73	2	---	---	---	---	451
40	---	8	14;34	20	5/73	2	---	---	---	---	452
33	33	8	20;28	17	5/73	20	1.8	---	---	---	453
40	40	8	36	20	6/72	30	15	---	---	---	454
41	41	8	20;31	20	11/68	30	30	200	720	---	455
80	65	8	20;36;56;72	22	3/77	10	.2	---	---	---	456
35	35	8	22;30;35	16	9/67	30	3.3	---	---	---	457
40	40	8	28;34	10	5/75	50	---	---	---	---	458
43	43	8	39	23	5/76	---	---	---	---	---	459
26	26	8	6;16;22	2	8/67	40	5	---	---	---	460
40	40	8	36	33	7/75	25	---	---	---	---	461
52	52	8	48	30	5/76	20	---	---	---	---	462
70	60	8	59	42	11/74	5	---	---	---	---	463
54	54	10	45	38	1/73	20	10	---	---	---	464
95	95	8	92	62	11/74	12	---	---	---	---	465
86	86	8	80	71	7/75	20	4	---	---	---	466

Table 12.

Well location		Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Number	Lat-Long							
Er- 467	4152-8012	Frederick Swift	Boyd Lee Hall	1970	H	1,349	S	Qt/u
468	4202-8014	T. E. Fitzgerald	Alfred L. Burch	1974	H	804	T	Qo/gr
469	4202-8014	Peter Wowk	George H. Ackerman	1976	H	815	S	Qo/clgr
470	4203-8007	David Shallenberger	Robert Anderson	1973	H	975	S	Qt/t
471	4203-8007	C. R. Shallenberger	do.	1972	H	1,010	H	Qt/t
472	4203-8007	J. A. Reitz	Donald L. Hermann	1973	H	900	S	Qo/sdgr
473	4203-8007	W. B. Conner	do.	1973	H	905	S	Dg/ssh
474	4203-8007	C. D. Artz	Alfred L. Burch	1965	H	1,028	H	Qo/gr
475	4203-8007	James Papucci	do.	1964	H	915	U	Qo/gr
476	4203-8008	R. E. Brucker	George H. Ackerman	1972	H	910	S	Dg/fsh
477	4203-8008	J. J. Sarback	do.	1973	H	870	S	Dg/fsh
478	4203-8008	A. R. Malena	Alfred L. Burch	1973	H	886	S	Qo/sdgr
479	4203-8008	C. F. Onorato	George H. Ackerman	1972	H	825	S	Dg/fsh
480	4203-8008	H. M. Love	Felix J. Waible	1974	H	850	S	Qt/clgr
481	4203-8008	R. D. Lutsch	Alfred L. Burch	1971	H	835	S	Qt/sd
482	4203-8008	J. D. Clouser	do.	1974	H	865	S	Qo/sdgr
483	4203-8009	Robert Vogel	George H. Ackerman	1976	H	830	S	Dg/fsh
485	4203-8009	J. H. Wittman	Donald L. Hermann	1972	H	855	S	Qo/sdgr
486	4203-8009	W. L. Green	Felix J. Waible	1975	H	862	S	Qo/gr
487	4203-8009	Baldwin Brothers Inc.	do.	1975	H	875	S	Qo/sdgr
488	4203-8009	James Edgett	George H. Ackerman	1976	H	876	S	Qo/sdgr
489	4203-8009	Henry Truchanowicz	Felix J. Waible	1975	H	865	S	Qo/gr
491	4203-8009	Thomas McLaughlin	do.	1976	H	880	S	Qo/gr
492	4203-8010	Richard Blose	B. W. Bateman and Son	1968	H	832	T	Qt/t
493	4203-8010	D. M. Schlabach	Alfred L. Burch	1971	H	835	H	Qo/sdgr
494	4203-8010	D. J. Strong	do.	1971	H	815	S	Qo/sd
495	4203-8010	B. R. Phillips	do.	1971	H	815	S	Qo/gr
496	4203-8009	Winston Warren	George H. Ackerman	1976	H	828	S	Qo/gr
497	4203-8010	Westminster Water Co.	Alfred L. Burch	1969	P	804	S	Qo/sdgr
498	4203-8010	Richard Samsel	do.	1969	H	862	H	Qo/gr
499	4203-8011	M. E. Vonbuseck	Donald L. Hermann	1972	H	805	S	Qo/gr
500	4203-8011	G. L. Locke	Alfred L. Burch	1972	H	840	H	Qo/sdgr
501	4203-8011	James Glazier	Robert Anderson	1972	H	818	S	Qo/gr
502	4203-8011	Mykola Kuvshinikov	George H. Ackerman	1973	H	750	S	Qb/sdgr
503	4152-8013	James Kearney	B. W. Bateman and Son	1968	H	1,264	S	Qo/gr
504	4203-8011	David Shontz	Felix J. Waible	1976	H	795	S	Qo/gr
505	4152-8013	Frank Connell	Max E. Hickernell	1966	H	1,275	S	MDbv/fst
506	4203-8011	L. R. Ritts	Bernard P. Kuntz	1950	H	798	S	Qo/gr
507	4203-8012	George Simitoski	Alfred L. Burch	1967	H	795	S	Qo/sdgr
508	4203-8012	Swanville Development Co.	do.	1974	H	800	S	Qo/sdgr
509	4203-8012	Erie Bronze and Aluminum Co.	do.	1972	N	748	T	Qb/sdgr
510	4203-8012	Anna Lazarow	George H. Ackerman	1973	H	786	S	Qb/u
511	4153-8014	Cyril Ley, Jr.	Max E. Hickernell	1966	H	1,273	S	MDbv/fst
512	4203-8014	D. J. Hart	Charles J. Richardson III	1973	H	735	T	Qb/sdgr
513	4203-8014	R. E. Erven	Alfred L. Burch	1964	H	704	T	Qb/t
514	4154-8013	Joseph Shepegi	John E. Gage, Jr.	1972	H	1,300	S	MDbv/sh
515	4154-8014	H. R. Grill	Alfred L. Burch	1967	H	1,300	H	Qt/clgr
516	4204-8008	Rose Bock	Robert Anderson	1975	H	918	H	Qo/gr
517	4204-8008	David Czarnecki	Max E. Hickernell	1963	H	910	U	Qt/gr
518	4204-8008	P. E. Wright	Robert Anderson	1975	H	900	H	Qo/gr
519	4204-8008	W. G. Shepard	do.	1974	H	900	S	Qo/gr
520	4204-8008	Leroy Peterson	Alfred L. Burch	1967	H	820	S	Qo/sd
521	4204-8008	Robert Brudnock	Michael W. Burch	1976	H	840	S	Qt/t
522	4204-8008	Springhurst Inc.	do.	1977	H	866	S	Qo/gr
523	4204-8008	R. E. Peterson	Robert Anderson	1972	H	866	H	Qo/gr
524	4204-8008	Walter Gorney	George H. Ackerman	1975	H	876	S	Qo/sdgr
525	4204-8009	J. J. Sturgeon	do.	1973	H	838	S	Qo/u
526	4204-8009	William Walker	Alfred L. Burch	1967	H	835	S	Qo/sdgr
527	4204-8008	Robert Brudnock	Michael W. Burch	1976	H	850	S	Dg/fsh
528	4204-8009	C. F. Kingston	Donald L. Hermann	1972	H	850	S	Qo/sdgr
529	4204-8009	John Williams	Felix J. Waible	1976	H	882	S	Qo/gr
530	4204-8009	Donald Fabian	Michael W. Burch	1975	H	860	S	Qo/u
531	4204-8009	J. E. Walaconis	Alfred L. Burch	1972	H	844	S	Qo/sd
532	4204-8009	Richard Estock	do.	1964	H	815	S	Qo/sd
533	4204-8009	Raymond Burns	do.	1964	H	820	S	Qo/sdgr
534	4204-8009	N. C. Calvano	Charles Rumsey	1973	H	850	S	Qo/sdgr
535	4204-8009	A. A. Krista	Felix J. Waible	1974	H	820	S	Qt/t
536	4204-8009	Theodore Stolz	Max E. Hickernell	1966	H	844	S	Qo/gr
537	4204-8010	Stanley Clark	Alfred L. Burch	1966	H	778	S	Qb/gr
539	4204-8010	Eighty-Four Lumber Co.	Felix J. Waible	1975	H	738	F	Qb/sdgr
540	4204-8010	Reginald Payne	Max E. Hickernell	1971	H	767	S	Qb/clgr
541	4204-8011	R. J. Dieter	Alfred L. Burch	1974	H	736	F	Qb/sd
542	4204-8011	G. J. Blattenberger	do.	1974	H	734	F	Qb/sd
543	4204-8011	J. F. Mahoney	do.	1972	H	734	F	Qb/sd

(Continued)

Total depth below land surface (feet)	Casing		Depth(s) to water-bearing zone(s) (feet)	Static water level		Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (µmho/cm at 25°C)	pH (units)	Well number
	Depth (feet)	Diameter (inches)		Depth below land surface (feet)	Date measured (mo/yr)						
54	29	6	29;51	10	11/70	45	4.5	---	---	---	Er- 467
57	57	8	51	37	7/74	5	---	---	---	---	468
42	42	8	36	20	6/76	12	---	---	---	---	469
123	95	8	75	69	1/73	4	.08	---	---	---	470
120	87	8	87	66	10/72	1	.02	---	---	---	471
41	41	8	35;40	12	7/63	30	3	---	---	---	472
70	29	8	18;27	18	7/73	8	.18	---	---	---	473
80	68	8	65	60	9/65	10	---	---	---	---	474
61	61	6	37;53	30	6/64	15	---	---	---	---	475
75	---	---	52	---	---	10	---	---	---	---	476
85	---	8	---	5	7/73	4	---	---	---	---	477
32	32	8	17;23	10	5/73	50	7.1	---	---	---	478
55	---	8	16;32	---	10/72	20	---	---	---	---	479
70	17	8	13	14	8/74	2	---	---	---	---	480
26	26	8	22;26	15	8/71	12	---	---	---	---	481
50	50	8	38;44	28	6/74	20	---	---	---	---	482
60	30	8	25;55	18	8/76	50	4	---	---	---	483
35	35	8	31	12	8/72	7	.39	---	---	---	485
66	66	8	62	48	5/75	20	---	---	---	---	486
73	73	8	69	50	8/75	20	---	---	---	---	487
101	101	8	95	65	8/76	50	3.8	---	---	---	488
66	66	8	62	---	6/75	20	---	---	---	---	489
80	80	8	76	57	10/76	20	---	---	---	---	491
65	20	6	21	15	8/68	1	.02	---	---	---	492
50	39	8	32	28	10/71	30	2.5	---	---	---	493
28	28	8	22	16	10/71	20	---	---	---	---	494
40	22	8	12	1	10/71	30	---	---	---	---	495
50	38	8	34	6	3/76	50	8.3	---	---	---	496
44	39	10	18;36	13	7/69	180	7.5	250	---	7.7	497
46	46	8	25;42	22	1/69	9	---	---	---	---	498
43	43	8	42	23	8/72	15	1.5	---	---	---	499
80	80	8	39;70;73	50	1/72	30	3	---	---	---	500
55	55	8	55	32	8/72	15	2.5	---	---	---	501
31	31	8	---	3	8/73	16	---	---	---	---	502
40	20	6	17;33	8	9/68	6	.27	720	2,700	---	503
45	45	8	40	12	8/76	15	---	---	---	---	504
41	22	8	26;33;38	6	1966	20	---	---	---	---	505
46	46	--	---	---	---	---	---	230	418	7.5	506
46	46	6	25;38	---	---	30	---	---	---	---	507
55	55	8	49	30	12/74	30	4.3	---	---	---	508
19	14	8	7	+2	9/72	75	---	---	---	---	509
49	49	8	44	7	7/73	18	---	---	---	---	510
44	33	6	29;37	6	10/66	20	---	---	---	---	511
23	23	24	11	11	5/73	16	8	---	---	---	512
44	44	6	14;32	12	11/64	5	---	---	---	---	513
61	47	8	12;48	10	6/72	3	.08	---	---	---	514
50	36	8	31	11	7/67	4	---	---	---	---	515
87	87	---	85	77	7/75	6	6	---	---	---	516
95	95	6	91	70	8/63	15	---	---	---	---	517
75	75	8	72	60	7/75	25	5	---	---	---	518
76	76	8	58;76	55	8/74	15	3.8	---	---	---	519
67	67	8	44;55	34	12/67	10	.3	---	---	---	520
60	60	8	31	26	4/76	1	.03	---	---	---	521
65	65	8	57	22	3/77	30	30	---	---	---	522
51	51	8	51	29	8/72	15	7.5	---	---	---	523
83	83	8	74	50	5/75	40	---	---	---	---	524
60	60	8	54	---	---	20	---	---	---	---	525
57	55	6	33;37	25	5/67	9	1.8	---	---	---	526
97	72	8	35;46;71	20	4/76	.2	---	---	---	---	527
46	46	8	34	12	12/72	7	.24	---	---	---	528
80	80	8	70	---	---	---	---	---	---	---	529
68	68	8	27;62	50	11/75	15	1	---	---	---	530
80	69	8	12;25;62	40	6/72	.8	---	---	---	---	531
72	65	8	22;54;61	30	6/64	2	---	---	---	---	532
42	40	6	36	29	10/64	10	---	---	---	---	533
75	55	8	---	---	---	---	---	---	---	---	534
70	54	12	50	29	11/74	1	---	---	---	---	535
40	40	9	36	10	5/66	17	---	190	460	---	536
50	48	8	30;44	24	11/66	6	.23	---	---	---	537
29	29	8	25	8	4/75	20	---	---	---	---	539
60	60	8	56	50	9/71	10	10	---	---	---	540
36	36	8	19;30	8	11/74	10	---	---	---	---	541
77	77	8	17;46;71	14	9/74	4	---	---	---	---	542
35	35	8	21;33	10	7/72	10	---	---	---	---	543

Table 12.

Well location		Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/lithology
Number	Lat-Long							
Er- 544	4204-8011	B. A. Brocious	Alfred L. Burch	1972	H	733	F	Qb/sdgr
545	4204-8011	A. G. Youngquist	do.	1971	H	734	F	Qb/sd
546	4204-8012	R. M. Kennelley	George H. Ackerman	1972	H	732	F	Qb/u
547	4204-8012	C. W. Bennett	Alfred L. Burch	1973	H	734	F	Qb/sdgr
548	4204-8012	Edward Bogert	do.	1968	H	728	F	Qb/sd
549	4204-8012	P. S. Rathmell	do.	1970	H	738	F	Qb/sd
550	4204-8012	Russell Wright	Bernard P. Kuntz	1948	H	730	F	Qb/gr
551	4204-8012	D. R. Blose	George H. Ackerman	1974	H	731	F	Qb/sdgr
552	4204-8011	Bruce Rogers	Alfred L. Burch	1966	H	738	F	Qb/t
553	4204-8012	Lake Shore Volunteer Fire Department	do.	1967	F	730	F	Qb/sdgr
554	4204-8012	D. S. Brougham	do.	1974	H	733	F	Qb/sdgr
555	4204-8012	Roy Dean	do.	1972	H	737	F	Qb/gr
556	4204-8013	J. N. Reed	do.	1969	H	690	F	Qb/sd
557	4205-8008	Elmer Shorts	do.	1969	H	764	S	Qb/sdgr
558	4152-8009	Thomas Kirdahy	Lorenze Lee Hall	1975	H	1,275	S	Dv/fsh
559	4152-8009	Culbertson Co.	Boyd Lee Hall	1976	H	1,313	S	Dv/fsh
560	4152-8009	The Country Villa	Max E. Hickernell	1972	P	1,300	S	Dv/fsh
561	4153-8007	F. F. Curtze	do.	1971	H	1,230	S	Qt/gr
562	4153-8009	John Yatzor, Jr.	Alfred L. Burch	1966	H	1,325	S	Dv/sh
563	4153-8009	Daniel Overheim	Boyd Lee Hall	1968	H	1,280	S	Qt/u
564	4153-8009	Orville Porterfield	do.	1968	H	1,248	S	Qt/u
565	4153-8009	Daniel Horn	do.	1968	H	1,258	S	Qt/u
566	4153-8009	P. A. Smith	Max E. Hickernell	1967	H	1,255	S	Dv/fsh
567	4153-8009	P. S. Smith	Boyd Lee Hall	1971	H	1,260	S	Dv/fsh
568	4153-8009	D. H. Karrfalt	Robert Anderson	1974	H	1,260	S	Dv/fsh
569	4153-8008	T. D. Hutchison	Boyd Lee Hall	1971	H	1,235	S	Dv/fsh
570	4153-8008	Gertrude McCracken	Felix J. Waible	1977	H	1,225	S	Qo/gr
571	4153-8008	Richard Goodenow	Boyd Lee Hall	1976	H	1,261	S	Dv/fsh
572	4153-8008	John Hebert	Moody Drilling Co., Inc.	1965	H	1,200	V	Qo/sdgr
573	4153-8008	M. L. Smith	Boyd Lee Hall	1970	H	1,264	S	Dv/fsh
574	4153-8008	T. N. Davies	Alfred L. Burch	1971	H	1,240	S	Dv/fsh
575	4153-8008	Glen Harned	do.	1968	H	1,222	S	Qt/gr
576	4153-8011	James Pfadt	do.	1968	H	1,416	S	MDbv/fsh
577	4153-8012	David Bucko	Lorenze Lee Hall	1975	H	1,355	S	MDbv/fsh
578	4153-8012	Finley Horn	Max E. Hickernell	1962	H	1,340	S	MDbv/fsh
579	4154-8007	John Lovett	Alfred L. Burch	1967	P	1,268	S	Qo/gr
580	4154-8009	Martha Chernichky	Robert Anderson	1977	H	1,390	S	Dv/fsh
581	4154-8012	Frank Reichart	Boyd Lee Hall	1972	H	1,310	S	MDbv/fsh
582	4154-8012	W. L. Harman	do.	1974	H	1,330	S	MDbv/fsh
583	4154-8012	D. E. Lohr	do.	1973	H	1,322	S	Qt/u
584	4154-8012	Ella Weed	do.	1966	H	1,323	S	Qt/u
585	4154-8012	Harold Fritzges	B. W. Bateman and Son	1967	H	1,338	S	MDbv/fsh
586	4154-8013	L. E. Pieper	Boyd Lee Hall	1970	H	1,322	S	MDbv/fsh
587	4155-8007	Ronald Coleman	Donald E. Hall	1976	H	1,264	S	Qt/u
588	4155-8008	H. E. Allen	Max E. Hickernell	1967	H	1,290	S	Dv/fst
589	4155-8008	R. P. Baxter	Boyd Lee Hall	1973	H	1,274	S	Qt/u
590	4155-8012	Gloria Bochert	B. W. Bateman and Son	1966	H	1,304	S	MDbv/fsh
591	4155-8012	Woodrow Mooney	do.	1967	H	1,308	S	MDbv/fsh
592	4155-8012	I. W. Hardman	Boyd Lee Hall	1971	H	1,268	S	MDbv/fsh
593	4155-8013	William Sheffer	Max E. Hickernell	1976	H	1,240	S	MDbv/fsh
594	4155-8014	Bernard Vincent	Felix J. Waible	1975	H	1,178	S	Qt/u
595	4156-8007	Ronald Price	Boyd Lee Hall	1974	H	1,360	S	Dv/fsh
596	4156-8008	C. M. Bolla	do.	1975	H	1,205	S	Qo/gr
597	4156-8008	T. M. Ponting	Robert Anderson	1974	H	1,208	S	Qt/clgr
598	4156-8008	J. B. Mares	Max E. Hickernell	1967	H	1,315	S	Dv/fsh
599	4156-8009	C. D. Irwin	Alfred L. Burch	1968	H	1,372	S	Qt/gr
600	4156-8009	Raymond Scalise	do.	1968	H	1,328	S	Dv/sh
601	4156-8011	R. P. Beck	do.	1966	H	1,300	S	Dv/fsh
602	4156-8011	do.	do.	1966	H	1,295	S	Dv/fsh
603	4156-8012	Albert Vogt	Max E. Hickernell	1974	H	1,282	S	Qt/gr
604	4156-8012	C. F. Krautter	do.	1970	H	1,265	S	MDbv/fsh
605	4156-8013	George Gresh	Alfred L. Burch	1968	H	1,224	S	MDbv/fsh
606	4156-8013	Franklin Center Church	Max E. Hickernell	1964	H	1,228	S	MDbv/fst
607	4156-8013	Robert Farmer	Alfred L. Burch	1967	H	1,224	S	Qt/sdgr
608	4156-8013	Timothy Broderick	Robert Anderson	1976	H	1,184	S	MDbv/sh
609	4156-8014	Alice Fernandes	Alfred L. Burch	1968	H	1,206	S	MDbv/fsh
610	4156-8014	D. M. Lewis	Donald L. Hermann	1972	H	1,193	S	MDbv/ssh
611	4156-8014	Paul Homchenko	Felix J. Waible	1975	H	1,191	S	Qt/t
612	4156-8014	Edward Pulinski	do.	1975	H	1,182	S	Qt/t
613	4157-8008	Edward Willey	Alfred L. Burch	1969	H	1,158	S	Qt/gr
614	4157-8008	Michael Wilkoz	Donald L. Hermann	1972	H	1,120	V	Dch/ssh
615	4157-8009	D. E. Osterberg	do.	1973	H	1,248	S	Dv/ssh
616	4157-8009	K. R. Gnagi	Alfred L. Burch	1973	H	1,294	H	Dv/sh

(Continued)

Total depth below land surface (feet)	Casing		Depth(s) to water-bearing zone(s) (feet)	Static water level		Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conduc-tance (μmho/cm at 25°C)	pH (units)	Well number
	Depth (feet)	Diameter (inches)		Depth below land surface (feet)	Date measured (mo/yr)						
51	51	8	36;46	29	7/72	10	---	---	---	---	Er- 544
65	65	8	18;28	10	10/71	10	---	---	---	---	545
90	---	8	86	12	6/72	1	---	---	---	---	546
77	77	8	21;72	12	4/73	20	.7	---	---	---	547
90	90	8	44;84	---	---	4	---	---	---	---	548
36	36	8	13;29	---	---	10	---	---	---	---	549
32	32	---	---	---	---	---	---	130	400	7.8	550
105	92	8	85	17	11/74	1	---	---	---	---	551
63	53	8	12;25;49	8	8/66	2	---	---	---	---	552
32	32	8	24	20	5/67	15	---	---	---	---	553
61	61	8	17;34;41	8	6/74	5	---	---	---	---	554
31	31	8	16;25	7	4/72	15	---	---	---	---	555
73	---	---	45;53	48	1/69	.1	---	310	3,500	---	556
50	27	8	32	14	4/69	7	---	---	---	---	557
50	20	8	28;45	5	5/75	23	.57	---	---	---	558
68	48	8	48;55	---	---	20	---	---	---	---	559
70	25	10	27;39	6	3/72	15	---	---	---	---	560
32	32	8	28	21	10/71	10	10	---	---	---	561
70	19	8	19	10	9/66	1	---	25	1,500	---	562
60	60	8	60	5	12/68	10	10	---	---	---	563
60	60	8	60	4	12/68	10	10	---	---	---	564
52	52	8	50	10	12/68	10	10	---	---	---	565
80	46	6	51;62;79	20	6/67	15	---	---	---	---	566
63	50	8	60	---	---	5	.6	---	---	---	567
68	44	8	44;52	14	4/74	6	.11	---	---	---	568
53	22	8	30;50	8	4/71	30	30	---	---	---	569
37	37	8	33	15	3/77	20	---	---	---	---	570
60	37	8	36;57	15	5/76	10	.25	---	---	---	571
47	47	7	21	4	11/65	20	2.5	---	---	---	572
52	30	8	32;47	10	10/70	22	1.8	---	---	---	573
60	41	8	21;50	7	5/71	19	---	---	---	---	574
39	39	8	22	20	12/68	10	1	---	---	---	575
53	17	8	14;40	5	6/68	15	---	---	---	---	576
55	33	8	21;49	2	5/75	46	1.6	---	---	---	577
48	26	7	---	20	5/62	4	---	---	---	---	578
50	---	8	17;43	12	4/67	2	---	---	---	---	579
87	15	8	20;75	7	3/77	30	1.5	---	---	---	580
55	14	8	21;51	4	5/72	7	.15	---	---	---	581
68	21	10	28;61	5	1974	15	.3	---	---	---	582
70	24	8	24	10	10/73	10	.2	---	---	---	583
65	30	6	51;63	14	8/66	20	20	---	---	---	584
40	22	6	24	15	5/67	4	.2	---	---	---	585
92	24	8	45	12	11/70	1	---	---	---	---	586
37	37	8	21;37	---	---	---	---	---	---	---	587
46	24	8	28;42	8	1/67	7	---	---	---	---	588
48	48	8	18	---	---	---	---	---	---	---	589
38	31	6	33	12	8/66	6	.3	---	---	---	590
52	38	6	40	8	6/67	3	.07	125	490	---	591
52	30	8	---	---	---	4	---	---	---	---	592
42	29	8	29;38	1	5/76	7	.2	---	---	---	593
40	13	8	9	1	5/75	6	---	---	---	---	594
110	54	8	90;105	6	8/74	50	.7	---	---	---	595
110	110	8	53;110	12	7/75	10	.14	105	430	---	596
44	44	8	22	2	3/74	7	.17	---	---	---	597
46	16	8	16;35	4	1/67	10	---	---	---	---	598
40	24	8	20;38	3	6/68	50	3.3	---	---	---	599
55	21	8	8;20	10	9/68	1	---	---	---	---	600
50	12	8	11;20;28	10	6/66	3	---	---	---	---	601
60	28	8	22;40	6	6/66	3	---	---	---	---	602
50	40	8	37	12	4/74	7	---	---	---	---	603
64	36	8	38	---	---	5	---	---	---	---	604
60	37	8	34;40	9	8/68	4	---	---	---	---	605
43	27	8	27;40	8	7/64	5	---	---	---	---	606
40	20	6	15;19;32	8	3/67	10	---	---	---	---	607
61	25	8	38	8	6/76	1	.02	---	---	---	608
70	55	8	18;65	15	11/68	3	---	---	---	---	609
35	15	8	12;15	4	6/72	2	.07	---	---	---	610
40	13	8	9	1	5/75	6	---	---	---	---	611
40	13	8	9	1	5/75	18	---	---	---	---	612
86	86	8	33	20	3/69	5	---	---	---	---	613
80	73	8	73	32	9/72	2	---	---	---	---	614
41	37	8	37	12	2/73	3	---	---	---	---	615
80	38	8	21;33;74	16	6/73	1	---	---	---	---	616

Table 12.

Well location		Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Number	Lat-Long							
Er- 617	4157-8012	William Bland	Robert Anderson	1974	H	1,196	S	MDbv/fsh
618	4151-7946	Hattie Miles	McCray Bros.	1974	H	1,558	S	MDcr/fsh
619	4151-7946	R. M. Fuller	do.	1974	H	1,615	S	MDcr/fsh
620	4151-7948	Leo Kusiak	Harold F. Anderson	1975	H	1,609	S	MDcr/fsh
621	4151-7949	L. E. Sorenson	Donald L. Hermann	1973	H	1,582	V	Mc/fsh
622	4151-7951	Delmont Taylor	McCray Bros.	1973	H	1,535	S	MDcr/fsh
623	4152-7945	Robert Crandall	do.	1972	H	1,522	S	MDcr/sh
624	4152-7945	John Edwards	do.	1972	H	1,515	H	MDcr/fsh
625	4152-7952	Clarence Baker	Robert Rindfuss	1974	H	1,450	S	MDcr/fsh
626	4151-7953	E. J. Brown	Alfred L. Burch	1972	H	1,590	S	MDcr/fsh
627	4151-7953	Paul Mongera	do.	1970	H	1,602	S	MDcr/fsh
628	4151-7954	W. J. Wurst, Jr.	Donald L. Hermann	1973	H	1,618	S	Mc/fsh
629	4151-7957	R. P. Cole	Robert Rindfuss	1972	H	1,516	S	MDcr/fsh
630	4151-7957	M. L. Blum	do.	1972	H	1,390	S	MDcr/fsh
631	4152-7957	J. T. Kerr	Alfred L. Burch	1970	H	1,262	S	Dv/fsh
632	4152-7958	R. A. Marzka	Robert Rindfuss	1977	H	1,275	S	Dv/fsh
633	4152-7958	W. C. Blum	Alfred L. Burch	1969	H	1,248	S	Dv/fsh
634	4158-7937	Terry Darnofall	McCray Bros.	1972	H	1,520	S	Qt/clgr
635	4207-7951	Robert Sedelmyer	George H. Ackerman	1976	H	1,449	S	Qt/sdgr
636	4208-7951	Nick Woznicki	Michael W. Burch	1976	H	1,480	S	Qt/sdgr
637	4207-7951	J. P. Heyer	Robert Anderson	1972	H	1,468	S	Dv/fsh
638	4208-7947	David Ihrig	George H. Ackerman	1976	H	1,425	S	Qt/u
639	4208-7950	A. F. Barnett	Harold F. Anderson	1974	H	1,480	H	Qo/gr
640	4208-7951	Richard Cass	Robert Rindfuss	1975	H	1,419	S	Dch/fsh
641	4208-7951	J. W. Sienicki	George H. Ackerman	1973	H	1,485	S	Qt/u
642	4208-7951	R. B. Abbey	Alfred L. Burch	1972	H	1,488	S	Qt/t
643	4208-7951	Paul Mosher	George H. Ackerman	1975	H	1,430	S	Qt/clgr
644	4209-7949	W. R. Brooks	Robert F. Rumball	1973	H	1,415	S	Dch/sh
645	4209-7950	C. J. Babcock	Alfred L. Burch	1968	H	1,360	S	Dch/fst
646	4209-7950	R. E. Snyder	do.	1974	H	1,350	S	Dch/fsh
647	4209-7950	do.	do.	1973	H	1,345	S	Dch/fst
648	4209-7950	do.	do.	1973	H	1,353	S	Dch/fsh
649	4209-7951	T. L. Fuller	Donald L. Hermann	1973	H	1,333	S	Dch/fsh
650	4209-7950	John Ferko	Ralph Wayne Grant	1973	H	1,270	S	Dch/fst
651	4209-7951	David Edwards	Robert Anderson	1976	H	1,335	S	Dch/ssh
652	4209-7951	Jerry Burkett	do.	1976	H	1,338	S	Dch/sh
653	4210-7946	Raymond Manning	Ralph C. Parmenter	1974	H	1,432	S	Qt/gr
654	4210-7947	Raymond Way	do.	1972	H	1,295	S	Dch/fsh
655	4210-7947	Gerald Wilcher	do.	1975	H	1,325	S	Dch/fsh
656	4210-7949	D. W. Gregory	George H. Ackerman	1975	H	1,230	S	Qt/clgr
657	4210-7949	Charles Herman	Ralph C. Parmenter	1976	H	1,302	S	Dch/fsh
658	4210-7951	G. V. McCumber	Robert Anderson	1972	H	1,230	S	Dch/fsh
659	4211-7946	J. D. Genet	George H. Ackerman	1972	H	1,354	S	Dch/fsh
660	4211-7947	R. L. Newton	do.	1973	H	1,165	S	Qt/u
661	4211-7950	N. F. Hubert	do.	1973	H	1,025	S	Qt/u
662	4211-7951	W. C. Walker, Jr.	Alfred L. Burch	1975	H	815	S	Dg/ssh
663	4211-7951	James Cook	Harold F. Anderson	1975	H	864	S	Qt/t
664	4211-7952	J. R. Culver	Alfred L. Burch	1971	H	855	S	Dg/sh
665	4212-7948	D. C. McClelland	Robert Anderson	1974	H	960	S	Dg/sh
666	4213-7948	J. M. Phillips-Fruit Acres	Ralph C. Parmenter	1974	H	820	U	Dne/fsh
667	4213-7950	Bernard Duda	do.	1974	H	670	S	Dne/fsh
668	4213-7950	G. J. Otto	Alfred L. Burch	1973	H	680	S	Dne/sh
669	4213-7951	William Edder	do.	1976	H	720	S	Qt/sdgr
670	4213-7952	George Crittendon	Ralph C. Parmenter	1974	H	732	F	Qt/u
671	4214-7946	Edward Orton	George H. Ackerman	1974	H	743	F	Qo/gr
672	4214-7946	John Verakis	do.	1974	H	744	F	Qo/u
673	4214-7947	Dennis Geraci	do.	1976	H	795	S	Qo/gr
674	4214-7949	Harry Schiemer	McCray Bros.	1974	H	625	H	Dne/fsh
675	4214-7950	E. E. Kent	Alfred L. Burch	1973	H	710	F	Qo/sdgr
676	4215-7948	Thomas McCoy	do.	1975	H	610	H	Qt/sdgr
677	4215-7946	Catherine Weyers	do.	1968	H	704	S	Qt/gr
678	4215-7947	T. C. Jones	Michael W. Burch	1976	H	600	S	Dne/ssh
679	4215-7947	do.	do.	1976	H	620	S	Dne/sh
680	4207-7953	D. G. Bliley	Robert Anderson	1972	H	1,390	S	Dch/fsh
681	4207-7957	James Carroll	Alfred L. Burch	---	U	994	V	Qt/clgr
682	4208-7958	Dean Etzel	do.	1968	H	920	S	Qo/sdgr
683	4208-7958	Joseph Garner	do.	1968	H	775	S	Dg/sh
684	4207-7958	R. H. Lapenz	Robert Anderson	1974	H	1,010	H	Qt/t
685	4207-7958	Monte Collier	do.	1976	H	1,020	H	Qo/sdgr
686	4207-7958	---	Michael W. Burch	1977	H	1,022	H	Dch/fsh
687	4207-7958	K. F. Bellotti	Alfred L. Burch	1971	H	1,000	H	Qo/sdgr
688	4208-7958	R. P. Overdorff	do.	1969	H	845	S	Dg/sh
689	4208-7954	Graydon Dougan	Ralph C. Parmenter	1974	H	1,165	U	Dch/fsh
690	4208-7954	William Gindy	Robert Anderson	1975	H	1,140	S	Dch/fsh

(Continued)

Total depth below land surface (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Depth(s) to water-bearing zone(s) (feet)	Static water level: Depth below land surface (feet)	Static water level: Date measured (mo/yr)	Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (μmho/cm at 25°C)	pH (units)	Well number
62	13	8	20;25	4	7/74	5	.09	---	---	---	Er- 617
105	41	6	45;63;79;100	37	4/74	12	.3	---	---	---	618
65	20	6	28;40;60	25	4/74	15	.75	---	---	---	619
60	21	8	21;55	6	10/75	5	---	60	190	---	620
45	20	8	15;32	12	8/73	5	.18	---	---	---	621
65	30	6	40;50;60	20	4/73	10	.33	110	305	---	622
120	60	6	70;80;90	20	7/72	2	.02	---	---	---	623
70	20	6	40;50;60	20	5/72	20	20	115	320	---	624
57	40	8	48	25	1974	30	1.3	---	---	---	625
80	14	8	12;14;70	30	12/72	30	1.5	---	---	---	626
80	35	8	13;17;32	13	12/70	14	---	---	---	---	627
75	27	12	27;65	15	11/73	10	.22	---	---	---	628
65	35	8	55	22	7/72	8	.2	---	---	---	629
48	---	8	38	15	6/72	10	---	---	---	---	630
55	---	8	17	5	9/70	15	---	---	---	---	631
71	45	8	42;61	---	---	5	.1	---	---	---	632
60	24	8	30;40	22	8/69	5	---	---	---	---	633
100	90	6	90	5	7/72	20	20	---	---	---	634
50	22	8	17	3	8/76	5	---	---	---	---	635
80	56	8	36;53	45	7/76	3	.12	---	---	---	636
50	25	8	25;30	6	10/72	6	.15	105	280	---	637
55	28	8	21	+2	5/76	15	---	---	---	---	638
82	62	8	62;70	---	---	7	---	---	---	---	639
75	35	8	42	9	8/75	4	.07	---	---	---	640
50	34	8	30	---	---	12	---	---	---	---	641
50	41	8	37;45	21	6/72	20	---	---	---	---	642
60	35	8	29;54	5	9/75	2	---	90	1,200	---	643
69	14	8	35;60	---	---	1	---	---	---	---	644
60	22	8	22;40;50	2	1/68	12	---	---	---	---	645
60	18	8	13	4	6/74	3	---	---	---	---	646
60	17	8	17;38	6	11/73	2	---	---	---	---	647
55	19	8	8;20;35	5	11/73	4	---	---	---	---	648
35	10	8	30	3	10/73	4	.15	---	---	---	649
50	25	8	30;45	12	2/73	---	---	170	410	---	650
35	11	12	14	4	2/76	1	.03	---	---	---	651
40	12	12	16;20	40	9/76	.5	---	---	---	---	652
168	168	5	---	60	7/74	3	.05	---	---	---	653
55	20	5	---	35	6/72	3	.3	75	330	---	654
50	15	6	20	7	9/75	4	.11	---	---	---	655
70	24	12	21;34;56	10	4/75	14	---	---	---	---	656
40	15	6	---	---	---	10	---	---	---	---	657
51	12	8	26	16	10/72	7	.23	310	840	7.0	658
78	22	8	16;38;46	6	7/72	12	---	---	---	---	659
62	21	8	21	---	---	2	---	85	590	---	660
60	22	8	20	---	---	12	---	---	---	---	661
50	19	8	5;18;20;32	8	6/75	5	---	---	---	---	662
30	16	12	14;28	---	---	6	---	60	525	---	663
35	10	8	12;14	9	9/71	.5	---	160	500	---	664
50	18	8	---	34	10/74	.1	---	---	---	---	665
43	20	6	---	20	7/74	5	.41	150	400	---	666
40	20	8	---	12	10/74	5	.36	---	---	---	667
65	22	8	17;30	5	6/73	2	.04	---	---	---	668
150	120	8	---	---	---	---	---	---	---	---	669
47	47	5	3	30	7/74	5	.5	---	---	---	670
70	42	12	36;62	23	11/74	5	---	---	---	---	671
87	31	8	30	12	2/74	.5	---	---	---	---	672
30	30	8	---	22	4/76	5	---	---	---	---	673
80	30	8	37;45;60	35	1/74	3	.08	---	---	---	674
94	94	8	45;86	60	6/73	10	---	70	330	---	675
50	33	8	23;48	30	10/75	5	---	---	---	---	676
50	16	8	9;15	7	6/68	2	---	170	600	---	677
89	12	8	9	7	1/76	.5	.006	---	---	---	678
60	23	8	16;20	4	1/76	.5	.009	---	---	---	679
53	10	8	12	12	10/72	7	.18	5	220	---	680
60	---	8	30	---	---	---	---	---	---	---	681
55	37	8	26;32;48	5	7/68	20	.5	---	---	---	682
50	14	8	14;27	6	2/68	.5	---	---	---	---	683
75	74	8	67;74	37	9/74	8	.27	---	---	---	684
66	66	8	65	45	3/76	17	2.4	---	---	---	685
110	97	8	99	52	3/77	2	.04	---	---	---	686
70	64	10	10;59	15	4/71	5	---	---	---	---	687
60	---	8	30	19	9/69	1	---	---	---	---	688
60	20	5	31	---	---	---	---	---	---	---	689
40	27	8	27	7	11/75	8	.29	170	460	---	690

Table 12.

Well location		Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Number	Lat-Long							
Er- 691	4208-7956	Gary Anderson	Donald E. Hall	1976	H	1,000	S	Qo/sdgr
692	4208-7957	R. T. Becker	Alfred L. Burch	1971	H	1,020	H	Qo/gr
693	4208-7957	Clara Merritt	do.	1969	H	982	H	Qo/gr
694	4209-7959	Lena Asel	do.	1972	H	720	V	Dne/sh
695	4208-7959	J. M. Trinoski	do.	1973	H	735	V	Dne/sh
696	4209-7953	R. M. Di Santi	Ralph C. Parmenter	1973	H	1,295	S	Dch/sh
697	4209-7953	J. S. Darby	Robert Rindfuss	1972	H	1,275	S	Dch/sh
698	4209-7956	Edward Jackson	Harold F. Anderson	1975	H	826	S	Dne/fsh
699	4209-7956	Robert Maison	Alfred L. Burch	1975	H	818	S	Dne/ssh
700	4209-7956	James Sider	Michael W. Burch	1976	H	795	S	Dne/ssh
701	4209-7956	L. D. Sweatman	Donald L. Hermann	1972	H	810	S	Dne/ssh
702	4209-7956	Charles Bauer	Michael W. Burch	1975	H	892	S	Dg/ssh
703	4209-7956	do.	do.	1975	H	872	C	Dg/fsh
704	4209-7956	C. J. Dill	Alfred L. Burch	1970	H	872	S	Dg/fsh
705	4209-7957	Robert Gindlespeger	do.	1969	P	727	V	Qb/clgr
706	4209-7959	John Lipchik	do.	1967	H	685	V	Dne/ssh
707	4210-7953	Mary Gelsie	Ralph C. Parmenter	1974	H	880	S	Dne/sh
708	4210-7953	D. A. Meehl	Robert Anderson	1974	H	867	S	Dne/fsh
709	4210-7956	D. F. Langer	Michael W. Burch	---	H	732	V	Dne/fsh
710	4211-7956	Louise Yaggie	George H. Ackerman	1976	H	674	V	Qo/sdgr
711	4211-7957	Susan Bossart	Alfred L. Burch	1968	H	660	F	Qt/sd
712	4211-7957	A. D. Bencivenga	Michael W. Burch	1975	H	664	F	Qt/sdgr
713	4212-7953	W. J. Filipkowski	Alfred L. Burch	1972	H	740	V	Qo/sdgr
714	4209-7958	John Waterhouse	J. W. Waterhouse	1975	H	715	F	Dne/sh
715	4208-7959	Gridler Builders	Donald L. Hermann	1972	H	864	S	Dch/fsh
716	4200-7953	D. R. Morey	George H. Ackerman	1974	H	1,475	S	Dv/fsh
717	4200-7953	Charles Leasure	do.	1976	H	1,412	S	Qt/u
718	4200-7953	Stephen Dylewski	Harold F. Anderson	1973	H	1,498	H	Dv/fsh
719	4201-7958	Penny Dias	Donald L. Hermann	1975	H	1,250	S	Dch/fsh
720	4201-7957	Carol Weiser	Robert Anderson	1976	H	1,370	S	Qo/gr
721	4202-7956	Raymond Peplinski	do.	1976	H	1,280	S	Qo/sdgr
722	4202-7959	Charles Schendlar	Alfred L. Burch	1972	H	1,358	S	Dch/fsh
723	4202-7959	Michael Paris	Robert Anderson	1974	H	1,350	S	Dv/sh
724	4203-7953	James Giles	do.	1976	H	1,360	H	Qo/gr
725	4203-7954	James Schreiber	George H. Ackerman	1976	H	1,343	S	Qo/gr
726	4203-7955	August Newcamp	Alfred L. Burch	1970	H	1,340	S	Qt/u
727	4203-7954	David Spaeder	Harold F. Anderson	1975	H	1,370	S	Dch/fsh
728	4203-7955	Ralph King	George H. Ackerman	1967	H	1,310	S	Qo/gr
729	4203-7957	Donald Johnston	Robert Anderson	1972	H	1,370	S	Dch/fsh
730	4203-7957	George Nellis	Donald L. Hermann	1972	H	1,385	S	Dch/ssh
731	4203-7957	Carl Rose	Robert Anderson	1973	H	1,352	S	Qt/gr
732	4204-7953	Charles Malliard	Harold F. Anderson	1973	H	1,363	S	Qo/gr
733	4204-7955	Steven Hoover	Donald L. Hermann	1975	H	1,393	S	Dch/fsh
734	4204-7957	Duane Rose	Alfred L. Burch	1971	H	1,390	S	Dch/sh
735	4204-7957	William Seelinger	George H. Ackerman	1973	H	1,358	S	Dch/fsh
736	4204-7957	E. C. Steele	Alfred L. Burch	1966	H	1,392	S	Dch/sh
737	4204-7957	William Ducz	Lowell Halstead	1973	H	1,370	S	Dch/fsh
738	4204-7957	Lloyd Baldwin	George H. Ackerman	1977	H	1,375	S	Qt/clgr
739	4204-7957	John Douglas	Michael W. Burch	---	H	1,370	S	Dch/fsh
740	4204-7958	James Kellogg	Harold F. Anderson	1972	H	1,232	S	Dch/fsh
741	4204-7959	Richard Nies	Alfred L. Burch	1966	H	1,370	S	Dch/fsh
742	4204-7959	Joseph Jendrack	Robert Anderson	1976	H	1,340	S	Qt/t
743	4204-7959	Edward Plonsky	do.	1972	H	1,348	S	Dch/sh
744	4204-7959	Marcelline Gibbs	Alfred L. Burch	1972	H	1,320	S	Dch/fsh
745	4204-7959	Walter Pieniazek	Harold F. Anderson	1974	H	1,300	S	Dch/fsh
746	4205-7952	Donald Spinks	George H. Ackerman	1976	H	1,504	S	Qt/u
747	4205-7954	Richard Page	Michael W. Burch	1975	H	1,260	H	Qo/sdgr
748	4205-7957	Robert Hunt	Alfred L. Burch	1975	H	1,340	S	Dch/fsh
749	4205-7957	Joseph Sharkey	do.	1971	H	1,350	S	Dch/fsh
750	4205-7958	William Hughes	do.	1975	H	1,215	S	Dch/sh
751	4205-7958	Walter Nowarowsky	George H. Ackerman	1974	H	1,212	S	Qt/u
752	4205-7958	Donald Kidder	Harold F. Anderson	1973	H	1,278	S	Dch/fsh
753	4205-7958	Richard Kirby	Donald L. Hermann	1973	H	1,200	S	Qo/sdgr
754	4205-7958	James Praetzel	Alfred L. Burch	1973	H	1,195	S	Qo/sd
755	4205-7959	Edward Bukowski	do.	1967	H	1,298	S	Dch/fss
756	4205-7959	Lynn Hofius	Michael W. Burch	1976	H	1,160	S	Dch/ssh
757	4205-7959	J. R. Young	Donald L. Hermann	1972	H	1,295	S	Dch/ssh
758	4206-7953	Alfred Grzegorzewski	Alfred L. Burch	1974	H	1,350	S	Qo/clgr
759	4206-7954	Ronald White	Ralph C. Parmenter	1975	H	1,370	S	Qt/u
760	4206-7955	D. L. Cosner	Robert Anderson	1975	H	1,300	S	Dch/fsh
761	4206-7955	R. G. Stelle	do.	1975	H	1,182	S	Dch/sh
762	4206-7955	J. B. Urbaniac	do.	1973	H	1,195	S	Dch/fsh
763	4206-7955	Richard Suscheck	do.	1976	H	1,207	S	Dch/fsh
764	4206-7956	T. J. Wood	Alfred L. Burch	1974	H	1,346	S	Dch/fsh

(Continued)

Total depth below land surface (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Depth(s) to water-bearing zone(s) (feet)	Static water level: Depth below land surface (feet)	Static water level: Date measured (mo/yr)	Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (μmho/cm at 25°C)	pH (units)	Well number
50	50	8	50	---	---	17	---	---	---	---	Er- 691
56	56	8	45;52	42	9/71	20	---	---	---	---	692
54	54	8	40;54	25	9/69	10	.53	---	---	---	693
35	11	8	38	---	---	.1	---	---	---	---	694
50	11	8	8;38	10	5/73	.4	---	---	---	---	695
50	22	5	4	40	6/73	1	---	---	---	---	696
38	25	8	27	10	9/72	6	---	---	---	---	697
38	13	8	18;30	---	---	9	---	---	---	---	698
50	16	8	15;20	12	10/75	4	---	---	---	---	699
50	25	8	8;10;12;19	3	4/76	19	.5	---	---	---	700
32	18	12	18	6	6/72	2	---	---	---	---	701
60	24	8	26	26	12/75	26	---	---	---	---	702
50	10	8	15;28	6	12/73	2	---	---	---	---	703
50	23	8	13;17;25	8	8/70	5	---	240	700	---	704
40	20	8	12;14;28	6	12/69	10	---	---	---	---	705
50	14	8	14;30	6	8/67	1	---	---	---	---	706
40	15	8	25	---	---	---	---	140	560	---	707
40	8	12	11	6	1/74	3	.09	---	---	---	708
30	---	6	14;17	10	---	6	---	---	---	---	709
42	30	8	24	2	2/76	2	---	---	---	---	710
82	72	8	24;68	50	4/68	.3	---	---	---	---	711
70	49	8	14;45	10	7/75	1	---	---	---	---	712
32	32	8	16;27	8	8/72	20	.9	200	530	---	713
30	20	8	20	15	7/75	1	---	200	600	---	714
50	25	8	22;30	8	11/72	8	---	---	---	---	715
70	28	8	26;45	---	---	2	---	---	---	---	716
55	31	8	25	10	7/76	40	---	---	---	---	717
72	---	8	70	---	---	20	---	---	---	---	718
66	50	8	40;60	12	6/75	20	4	---	---	---	719
69	69	8	67	58	8/76	15	3	---	---	---	720
66	66	8	18;63	2	4/76	4	.06	---	---	---	721
50	33	8	26;32;40	5	7/72	18	---	---	---	---	722
65	27	8	28	4	1/74	.5	.01	---	---	---	723
128	128	8	75;127	30	6/76	6	.12	---	---	---	724
94	94	8	45;90	54	9/76	10	---	---	---	---	725
106	70	5	70	31	5/70	2	---	100	260	---	726
72	29	8	30;50	30	8/75	2	.09	---	---	---	727
69	69	6	---	F	5/67	12	---	---	---	---	728
95	73	8	75	31	11/72	7	.12	---	---	---	729
80	47	8	---	12	7/72	4	.07	---	---	---	730
70	70	8	68	47	1/73	7	.4	---	---	---	731
60	60	8	49;60	---	---	12	---	---	---	---	732
50	32	8	26;28	---	---	4	---	---	---	---	733
70	15	12	13;48	7	7/71	1	---	---	---	---	734
75	35	8	31;52	---	---	20	---	---	---	---	735
80	26	8	10;35	6	5/26	1	---	---	---	---	736
50	23	8	20;24	---	---	20	---	---	---	---	737
72	56	8	52	37	3/77	30	---	---	---	---	738
90	---	8	60;75	20	5/75	8	---	---	---	---	739
110	28	8	50;80	10	8/72	2	---	---	---	---	740
80	28	8	23;30	15	10/66	1	---	---	---	---	741
25	24	8	16;25	12	10/76	30	10	---	---	---	742
50	14	12	30	25	8/72	.2	.01	---	---	---	743
60	14	8	14;25	18	9/72	1	---	---	---	---	744
60	23	12	43;50;58	---	---	20	---	---	---	---	745
45	28	8	23	20	7/76	4	---	---	---	---	746
58	58	8	24;45;53	21	9/75	30	15	---	---	---	747
70	30	8	22;42	10	5/75	4	---	---	---	---	748
60	15	8	17	13	7/71	10	---	---	---	---	749
75	22	8	20;28;62	18	7/75	2	---	---	---	---	750
40	20	8	20	---	---	1	---	---	---	---	751
150	42	8	54;75;114	---	---	4	---	---	---	---	752
152	152	8	90;120;150	70	3/73	20	.7	---	---	---	753
114	114	8	11;87	62	8/73	14	---	---	---	---	754
80	19	8	20;55	23	10/67	1	---	---	---	---	755
55	17	8	12	8	6/76	15	.5	95	230	---	756
72	21	8	18;22	10	9/72	2	.03	---	---	---	757
72	34	8	28;40	24	6/74	2	---	---	---	---	758
45	15	6	4	8	9/75	3	.1	---	---	---	759
60	11	8	20;41	5	10/75	6	---	---	---	---	760
60	17	12	22	7	5/75	15	---	---	---	---	761
55	17	8	17;22;30	4	3/73	3	.06	---	---	---	762
61	16	8	16;19	14	4/76	6	.11	---	---	---	763
50	20	8	12;38;40	6	5/74	20	---	---	---	---	764

Table 12.

Well location		Owner	Driller	Year completed	Use	Alti-tude of land surface (feet)	Topo-graphic setting	Aquifer/ lithology
Number	Lat-Long							
Er- 765	4206-7956	M. K. Simmons	Michael W. Burch	1975	H	1,274	S	Qt/clgr
766	4206-7956	Vince Pepicello	Alfred L. Burch	1973	H	1,263	S	Dch/fsh
767	4205-7957	Arthur Jenson	Harold F. Anderson	1973	H	1,360	S	Qo/gr
768	4204-7957	Rodney Riblett	George H. Ackerman	1973	H	1,422	S	Qt/u
769	4205-7958	Daryl Waldinger	Robert Anderson	1976	H	1,100	S	Qt/gr
770	4206-7956	L. J. Rodler	Alfred L. Burch	1972	H	1,243	S	Dch/fsh
771	4206-7956	Jerry Lindenberger	do.	1972	H	1,250	S	Dch/fsh
772	4206-7956	Atlas Homes Inc.	do.	1967	H	1,240	S	Dch/fsh
773	4205-7959	Bernard Hill	Robert Anderson	1976	H	1,135	H	Qt/clgr
774	4206-7958	William De Platchett	Michael W. Burch	1976	H	1,175	S	Dch/ssh
775	4206-7958	Paul Daube	do.	1976	H	1,190	S	Dch/fsh
776	4206-7959	Nick Mindek	do.	---	H	995	S	Qt/u
777	4207-7952	Eugene Trayer	Alfred L. Burch	1969	H	1,480	S	Dv/fsh
778	4207-7953	C. F. Merhar	George H. Ackerman	1974	H	1,412	S	Qt/t
779	4205-7955	Rosemary Preece	Alfred L. Burch	1968	H	1,433	H	Dch/fsh
780	4206-7957	C. M. Young	Ralph Wayne Grant	1974	H	1,270	S	Dch/fst
781	4204-7959	Edward Monkowski	Alfred L. Burch	1972	H	1,343	S	Qt/t
782	4206-7958	W. D. Martin	do.	1968	H	1,295	S	Qt/t
783	4207-7958	James Moser	Ralph Wayne Grant	1974	H	1,120	S	Dch/fst
784	4200-7953	Phillip Carlson	Donald L. Hermann	1973	H	1,430	S	Dch/ssh
785	4204-7958	William Schick	do.	1972	H	1,210	S	Dch/fsh
786	4205-7959	Ralph Shaw	Alfred L. Burch	1968	H	1,140	H	Dch/fsh
787	4204-7957	Otto Stablein	do.	1973	H	1,400	S	Dv/fsh
788	4205-7958	Parmney Sprouse	do.	1973	H	1,296	S	Dch/fsh
789	4205-7954	Joseph Stubenhofer	do.	1968	H	1,350	H	Qo/sdgr
790	4205-7954	Kenneth Weed	do.	1968	H	1,350	S	Qo/sdgr
791	4203-7956	W. W. Yaple	McCray Bros.	1974	H	1,310	S	Qo/sd
792	4205-7958	Thomas Kirsch	Donald L. Hermann	1972	H	1,220	S	Qo/sdgr
793	4206-7959	George Church	Alfred L. Burch	1971	H	970	S	Dch/fsh
794	4205-7955	Gary Cage	do.	1973	H	1,433	H	Dch/fsh
795	4205-7957	Charles Lander	do.	1973	H	1,372	S	Dch/fsh
796	4201-7957	David Kaschak	Robert Rindfuss	1974	H	1,310	S	Qo/gr
797	4205-7956	J. W. Houpt	George H. Ackerman	1973	H	1,450	H	Dv/fsh
798	4203-7956	George Burbules	Michael W. Burch	1976	H	1,356	T	Dch/fsh
799	4203-7957	William Lapenz	Robert Anderson	1977	H	1,405	H	Qt/t
800	4202-7959	Terry Ottaway	Alfred L. Burch	1975	H	1,398	S	Dv/ssh
801	4203-7958	Edward Kearney	do.	1975	H	1,350	U	Dch/fsh
802	4204-7958	Al Kirsch	Robert Anderson	1976	H	1,260	S	Qt/t
803	4204-7958	James Saltsman	Alfred L. Burch	1966	H	1,274	S	Qt/t
804	4204-7958	Edward Vallimont	Donald L. Hermann	1975	H	1,270	S	Qo/sdgr
805	4205-7955	Walter Kuhl	Robert Anderson	1977	H	1,418	S	Qt/t
806	4200-7948	Ronald Huzinec	Harold F. Anderson	1975	H	1,302	S	Qo/sdgr
807	4202-7949	Roy Huntley	Ralph C. Parmenter	1974	H	1,350	V	Qo/u
808	4204-7950	Leslie Burlingham	Alfred L. Burch	1964	H	1,320	V	Qo/sd
809	4206-7951	G. W. Dana	Felix J. Waible	1975	H	1,420	S	Qo/gr
810	4206-7951	E. D. Boyd	Alfred L. Burch	1974	H	1,470	S	Qt/u
811	4206-7951	L. A. Wescott	Raymond L. Butterfield	1970	H	1,400	S	Dch/fsh
812	4206-7951	Louis Ganza	Alfred L. Burch	1973	H	1,490	S	Dv/fsh
813	4206-7951	John Pomorski	George H. Ackerman	1976	H	1,415	S	Qt/sdgr
814	4207-7947	Ralph Neal	Ralph C. Parmenter	1974	H	1,425	H	Qt/u
815	4207-7951	R. E. Snyder	Alfred L. Burch	1970	H	1,455	S	Dv/fsh
816	4207-7951	Betty Angerer	Michael W. Burch	1975	H	1,467	S	Dv/fsh
817	4200-8002	R. D. Beals	Donald L. Hermann	1972	H	1,445	S	Dv/fsh
818	4200-8002	Shaul Equipment and Supply	Alfred L. Burch	1969	H	1,428	S	Dv/fsh
819	4200-8004	John Brozell	do.	1972	H	1,434	H	Dv/fsh
820	4200-8004	C. C. Moore	Ralph Wayne Grant	1974	H	1,115	V	Qo/sdgr
821	4200-8005	Anthony Pastore	Alfred L. Burch	1972	H	1,140	S	Qo/sdgr
822	4200-8006	R. P. Eck	Tony Simonetti	1972	H	1,058	V	Qo/sdgr
823	4200-8006	W. W. Spires	Max E. Hickernell	1969	H	1,070	V	Qo/gr
824	4200-8007	F. J. Dylewski	Donald L. Hermann	1972	H	1,035	S	Dch/ssh
825	4200-8007	Lauren Krautter	Alfred L. Burch	1967	H	1,040	S	Qt/gr
826	4201-8000	L. R. Kulik	Robert Anderson	1972	H	1,240	V	Qo/sdgr
827	4201-8002	Jerry Dunn	do.	1974	H	1,405	S	Qt/t
828	4201-8002	Gene Groenendaal	do.	1974	H	1,415	S	Qt/t
829	4201-8002	Walter Lego	Alfred L. Burch	1967	H	1,400	S	Dv/fsh
830	4201-8002	John Chojnacki	do.	1976	H	1,388	H	Dch/fsh
831	4201-8003	J. K. Robinson	Donald L. Hermann	1972	H	1,358	S	Dv/fsh
832	4201-8003	Lovittie Schaffer	do.	1973	H	1,374	S	Dv/fsh
833	4201-8003	J. F. Donahue	George H. Ackerman	---	H	1,375	S	Qt/u
834	4201-8003	Robert Huffman	Tony Simonetti	1973	H	1,362	S	Dv/fsh
835	4201-8003	Gartner Harf Co.	Donald L. Hermann	1972	S	1,434	S	Dv/fsh
836	4201-8004	Larry Lucas	do.	1974	H	1,412	S	Dv/fsh
837	4201-8005	J. C. Lander	do.	1972	H	1,260	S	Dch/fsh
838	4201-8006	J. F. Regan	Alfred L. Burch	1972	H	1,132	S	Dch/fsh

(Continued)

Total depth below land surface (feet)	Casing		Depth(s) to water-bearing zone(s) (feet)	Static water level		Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (µmho/cm at 25°C)	pH (units)	Well number
	Depth (feet)	Diameter (inches)		Depth below land surface (feet)	Date measured (mo/yr)						
50	18	8	16;19	4	10/75	30	---	---	---	---	Er- 765
60	17	8	14;22;48	8	7/73	2	---	140	380	---	766
40	22	8	20;35	---	6/73	20	---	---	---	---	767
100	---	8	18;48	6	3/73	3	---	---	---	---	768
92	92	8	90	74	5/76	20	2	---	---	---	769
50	19	10	12;18;36	5	10/72	10	---	---	---	---	770
50	19	8	16;19;36	8	10/72	10	---	---	---	---	771
50	30	8	15;20	8	6/67	10	---	---	---	---	772
60	17	8	---	4	7/76	5	.09	---	---	---	773
65	14	12	10;16	7	5/76	1	---	---	---	---	774
60	12	8	12;21	8	10/76	2	.04	---	---	---	775
47	22	10	18	11	12/76	1	---	---	---	---	776
60	14	8	14;40	10	9/69	1	---	140	400	---	777
65	28	8	26	8	6/74	1	---	---	---	---	778
140	16	8	10;130	4	5/68	2	---	---	---	---	779
50	19	8	---	---	---	10	---	---	---	---	780
60	40	8	30;52	27	8/72	8	---	---	---	---	781
50	20	8	16;40	8	10/68	10	---	---	---	---	782
55	25	8	---	---	---	---	---	---	---	---	783
60	24	8	20;23	---	---	4	---	---	---	---	784
80	42	8	45	28	12/72	2	---	---	---	---	785
50	15	8	12;14;20	1	5/68	.5	---	---	---	---	786
90	18	8	17;20;50	3	11/73	1	---	---	---	---	787
60	33	8	25;28;57	2	6/73	17	---	---	---	---	788
67	67	8	40;63;67	57	10/68	15	---	---	---	---	789
58	58	8	48	43	5/68	10	---	---	---	---	790
140	140	8	---	---	---	---	---	---	---	---	791
129	129	8	126	90	7/72	15	.75	---	---	---	792
54	21	12	---	19	12/71	4	---	---	---	---	793
150	16	8	12;130	8	7/73	2	---	---	---	---	794
95	28	8	24;80	18	8/73	5	---	---	---	---	795
78	78	8	75	20	5/74	30	.8	---	---	---	796
50	24	8	24	---	8/73	2	---	---	---	---	797
50	29	8	13;24;42	4	11/76	9	.22	---	---	---	798
125	91	8	95	52	3/77	2	.01	---	---	---	799
65	26	8	24;52	24	9/75	4	---	---	---	---	800
75	57	8	58	25	9/75	5	---	---	---	---	801
54	26	8	25;35	9	3/76	11	.27	---	---	---	802
60	30	6	15;30	20	5/66	2	---	---	---	---	803
149	149	6	59;148	1	10/75	10	.08	---	---	---	804
78	14	8	16;25	6	1/77	30	3	---	---	---	805
45	32	8	25;35	9	7/75	5	---	120	290	---	806
110	110	5	---	30	6/74	8	.16	---	---	---	807
100	100	6	12;90	3	7/64	20	---	---	---	---	808
43	43	8	39	9	5/75	6	---	---	---	---	809
43	---	5	15	15	4/74	9	---	---	---	---	810
68	37	6	40;64	15	7/70	15	1	---	---	---	811
60	27	8	15;24;35	10	7/73	9	---	---	---	---	812
60	32	8	27;55	15	8/76	8	---	---	---	---	813
43	43	5	---	12	6/74	3	.12	---	---	---	814
70	22	8	20	1	1/70	1	---	---	---	---	815
73	22	8	30	7	5/75	1	.02	---	---	---	816
50	37	8	35;37	8	10/72	10	---	---	---	---	817
65	30	8	20;30	6	11/69	1	---	---	---	---	818
50	37	8	32;40	8	7/72	6	---	---	---	---	819
71	62	8	---	---	---	---	---	---	---	---	820
46	46	8	40;46	7	---	70	---	---	---	---	821
65	65	8	46;65	10	9/72	10	.25	110	550	---	822
80	80	8	77	---	---	15	---	---	---	---	823
50	22	8	18	---	---	.3	---	---	---	---	824
31	31	8	5;21;31	---	---	20	---	---	---	---	825
20	20	8	17	5	9/72	6	.46	---	---	---	826
62	28	8	28	2	2/74	.6	.01	---	---	---	827
63	31	8	31	8	6/74	.5	.01	---	---	---	828
50	24	8	12;18;40	8	5/67	14	---	115	620	---	829
100	57	8	75	37	4/76	.7	---	---	---	---	830
48	38	8	35;45	10	10/72	10	.36	---	---	---	831
50	23	8	20	20	7/73	3	.1	---	---	---	832
55	30	8	30	---	---	4	---	---	---	---	833
43	42	8	38	8	8/73	20	1.2	---	---	---	834
60	41	8	36;41;45	15	9/72	20	.6	---	---	---	835
60	26	8	25;45	16	5/74	3	---	---	---	---	836
50	22	12	22	8	6/72	2	---	---	---	---	837
70	15	8	7;15;62	2	5/72	10	---	---	---	---	838

Table 12.

Well location								
Number	Lat-Long	Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Er- 839	4201-8006	Donna Barrows	Alfred L. Burch	1967	H	1,185	S	Dch/fsh
840	4201-8007	Robert Griffith	do.	1974	H	1,073	V	Dch/fsh
841	4201-8007	C. E. Nelson	Donald L. Hermann	1972	H	1,084	F	Dch/fsh
842	4202-8001	P. A. Laughery	Alfred L. Burch	1970	H	1,230	S	Dch/fsh
843	4202-8001	R. A. Hodas	Donald L. Hermann	1973	H	1,275	S	Dch/fsh
844	4202-8001	N. P. Pederson	do.	1972	H	1,312	S	Dch/fsh
845	4202-8001	Gary Osborne	do.	1975	H	1,266	V	Qo/sdgr
846	4202-8001	Robert Kightlinger	Michael W. Burch	1976	H	1,212	S	Dch/fsh
847	4202-8002	Eugene Bosch	Alfred L. Burch	1968	H	1,332	S	Dch/sh
848	4202-8002	Summit Township	Donald L. Hermann	1975	H	1,280	S	Dch/ssh
849	4202-8002	Melvin Davis	Charles J. Richardson III	1974	H	1,295	S	Qt/sdgr
850	4202-8002	Lee Strain	Donald L. Hermann	1972	H	1,270	S	Dch/fsh
851	4202-8003	William Winkleman	do.	1972	H	1,360	H	Dv/fsh
852	4202-8003	Carl Gentile	do.	1974	H	1,358	H	Qt/t
853	4202-8003	John Mospan	Alfred L. Burch	1975	H	1,342	S	Dv/fsh
854	4202-8004	WUET Television	do.	1971	H	1,305	S	Qt/clgr
855	4202-8004	Virgil Lawson	do.	1967	H	1,212	S	Dch/fsh
856	4202-8004	R. C. Herman	Donald L. Hermann	1972	H	1,270	S	Qt/t
857	4202-8004	Paul Wetzel	Robert Anderson	1975	C	1,309	S	Dch/fsh
858	4202-8005	Alex Horwath	Alfred L. Burch	1974	H	1,235	S	Dch/fsh
859	4202-8006	Norman Grode	do.	1965	H	1,070	T	Dch/fsh
860	4202-8006	C. F. Sult	George H. Ackerman	1973	H	1,133	S	Dch/fsh
861	4202-8006	George Havican	Lorenze Lee Hall	1973	H	1,124	S	Dch/fsh
862	4202-8006	Emil Kesselring	Michael W. Burch	1976	S	1,096	S	Dch/fsh
863	4202-8006	do.	do.	---	H	1,103	S	Dch/fsh
864	4203-8001	E. C. Hull	Ralph Wayne Grant	1974	H	1,175	S	Dch/fsh
865	4203-8001	Joseph Ferraro	Donald L. Hermann	1973	H	1,190	S	Dch/fsh
866	4203-8001	Frank Starvaggi	do.	1974	H	1,140	S	Dch/fsh
867	4203-8001	Gerald Leib	do.	1972	S	1,220	S	Qt/t
868	4203-8002	Joseph Kula	do.	1974	H	1,245	S	Dch/fsh
869	4203-8002	W. E. Klick	Alfred L. Burch	1972	H	1,170	S	Dch/sh
870	4203-8002	M. L. Small	Robert Anderson	1972	H	1,128	S	Dch/fsh
871	4203-8002	Ruby Snyder	Donald L. Hermann	1973	H	1,155	S	Dch/fsh
872	4203-8002	Judge Lawson	Alfred L. Burch	1971	H	1,105	S	Dch/fsh
873	4203-8002	W. M. Curtis	Donald L. Hermann	1973	H	1,115	S	Dch/fsh
874	4203-8003	John Ollarek	do.	1972	H	1,188	S	Dch/fsh
875	4203-8004	Merton Wilson	Alfred L. Burch	1975	H	1,110	S	Qo/sdgr
876	4203-8004	Gregory Gehrlein	do.	1972	H	1,110	H	Qt/clgr
877	4203-8004	T. A. DeGeorge	Robert Anderson	1974	H	1,100	H	Qt/clgr
878	4203-8004	J. M. McCreary	Donald L. Hermann	1972	H	1,110	H	Dch/fsh
879	4203-8004	Leonard Niederriter	Robert Anderson	1974	H	1,095	H	Qo/gr
880	4203-8004	Lee Schaaf	Donald L. Hermann	1973	H	1,104	H	Qo/gr
881	4203-8004	Leo Ranowiecki	Robert Rindfuss	1972	H	1,013	S	Dch/fsh
882	4203-8004	H. T. Welka	Donald L. Hermann	1973	H	1,070	S	Dch/fsh
883	4203-8004	Dale Kibbe	Robert Anderson	1976	H	1,015	S	Dch/fsh
884	4203-8004	L. A. Wurst	Alfred L. Burch	1972	H	1,050	S	Qo/clgr
885	4203-8004	Paul Lorei	do.	1968	H	1,065	S	Dch/fsh
886	4203-8005	Robert Hutchinson	Donald L. Hermann	1972	H	990	S	Dch/fsh
887	4203-8005	Rose Mozur	do.	1972	H	1,050	S	Dch/fsh
888	4203-8005	Jerry Lindenberger	Alfred L. Burch	1967	H	1,063	S	Qo/gr
889	4203-8005	Richard Camphausen	do.	1967	H	1,070	H	Qt/gr
890	4203-8005	P. B. Balkovic	do.	1972	H	1,052	S	Dch/fsh
891	4203-8005	E. A. Rohan	do.	1973	H	1,070	H	Qt/clgr
892	4203-8005	Ivan Yaple	do.	1966	H	1,070	S	Dch/fsh
893	4203-8006	R. E. McNaughton	Donald L. Hermann	1973	H	1,030	V	Qo/sdgr
894	4203-8006	Raymond Feikls	do.	1974	H	1,085	S	Qt/clgr
895	4203-8006	J. J. Desser	do.	1973	H	1,060	H	Qt/sd
896	4203-8006	J. P. Dedinsky	do.	1972	H	972	S	Qt/sdgr
897	4203-8007	Charles Ives	Robert Anderson	1976	H	888	S	Dg/fsh
898	4203-8007	Dolores Reitz	Donald L. Hermann	1972	H	906	U	Qt/clgr
899	4203-8007	Thomas Bujnoski	Lorenze Lee Hall	1973	H	1,013	F	Dch/fsh
900	4204-8000	Donald Harrah	Harold F. Anderson	1973	H	1,255	S	Dch/fsh
901	4204-8000	Richard Lakari	Michael W. Burch	1976	H	1,266	S	Dch/fsh
902	4204-8000	Robert Amendola	Alfred L. Burch	1970	H	1,360	S	Dch/fsh
903	4204-8001	William Koppes	Michael W. Burch	1976	H	1,206	S	Dch/fsh
904	4204-8001	Roger Baker	Felix J. Waible	1975	H	1,160	S	Qt/t
905	4204-8002	Delbert Shopene	Donald L. Hermann	1972	H	1,100	U	Qo/sdgr
906	4200-8002	Derrick Rosaire	Robert Anderson	1972	H	1,445	S	Dv/fsh
907	4204-8003	David Lawrence	George H. Ackerman	1976	H	1,070	S	Dch/sh
908	4204-8003	Theodore Nowak	do.	1973	H	1,050	H	Dch/fsh
909	4204-8003	A. S. Ferralli, Jr.	do.	1975	H	1,042	S	Qt/clgr
910	4204-8003	Douglas Courter	Alfred L. Burch	1974	H	922	S	Qt/clgr
911	4204-8003	Edward Kuhn	do.	1973	H	960	S	Qo/gr
912	4204-8003	D. A. Hill	Michael W. Burch	1975	H	972	S	Qo/clgr

(Continued)

Total depth below land surface (feet)	Casing		Depth(s) to water-bearing zone(s) (feet)	Static water level		Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (μmho/cm at 25°C)	pH (units)	Well number
	Depth (feet)	Diameter (inches)		Depth below land surface (feet)	Date measured (mo/yr)						
52	21	8	---	10	8/67	2	---	---	---	---	Er- 839
50	16	8	14;35	3	1/74	10	---	---	---	---	840
90	20	8	20	18	8/72	.4	---	---	---	---	841
70	30	6	30;45	13	5/70	3	---	---	---	---	842
52	34	8	23;28	15	2/73	10	.37	---	---	---	843
80	49	8	49	32	7/72	2	---	---	---	---	844
30	30	8	27	12	12/75	10	1.2	---	---	---	845
55	25	8	20	10	10/76	22	.5	---	---	---	846
50	33	8	11;34	2	3/68	2	---	---	---	---	847
62	61	12	29;61	12	9/75	3	---	---	---	---	848
20	20	30	8	8	7/74	5	.5	---	---	---	849
60	46	8	46	20	7/72	2	.04	---	---	---	850
46	40	8	32;35;40	10	10/72	6	.25	---	---	---	851
50	39	8	36	8	6/74	6	.19	160	600	---	852
50	37	8	13;20;32;45	8	4/75	10	.3	---	---	---	853
60	23	12	16;19;20	8	9/71	5	---	---	---	---	854
50	15	8	3;20	1	12/67	1	---	---	---	---	855
46	18	12	18	12	10/72	2	.06	---	---	---	856
59	21	8	23;30	1	---	1	.02	---	---	---	857
60	15	8	13;24	5	11/74	4	---	---	---	---	858
50	20	12	18;30;40	13	3/65	.3	---	---	---	---	859
35	20	12	20	---	---	1	---	---	---	---	860
63	20	8	23	9	7/73	8	.16	---	---	---	861
37	17	8	9;32	9	6/76	2	.07	---	---	---	862
50	20	8	---	16	6/76	1	.03	76	---	7.8	863
55	20	8	---	---	---	---	---	---	---	---	864
68	18	12	25	25	12/73	1	---	---	---	---	865
70	22	12	20;40	18	3/74	2	---	---	---	---	866
40	22	8	22	15	10/72	.5	.02	---	---	---	867
50	20	8	18;26	15	6/74	4	---	---	---	---	868
50	17	12	17;42	17	8/72	1	---	---	---	---	869
40	14	12	14;21	5	8/72	2	.05	---	---	---	870
48	25	8	19;25	8	1/73	4	---	---	---	---	871
50	17	8	12;23	10	7/71	.8	.08	---	---	---	872
50	28	8	23;28	8	1/73	10	.3	---	---	---	873
65	20	8	20;45	12	6/72	2	.04	---	---	---	874
65	18	8	13;55	6	3/75	6	.43	---	---	---	875
70	45	8	39	35	9/72	5	---	---	---	---	876
24	24	12	22	12	8/74	9	1.1	---	---	---	877
70	40	8	35	28	6/72	5	---	---	---	---	878
23	23	8	10;22	6	5/74	30	---	240	625	---	879
38	38	8	32;35	18	4/73	15	1.1	---	---	---	880
60	30	8	33	25	6/72	2	---	---	---	---	881
60	32	12	21;32	18	4/73	4	---	---	---	---	882
51	15	8	15;20	12	7/76	1	.04	---	---	---	883
56	42	8	37;42	8	7/72	6	---	---	---	---	884
50	24	8	20;30	14	4/68	7	---	---	---	---	885
70	58	8	62;68	30	7/72	10	---	---	---	---	886
83	76	8	70;76	45	7/72	15	---	---	---	---	887
95	81	8	76	70	5/67	18	1.8	---	---	---	888
120	65	8	12;64;80	66	10/67	.5	---	---	---	---	889
95	58	8	55	50	1/72	2	---	---	---	---	890
36	36	8	29	18	5/73	30	---	---	---	---	891
105	69	8	70	70	10/66	1	---	---	---	---	892
35	26	8	24	12	9/73	10	1.7	120	565	---	893
50	20	8	18;25	15	4/74	4	---	---	---	---	894
80	74	8	69	40	9/73	4	.12	---	---	---	895
78	63	8	58	40	6/72	8	.32	---	---	---	896
65	22	8	29	17	10/76	.7	.01	---	---	---	897
36	36	8	33	6	10/72	20	1	---	---	---	898
57	14	12	28	10	7/73	6	.12	---	---	---	899
50	14	12	30;40	---	---	4	---	---	---	---	900
50	17	8	8;24	7	1/76	5	.12	---	---	---	901
50	23	8	7;15;33	8	9/70	5	---	---	---	---	902
51	20	6	30	20	6/76	2	.08	---	---	---	903
50	20	12	16	5	3/75	2	---	---	---	---	904
103	103	8	60;95	63	6/72	30	2.5	---	---	---	905
67	37	8	38	21	12/72	2	.04	---	---	---	906
70	23	12	18	22	7/76	.8	---	---	---	---	907
118	108	8	---	90	6/73	15	---	---	---	---	908
120	102	8	97	---	---	.6	---	---	---	---	909
55	20	8	16;19	16	2/74	1	---	---	---	---	910
31	31	8	22;25	20	3/73	20	---	---	---	---	911
50	25	8	24	18	8/75	10	---	---	---	---	912

Table 12.

Well location		Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/lithology
Number	Lat-Long							
Er- 913	4204-8003	Hamilton Lumber Co.	Donald L. Hermann	1972	H	1,005	S	Qt/sd
914	4204-8003	Cyrus Lee	do.	1972	H	990	S	Qt/sd
915	4204-8003	H. E. Camp	George H. Ackerman	1973	H	990	S	Qo/u
916	4204-8003	L. H. Carnicelli	Alfred L. Burch	1971	H	1,045	H	Qo/gr
917	4204-8003	E. R. Greenfield, Jr.	George H. Ackerman	1973	H	1,040	U	Qt/u
918	4204-8003	D. M. Granahan	Alfred L. Burch	1972	H	1,032	S	Qt/clgr
919	4204-8003	do.	do.	1973	H	1,025	S	Qt/sd
920	4204-8003	M. J. Cipicchio	do.	1973	H	1,037	S	Qo/gr
921	4204-8003	Robert Wally	Robert Anderson	1974	H	1,048	H	Dch/fsh
922	4204-8004	M. C. Wolfe	Alfred L. Burch	1967	H	990	S	Qo/sdgr
923	4204-8004	D. B. Siggins	Robert Anderson	1973	H	1,032	S	Qt/t
924	4204-8004	R. W. Heidt	Tony Simonetti	1972	H	1,050	H	Dch/fsh
925	4204-8005	La Nar Corp.	Alfred L. Burch	1967	N	905	V	Qo/gr
926	4204-8005	J. L. Shauberger	Donald L. Hermann	1972	H	924	U	Qo/sdgr
927	4204-8005	Texaco Oil Co.	Max E. Hickernell	1971	C	920	S	Dg/fsh
928	4204-8005	Frank Roscher	Michael W. Burch	1975	H	958	S	Qt/u
929	4204-8005	Atlas Homes Co.	Alfred L. Burch	1968	H	1,020	H	Qt/gr
930	4204-8005	David Spath	Donald L. Hermann	1973	H	924	U	Qt/sd
931	4204-8006	Donald Morrison	George H. Ackerman	1974	H	920	S	Qo/gr
932	4204-8006	Harry Wagner	Robert Anderson	1972	H	885	V	Qo/gr
933	4204-8006	G. W. Schermer	do.	1975	H	900	S	Qt/clgr
934	4204-8007	Kenneth Foht	Felix J. Waible	1976	H	937	U	Qo/gr
935	4204-8007	E. A. Nicholson	Michael W. Burch	1975	H	922	U	Qt/u
936	4205-8000	Robert Praetzel	Alfred L. Burch	1971	H	1,118	U	Qo/gr
937	4205-8000	Ted Gray	do.	1970	H	1,100	S	Qo/sdgr
938	4204-8000	Charles Huff	do.	1968	H	1,258	S	Dch/fsh
939	4205-8000	Ramada Inn	Max E. Hickernell	1971	P	1,110	U	Qo/gr
940	4205-8001	Ernest Simpson	Robert Anderson	1976	H	1,102	S	Qo/t
941	4205-8001	E. C. Onorato	Harold F. Anderson	1973	H	1,100	S	Qo/gr
942	4205-8001	Paul Martin	Alfred L. Burch	1969	H	1,010	S	Qo/gr
943	4205-8001	do.	do.	1969	H	1,080	S	Qo/sdgr
944	4205-8002	John Becker	Michael W. Burch	1976	H	978	S	Qo/clgr
945	4205-8002	Norman Rapela	George H. Ackerman	1974	H	975	S	Qo/u
946	4205-8002	Ronald Walter	Robert Anderson	1977	H	925	S	Dch/fsh
947	4205-8002	Kenneth Boyles	Max E. Hickernell	1963	H	1,089	S	Qo/gr
948	4205-8002	Richard Bilski	Alfred L. Burch	1970	H	1,082	S	Qo/sdgr
949	4205-8002	M. J. Sznajder	Michael W. Burch	1975	H	955	S	Qo/u
950	4205-8003	Arthur Whiteman	do.	1975	H	960	H	Qo/u
951	4205-8003	Harry Shaffer	Alfred L. Burch	1971	H	928	S	Dg/fsh
952	4205-8003	P. R. Amendola	do.	1972	H	970	S	Qo/clgr
953	4205-8003	Max Stankowski	do.	1964	H	835	S	Dg/fsh
954	4205-8001	P. J. Martin	do.	1971	H	1,000	S	Qo/clgr
955	4205-8007	Frederick Steger	---	---	U	775	F	Qt/u
956	4205-8000	Robert Halmuth	Alfred L. Burch	1976	H	1,124	S	Qo/sdgr
957	4206-8000	E. C. Messenger	George H. Ackerman	1975	H	1,002	S	Qt/clgr
958	4206-8000	Robert Hostetler	Michael W. Burch	1976	H	1,108	S	Qt/gr
959	4206-8000	Andreas Zafiropoulos	do.	1975	P	1,068	S	Qt/clgr
960	4206-8000	do.	do.	1976	P	1,105	S	Qt/clgr
961	4206-8000	do.	do.	1975	P	1,115	S	Qt/gr
962	4206-8001	John Schertzer	Ralph Wayne Grant	1973	H	1,002	S	Dg/fsh
963	4206-8001	George Bennett	Harold F. Anderson	1974	H	975	S	Qt/t
964	4206-8001	Millcreek School District	Robert Anderson	1974	T	960	V	Dg/fsh
965	4206-8001	M. M. Phillips	Donald L. Hermann	1972	H	925	S	Dg/fsh
966	4206-8001	George Jackson	Alfred L. Burch	1968	H	945	V	Qt/sdgr
967	4153-7943	Blaine Geddes	Harold F. Anderson	1974	H	1,522	S	Qo/sdgr
968	4154-7937	Joseph Sanders	Alfred L. Burch	1964	H	1,725	S	MDcr/fsh
969	4154-7942	Gerald Parsons	Harry Bros.	1968	H	1,372	V	Qo/t
970	4154-7943	Paul Balek	McCray Bros.	1974	H	1,380	V	Qo/gr
971	4155-7940	Gerald Krasa	do.	1971	H	1,392	V	Qo/clgr
972	4155-7944	Hughpert Dawdy	Max E. Hickernell	1977	H	1,387	V	Qo/gr
973	4155-7943	Ferdinand Mihalus	Harold F. Anderson	1974	H	1,395	V	Qo/gr
974	4156-7939	Keppel Tiffany	Alfred L. Burch	1964	H	1,462	U	Qo/sd
975	4159-7943	Cash Szymanski	Boyd Lee Hall	1973	H	1,826	H	Qo/gr
976	4152-8014	R. F. Felix	John E. Gage, Jr.	1974	H	1,265	S	MDbv/fsh
977	4203-8016	Michael Bond	Charles J. Richardson III	1974	H	652	F	Qb/sd
978	4202-8016	George Dohanic	do.	1973	H	694	S	Qb/sdgr
979	4204-8009	L. C. Penna	George H. Ackerman	1972	H	920	S	Qo/u
980	4209-8000	M. H. Harriger	Alfred L. Burch	1971	H	647	U	Dne/fsh
981	4209-8000	E. D. Campbell	Robert F Rumball	1973	H	612	U	Qo/sdgr
982	4204-8009	R. W. Mills	George H. Ackerman	1972	H	855	S	Qt/u
983	4203-8013	Louis Kulczycke	McCray Bros.	1972	H	712	S	Qo/gr
984	4202-8007	Theodore Zelinski	Alfred L. Burch	1967	H	1,018	F	Qo/sdgr
985	4202-8016	Betty Kinsinger	do.	1967	H	670	F	Qb/u
986	4202-8013	Laverne Brace	George H. Ackerman	1973	H	802	F	Qo/u

(Continued)

Total depth below land surface (feet)	Casing Depth (feet)	Casing Diameter (inches)	Depth(s) to water-bearing zone(s) (feet)	Static water level Depth below land surface (feet)	Static water level Date measured (mo/yr)	Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (μmho/cm at 25°C)	pH (units)	Well number
105	95	8	92	45	8/72	2	---	---	---	---	Er- 913
76	76	8	73	38	10/72	5	---	---	---	---	914
90	86	8	76	---	---	25	---	---	---	---	915
103	103	8	98;103	90	8/71	19	---	---	---	---	916
120	94	8	94	---	---	3	---	---	---	---	917
110	79	8	75;80	60	11/72	2	---	---	---	---	918
115	84	8	51;78	59	2/73	2	---	---	---	---	919
100	100	8	50;95	86	4/73	20	---	---	---	---	920
130	106	8	108	88	8/74	.5	.01	---	---	---	921
105	90	8	94	60	1/67	15	---	---	---	---	922
52	19	12	19	17	1/73	2	.06	---	---	---	923
63	48	8	44;48	32	9/72	10	.5	---	---	---	924
45	27	8	15;19	6	7/67	75	8	---	---	---	925
52	52	8	47	22	9/72	20	2	---	---	---	926
70	27	10	30	20	12/71	2	---	---	---	---	927
45	45	5	45	30	5/75	10	3.3	---	---	---	928
91	87	8	84	66	3/68	10	---	---	---	---	929
60	57	8	54	---	---	8	---	---	---	---	930
87	87	8	---	57	7/74	40	---	---	---	---	931
25	22	8	18;21	7	8/72	15	5	---	---	---	932
53	24	8	22	14	4/75	9	.26	---	---	---	933
98	98	8	90	53	7/76	20	---	---	---	---	934
98	98	6	---	87	6/75	10	---	---	---	---	935
30	30	8	22;26	18	7/71	30	---	---	---	---	936
57	53	8	10;18;52	12	3/70	20	---	---	---	---	937
55	18	8	14;37;48	10	---	5	---	---	---	---	938
42	---	16	36	26	5/71	60	6	---	---	---	939
131	116	8	115	100	12/76	5	.17	---	---	---	940
130	115	8	115;125	---	---	6	---	---	---	---	941
60	---	8	16;29	3	7/69	50	2.5	---	---	---	942
50	---	8	40	32	7/69	15	---	---	---	---	943
45	45	8	45	24	9/76	7	.37	---	---	---	944
65	52	8	48	30	4/74	15	---	---	---	---	945
57	11	8	12;24	5	3/77	10	.22	---	---	---	946
119	118	6	119	90	3/63	8	---	---	---	---	947
96	96	8	92	84	6/70	20	---	---	---	---	948
43	30	6	---	21	3/75	10	1.1	---	---	---	949
48	48	8	48	30	11/75	9	.9	---	---	---	950
75	25	8	25;68	22	11/71	2	---	---	---	---	951
40	40	8	32;35	28	5/72	30	---	---	---	---	952
56	16	8	14;36	10	6/64	2	---	---	---	---	953
60	34	10	16;27	4	3/71	20	6.6	---	---	---	954
44	---	6	---	21	7/51	---	---	---	---	---	955
43	43	8	32	---	---	20	---	---	---	---	956
70	30	8	24	17	7/75	2	---	140	540	---	957
45	45	8	21;30	21	7/76	28	3.1	---	---	---	958
50	37	8	29	0	8/75	50	3.3	---	---	---	959
80	72	8	30;68	52	6/76	30	1.5	---	---	---	960
96	95	8	90	56	6/75	15	.47	---	---	---	961
50	30	8	---	---	---	---	---	---	---	---	962
50	22	8	22;45	---	---	12	---	---	---	---	963
63	20	8	23;33;60	20	8/74	10	.3	---	---	---	964
75	66	8	62;65	---	---	10	---	---	---	---	965
30	14	12	10;14;27	2	1/68	6	1.5	---	---	---	966
55	26	8	---	---	7/74	3	---	140	370	---	967
72	19	6	40	30	4/64	15	---	120	280	---	968
70	70	6	70	F	1/68	24	1	95	300	---	969
246	246	6	---	0	9/74	15	.6	---	---	---	970
220	214	6	110;200;220	0	3/71	20	1	90	700	---	971
126	126	6	122	F	3/77	12	12	---	---	---	972
112	112	6	60;90	F	10/74	6	6	---	---	---	973
50	---	---	15;40	---	---	---	---	---	---	---	974
71	19	8	14;30;58	10	8/73	20	.5	---	---	---	975
60	17	8	16;28	12	6/74	4	.22	---	---	---	976
30	30	30	22	12	7/74	10	---	---	---	---	977
14	14	24	8	8	10/73	8	2	---	---	---	978
92	---	8	88	15	7/72	16	---	---	---	---	979
30	---	---	8;14	1	1/71	2	---	---	---	---	980
66	66	8	---	---	---	23	---	---	---	---	981
100	100	8	96	18	9/72	3	---	---	---	---	982
72	---	8	20;30;50	20	5/72	2	.08	---	---	---	983
42	22	12	16;18	12	3/67	30	3	---	---	---	984
14	14	24	---	0	11/67	5	2.5	---	---	---	985
55	55	8	51	18	8/73	25	---	---	---	---	986

Table 12.

Well location Number	Lat-Long	Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Er- 987	4203-8007	Richard Harrington	Donald L. Hermann	1973	H	913	S	Qt/sd
988	4200-8008	Harborcreek School for Boys	Felix J. Waible	1974	H	1,025	S	Qt/u
989	4205-8008	Henry Woodworth	Boyd Lee Hall	---	H	714	F	Dne/fsh
990	4152-8013	Richard Koob	Michael W. Burch	1976	H	1,340	S	Qt/clgr
991	4154-8008	Ralph Scrafford	George H. Ackerman	1967	H	1,255	S	Qo/gr
992	4159-8008	Eleanor Musica	---	---	H	1,145	S	Dch/fsh
993	4158-8011	Edward Chernichky	Robert Anderson	1974	H	1,153	S	Dch/fsh
994	4157-8012	J. D. Parker	do.	1974	H	1,193	S	MDbv/fsh
995	4157-8012	Bernard Franks	Max E. Hickernell	1968	H	1,225	S	MDbv/fst
996	4155-8012	Stanley Hudy	B. W. Bateman and Son	1967	H	1,290	S	MDbv/sh
997	4155-8011	Richard Lewandowski	Lorenze Lee Hall	1976	H	1,290	S	Dv/fsh
998	4155-8011	Louis Beck	Alfred L. Burch	1967	H	1,308	U	MDbv/fsh
999	4155-8011	do.	do.	1975	H	1,313	U	MDbv/sh
1000	4153-8014	Bernard Rosenberg	B. W. Bateman and Son	1968	H	1,275	S	MDbv/fsh
1001	4154-8014	Henry Brown	Lowell Halstead	1975	H	1,264	U	Qt/clgr
1002	4154-8010	Makco Manufacturing Co.	Max E. Hickernell	1968	N	1,300	S	MDbv/fst
1003	4158-8012	Donovan Rounds	Boyd Lee Hall	1971	H	1,180	S	MDbv/fsh
1004	4157-8012	Edward Kuzma	Max E. Hickernell	1962	H	1,206	U	MDbv/fsh
1005	4157-8013	Thomas Noble	Alfred L. Burch	1968	H	1,170	U	MDbv/fsh
1006	4157-8013	T. J. Kitcey	do.	1972	H	1,172	U	MDbv/fsh
1007	4157-8013	Marvin Wilkinson	Robert Anderson	1972	H	1,183	S	Qt/clgr
1008	4157-8013	F. L. Heibel	do.	1974	H	1,180	S	Qt/gr
1009	4157-8014	S. E. Thornton	Lowell Halstead	1973	H	1,124	S	Dch/fsh
1010	4158-8009	R. E. Griffith	Donald L. Hermann	1973	H	1,242	S	Dv/sh
1011	4158-8009	Robert Osterberg	do.	1973	H	1,215	S	Dv/ssh
1012	4158-8011	M. M. Sharpe	Robert Anderson	1974	H	1,223	S	Dv/fsh
1013	4158-8012	Marion Russell	George H. Ackerman	1976	H	1,138	S	Dch/fsh
1014	4158-8012	Thomas Kozlowski	do.	1976	H	1,125	S	Dch/fsh
1015	4158-8012	J. A. Tupitza	do.	1975	H	995	S	Dch/sh
1016	4159-8008	Edwin Sterrett	Alfred L. Burch	1971	H	1,103	S	Qt/sdgr
1017	4159-8008	Paul Keller	Robert Anderson	1975	H	1,102	S	Dch/fsh
1018	4159-8008	Theodore Stossmeister	Donald L. Hermann	1973	H	1,028	S	Dch/fsh
1019	4159-8008	B. J. Clapper	do.	1972	H	1,013	S	Dch/ssh
1020	4159-8008	F. F. Harrison	Robert Anderson	1975	H	1,050	S	Dch/fsh
1021	4159-8008	B. J. Clapper	Donald L. Hermann	1972	H	1,022	S	Dch/fsh
1022	4159-8008	D. A. Meyer	Alfred L. Burch	1974	H	1,070	S	Dch/fsh
1023	4159-8008	Clarence Baker	do.	1966	H	1,102	S	Dch/fsh
1024	4159-8009	Daniel Corwin	Ralph Wayne Grant	1974	H	975	V	Dch/fsh
1025	4159-8009	M. J. Ferrick	Donald L. Hermann	1974	H	990	V	Dch/fsh
1026	4159-8011	Kenneth Neuberger	do.	1975	H	958	U	Dch/fsh
1027	4159-8012	Thomas Kaliszewsky	Herbert G. Orr	1976	H	923	F	Dch/fsh
1028	4159-8012	Anthony Milano	Robert Anderson	1972	H	897	S	Dg/fsh
1029	4159-8014	A. L. Farley	Charles J. Richardson III	1973	H	897	F	Qo/sdgr
1030	4159-8014	L. J. Nelson	Alfred L. Burch	1971	H	933	U	Qo/clgr
1031	4152-7953	Walter Bujnowski	do.	1974	H	1,352	S	Dv/fsh
1032	4152-7953	Kenneth Ignasiak	Donald L. Hermann	1972	H	1,377	S	Dv/fsh
1033	4152-7953	Gordon Ward	Alfred L. Burch	1972	H	1,358	S	Dv/fsh
1034	4152-7955	R. P. Langdon	Robert Rindfuss	---	H	1,377	S	Dv/fsh
1035	4152-7957	Steven Lesik	Max E. Hickernell	1973	H	1,350	S	Dv/fsh
1036	4152-7958	Nathan Carr	McCray Bros.	1972	H	1,180	V	Qo/sdgr
1037	4153-7959	Ronald Bennett	Robert Rindfuss	1974	H	1,180	S	Dv/fsh
1038	4153-7959	J. A. Bennett	do.	1972	H	1,182	V	Qo/gr
1039	4153-7959	A. J. Eckard	do.	1974	H	1,225	S	Dv/fsh
1040	4153-7959	H. D. Williams	do.	1972	H	1,180	S	Dch/fsh
1041	4154-7955	George Hall	Alfred L. Burch	1969	H	1,214	V	Qo/sdgr
1042	4154-7959	Elizabeth Wilkins	Robert Rindfuss	1972	H	1,225	S	Dch/sh
1043	4154-7959	B. F. Holewski	do.	1974	H	1,308	S	Dv/fsh
1044	4155-7953	Lester Swaim	Max E. Hickernell	1966	H	1,332	S	Dv/ss
1045	4155-7955	Thomas Holman	Alfred L. Burch	1967	H	1,368	S	Dv/fsh
1046	4155-7955	do.	do.	1973	H	1,392	S	Dv/fsh
1047	4155-7955	William Weber	Michael W. Burch	1976	H	1,380	S	Dv/fsh
1048	4155-7954	Ormal Brown	Alfred L. Burch	1972	H	1,409	S	Dv/sh
1049	4155-7955	Paul Wester	Robert Rindfuss	1973	H	1,324	S	Dv/fsh
1050	4155-7956	Thomas Post	do.	1972	H	1,233	S	Qo/gr
1051	4156-7954	Robert Verga	Alfred L. Burch	1974	H	1,355	S	Dv/fsh
1052	4157-7953	Thomas Davies	do.	1975	H	1,290	S	Qo/sdgr
1053	4156-7955	Joseph Borczon	George H. Ackerman	1967	H	1,354	S	Qo/gr
1054	4156-7955	Dennis Alloway	Lorenze Lee Hall	1973	H	1,350	S	Qt/u
1055	4156-7956	Patricia Adams	Robert Rindfuss	1975	H	1,380	S	Qt/t
1056	4156-7955	T. S. Salusky	Donald E. Hall	1973	H	1,312	S	Qo/gr
1057	4156-7957	H. E. Ruckman	Boyd Lee Hall	1971	H	1,205	S	Dch/fsed
1058	4156-7958	J. R. Goldsmith	Robert Rindfuss	1972	H	1,222	S	Qo/gr
1059	4155-7958	Raymond Hershey	Lowell Halstead	1973	H	1,190	T	Qo/gr
1060	4156-7959	Cynthia Lane	Michael W. Burch	1976	H	1,190	V	Qo/sdgr

(Continued)

Total depth below land surface (feet)	Casing		Depth(s) to water-bearing zone(s) (feet)	Static water level		Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (μmho/cm at 25°C)	pH (units)	Well number
	Depth (feet)	Diameter (inches)		Depth below land surface (feet)	Date measured (mo/yr)						
60	57	8	54	---	---	8	---	---	---	---	Er- 987
50	22	12	18	14	6/74	3	---	---	---	---	988
70	45	8	60;69	---	---	25	25	---	---	---	989
23	23	8	8;17	1	12/76	9	.5	---	---	---	990
98	98	8	98	24	6/67	3	---	---	---	---	991
82	40	8	42	40	10/76	.5	---	---	---	---	992
53	12	8	15;30	15	6/74	5	.15	---	---	---	993
60	17	8	23;28	4	7/74	4	.07	---	---	---	994
53	15	6	23;48	6	5/68	7	---	---	---	---	995
100	30	6	18	---	---	---	---	---	---	---	996
49	30	8	34;46	8	11/76	25	2	---	---	---	997
60	15	8	15;40	7	8/67	1	---	---	---	---	998
40	19	8	19;22	15	7/75	1	---	---	---	---	999
65	42	6	45	10	7/68	10	.04	---	---	---	1000
50	30	8	26	---	---	2	---	---	---	---	1001
90	44	6	54;68;85	17	5/68	10	---	---	---	---	1002
58	18	8	40;50	12	3/71	6	.16	---	---	---	1003
41	26	7	28	20	5/62	20	4	---	---	---	1004
50	22	8	20;30	8	6/68	20	.5	---	---	---	1005
50	15	8	12;30	1	1/72	---	---	---	---	---	1006
21	21	8	21	8	10/72	18	9	---	---	---	1007
25	24	8	21;24	12	9/74	28	5.6	---	---	---	1008
40	18	8	21	35	7/73	6	---	---	---	---	1009
50	18	12	18	8	9/73	2	.05	---	---	---	1010
45	29	8	24;29	10	3/73	10	---	---	---	---	1011
67	11	8	18	2	6/74	1	.01	---	---	---	1012
70	16	12	---	11	7/76	1	---	---	---	---	1013
75	18	12	17;28	17	6/76	1	---	---	---	---	1014
35	20	8	14;22	10	5/75	9	---	110	265	---	1015
50	31	12	16;22	10	9/71	4	---	---	---	---	1016
51	20	8	---	12	6/75	5	.14	---	---	---	1017
50	29	8	22;27	11	1/73	15	---	---	---	---	1018
80	53	8	49;52	18	8/72	4	---	---	---	---	1019
65	---	12	15;25	4	4/75	.7	---	---	---	---	1020
60	43	8	38;44	10	8/72	10	---	---	---	---	1021
60	20	12	22;35;48	20	8/74	4	---	---	---	---	1022
65	28	8	21;40	20	7/66	4	---	---	---	---	1023
50	30	8	---	---	---	---	---	---	---	---	1024
55	20	12	15	3	5/74	3	---	---	---	---	1025
50	21	8	17;20	8	5/75	2	---	200	500	---	1026
80	38	8	35	30	5/76	9	.22	---	---	---	1027
47	10	8	24	13	6/72	2	.08	---	---	---	1028
25	25	24	23	12	5/73	6	.75	400	1,000	---	1029
105	93	8	60;80;87	25	3/71	4	---	---	---	---	1030
60	20	8	15;22;47	5	5/74	10	---	---	---	---	1031
70	37	8	---	14	8/72	5	.1	120	420	---	1032
100	17	8	18;20;23;70	6	12/72	6	.06	---	---	---	1033
65	---	8	27	---	---	15	---	---	---	---	1034
93	34	6	54;84	40	2/73	15	---	---	---	---	1035
51	51	8	10;20;50	1	6/72	5	.11	---	---	---	1036
83	73	8	76	40	7/74	30	6	---	---	---	1037
48	48	8	48	25	6/72	13	.65	---	---	---	1038
87	20	8	25	12	1974	2	---	---	---	---	1039
73	45	8	55	35	10/72	3	---	---	---	---	1040
70	70	8	48;64	35	10/69	4	---	120	220	---	1041
100	25	8	25	20	7/72	2	---	85	370	---	1042
75	45	8	62	---	---	15	.27	---	---	---	1043
54	43	6	51	33	10/66	7	---	---	---	---	1044
45	25	8	21;25	11	7/67	6	---	---	---	---	1045
36	18	8	20;25	10	12/73	8	---	---	---	---	1046
80	13	8	12;60	10	9/76	2	.04	---	---	---	1047
45	25	8	12;34	15	6/72	10	---	120	300	---	1048
73	25	8	55	25	3/73	12	---	---	---	---	1049
210	190	8	190	14	11/72	.2	---	---	---	---	1050
145	130	8	17;110;130	37	7/74	4	---	---	---	---	1051
52	52	8	31;47	25	9/75	9	---	---	---	---	1052
68	68	8	12	4	10/67	10	---	---	---	---	1053
90	86	8	76;86	14	11/73	2	.03	---	---	---	1054
53	29	8	29;56	12	9/75	12	.36	---	---	---	1055
32	32	8	32	---	---	8	---	---	---	---	1056
82	72	8	79	20	9/71	22	.55	---	---	---	1057
43	43	8	40	32	9/72	6	.86	---	---	---	1058
130	130	8	130	110	11/73	30	2	---	---	---	1059
33	33	8	3;28	1	8/76	9	.33	---	---	---	1060

Table 12.

Well location		Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Number	Lat-Long							
Er-1061	4156-7959	Victor Malinowski	Robert Rindfuss	1974	H	1,200	V	Qo/gr
1062	4157-7955	Charles Whitney	do.	1975	H	1,394	S	Dv/fsh
1063	4157-7956	David Risjan	do.	1975	H	1,458	S	Dv/fsh
1064	4155-7958	Frank Ethridge	---	---	H	1,092	V	Qo/gr
1065	4157-7956	Joseph Krol	Harold F. Anderson	1972	H	1,506	H	Dv/fsh
1066	4157-7957	J. G. Risjan	Robert Rindfuss	1974	H	1,210	S	Dch/fsh
1067	4157-7958	S. T. Chase	do.	1972	H	1,310	H	Qo/gr
1068	4157-7958	M. C. Vogt	Alfred L. Burch	1973	H	1,310	S	Qo/sdgr
1069	4157-7958	R. S. Petko	Robert Anderson	1974	H	1,290	S	Qo/gr
1070	4158-7957	R. A. Hull	Max E. Hickernell	1967	H	1,280	S	Qo/gr
1071	4159-7957	Arnold Burlingham	do.	1967	H	1,282	S	Qo/gr
1072	4158-7959	L. G. McClimans	Donald L. Hermann	1972	H	1,220	S	Qo/gr
1073	4158-7959	D. K. Coon	Robert Rindfuss	1973	H	1,238	U	Dch/fsh
1074	4159-7957	J. J. Capenos	Robert Anderson	1974	H	1,385	S	Dch/fsh
1075	4159-7953	D. A. Kirik	Max E. Hickernell	1971	H	1,340	S	Dch/fsh
1076	4158-7953	George Lowe	Harold F. Anderson	1975	H	1,310	V	Qo/sd
1077	4158-7957	Daniel Haibach	George H. Ackerman	1968	H	1,340	S	Qo/sd
1078	4157-7958	Raymond Baker	Alfred L. Burch	1975	H	1,310	S	Qo/sdgr
1079	4154-7954	Glenn Troyer	do.	1975	H	1,390	S	Dv/ss
1080	4154-7954	Marian Lopus	do.	1967	H	1,400	S	Dv/fsh
1081	4154-7958	Portia Lewis	Max E. Hickernell	1966	H	1,175	V	Qo/gr
1082	4152-7948	V. C. Akam	Harold F. Anderson	1973	H	1,360	S	Dv/fsh
1084	4152-7951	J. E. Musiek	Max E. Hickernell	1966	H	1,412	S	Qo/sdgr
1085	4153-7947	W. G. Shamp	Harold F. Anderson	1973	H	1,346	S	Dv/fsh
1086	4153-7949	Thomas Shayko	Alfred L. Burch	1964	H	1,312	S	Qo/gr
1087	4153-7949	Connie Ainsworth	Max E. Hickernell	1974	H	1,380	S	Dv/fst
1088	4153-7951	N. G. Troyer	do.	1973	H	1,355	S	Dv/fsed
1089	4153-7951	do.	do.	1972	H	1,367	S	Dv/fsed
1090	4154-7949	Gladys Chase	do.	1971	H	1,338	S	Qo/gr
1091	4154-7951	James Edwards	do.	1971	H	1,460	S	Dv/fsh
1092	4155-7950	Paul Gregor	Alfred L. Burch	1969	H	1,485	S	Qt/clgr
1093	4155-7952	G. L. Hinkson	Donald L. Hermann	1973	H	1,500	U	Dv/fsh
1094	4156-7947	Walter Ingalls	Lorenze Lee Hall	1975	H	1,538	S	Qo/gr
1095	4156-7947	Floyd McClellan	Harold F. Anderson	1973	H	1,524	S	Dv/fsh
1096	4156-7949	Herman Manross	do.	1974	H	1,610	H	MDcr/fsh
1097	4156-7949	Nelan Seltzer	Max E. Hickernell	1971	H	1,590	T	MDcr/fsh
1098	4156-7949	George Kirik	do.	1971	H	1,610	S	MDcr/fsh
1099	4155-7950	Rulaf Chapin	do.	1971	H	1,440	S	Dv/fsh
1100	4157-7951	S. H. Capela	Robert Rindfuss	1972	H	1,508	H	Dv/fsh
1101	4158-7947	Harold Amann	Alfred L. Burch	1966	H	1,564	S	Dv/fsh
1102	4157-7949	Robert Harrison	Harold F. Anderson	1973	H	1,355	S	Qo/gr
1103	4154-7950	Donald Thomas	McCray Bros.	1974	H	1,485	H	Dv/fsh
1104	4155-7950	Victor Cross	George H. Ackerman	1976	H	1,432	S	Dv/fsh
1105	4155-7950	Larry Beezub	Harold F. Anderson	1975	H	1,478	H	Dv/fsh
1106	4156-7951	Thomas Sebald	Robert Rindfuss	1975	H	1,468	S	Dv/fsh
1107	4154-7951	Cross and Co.	George H. Ackerman	1976	H	1,243	V	Qo/sdgr
1108	4201-7950	Robert Waite	McCray Bros.	1972	H	1,326	V	Qt/clgr
1109	4155-7937	Viking Plastics	do.	1972	N	1,400	V	Qo/sd
1110	4151-8000	Kathryn Van Zandt	Robert Rindfuss	1973	H	1,485	H	MDbr/fsh
1111	4152-8000	Marvin Armogost	Alfred L. Burch	1964	H	1,310	S	Dv/fsh
1112	4151-8001	P. A. Davis	Robert Rindfuss	1974	H	1,480	S	MDbr/fsh
1113	4151-8003	G. E. Collier	Boyd Lee Hall	1975	H	1,168	V	Qo/gr
1114	4151-8005	G. E. Vierkorn	Robert Anderson	1972	H	1,370	S	MDbr/fsh
1115	4151-8006	G. P. Woods	Boyd Lee Hall	1973	H	1,220	S	Dv/fsh
1116	4152-8003	D. L. Klakamp	Robert Rindfuss	1972	H	1,175	V	Qo/gr
1117	4151-8005	Ralph Burger	Alfred L. Burch	1968	H	1,404	S	Qo/sdgr
1118	4151-8004	N. L. Sauers	B. W. Bateman and Son	1969	H	1,450	S	Qo/sd
1119	4152-8001	Eugene Wright	Max E. Hickernell	1969	H	1,560	S	MDbr/fst
1120	4152-8003	D. A. Trowbridge	Boyd Lee Hall	1971	H	1,200	V	Qo/gr
1121	4152-8004	Gary Kuffer	Felix J. Waible	1976	H	1,400	S	Qt/t
1122	4152-8005	Lucman Land Corp.	Moody Drilling Co., Inc.	1972	P	1,465	S	MDbr/fst
1123	4152-8005	do.	do.	1972	P	1,450	S	MDbr/fst
1124	4152-8005	Edward Yurcak	B. W. Bateman and Son	1969	H	1,485	S	MDbr/fsh
1125	4152-8006	David Davis	Donald E. Hall	1973	H	1,380	S	Dv/fsed
1126	4153-8001	Jack Hoffman	Donald L. Hermann	1976	H	1,550	S	MDbr/fsh
1127	4153-8001	Edward Kovschak	Lorenze Lee Hall	1972	H	1,443	H	MDbr/fst
1128	4153-8001	Beatrice May	do.	1973	H	1,480	S	MDbr/fsec
1129	4153-8002	Richard Babbitt	Max E. Hickernell	1968	H	1,423	H	Dv/fsh
1130	4153-8002	Terry Hall	John E. Gage, Jr.	1971	H	1,309	S	Qt/t
1131	4153-8005	David Sundean	Max E. Hickernell	1971	H	1,495	S	MDbr/fsh
1132	4153-8005	Alton Huntley	Alfred L. Burch	1968	H	1,432	S	MDbr/fsh
1133	4153-8008	Edward Meinert	Max E. Hickernell	1969	H	1,210	V	Qo/sdgr
1134	4154-8000	Herbert Yaple	Robert Rindfuss	1975	H	1,260	S	Dv/fsh
1135	4154-8003	George Smith	Alfred L. Burch	1967	H	1,400	S	Dv/ssh

(Continued)

Total depth below land surface (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Depth(s) to water-bearing zone(s) (feet)	Static water level: Depth below land surface (feet)	Static water level: Date measured (mo/yr)	Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (µmho/cm at 25°C)	pH (units)	Well number
165	135	8	135	45	8/74	2	---	510	4,800	---	Er-1061
133	85	8	123	35	4/75	5	.06	---	---	---	1062
75	25	8	26;58	3	1/75	4	---	---	---	---	1063
201	201	4	---	24	---	---	---	90	245	---	1064
70	41	8	40;45;50	---	---	6	---	---	---	---	1065
77	45	8	62	8	5/74	15	---	---	---	---	1066
51	51	8	50	35	7/72	12	1.2	---	---	---	1067
45	45	8	34	28	5/73	30	4.3	---	---	---	1068
46	46	8	43	31	2/74	20	1.5	---	---	---	1069
82	82	8	76	40	3/67	20	---	---	---	---	1070
41	41	8	35	20	3/67	15	---	---	---	---	1071
52	52	8	49	6	6/72	12	.5	---	---	---	1072
95	83	8	85	35	12/73	23	.42	85	245	---	1073
69	25	8	25;35;50	12	8/74	6	.11	---	---	---	1074
68	---	6	35;52;64	23	9/71	15	---	---	---	---	1075
55	29	8	30;50	---	---	10	---	---	---	---	1076
142	142	6	142	60	4/68	4	---	140	320	---	1077
58	58	8	40;50	34	9/75	8	---	---	---	---	1078
200	24	8	15;65;120	59	9/75	4	---	---	---	---	1079
125	18	8	30;95	95	2/67	10	.33	---	---	---	1080
34	34	8	10;12	10	10/66	20	---	---	---	---	1081
116	74	8	100;116	---	---	5	---	---	---	---	1082
28	28	8	24	18	10/66	6	---	---	---	---	1084
71	35	8	53;61;66	---	---	15	---	50	300	---	1085
123	122	6	21;121	9	10/64	20	---	120	300	---	1086
92	19	6	64;87	15	8/74	20	---	230	600	---	1087
116	56	6	89	32	9/73	8	---	---	---	---	1088
130	26	8	75;118	14	7/72	5	---	---	---	---	1089
105	105	6	102	20	11/71	20	1.3	---	---	---	1090
76	37	8	46;59;68	16	4/71	20	---	180	530	---	1091
50	36	8	25;34	23	8/69	20	2.9	180	420	---	1092
50	29	8	25;27;29	6	4/73	8	---	---	---	---	1093
35	34	6	32	22	6/75	6	1	90	290	---	1094
50	39	8	45	---	---	7	---	---	---	---	1095
40	21	8	22;30	---	---	33	---	85	240	---	1096
85	24	6	46;76	47	9/71	5	---	---	---	---	1097
67	26	8	32;46;59	12	3/71	20	---	---	---	---	1098
44	25	6	29;39	6	11/71	20	---	---	---	---	1099
84	35	8	40;70	20	1972	10	---	160	500	---	1100
50	16	6	18;40	8	6/66	5	---	150	375	---	1101
30	28	8	30	---	---	6	---	---	---	---	1102
85	40	6	75;80;85	20	5/74	10	.2	---	---	---	1103
80	60	8	54;72	32	6/76	50	3	---	---	---	1104
55	25	8	29;50	10	10/75	12	---	---	---	---	1105
41	22	8	32	6	7/75	10	.4	---	---	---	1106
76	76	8	72	7	6/76	70	5.4	---	---	---	1107
180	96	6	90	20	8/72	2	.01	---	---	---	1108
20	20	---	20	10	6/72	50	50	---	---	---	1109
115	---	8	110	60	3/73	10	.2	210	480	---	1110
95	56	8	54;85	---	3/64	2	.04	---	---	---	1111
84	45	8	73	30	6/74	18	.53	---	---	---	1112
45	45	8	45	10	5/75	7	---	90	225	---	1113
56	13	8	35	13	9/72	17	.46	---	---	---	1114
45	35	8	32	10	10/73	20	.8	160	360	---	1115
60	60	8	58	13	6/72	25	2.1	---	---	---	1116
50	46	8	42	35	10/68	8	---	---	---	---	1117
50	42	5	12;43	8	10/69	10	1.2	---	---	---	1118
51	---	8	34;47	---	---	15	---	---	---	---	1119
49	49	8	44	30	11/71	12	1.2	100	220	---	1120
55	19	8	15	12	4/76	20	---	110	300	---	1121
442	19	12	62;77;377	F	4/72	25	.12	158	---	7.8	1122
407	14	12	77;167	5	4/72	15	.19	---	---	---	1123
40	20	5	27	16	10/69	8	1	---	---	---	1124
60	23	8	34;55	---	---	16	---	---	---	---	1125
60	35	8	32;36	21	3/76	6	---	---	---	---	1126
70	31	8	40;63	8	6/72	25	.64	---	---	---	1127
58	28	6	26;47	8	10/73	15	.4	---	---	---	1128
104	97	6	99	20	11/68	10	---	120	380	---	1129
50	40	8	40	6	7/71	3	.09	---	---	---	1130
73	32	6	49;61;68	14	10/71	15	---	120	300	---	1131
75	12	8	14;30;50	20	7/68	---	---	---	---	---	1132
68	68	6	15;68	16	8/69	15	---	---	---	---	1133
100	78	8	90	45	5/75	8	.18	---	---	---	1134
43	30	8	30;40	25	6/67	20	---	120	310	---	1135

Table 12.

Well location Number	Lat-Long	Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Er-1136	4154-8004	I. O. Murphy	Alfred L. Burch	1970	H	1,422	S	Dv/fsh
1137	4154-8005	Joseph Kuhn	Robert Anderson	1976	H	1,495	S	MDbr/fsh
1138	4154-8007	John Lovett	Alfred L. Burch	1967	P	1,330	H	Dv/fsh
1139	4154-8007	do.	do.	1967	P	1,282	S	Qo/gr
1140	4154-8007	do.	do.	1967	P	1,319	S	Qt/clgr
1141	4155-8000	R. J. Schroeck	do.	1971	H	1,370	S	Dv/fsh
1142	4155-8000	James Wolfe	do.	1969	H	1,360	S	Dv/fsh
1143	4155-8000	Dominick Cisson	Robert Rindfuss	1972	H	1,403	H	Dv/fsh
1144	4155-8001	Stanley Orbanick	Max E. Hickernell	1967	H	1,410	S	Dv/fst
1145	4155-8003	Emil Loesel	Donald L. Hermann	1972	H	1,580	S	MDbr/ssh
1146	4155-8004	Jerry Fellows	do.	1975	H	1,386	H	Dv/sh
1147	4156-8004	Merle Kifer	do.	1975	H	1,425	S	Qt/gr
1148	4156-8000	W. A. Flook	Alfred L. Burch	1970	H	1,310	S	Dv/fsh
1149	4156-8000	Alfred Miles	Boyd Lee Hall	1972	H	1,320	S	Dv/fsed
1150	4156-8000	Joseph Yakulis	Alfred L. Burch	1970	H	1,300	S	Qo/gr
1151	4156-8003	William Fetzner	Robert Rindfuss	1973	H	1,595	H	MDbr/fsh
1152	4156-8007	F. J. Soboski	Boyd Lee Hall	---	H	1,350	S	Dv/fsed
1153	4156-8007	W. J. Keith, Sr.	Robert Anderson	1974	H	1,408	S	Dv/ssh
1154	4156-8007	Chester Kutz	Alfred L. Burch	1966	H	1,298	S	Dv/fsh
1155	4156-8007	Robert Eastman	do.	1964	H	1,395	S	Dv/ssh
1156	4157-8000	Raymond Paproski	Robert Rindfuss	1974	H	1,294	S	Dv/fsh
1157	4157-8002	T. W. Arneman	Alfred L. Burch	1973	H	1,270	S	Qo/gr
1158	4157-8003	John Beres	Max E. Hickernell	1967	H	1,408	S	Dv/ss
1159	4157-8003	Ralph Klapthor	Donald L. Hermann	1975	H	1,550	S	MDbr/fsh
1160	4158-8003	David Winkelbauer	Alfred L. Burch	1966	H	1,360	S	Dv/fsh
1161	4157-8005	Richard Babo	do.	1967	H	1,465	S	Qo/sdgr
1162	4157-8006	Philip Wilkosz	Boyd Lee Hall	1973	H	1,435	S	Dv/fsh
1163	4158-8002	Robert Behrendt	Alfred L. Burch	1968	H	1,333	H	Qo/sdgr
1164	4158-8005	C. N. Villa, Jr.	do.	1974	H	1,418	U	Dv/fsh
1165	4158-8006	Theo Scarlett	Michael W. Burch	1976	H	1,384	U	Dv/fsh
1166	4159-8001	Elmer Johnson	Donald L. Hermann	1975	H	1,470	H	Dv/fsh
1167	4159-8001	Harry Rearick	Alfred L. Burch	1967	H	1,495	H	Dv/fsh
1168	4159-8002	A. C. Haibach	Donald L. Hermann	1972	H	1,282	S	Qo/sdgr
1169	4159-8002	do.	do.	1972	H	1,254	S	Dch/ssh
1170	4159-8002	do.	do.	1972	H	1,284	S	Dch/fsh
1171	4159-8003	Robert Shupala	Alfred L. Burch	1968	H	1,228	S	Qt/t
1172	4159-8003	Jeffrey Young	do.	1975	H	1,325	S	Dv/fsh
1173	4159-8004	Herbert Hafenmaier	do.	1975	H	1,280	S	Qo/sdgr
1174	4156-8016	Edward Marhola	Lowell Halstead	1973	H	1,080	S	Qt/gr
1175	4155-8020	Eugene Brooks	Max E. Hickernell	1965	H	920	V	Qo/u
1176	4156-8015	Richard Agresti	Robert Anderson	1974	H	1,120	S	Dch/fsh
1177	4156-8019	Kenneth Baker	Lowell Halstead	1973	H	930	V	Qo/gr
1178	4153-8008	John Walsh	Max E. Hickernell	1964	H	1,288	S	Dv/fst
1179	4156-8009	George Smith	Alfred L. Burch	1966	H	1,345	S	Dv/fsh
1180	4157-8011	Michael Kavelish	Boyd Lee Hall	1974	H	1,254	S	MDbv/fsh
1181	4157-8014	Ronald Farmer	Michael W. Burch	1975	H	1,090	S	Dch/fsh
1182	4154-8026	James Case, Jr.	Richard L. Ticknor	1975	H	924	V	Qt/gr
1183	4210-7956	Mary O'Brien	Michael W. Burch	1975	H	733	T	Dne/fst
1184	4153-8029	Wilber Brown	Max E. Hickernell	1963	H	922	V	Qt/clgr
1185	4202-7954	Charles Cottrell	Robert Rindfuss	1972	H	1,382	H	Qo/gr
1186	4205-7959	Thomas Welsh	George H. Ackerman	---	H	1,134	H	Qt/u
1187	4206-7959	Joseph Helsley	do.	1973	H	1,134	H	Dch/fsh
1188	4208-8000	Whipple and Allen Co.	Michael W. Burch	1975	H	715	T	Qb/sdgr
1189	4159-8027	Robert Dumars	---	---	H	642	T	Qb/gr
1190	4154-8030	Sulo Mackey	---	1921	H	833	S	Qo/gr
1191	4155-8027	Harold Thayer	---	---	H	873	T	Qo/gr
1192	4157-8024	Emery Sherman	---	---	H	730	T	Qb/u
1193	4159-8014	George Luther	---	---	H	810	S	Dch/sed
1194	4159-8012	Ralph Leopold	---	---	H	948	S	Qo/sdgr
1195	4202-8016	Hazel Soule	---	---	H	672	F	Qb/gr
1196	4202-8018	Joseph Ziesenheim	---	1948	C	683	F	Qb/gr
1197	4200-8017	John Borsukoff	---	1941	H	790	F	Qb/u
1198	4157-8017	John Wagner	---	---	H	900	S	Dg/sh
1199	4159-8020	Eugene Miller	---	1930	H	868	H	Qo/u
1200	4156-8019	John Kuvik	---	1930	H	876	U	Dch/fsh
1201	4202-8008	Ernest Abbott	Vernon Reed	---	H	1,000	S	Dch/fsh
1202	4204-8007	Harold Stiles	Bernard P. Kuntz	1949	H	950	H	Qo/gr
1203	4203-8009	John Kort	Vernon Reed	1950	H	870	U	Qo/sdgr
1204	4210-7954	James Bernet	---	---	H	784	S	Qb/gr
1205	4204-8005	George Smith	Bernard P. Kuntz	1949	H	933	U	Qo/gr
1206	4204-8005	Leroy Grossholz	do.	1948	H	915	U	Qo/gr
1207	4205-8007	Harry Kuhns	do.	1946	H	850	S	Qo/gr
1208	4204-8005	Frank Swalley	do.	1938	H	915	U	Qo/sdgr
1209	4204-8002	Arthur Schultz	do.	---	H	1,090	S	Qo/sdgr

(Continued)

Total depth below land surface (feet)	Casing		Depth(s) to water-bearing zone(s) (feet)	Static water level		Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conduc-tance (μmho/cm at 25°C)	pH (units)	Well number
	Depth (feet)	Diameter (inches)		Depth below land surface (feet)	Date measured (mo/yr)						
110	70	8	65;96	32	11/70	12	.17	---	---	---	Er-1136
64	28	12	28;32	16	1/76	40	1.2	---	---	---	1137
57	34	8	32;40	21	4/67	6	---	---	---	---	1138
40	---	---	12	---	---	1	---	---	---	---	1139
40	11	8	11	---	---	---	---	---	---	---	1140
60	28	8	12;34	10	4/71	10	---	85	340	---	1141
50	24	8	30;40	4	6/69	5	---	---	---	---	1142
60	30	8	45	14	6/72	2	---	180	410	---	1143
70	31	8	33;45;60	12	3/67	10	---	---	---	---	1144
60	49	8	49	30	6/72	5	.2	---	---	---	1145
145	75	8	74	45	5/75	1	---	20	580	---	1146
70	57	8	46	12	7/75	2	---	---	---	---	1147
50	17	8	13;25	10	5/70	5	---	---	---	---	1148
52	22	8	26;46	9	4/72	10	.3	---	---	---	1149
24	24	8	16;20	5	5/70	10	---	---	---	---	1150
73	55	8	65	25	3/73	11	---	---	---	---	1151
70	32	8	63;70	8	---	15	1.2	---	---	---	1152
51	25	8	26	6	4/74	15	.37	150	650	---	1153
70	18	8	40	12	12/66	5	.09	---	---	---	1154
110	47	8	16;45	15	7/64	4	---	---	---	---	1155
83	62	8	65	30	5/74	2	---	---	---	---	1156
46	46	8	20;38	19	4/73	30	2.7	---	---	---	1157
69	38	6	48;57	8	6/67	15	---	---	---	---	1158
72	56	8	53;59	23	9/75	5	.12	---	---	---	1159
70	36	8	30;50	42	10/66	10	---	---	---	---	1160
50	47	8	23;47	18	6/67	4	---	---	---	---	1161
52	45	8	18;45	3	---	12	.3	---	---	---	1162
200	162	6	20;145;158	85	11/68	5	---	---	---	---	1163
60	33	8	28;33	9	6/74	10	---	---	---	---	1164
50	20	8	15;38	4	12/76	5	.11	---	---	---	1165
55	35	8	27;33	8	7/75	6	.14	---	---	---	1166
55	30	8	---	6	2/67	10	---	---	---	---	1167
35	35	8	31	18	6/72	8	---	---	---	---	1168
50	41	8	38;41	24	6/72	15	.8	---	---	---	1169
50	38	8	35;42	24	6/72	8	.4	---	---	---	1170
45	45	8	---	26	8/68	8	---	---	---	---	1171
160	130	8	30;126;145	62	5/75	10	---	60	1,200	---	1172
87	87	8	64	25	1/75	4	---	---	---	---	1173
100	26	8	23	---	---	2	---	---	---	---	1174
55	25	8	---	11	8/65	3	---	95	1,700	---	1175
35	10	8	13	2	4/74	5	.18	---	---	---	1176
43	43	8	38	---	---	---	---	---	---	---	1177
57	27	6	29;41;48	7	9/64	10	.3	---	---	---	1178
60	18	8	14;40	8	7/66	.6	---	---	---	---	1179
50	33	8	42	---	---	11	---	120	560	---	1180
60	18	8	12;18	2	---	3	.05	---	---	---	1181
55	55	8	35	20	5/75	25	1.7	---	---	---	1182
30	26	5	18	12	5/75	4	---	---	---	---	1183
52	52	8	---	5	3/63	15	---	---	---	---	1184
80	80	8	80	20	9/72	30	1.5	140	340	---	1185
65	19	12	19	---	---	2	---	---	---	---	1186
70	44	8	44;50	---	---	6	---	---	---	---	1187
45	13	8	6;18	15	5/75	4	.14	---	---	---	1188
15	15	---	---	10	7/51	---	---	160	340	7.0	1189
20	20	---	---	---	---	---	---	220	433	6.9	1190
18	18	---	---	---	---	---	---	---	---	---	1191
20	20	---	---	---	---	---	---	110	281	6.9	1192
60	---	---	---	---	---	---	---	230	747	7.1	1193
15	15	---	---	---	---	---	---	48	146	6.2	1194
18	18	---	---	---	---	---	---	290	661	7.3	1195
30	30	---	---	---	---	---	---	200	---	7.0	1196
72	72	---	---	---	---	---	---	140	558	7.8	1197
50	---	6	---	20	7/51	---	---	340	655	7.4	1198
80	---	---	---	---	---	---	---	230	445	7.7	1199
47	---	---	---	---	---	---	---	200	1,110	7.6	1200
60	---	---	---	---	---	---	---	70	228	7.6	1201
121	121	---	---	---	---	---	---	200	394	7.6	1202
80	80	---	---	---	---	---	---	180	337	7.8	1203
28	28	---	---	24	---	---	---	---	---	---	1204
57	57	---	---	---	---	---	---	170	493	7.7	1205
48	48	---	---	---	---	---	---	240	1,810	6.9	1206
44	44	---	---	---	---	---	---	230	449	7.4	1207
40	40	---	---	---	---	---	---	72	160	6.6	1208
97	97	---	---	---	---	12	---	170	517	---	1209

Table 12.

Well location		Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Number	Lat-Long							
Er-1210	4205-8003	Otto Meyer, Jr.	Bernard P. Kuntz	---	H	980	H	Qo/sdgr
1211	4157-8017	Donald Lewis	---	1948	H	905	H	Dch/fsh
1212	4204-8011	Port Erie Airport	Vernon Reed	---	C	732	F	Qo/sdgr
1213	4205-8007	Jack Kilpatrick	do.	1949	H	784	T	Qb/u
1214	4204-8009	Robert Becker	Bernard P. Kuntz	1949	H	780	T	Qb/gr
1215	4204-8009	George Singer	Vernon Reed	1950	H	824	T	Qo/sdgr
1216	4205-8008	Byrd Tool and Mold Co.	do.	1949	H	712	F	Qb/gr
1217	4204-8011	Daniel Wiley	do.	1944	H	730	F	Qo/gr
1218	4204-8011	August Hohnke	---	---	H	730	F	Qb/u
1219	4204-8011	Jay Nelson	Oakes and Bennett	1947	H	734	F	Dne/fsh
1220	4204-8011	do.	---	---	H	734	F	Qb/gr
1221	4204-8005	Calvin Johnson	Bernard P. Kuntz	1947	H	925	T	Dg/---
1222	4158-8016	William Bushelman	---	---	H	755	H	Dg/fsh
1223	4156-7958	Charles Gardner	---	---	H	1,209	V	Qo/gr
1224	4152-8018	Michael Hayes	John E. Gage, Jr.	1974	H	1,168	H	MDbv/sh
1225	4159-8019	Judd Seldon	Moody Drilling Co., Inc.	1953	H	775	T	Qo/gr
1226	4159-8020	Pennsylvania State Police Barracks	do.	1954	H	740	T	Qo/gr
1227	4159-8021	Jim Frey	do.	1954	H	740	T	Qo/gr
1228	4158-8021	Lawrence Frey	do.	1954	H	760	V	Qo/t
1229	4158-8022	G. H. Cox	do.	1956	H	755	V	Qo/gr
1230	4157-8017	Mike Felege	do.	1951	H	902	S	Dch/fsh
1231	4157-8019	Lewis Stafford	do.	1954	H	869	U	Qt/gr
1232	4153-8009	Bruce Iffi	do.	---	H	1,360	H	Dv/fsh
1233	4152-8028	Roy Sawalter	do.	1957	U	960	F	Dch/sh
1234	4152-8024	Sam Russin	do.	1958	H	854	V	Qo/gr
1235	4154-8030	Roland Hammer	do.	1956	H	850	U	Qo/gr
1236	4151-8022	M. L. Cherry	do.	1959	H	1,065	S	MDbv/fsh
1237	4151-8022	Herb Cherry	do.	1956	H	1,060	S	MDbv/fsh
1238	4151-8022	Sam Pittsenberger	do.	1955	H	960	S	MDbv/fsh
1239	4151-8019	Alfred Fahlen	do.	1950	H	1,110	U	Dch/fst
1240	4151-8018	Kenneth Raymond	do.	1957	H	1,130	V	Qo/gr
1241	4153-8025	Milo Brown	do.	1955	H	900	U	Dch/fsh
1242	4157-8025	Chester Osterberg	do.	1956	H	735	F	Qb/gr
1243	4157-8023	Ernest Testo	do.	1957	U	810	V	Qt/t
1244	4154-8028	Tom Freeman	do.	1956	H	825	S	Qo/gr
1245	4153-8022	Bill Tucker	do.	1956	H	890	S	Qt/gr
1246	4153-8028	Kane Stanton	do.	1957	H	930	V	Dch/fsh
1247	4153-8023	Noble Lawrence	do.	1955	H	865	V	Dch/fsh
1248	4153-8023	V.F.W. Club	do.	1958	C	865	V	Qt/sd
1249	4151-8024	Albion Sportsmens Club	Lorenze Lee Hall	1977	R	860	V	Qo/sdgr
1250	4151-8025	Gary Simpson	Alfred L. Burch	1977	H	930	S	Dch/fsh
1251	4153-8026	William Palo	Moody Drilling Co., Inc.	1956	H	915	U	Dch/fsh
1253	4154-8025	Neil Shade	Alfred L. Burch	1977	H	890	U	Dch/sh
1254	4154-8023	Carlyle Krieg	Lorenze Lee Hall	1977	H	890	S	Qo/gr
1255	4156-8027	Minute Man Service	Harry Bros.	1977	C	734	U	Qb/sd
1256	4152-8015	James Crosby	Jack Young	1977	H	1,205	V	Qo/gr
1257	4152-8013	John Dascanio	Robert Anderson	1977	H	1,274	S	MDbv/fsh
1258	4151-8013	Charles Lupka	Boyd Lee Hall	1977	H	1,265	S	MDbv/fsh
1259	4151-8016	Jerry Skelton	do.	1977	H	1,260	U	Qt/t
1260	4151-8018	James Kreider	Lorenze Lee Hall	1977	H	1,070	V	Qo/gr
1261	4152-8019	Albert Bainbridge	do.	1977	H	1,005	V	Dch/ssh
1262	4151-8020	James Beveridge	Alfred L. Burch	1976	H	1,130	U	MDbv/fsh
1263	4159-8016	J. Spaulding	Robert Anderson	1978	H	835	S	Qo/gr
1264	4159-8015	Charles Longnecker	do.	1977	H	868	S	Qt/sdgr
1265	4159-8020	Samuel Orlando	Alfred L. Burch	1976	H	814	S	Qo/sdgr
1266	4159-8020	Boehm Realty	do.	1976	H	780	S	Qo/sd
1267	4159-8015	Anthony Mitcho	do.	1976	H	910	U	Qt/sd
1268	4159-8014	Barry Smitti	George H. Ackerman	1977	H	924	S	Qo/sdgr
1269	4159-8014	Adam Brezinski	Michael W. Burch	1977	H	930	S	Qo/gr
1270	4159-8013	G. Bennett	Felix J. Waible	1977	H	940	F	Qt/gr
1271	4203-8014	Patrick Luciano	Donald L. Hermann	1976	H	720	F	Qb/gr
1272	4202-8014	Keith Johnson	Alfred L. Burch	1976	H	820	T	Qo/u
1273	4203-8013	Ralph Baybrook	George H. Ackerman	1977	H	750	T	Qo/sdgr
1274	4203-7958	Gorniak Bros.	Moody Drilling Co., Inc.	1958	H	1,352	U	Dch/fsh
1275	4203-8011	Michael Yarbenet	Donald L. Hermann	1976	H	845	U	Qo/gr
1276	4203-8012	Lynwood Nursery	Felix J. Waible	1977	I	790	U	Qo/gr
1277	4202-8013	Kenneth Swift	Alfred L. Burch	1939	H	820	F	Qo/u
1278	4200-8014	Alice Olmstead	do.	1976	H	930	U	Qo/sd
1279	4156-8014	Yvette Rosenberg	Felix J. Waible	1927	H	1,190	U	MDbv/fsh
1280	4154-8014	John Levis	Robert Anderson	1977	H	1,260	U	MDbv/fsh
1281	4153-8009	Bruce Iffi	Alfred L. Burch	1976	N	1,360	F	Dv/fsh
1282	4153-8013	Fred Suhy	Robert Anderson	1977	H	1,285	U	MDbv/fsh
1283	4159-8009	J. Hicks	do.	1978	H	1,069	S	Dch/sh

(Continued)

Total depth below land surface (feet)	Casing Depth (feet)	Casing Diameter (inches)	Depth(s) to water-bearing zone(s) (feet)	Static water level Depth below land surface (feet)	Static water level Date measured (mo/yr)	Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (µmho/cm at 25°C)	pH (units)	Well number
81	81	---	---	---	---	9	---	220	620	7.6	Er-1210
49	---	5	---	6	7/51	---	---	200	401	7.6	1211
90	90	---	---	---	---	---	---	150	857	7.9	1212
55	---	---	---	---	---	---	---	180	359	7.9	1213
40	40	---	---	---	---	---	---	200	493	7.7	1214
75	75	---	---	---	---	---	---	180	442	7.7	1215
30	30	8	---	---	---	---	---	230	580	7.7	1216
70	70	---	---	---	---	---	---	330	613	7.3	1217
28	28	---	---	---	---	---	---	140	314	6.5	1218
78	---	---	---	---	---	---	---	120	1,280	7.8	1219
38	38	---	---	---	---	---	---	260	500	7.3	1220
54	---	---	---	---	---	---	---	170	923	7.3	1221
84	---	---	---	---	---	---	---	110	2,080	7.5	1222
242	242	6	---	---	---	---	---	---	---	---	1223
49	30	8	14;20	5	8/74	3	.09	---	---	---	1224
34	34	12	20	15	5/53	20	---	---	---	---	1225
53	53	7	49	18	9/54	6	---	---	---	---	1226
46	46	7	38	27	9/54	20	---	---	---	---	1227
127	120	7	31;62;127	---	---	.1	---	---	---	---	1228
34	34	8	29	24	10/56	9	---	---	---	---	1229
58	44	10	39	30	9/51	3	---	190	700	---	1230
93	93	7	89	63	8/54	5	---	---	---	---	1231
83	28	8	---	13	---	1	---	---	---	---	1232
40	---	---	---	---	---	.2	---	---	---	---	1233
135	135	6	59;130	15	1/58	5	---	---	---	---	1234
52	52	8	45	38	10/56	20	---	---	---	---	1235
78	20	8	20	8	8/59	4	---	---	---	---	1236
54	14	8	---	3	6/56	33	---	80	520	---	1237
65	11	8	---	11	9/55	10	---	---	---	---	1238
51	35	5	---	39	9/50	5	---	50	275	---	1239
22	22	8	17	15	11/57	6	---	---	---	---	1240
50	18	6	---	2	11/55	2	---	---	---	---	1241
34	34	8	29	11	12/56	10	---	---	---	---	1242
42	---	---	---	---	---	---	---	---	---	---	1243
48	48	8	---	25	8/56	10	---	---	---	---	1244
46	46	7	41	36	9/56	5	---	5	650	---	1245
40	10	10	---	7	6/57	6	---	---	---	---	1246
110	107	6	---	---	---	6	---	---	---	---	1247
195	182	8	---	---	---	.1	---	---	---	---	1248
62	62	8	27;56	14	9/77	24	.9	---	---	---	1249
50	39	8	18;41	10	3/77	10	---	---	---	---	1250
38	24	7	---	8	8/56	4	---	---	---	---	1251
90	35	8	---	40	3/77	.1	---	---	---	---	1253
120	120	6	93;120	80	9/77	2	.06	120	1,850	---	1254
31	24	8	24	---	---	3	.6	---	---	---	1255
20	20	8	12;17	10	5/77	10	10	100	275	---	1256
71	17	8	35;45	10	8/77	1	.02	---	---	---	1257
112	33	8	33;105	8	6/77	8	.08	---	---	---	1258
62	62	8	45;60	10	5/77	30	30	10	525	---	1259
52	28	6	30;47	15	8/77	40	2.6	---	---	---	1260
52	25	10	20;39	11	3/77	1	.03	---	---	---	1261
60	32	8	10;25	4	11/76	10	---	---	---	---	1262
52	52	8	49	9	1/78	5	.1	---	---	---	1263
55	55	8	27;53	16	7/77	4	.1	---	---	---	1264
50	50	8	40	30	7/76	20	---	---	---	---	1265
35	35	8	24	12	6/76	20	---	---	---	---	1266
100	94	8	77;90	64	9/76	2	---	230	800	---	1267
120	108	8	101	32	9/77	50	4.5	---	---	---	1268
71	71	8	26;65	29	5/77	30	1.9	---	---	---	1269
78	78	8	75	28	5/77	5	---	---	---	---	1270
34	34	8	30	18	6/76	15	2.1	---	---	---	1271
86	---	6	85	70	12/76	6	.6	---	---	---	1272
40	40	8	31	20	10/77	50	10	---	---	---	1273
80	48	8	---	4	6/58	5	---	---	---	---	1274
89	89	8	82;86	42	9/76	15	.5	---	---	---	1275
45	45	8	40	22	7/77	20	---	---	---	---	1276
49	49	6	49	35	9/76	14	---	---	---	---	1277
47	47	8	40	22	10/76	30	---	---	---	---	1278
31	18	8	14	14	10/27	20	---	110	300	---	1279
70	26	8	27;37	5	5/77	1	.02	180	2,800	---	1280
70	43	8	36;50	10	6/76	4	---	---	---	---	1281
60	13	8	35	5	6/77	1	.02	---	---	---	1282
63	18	8	20;29	5	3/78	6	.1	200	520	---	1283

Table 12.

Well location		Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/lithology
Number	Lat-Long							
Er-1284	4158-8009	Leroy Preston	Michael W. Burch	1977	H	1,165	S	Dch/fsh
1285	4201-8011	Sun Oil Co.	Donald L. Hermann	1977	C	1,100	H	Qo/sdgr
1286	4200-8009	James Wittmaak	do.	1976	H	1,065	S	Dch/ssh
1287	4200-8009	John Schultz	Michael W. Burch	1977	H	1,025	S	Qt/gr
1288	4200-8010	Theodore Waisley	Donald L. Hermann	1976	H	960	V	Dch/fsh
1289	4157-8007	Adam Jaroszewski	George H. Ackerman	1977	H	1,405	S	Qt/gr
1290	4201-8006	Thomas West	Donald L. Hermann	1976	H	1,190	S	Dch/sh
1291	4200-8004	David Sharie	George H. Ackerman	1977	H	1,145	V	Qo/sdgr
1292	4155-7944	James Platt	Max E. Hickernell	1977	H	1,400	V	Qo/gr
1293	4156-7946	David Jagta	George H. Ackerman	1977	H	1,590	S	MDcr/fsed
1294	4156-7946	David Lindberg	do.	1977	H	1,595	S	MDcr/fsh
1295	4210-7945	William Desin	Ralph C. Parmenter	1977	H	1,508	S	Qt/u
1296	4209-7947	Eugene Groves	do.	1977	H	1,382	S	Dch/fsh
1297	4153-8001	Ronald Poker	Robert Rindfuss	1976	H	1,560	S	MDbr/fsh
1298	4153-8001	Joseph Shesman	Robert Anderson	1977	H	1,515	S	MDbr/fsh
1299	4153-8001	Charles Merry	Donald L. Hermann	1976	H	1,525	S	MDbr/fsh
1300	4152-8000	Carl Miller	Robert Rindfuss	1976	H	1,220	S	Dv/fsh
1301	4152-8000	do.	do.	1976	H	1,245	S	Dv/fsh
1302	4151-7957	George Peters	do.	1976	H	1,470	S	MDcr/fsh
1303	4159-8054	Arthur Loop	Michael W. Burch	1977	H	1,375	S	Dch/ssh
1304	4156-7957	Gary Tagliente	Robert Rindfuss	1976	H	1,310	U	Dv/fsh
1305	4155-7955	Merle Willey	do.	1976	S	1,305	U	Dv/fsh
1306	4158-7953	Brady Marks	Robert Anderson	1977	H	1,405	S	Dv/fsh
1307	4205-7953	John Afton	Michael W. Burch	1977	H	1,370	U	Dv/fsh
1308	4204-7946	Calvin Pifer	George H. Ackerman	1977	H	1,690	S	Qo/sdgr
1309	4203-7953	David Rockwell	Donald L. Hermann	1977	H	1,370	S	Qo/sd
1310	4203-7953	Arlo Applebee	Michael W. Burch	1977	H	1,350	S	Qo/gr
1311	4202-7952	Steven Gorniak	Alfred L. Burch	1976	H	1,475	H	Dch/fsh
1312	4206-7951	Merle Lewis	Robert Anderson	1977	H	1,415	S	Dch/fsh
1313	4206-7946	Robert Gibbons	Ralph C. Parmenter	1977	H	1,670	S	Qt/u
1314	4206-7951	Greenfield Fire Co.	do.	1976	H	1,475	S	Qt/u
1315	4209-7952	Daniel Lyons	do.	1976	H	1,325	S	Dch/fsh
1316	4209-7953	John Skinner	Michael W. Burch	1977	H	1,305	S	Dch/sh
1318	4211-7955	Richard Kosik	Alfred L. Burch	1976	H	665	V	Qb/sd
1319	4210-7956	Richard Eisert	do.	1976	H	765	S	Dne/fsh
1320	4208-7958	Ruth Speice	Michael W. Burch	1977	H	842	S	Dg/fsh
1321	4209-7955	Roy Shannon	do.	1977	H	910	S	Dg/ssh
1322	4207-7958	James Stensen	J. W. Waterhouse	1977	H	1,020	S	Dch/sed
1323	4206-7958	Erie County Cable TV	Michael W. Burch	1977	H	1,170	S	Dch/fsh
1324	4206-7957	Charles Young	do.	1977	H	1,272	S	Dch/fsh
1325	4204-8000	Ralph Semrau	Robert Anderson	1977	H	1,318	S	Dch/fsh
1326	4204-8000	D. O. Nupp	Felix J. Waible	1977	H	1,380	S	Dch/fsh
1327	4205-7959	J. Kirby	Michael W. Burch	1978	H	1,140	S	Dch/ssh
1328	4206-7957	Sal Randazzo	Donald L. Hermann	1976	H	1,358	S	Dch/fsh
1329	4205-7954	John Phelps	George H. Ackerman	1977	H	1,300	S	Qo/gr
1330	4206-7954	Perry Bennett	Robert Anderson	1977	H	1,210	V	Dch/fsh
1331	4204-7958	D. Kreger	Michael W. Burch	1977	H	1,210	S	Qo/sdgr
1332	4204-7959	Donn Nicalo	Felix J. Waible	1977	H	1,360	S	Qt/clgr
1333	4202-7957	Roger Klein	Michael W. Burch	1977	H	1,310	S	Qt/sdgr
1334	4204-7957	Raymond Orlemanski	Alfred L. Burch	1976	H	1,355	S	Dch/fsh
1335	4203-7956	David Hale	Felix J. Waible	1977	H	1,368	S	Dch/fsh
1336	4203-7956	George Palmer	Michael W. Burch	1977	H	1,359	S	Dch/fsh
1337	4203-7954	Edward Snippert	George H. Ackerman	1977	H	1,335	S	Qo/sd
1338	4201-7955	James Spaeder	Robert Rindfuss	1976	H	1,395	S	Qo/gr
1339	4201-7959	James Collins	Donald L. Hermann	1976	H	1,352	S	Dch/ssh
1340	4201-7958	Jack Farrell	do.	1976	H	1,240	V	Dch/fsh
1341	4154-8009	Robert Sokolowski	Robert Anderson	1977	H	1,384	S	Dv/fsh
1342	4153-8009	James Hobbs	Boyd Lee Hall	1977	H	1,250	S	Dv/fsed
1343	4156-7957	Terry Page	Alfred L. Burch	1976	H	1,214	V	Qt/clgr
1344	4156-7957	do.	Moody Drilling Co., Inc.	1976	H	1,220	V	Qt/clgr
1345	4153-8009	R. D. Overheim	Max E. Hickernell	1977	H	1,275	S	Dv/fsh
1346	4153-8005	Len Krzywicki	Boyd Lee Hall	1976	H	1,505	S	MDbr/fsed
1347	4151-8005	John Berger	Donald L. Hermann	1976	H	1,430	S	MDbr/fsh
1348	4202-8006	Raymond Andrus	do.	1976	H	1,125	S	Dch/ssh
1349	4202-8006	Carl Hahn	Robert Anderson	1977	H	1,080	U	Dch/fsh
1350	4203-8003	David Menzies	Alfred L. Burch	1977	H	1,050	S	Dch/fsh
1351	4203-8001	Caesar Lombardozzi	Donald L. Hermann	1977	H	1,214	S	Dch/sh
1352	4202-8005	Sal Altadonna	George H. Ackerman	1977	H	1,210	S	Qt/gr
1353	4202-8006	Andrew Glass	Moody Drilling Co., Inc.	1976	H	1,190	S	Dch/ssh
1354	4201-8005	Michael Rock	Donald L. Hermann	1976	H	1,272	S	Dch/ssh
1355	4201-8004	Lawrence Gehrlein	do.	1976	S	1,370	S	Dv/ssh
1356	4201-8001	George Kuebel	Michael W. Burch	1977	U	1,230	V	Qt/gr
1357	4201-8000	Leonard Siegel	do.	1977	U	1,226	V	Qo/sdgr
1358	4201-8001	Michael Komarow	Donald L. Hermann	1976	H	1,242	V	Dch/fsh

(Continued)

Total depth below land surface (feet)	Casing		Depth(s) to water-bearing zone(s) (feet)	Static water level		Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (μmho/cm at 25°C)	pH (units)	Well number
	Depth (feet)	Diameter (inches)		Depth below land surface (feet)	Date measured (mo/yr)						
55	23	8	17	8	4/77	10	.2	---	---	---	Er-1284
145	140	8	75;134	78	4/77	20	.5	---	---	---	1285
50	22	8	---	10	6/76	3	---	---	---	---	1286
65	43	8	39	13	5/77	2	.04	---	---	---	1287
60	16	12	18	6	9/76	2	---	---	---	---	1288
65	36	8	30;58	F	5/77	50	1.6	---	---	---	1289
55	22	8	18	8	10/76	1	---	---	---	---	1290
78	78	8	76	F	5/77	25	---	90	380	---	1291
127	127	6	124	F	5/77	20	---	---	---	---	1292
60	21	8	14;52	6	8/77	25	1.8	---	---	---	1293
70	21	8	16;62	7	8/77	50	1.1	---	---	---	1294
50	15	6	4	---	---	2	---	---	---	---	1295
40	18	6	10	6	6/77	3	.3	---	---	---	1296
65	27	8	55	35	7/76	35	1.8	---	---	---	1297
76	53	8	62;73	33	9/77	30	1.5	---	---	---	1298
50	24	8	21;30	18	6/76	12	.5	---	---	---	1299
66	46	8	55	30	5/76	20	.5	---	---	---	1300
91	73	8	83	31	4/76	6	.1	---	---	---	1301
113	40	8	42;103	52	9/76	13	.2	---	---	---	1302
50	31	8	15;27	12	5/77	12	---	---	---	---	1303
65	35	8	38	9	3/76	6	.1	---	---	---	1304
130	45	8	45;98	25	5/76	10	.1	---	---	---	1305
110	73	8	75;90	32	11/77	30	3	---	---	---	1306
95	20	5	18;25	15	9/77	2	.02	---	---	---	1307
67	67	8	34	34	8/77	20	---	---	---	---	1308
95	95	8	27;92	35	3/77	2	.04	---	---	---	1309
48	48	8	40	18	4/77	8	.4	---	---	---	1310
60	57	8	37;57	16	8/76	10	---	110	275	---	1311
64	13	8	20;25	1	9/77	2	.03	---	---	---	1312
64	32	6	10	30	9/77	4	.2	100	270	---	1313
60	20	12	---	10	12/76	5	.2	---	---	---	1314
40	16	6	20	10	5/76	3	.1	---	---	---	1315
55	15	8	8;25	20	7/77	5	---	120	610	---	1316
40	36	8	34	18	5/76	2	---	---	---	---	1318
50	9	8	9;11	5	5/76	5	---	120	420	---	1319
52	22	8	15;24	15	6/77	1	.02	---	---	---	1320
40	26	8	20;28;34	7	5/77	5	.2	220	650	---	1321
68	35	8	39;50	20	9/77	10	---	---	---	---	1322
71	15	8	11	8	11/77	5	.08	---	---	---	1323
55	12	---	12;18	8	7/77	8	.2	---	---	---	1324
55	12	8	15;26	10	4/77	5	.1	75	305	---	1325
55	15	8	9	8	7/77	5	---	---	---	---	1326
50	25	8	21	5	3/78	15	---	---	---	---	1327
55	18	8	16;23	5	8/76	6	.1	---	---	---	1328
120	120	8	72;113	54	10/77	50	2.1	---	---	---	1329
60	12	8	10;15	3	9/77	7	.1	55	490	---	1330
108	94	8	9;24;36	F	11/77	3	---	---	---	---	1331
51	49	8	48	25	6/77	5	---	---	---	---	1332
90	90	8	17;82	11	8/77	45	2.4	---	---	---	1333
70	17	8	17;22	---	9/76	3	---	80	260	---	1334
60	35	8	30	18	10/77	4	---	---	---	---	1335
60	23	8	14;33	16	8/77	45	45	---	---	---	1336
80	80	8	75	15	7/77	12	---	---	---	---	1337
84	84	8	75	60	8/76	9	.5	---	---	---	1338
55	26	8	20	3	6/76	5	---	---	---	---	1339
70	56	8	48;62	35	7/76	15	1.4	---	---	---	1340
72	31	8	29;35	2	10/77	30	1.5	---	---	---	1341
75	40	8	55;70	25	6/77	8	1.6	---	---	---	1342
80	65	8	50;60	28	10/76	.5	---	140	350	---	1343
66	65	8	---	30	10/76	.1	---	---	---	---	1344
60	19	8	21;36	5	5/77	15	---	---	---	---	1345
105	44	8	56;103	20	8/76	30	.5	---	---	---	1346
75	33	8	28;55	23	10/76	15	.4	---	---	---	1347
50	18	8	14;19	8	8/76	4	---	---	---	---	1348
55	15	8	18	13	4/77	1	.04	---	---	---	1349
40	17	8	9;35	6	2/77	5	---	---	---	---	1350
53	24	8	28;38	12	2/77	7	.2	---	---	---	1351
55	14	8	9	5	6/77	5	---	---	---	---	1352
50	17	8	17	8	8/76	5	.1	---	---	---	1353
35	18	8	19	5	7/76	2	---	150	600	---	1354
55	28	8	19;24	8	8/76	3	---	---	---	---	1355
60	57	8	13;48	7	5/77	50	1.5	---	---	---	1356
66	60	8	6;59	1	5/77	60	1.5	---	---	---	1357
52	26	8	20;35	8	11/76	18	1	---	---	---	1358

Table 12.

Well location: Number	Well location: Lat-Long	Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Er-1359	4201-8000	Daniel Collins	Donald L. Hermann	1976	H	1,318	S	Dch/ssh
1360	4200-8002	Harry Winkleman	do.	1976	H	1,442	S	Dv/ssh
1361	4201-8003	Frank Di Bartolomeo	Robert Anderson	1977	H	1,372	V	Qt/gr
1362	4203-8000	Great Lakes Communication	Moody Drilling Co., Inc.	1957	H	1,380	S	Dv/fst
1363	4205-8007	Marshall Thompson	do.	1955	H	730	F	Qb/gr
1364	4201-8002	Summit Central Elementary School	do.	1955	T	1,340	S	Dv/fst
1365	4201-8003	Stanley Przybylak	do.	1957	H	1,330	S	Dv/fsh
1366	4202-8002	John Sloan	do.	1956	H	1,282	U	Dch/fsh
1367	4202-8004	Miles Baker	do.	1955	H	1,269	V	Dch/fsh
1368	4201-8003	Pennsylvania Department of Transportation	McCray Bros.	1964	D	1,400	U	Dv/fss
1369	4203-8003	Ed Bronakowski	Moody Drilling Co., Inc.	1955	H	1,253	S	Dch/fst
1370	4201-8003	Marcella Hanes	do.	1956	H	1,390	U	Dv/fsh
1371	4206-8002	Dorothy Wagner	do.	1957	H	809	F	Qt/t
1372	4203-8002	Walter Brogeuricz	do.	1956	H	1,262	S	Dch/fsh
1373	4204-8005	Lillian Conner	do.	1955	H	925	S	Qt/gr
1374	4203-8005	Boy Scouts of America	do.	1956	U	960	V	Dch/fsh
1375	4205-8004	William Sapper	do.	1955	H	902	S	Qo/gr
1376	4204-8006	John Parmertor	do.	1955	H	930	U	Dg/fsh
1377	4205-7959	Richard Conyngham	do.	1956	H	1,180	S	Dch/fsh
1378	4204-8005	Cornell Cracium	do.	1955	H	912	V	Dg/fsh
1379	4205-8005	F. M. Carlson	do.	1955	H	940	U	Qt/clgr
1380	4206-8007	Jewish Temple	do.	---	U	665	F	Qb/sd
1381	4209-8004	U.S. Coast Guard	do.	1954	H	581	F	Qs/sdgr
1382	4205-8009	Brown	do.	1953	H	715	F	Qo/u
1383	4206-8008	Clem Schwab	do.	1954	U	700	F	Dne/fst
1384	4204-8011	Miriam Bowman	do.	1957	H	733	F	Qo/gr
1385	4205-8008	Edward Zielinski	do.	1956	H	715	F	Qb/gr
1386	4204-8011	Siemieniak	do.	1956	H	730	F	Qo/gr
1387	4204-8009	Bob Parker	do.	1956	H	769	U	Qo/gr
1388	4204-8008	Ralph Riehl	do.	1957	H	875	U	Qo/gr
1389	4204-8008	do.	do.	1957	H	898	U	Qo/gr
1390	4204-8008	James Sebastian	do.	1958	H	879	U	Qo/gr
1391	4204-8008	Jack Spiriti	do.	1955	H	900	U	Qo/gr
1392	4204-8009	Wayne Pemberton	do.	1955	H	880	U	Qo/gr
1393	4203-8009	W. C. Hengalbrok	do.	1954	H	888	U	Qo/gr
1394	4151-8007	James Skelton	do.	1952	H	1,192	V	Qo/sd
1395	4152-8002	John Kovshak	do.	1957	H	1,240	S	Dv/fsh
1396	4152-8001	Carlton Palmer	do.	1957	H	1,553	S	MDbr/fsh
1397	4154-8011	Peter Gregan	do.	1951	H	1,318	S	Dv/fst
1398	4152-8012	T. H. Young	do.	1956	H	1,370	S	MDbv/fsh
1399	4152-8008	Robert Bender	do.	1956	H	1,215	S	Qo/gr
1400	4152-8008	William Ulbing	do.	1958	H	1,241	S	Dv/fsh
1401	4203-8017	Galbo	do.	1955	H	652	F	Qb/clgr
1402	4200-8014	Arthur Ihsen	do.	1957	U	910	U	Qo/sd
1403	4200-8014	Ted Niebeauer	do.	1957	H	919	U	Qo/gr
1404	4200-8026	Baptist Church	do.	1958	H	600	F	Qb/c
1405	4200-8017	John Runser	do.	1957	H	784	F	Qb/gr
1406	4202-8019	Carl Rimpa	do.	1958	H	696	F	Qb/sd
1407	4202-8014	Herbert Wilson	do.	1954	H	802	U	Qb/gr
1408	4200-7953	C. V. Myers	do.	1955	H	1,349	S	Dch/fst
1409	4203-7953	Gerald Arnold	do.	1956	H	1,355	U	Qo/gr
1410	4205-7959	John Nesselhauf	do.	1957	H	1,140	F	Dch/fsh
1411	4201-7955	P. E. Smock	do.	1957	H	1,406	H	Qo/gr
1412	4205-7953	J. A. Jantzer	do.	1958	H	1,446	S	Qo/gr
1413	4207-7958	Louis Balmer	do.	1956	H	1,015	S	Dch/fsh
1414	4210-7957	Elroy McArthur	do.	1957	H	651	S	Qb/sd
1415	4211-7956	Kenneth McGuigan	do.	1957	H	658	F	Qb/sd
1416	4211-7956	Alexander Kuklinski	do.	1958	H	674	F	Qb/clgr
1417	4210-7956	George Palmer	do.	1957	H	738	F	Dne/fsh
1418	4208-7959	Bert Sharaff	do.	1954	H	818	S	Dg/fst
1419	4208-7959	Leo Ranawiecki	do.	1957	H	805	S	Dg/fsh
1420	4207-7959	Sam Richardson	do.	1958	H	838	S	Qt/clgr
1421	4155-7958	Deane Schlosser	do.	1963	H	1,182	V	Qo/sdgr
1422	4157-7957	Raymond Schuschu	do.	1957	H	1,400	U	Dv/fst
1423	4156-7958	E. H. Hopkins	do.	1956	H	1,180	V	Qo/t
1424	4204-7951	G. A Smith	do.	1954	H	1,363	S	Qo/gr
1425	4203-8013	Concrete Paper Co. of America	do.	---	N	740	U	Qb/sdgr
1426	4203-8012	Whitlings Motel	do.	1958	H	773	U	Qb/gr
1427	4200-8014	Ernest Kemling	do.	---	H	908	U	Qo/gr
1428	4204-8008	Jack Van Tassell	do.	1957	H	920	U	Qo/gr
1429	4204-8011	Mary Sheall	Alfred L. Burch	1976	H	733	F	Qb/sdgr

(Continued)

Total depth below land surface (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Depth(s) to water-bearing zone(s) (feet)	Static water level: Depth below land surface (feet)	Static water level: Date measured (mo/yr)	Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (μmho/cm at 25°C)	pH (units)	Well number
56	26	8	23	3	6/76	5	---	---	---	---	Er-1359
50	31	8	29;39	10	7/76	30	2.7	---	---	---	1360
52	46	8	18	7	8/77	5	.1	---	---	---	1361
65	31	10	---	---	---	15	---	---	---	---	1362
31	31	6	25	12	8/55	5	---	---	---	---	1363
153	37	36	---	12	10/55	8	---	---	---	---	1364
68	37	8	---	18	6/57	3	---	---	---	---	1365
71	38	8	---	12	1/56	3	---	---	---	---	1366
40	19	12	---	9	9/55	2	---	---	---	---	1367
65	22	12	16;45	10	9/64	11	.2	---	---	---	1368
35	20	8	---	7	6/55	15	---	---	---	---	1369
68	47	10	---	22	6/56	1	---	---	---	---	1370
30	2	24	---	---	---	---	---	---	---	---	1371
52	21	8	---	3	4/56	5	---	55	745	---	1372
60	60	7	55	30	4/55	5	---	---	---	---	1373
50	---	---	---	---	---	---	---	---	---	---	1374
48	48	6	42	10	11/55	15	---	---	---	---	1375
100	96	6	---	---	---	1	---	---	---	---	1376
65	15	8	---	6	7/56	3	---	---	---	---	1377
35	21	6	---	6	8/55	15	---	---	---	---	1378
84	84	8	---	40	6/55	30	---	---	---	---	1379
20	16	---	---	---	---	---	---	---	---	---	1380
26	---	7	21	3	2/54	30	---	---	---	---	1381
62	62	---	---	1	4/53	5	---	---	---	---	1382
50	---	---	---	4	5/54	10	---	---	---	---	1383
60	60	7	33;55	45	10/57	9	---	---	---	---	1384
28	28	8	23	3	9/56	8	---	---	---	---	1385
41	41	8	36	28	6/56	15	---	---	---	---	1386
87	87	8	26;82	60	8/56	20	---	---	---	---	1387
69	69	7	62	45	10/57	20	---	---	---	---	1388
76	76	6	71	45	12/57	15	---	---	---	---	1389
70	70	---	64	43	3/58	20	---	---	---	---	1390
90	90	7	84	65	4/55	15	---	---	---	---	1391
79	79	---	69	50	6/55	30	---	---	---	---	1392
79	79	7	74	64	11/54	15	---	---	---	---	1393
27	27	---	---	5	12/52	5	---	110	320	---	1394
100	67	7	---	17	10/57	2	---	---	---	---	1395
80	31	6	---	48	5/57	30	---	200	440	---	1396
63	17	8	---	10	9/51	1	---	55	780	---	1397
50	40	6	---	12	1/56	6	---	---	---	---	1398
42	42	8	38	12	12/56	7	---	---	---	---	1399
68	53	8	---	30	4/58	3	---	---	---	---	1400
86	75	8	---	---	---	---	---	---	---	---	1401
100	100	---	---	---	---	---	---	---	---	---	1402
47	47	6	42	29	7/57	20	---	---	---	---	1403
9	9	24	---	---	---	---	---	---	---	---	1404
45	45	8	40	35	12/57	7	---	---	---	---	1405
21	21	24	---	4	7/58	2	---	---	---	---	1406
40	40	7	35	20	11/54	10	---	---	---	---	1407
80	43	7	---	---	---	.6	---	35	420	---	1408
23	23	8	19	10	6/56	5	---	---	---	---	1409
51	22	8	---	10	4/57	3	---	---	---	---	1410
112	112	7	107	75	10/57	15	---	100	300	---	1411
43	43	8	38	10	2/58	4	---	---	---	---	1412
60	21	8	---	7	1956	10	---	85	240	---	1413
26	26	24	---	---	---	---	---	---	---	---	1414
17	17	24	---	6	10/57	2	---	160	1,450	---	1415
16	16	24	---	8	5/58	1	---	---	---	---	1416
45	29	8	16	10	9/57	20	---	120	400	---	1417
30	20	7	---	8	11/54	3	---	---	---	---	1418
41	25	8	---	---	---	3	---	---	---	---	1419
17	17	---	---	3	4/58	1	---	---	---	---	1420
56	36	6	---	12	6/63	60	---	---	---	---	1421
70	21	7	---	25	11/57	15	---	---	---	---	1422
227	155	7	---	80	---	---	---	---	---	---	1423
55	55	7	40	10	10/54	4	---	100	270	---	1424
23	23	10	---	6	---	85	5.4	---	---	---	1425
47	20	8	---	46	7/58	30	---	---	---	---	1426
37	37	8	---	22	---	10	---	---	---	---	1427
100	100	7	95	82	11/57	20	---	---	---	---	1428
43	43	8	12;36	12	11/76	5	---	---	---	---	1429

Table 12.

Well location		Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Number	Lat-Long							
Er-1430	4203-8011	John Seber	George H. Ackerman	1977	H	814	U	Qo/sdgr
1431	4204-8007	John Kielczewski	Robert Anderson	---	H	882	S	Qt/gr
1432	4204-8008	James Jones	Moody Drilling Co., Inc.	---	H	880	U	Qt/gr
1433	4204-8009	Springhurst Inc.	Michael W. Burch	1977	H	850	U	Qt/gr
1434	4203-8009	Chester Kubiak	Felix J. Waible	1978	H	888	U	Qo/gr
1436	4203-8007	Rickey Taraszki	George H. Ackerman	1977	H	908	U	Qo/sdgr
1437	4206-8000	T. Kellogg	Michael W. Burch	1978	H	1,069	S	Qt/clgr
1438	4203-8008	Paul Canfield	Robert Anderson	1977	H	870	U	Qt/clgr
1439	4203-8008	David McDonald	do.	1977	H	882	T	Qo/gr
1440	4205-8003	Robert Gehrlein	Michael W. Burch	1977	H	950	F	Qt/sdgr
1441	4204-8003	John Maleno	George H. Ackerman	1977	H	984	S	Qt/gr
1442	4205-8001	James Clark	Donald L. Hermann	1976	H	1,056	S	Dch/fsh
1443	4202-8008	Joseph Leonardi	Robert Anderson	1977	H	932	U	Qo/gr
1444	4203-8006	C. Black	do.	1978	H	1,045	S	Qt/t
1445	4205-7959	A. Kirby	Michael W. Burch	1978	H	1,130	F	Dch/fsh
1446	4152-8027	George Kessler	Lorenze Lee Hall	1977	H	953	U	Dch/fsh
1447	4151-8025	Ronald Noe	Alfred L. Burch	1977	H	869	S	Dch/fsh
1448	4152-8019	Ward Norton, Jr.	Lorenze Lee Hall	1977	H	1,008	S	Dch/fsh
1449	4152-8020	Richard Johnson	Jack Young	1977	H	1,068	S	MDbv/fsh
1450	4157-8016	Michael Pacansky	Moody Drilling Co., Inc.	---	H	912	S	Qt/u
1451	4159-8016	David Thomas	Robert Anderson	1977	H	870	U	Qt/gr
1452	4200-8016	William Nies	Felix J. Waible	1977	H	850	F	Qo/gr
1453	4201-8015	Carl Triola	George H. Ackerman	1977	H	830	F	Dg/sh
1454	4203-8014	Harold Litzel	Donald L. Hermann	1977	H	751	F	Qb/gr
1455	4155-8013	James Will	Michael W. Burch	1977	H	1,272	S	MDbv/fsh
1456	4157-8011	Al Machinski	Robert Anderson	1977	H	1,222	S	Qt/clgr
1457	4158-8010	David Hutnyak	Donald L. Hermann	1976	H	1,222	S	Dv/fsh
1458	4159-8008	Mark Benson	Robert Anderson	1977	H	1,185	S	Dch/fsh
1459	4200-8007	Stanley Paschel	Donald L. Hermann	1976	H	1,063	S	Qt/gr
1460	4154-7944	John Wisniewski	McCray Bros.	1975	H	1,395	T	Qo/gr
1461	4158-7952	Ronald Waite	Robert Rindfuss	1976	H	1,315	S	Dch/sh
1462	4159-8006	Joseph Seth	Donald L. Hermann	1976	H	1,252	S	Dch/fsh
1463	4200-8004	Robert Franz	Felix J. Waible	1977	H	1,200	S	Qt/gr
1464	4151-7950	Harold Maynard	Max E. Hickernell	1977	H	1,610	H	Mc/st
1465	4151-7950	Inspirational Times Inc.	do.	---	H	1,605	H	Mc/fsh
1466	4156-8003	Richard Falkowski	Robert Anderson	1977	H	1,540	U	MDbr/fsh
1467	4155-8001	Ronald Shields	Robert Rindfuss	1976	H	1,425	V	MDbr/fsh
1468	4203-7952	Theodore Wolozanski	George H. Ackerman	1977	H	1,335	V	Qo/gr
1469	4200-7946	Stuart Foradora	do.	1977	H	1,335	V	Qo/sdgr
1470	4202-7952	Mario Farino	Robert Anderson	1978	H	1,425	S	Dch/fsh
1471	4203-7952	Robert Kruse	Michael W. Burch	1977	H	1,370	S	Qo/sdgr
1472	4205-7957	Charles Lander	do.	1977	H	1,372	S	Dch/fsh
1473	4202-7959	William Peters	Robert Anderson	1977	H	1,352	S	Dch/fsh
1474	4203-7958	James Kennerknecht	Lorenze Lee Hall	1977	H	1,350	U	Dch/fsh
1475	4200-7954	Dennis Hancock	Michael W. Burch	1977	H	1,330	T	Dch/ssh
1476	4204-7959	R. Sandle	George H. Ackerman	1977	H	1,374	F	Dv/fsh
1477	4205-7954	Richard Trimble	Michael W. Burch	1977	H	1,306	S	Qo/gr
1478	4207-7950	Tim Buck	do.	1977	H	1,484	U	Dv/fsh
1479	4206-7954	L. Vincent	Robert Rindfuss	1976	H	1,188	S	Dch/fsh
1480	4201-8002	W. Williams	Robert Anderson	1978	H	1,400	U	Dv/fsh
1481	4156-8021	Richard Gloskey	Max E. Hickernell	1978	U	850	U	Qt/sd
1482	4157-8019	Howard Bowen	John E. Gage, Jr.	1973	H	885	U	Qt/sd
1483	4154-8021	Albion Borough	Moody Drilling Co., Inc.	1960	Z	870	V	Qo/gr
1484	4154-8021	do.	do.	1960	Z	892	S	Qo/gr
1485	4203-8009	Michael Haggerty	George H. Ackerman	1977	H	892	U	Qo/gr
1486	4206-8006	National Forge	Moody Drilling Co., Inc.	1957	N	710	F	Qb/gr
1487	4158-8014	Girl Scouts of America	do.	---	H	1,000	S	Dch/fsh
1488	4152-8000	J. W. Hanas	Robert Rindfuss	1972	H	1,300	S	Qo/gr
1489	4152-8000	John Hanas	Moody Drilling Co., Inc.	1952	H	1,210	S	Qo/gr
1490	4152-8000	Mrs. John Hanas	Donald L. Hermann	1973	H	1,300	S	Dv/fsh
1491	4158-8004	Walter Kosienski	do.	1972	H	1,450	U	Dv/ssh
1492	4157-8000	Charles Brace	do.	1975	H	1,278	S	Dch/fsh
1493	4157-8004	William Pennock	do.	1976	H	1,520	S	MDbr/fsh
1494	4153-8005	Robert Hamilton	Boyd Lee Hall	1977	H	1,483	S	MDbr/fsh
1495	4159-8006	Kenneth Felix	Michael W. Burch	1976	H	1,340	S	Dv/fsh
1496	4159-8006	Gordon Smith	do.	1976	H	1,338	S	Qt/sdgr
1497	4159-8006	do.	do.	1976	H	1,345	S	Dv/fsh
1499	4157-8007	Janice Dennis	Robert Anderson	1976	H	1,409	S	Dv/fsh
1500	4151-8017	Albion Borough	---	1930	P	1,085	V	Qo/sdgr
1501	4156-7959	Waterford Borough	---	---	P	1,180	V	Qo/sdgr
1502	4156-7938	Corry Water Supply Co.	---	1947	P	1,415	V	Qo/sdgr
1503	4156-7938	do.	---	---	P	1,425	V	Qo/sdgr
1504	4156-7938	do.	---	---	P	1,430	V	Qo/gr
1505	4152-8007	Edinboro Municipal Water Works	---	1910	P	1,200	V	Qo/sdgr

(Continued)

Total depth below land surface (feet)	Casing Depth (feet)	Casing Diameter (inches)	Depth(s) to water-bearing zone(s) (feet)	Static water level: Depth below land surface (feet)	Static water level: Date measured (mo/yr)	Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (μmho/cm at 25°C)	pH (units)	Well number
67	67	8	32;62	38	10/77	50	3.6	---	---	---	Er-1430
65	65	8	60;65	57	---	10	3.3	---	---	---	1431
63	63	---	59	37	---	20	---	---	---	---	1432
90	90	8	47;82	60	9/77	30	30	---	---	---	1433
73	73	8	70	55	3/78	20	20	---	---	---	1434
62	62	8	32;57	20	4/77	25	---	---	---	---	1436
50	47	8	42	30	3/78	15	3	---	---	---	1437
55	55	8	50	28	10/77	30	3	---	---	---	1438
50	35	8	33	19	7/77	8	---	---	---	---	1439
38	38	8	33	23	8/77	18	9	240	830	---	1440
63	43	8	---	8	12/77	30	---	---	---	---	1441
100	81	8	77	42	7/76	4	---	---	---	---	1442
53	53	8	51	20	6/77	12	.6	---	750	---	1443
89	70	8	68	64	2/78	18	.9	---	---	---	1444
55	12	8	8;20;26	5	3/78	2	---	80	405	---	1445
51	26	8	31;41	6	4/77	8	.2	---	---	---	1446
70	53	8	30;47	10	3/77	---	---	---	---	---	1447
52	27	8	15;28	24	6/77	12	.5	100	340	---	1448
45	23	8	20;27	8	3/77	10	5	---	---	---	1449
34	34	8	15	13	---	5	.3	---	---	---	1450
31	31	8	30	15	5/77	12	1.2	---	---	---	1451
52	52	8	47	19	4/77	20	---	210	450	---	1452
140	115	8	28;95;112	78	---	---	---	---	---	---	1453
27	27	8	---	12	3/77	15	2.5	---	---	---	1454
50	32	8	14;44	1	5/77	10	.2	---	---	---	1455
43	43	8	37;42	17	5/77	10	.5	---	---	---	1456
53	36	8	31;45	7	10/76	5	.1	---	---	---	1457
66	37	8	38;40	20	6/77	8	.2	120	300	---	1458
50	29	8	24	8	9/76	2	---	---	---	---	1459
112	112	6	112	F	2/75	5	.5	75	200	---	1460
101	85	8	90	50	7/76	3	.07	---	---	---	1461
65	30	12	24	12	7/76	.5	---	---	---	---	1462
45	41	8	41	12	7/77	20	---	---	---	---	1463
91	19	8	55;84	22	4/77	30	.6	---	---	---	1464
82	27	6	58;76	8	---	15	.5	---	---	---	1465
50	17	8	20;25	3	5/77	7	.2	---	---	---	1466
67	41	8	57	22	10/76	9	.2	---	---	---	1467
97	97	8	30;78;92	5	5/77	25	.4	---	---	---	1468
104	104	8	42;96	F	5/77	25	.5	95	260	---	1469
66	30	8	31	2	3/78	20	.5	---	---	---	1470
107	107	8	14;103	40	9/77	15	.3	---	---	---	1471
100	28	8	12;27	7	9/77	2	.02	---	---	---	1472
56	25	8	26;30	10	6/77	9	.2	---	---	---	1473
66	52	8	35;48;57	21	6/77	16	.4	140	370	---	1474
71	71	8	15;33;66	23	5/77	45	6.4	---	---	---	1475
55	32	8	23;45	5	11/77	50	---	---	---	---	1476
55	55	8	45	22	4/77	30	1.6	120	310	---	1477
60	17	8	10;20	1	10/77	1	---	---	---	---	1478
65	38	8	48	12	6/76	8	.2	---	---	---	1479
64	29	8	30	6	1/78	6	.1	---	---	---	1480
141	111	8	---	35	10/78	5	.03	95	2,500	---	1481
115	112	6	32	70	9/73	1	---	120	600	---	1482
70	67	---	15	6	8/60	235	---	---	---	---	1483
111	110	--	22;25;53	---	---	---	---	---	---	---	1484
96	96	8	92	70	6/77	25	---	---	---	---	1485
36	36	20	---	20	1957	70	4.6	---	---	---	1486
33	15	7	---	6	---	25	---	---	---	---	1487
96	---	8	---	35	8/72	33	.6	125	340	---	1488
97	96	7	---	4	11/52	10	.16	---	---	---	1489
80	39	8	36	32	10/73	2	.05	140	340	---	1490
75	60	8	55;60	22	7/72	4	---	---	---	---	1491
80	57	8	54	32	8/75	2	---	---	---	---	1492
52	34	8	34;48	1	8/76	20	.8	---	---	---	1493
88	44	6	---	78	6/77	5	1.7	---	---	---	1494
61	29	8	9;12;21;52	4	4/76	4	.06	160	2,800	---	1495
55	24	8	19	10	7/76	4	.1	---	---	---	1496
65	53	8	25;40	12	3/76	10	.3	---	---	---	1497
62	30	8	31;45	12	7/76	4	.08	---	---	---	1499
40	38	8	---	0	1930	65	---	200	---	7.2	1500
100	58	12	---	---	---	1,000	34	150	---	7.8	1501
32	24	12	24	5	1947	250	28	120	---	7.5	1502
65	48	---	---	12	---	500	---	120	---	7.9	1503
65	52	---	---	16	---	400	11	120	308	7.9	1504
20	20	20	---	---	---	350	---	220	---	7.5	1505

Table 12.

Well location		Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Number	Lat-Long							
Er-1506	4152-8007	Edinboro Municipal Water Works	---	---	P	1,200	V	Qo/sdgr
1507	4202-8015	Whitehall Village	---	1967	P	680	F	Qb/u
1508	4202-8015	do.	---	---	P	680	F	Qb/u
1509	4202-8015	do.	---	---	P	692	F	Qb/u
1510	4200-8020	Lake City Borough	---	---	P	725	F	Qb/u
1511	4200-8019	do.	---	---	P	735	F	Qb/u
1512	4202-8016	Palmer Shores Water Co.	---	---	P	680	F	Qb/gr
1513	4200-8019	Girard Borough	---	---	P	735	F	Qb/u
1514	4200-8019	do.	---	---	P	735	F	Qb/u
1515	4201-8018	do.	---	---	P	740	F	Qb/u
1516	4201-8015	Fairview Borough	---	---	P	825	F	Qb/u
1517	4201-8015	do.	---	---	P	820	F	Qb/u
1518	4201-8015	do.	---	1961	P	815	F	Qb/u
1519	4202-8013	Westminster Water Co.	Moody Drilling Co., Inc.	---	P	800	F	Qb/gr
1520	4202-8013	do.	---	---	P	800	F	Qb/sdgr
1521	4203-8011	Greenbrier Hill Corp.	---	1964	P	855	H	Qo/u
1522	4204-8014	Manchester Heights	---	---	P	580	F	Qb/u
1523	4205-8009	Erie Suburban Water Co.	---	---	P	731	F	Qb/u
1524	4204-8010	do.	---	---	P	740	F	Qb/u
1525	4204-8010	do.	---	---	P	740	F	Qb/u
1526	4204-8010	do.	---	---	P	770	F	Qb/sdgr
1527	4204-8010	do.	---	---	P	770	F	Qb/u
1528	4204-8010	do.	---	---	P	770	F	Qb/u
1529	4205-8009	do.	---	---	P	740	F	Qb/u
1530	4205-8009	do.	---	---	P	740	F	Qb/u
1531	4205-8009	do.	---	---	P	740	F	Qb/u
1532	4159-8009	Idyll Whyle Village, Inc.	---	---	P	970	V	Qo/u
1533	4201-8007	Happy Homes Mobile Park	---	---	P	1,076	F	Dch/fsh
1534	4203-8013	Erie Suburban Water Co.	---	---	P	735	F	Qb/u
1535	4203-8012	do.	---	1972	P	765	F	Qb/sdgr
1536	4156-7938	Corry Water Supply Co.	Moody Drilling Co., Inc.	1974	U	1,415	V	Qo/sdgr
1537	4204-8013	Lake Shore Maintenance Association	do.	---	P	730	F	Qb/u
1539	4204-7958	James Foltz	Alfred L. Burch	1976	H	1,262	S	Dch/fsh
1540	4200-8018	Patrick Luciano	Moody Drilling Co., Inc.	1972	H	788	F	Qb/sdgr
1541	4157-8007	David Hogan	Felix J. Waible	1974	H	1,406	S	Dv/fsh
1542	4157-8001	D. J. Dolph	Robert Anderson	1975	H	1,290	S	Qo/sdgr
1544	4157-8001	Ted Goring	Robert Rindfuss	1975	H	1,270	S	Qo/gr
1545	4158-8001	Abram Thomas	Alfred L. Burch	1972	P	1,285	S	Qt/gr
1546	4158-8001	do.	do.	1973	P	1,300	S	Dv/fsh
1547	4153-8003	Edward Humes	Max E. Hickernell	1963	H	1,540	S	Dv/fst
1548	4155-8000	Charles Burge	Moody Drilling Co., Inc.	---	H	1,394	H	Dv/fsh
1549	4159-8002	Deimel-Heynes Farm	Michael W. Burch	---	S	1,450	S	Dv/fsh
1550	4153-8030	Robert Taylor	Lowell Halstead	1973	H	870	U	Qo/gr
1551	4203-8007	First Alliance Church	W. K. Bailey	1976	H	908	U	Qt/sd
1552	4205-8002	A. C. Schenck	Alfred L. Burch	1971	H	1,050	S	Qt/gr
1553	4205-8000	Andy Zafiropoulous	Michael W. Burch	1977	H	1,130	U	Qt/t
1554	4206-8000	do.	do.	1977	H	1,110	U	Qt/t
1555	4206-8000	do.	do.	1977	H	1,058	U	Qt/gr
1556	4200-8006	J. A. Meyer	do.	1975	H	1,240	S	Dch/sh
1557	4202-8003	Great Lakes Television	Moody Drilling Co., Inc.	1954	H	1,340	S	Dv/fst
1558	4202-8001	Joseph Mientkiewicz	George H. Ackerman	1977	H	1,332	H	Dch/sh
1559	4204-8002	Robert Stewart	Donald L. Hermann	1972	H	1,029	V	Dch/ssh
1560	4201-8005	J. R. Ott	do.	1972	H	1,335	S	Dv/fsh
1561	4200-8000	Kevin Osborne	do.	1976	H	1,255	S	Dch/fsh
1562	4151-8022	Larry Kadley	Jack Young	1978	H	1,048	S	Dch/fsh
1563	4151-8016	Nevin Shoaf	Alfred L. Burch	1966	H	1,222	S	MDbv/ssh
1564	4158-8008	J. A. Lange	George H. Ackerman	1975	H	1,210	S	Dch/fsh
1565	4156-8013	Frank Pertl	John E. Gage, Jr.	1974	H	1,195	S	Qt/t
1566	4157-8012	J. R. Crandall	Donald L. Hermann	1972	H	1,210	U	MDbv/fsh
1567	4154-8007	W. E. Adams	Donald L. Hermann	1972	N	1,265	T	Qo/sdgr
1568	4159-8013	W. C. Kinstler	Moody Drilling Co. Inc.	1957	H	955	F	Qt/clgr
1569	4155-8008	Roger Soth	Alfred L. Burch	1976	H	1,375	S	Dv/fsh
1570	4158-8011	J. R. Baldwin	do.	1972	H	1,175	S	Dch/fsh
1571	4156-8011	Wayne Washburn	do.	1967	H	1,303	U	MDbv/fsh
1572	4159-8014	Adam Brezinski	Herbert G. Orr	1976	H	930	S	Dch/fsh
1573	4152-8014	L. K. Stroup	John E. Gage, Jr.	1970	H	1,282	H	MDbv/ss
1574	4152-8010	David Robinson	Max E. Hickernell	1966	H	1,491	U	MDbr/fss
1575	4201-8017	West Ridge Gravel Co.	Charles J. Richardson III	1973	N	790	F	Qb/sd
1576	4202-8016	M. A. Roseman	Robert Anderson	1972	H	672	F	Dne/sh
1577	4201-8016	Erie County Infirmary	Moody Drilling Co., Inc.	---	T	808	F	Qo/sdgr
1578	4202-8015	Robert Gidner	do.	1951	H	780	T	Qo/gr
1579	4201-8016	Michael Tarasovitch	Alfred L. Burch	1968	C	810	F	Qb/sdgr
1580	4201-8016	Erie County Infirmary	do.	1971	T	805	F	Qb/gr

(Continued)

Total depth below land surface (feet)	Casing Depth (feet)	Casing Diameter (inches)	Depth(s) to water-bearing zone(s) (feet)	Static water level Depth below land surface (feet)	Static water level Date measured (mo/yr)	Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (μmho/cm at 25°C)	pH (units)	Well number
38	36	12	36	0	---	500	---	220	---	7.3	Er-1506
30	24	120	24	4	7/67	32	---	540	---	6.9	1507
30	24	120	24	4	---	14	---	390	---	7.0	1508
22	15	120	15	3	---	49	---	320	---	7.6	1509
16	15	180	15	---	---	250	---	200	---	7.1	1510
44	39	10	---	4	12/64	600	---	260	---	7.0	1511
17	17	120	---	---	---	100	---	200	600	7.4	1512
30	---	---	---	6	---	850	67	220	400	7.4	1513
17	17	216	---	8	---	300	270	220	420	7.4	1514
12	12	120	---	8	---	200	---	200	420	7.4	1515
43	43	---	---	---	---	120	---	220	---	7.4	1516
38	38	8	---	---	---	44	50	220	---	7.4	1517
46	38	12	---	28	8/63	90	29	190	---	7.4	1518
46	41	12	---	---	---	200	---	260	---	7.1	1519
65	---	12	36	---	---	100	---	330	---	7.0	1520
73	68	7	---	50	1/64	70	140	240	530	7.9	1521
10	---	96	---	6	---	40	---	300	---	7.0	1522
34	24	12	---	---	---	75	---	420	2,400	8.0	1523
32	---	---	---	---	---	200	---	220	---	7.5	1524
30	28	120	---	---	---	150	19	320	---	7.5	1525
29	24	72	---	---	---	100	---	250	---	7.4	1526
34	24	72	---	15	---	75	15	260	---	7.6	1527
43	36	72	---	---	---	50	---	220	---	8.0	1528
20	18	---	---	---	---	50	---	260	---	7.6	1529
25	---	12	---	---	---	200	---	260	---	6.9	1530
24	---	72	---	---	---	100	---	240	---	6.8	1531
13	13	60	---	---	---	15	---	170	---	7.6	1532
26	22	96	---	10	---	55	---	120	---	7.6	1533
16	---	---	---	---	---	50	---	300	---	7.6	1534
20	---	120	15	---	---	160	---	230	---	7.5	1535
209	---	8	---	---	---	---	---	---	---	---	1536
17	17	60	---	---	---	100	---	---	---	---	1537
62	19	8	35	---	---	.1	---	---	---	---	1539
80	80	---	---	---	---	---	---	200	---	7.0	1540
45	30	8	26	12	6/74	12	---	---	---	---	1541
85	44	8	42;50	F	7/75	15	.2	---	---	---	1542
56	56	8	50	11	7/75	6	.1	120	320	---	1544
33	33	8	3;14;25	4	7/72	50	---	---	---	---	1545
60	27	8	14;20	7	7/73	8	---	---	---	---	1546
54	21	6	28;51	14	8/63	10	.2	---	---	---	1547
80	51	8	---	40	4/56	3	---	---	---	---	1548
82	34	8	21;64;72	15	9/77	7	.1	---	---	---	1549
46	46	8	42	---	---	---	---	---	---	---	1550
55	48	8	44	27	5/76	10	.4	---	---	---	1551
82	82	8	77	69	10/71	18	---	---	---	---	1552
105	97	8	98	65	6/77	1	.02	---	---	---	1553
70	64	8	5;68	54	6/77	.2	---	---	---	---	1554
34	30	8	21	F	6/77	45	2.2	---	---	---	1555
80	16	8	42	---	---	.6	---	---	---	---	1556
65	30	8	---	7	3/54	10	---	---	---	---	1557
80	52	8	46	18	6/77	1	---	---	---	---	1558
82	73	8	67;73	---	---	5	---	---	---	---	1559
47	30	8	26;30;32	12	6/72	15	.8	---	---	---	1560
75	60	8	58;61	55	7/76	15	3	210	635	---	1561
35	9	---	---	---	---	---	---	---	---	---	1562
45	32	8	26;40	12	12/66	20	1.5	---	---	---	1563
60	24	8	14;48	---	6/75	50	---	100	395	---	1564
49	32	8	13;25	10	7/74	2	.09	---	---	---	1565
70	20	8	22	---	---	.2	---	---	---	---	1566
30	30	8	26	10	9/72	15	3	150	440	---	1567
111	111	8	---	32	3/57	3	---	---	---	---	1568
60	31	8	15;25;40	13	10/76	10	---	120	310	---	1569
75	17	8	17;40;68	38	7/72	3	---	---	---	---	1570
40	32	8	29;36	7	7/67	20	.6	---	---	---	1571
134	85	8	110;125	25	7/76	4	.04	---	---	---	1572
43	43	5	33;43	3	7/70	10	.3	---	---	---	1573
107	29	8	51;83;96	12	8/66	30	---	140	360	---	1574
24	24	30	6;20	6	10/73	52	3.7	190	480	---	1575
74	61	8	23;61	22	6/72	.5	---	---	---	---	1576
79	79	5	---	54	---	20	3.3	---	---	---	1577
140	90	7	---	---	---	---	---	---	---	---	1578
53	53	8	46	36	6/68	40	40	140	430	---	1579
46	46	8	20;36	9	9/71	40	---	---	---	---	1580

Table 12.

Well location		Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Number	Lat-Long							
Er-1581	4201-8015	Parker White Metal	Moody Drilling Co., Inc.	---	N	785	F	Qb/gr
1582	4203-7957	William Marie	George H. Ackerman	1975	H	1,320	S	Dch/fsh
1583	4202-7956	Richard Kircher	do.	1967	H	1,335	S	Qo/gr
1584	4206-7958	Pennsylvania Department of Transportation	Robert Anderson	1974	P	1,170	S	Dch/sh
1585	4203-7959	David Young	do.	1975	H	1,415	S	Dv/fsh
1586	4202-7956	Wayne Price	George H. Ackerman	1975	H	1,385	H	Qo/sdgr
1587	4200-7956	Lawrence Yaple	Donald L. Hermann	1972	H	1,405	S	Dch/fsh
1588	4203-7957	John Noonan	Ralph Wayne Grant	1974	H	1,330	S	Qo/sdgr
1589	4207-7957	Humble Oil Co.	Alfred L. Burch	1971	C	1,150	F	Dch/fsh
1590	4202-7956	Robert Smith	Donald L. Hermann	1975	H	1,325	S	Qo/sdgr
1591	4151-7959	Mystic Inc.	Robert Rindfuss	1974	N	1,158	V	Qo/gr
1592	4152-7958	Floyd King	Alfred L. Burch	1964	H	1,250	S	Dv/fsh
1593	4151-7954	Stanley Allen	do.	1970	H	1,594	U	MDcr/fsh
1594	4151-7956	Max Brown	Max E. Hickernell	1968	H	1,560	H	MDcr/fsh
1595	4213-7950	Max Reid	Moody Drilling Co., Inc.	1957	H	793	F	Qo/sd
1596	4209-7948	George Pilch	Ralph C. Parmenter	1974	H	1,380	S	Qo/u
1597	4215-7947	Ruth Mattson	Alfred L. Burch	1972	H	605	S	Qt/t
1598	4211-7949	Lake View Motel	McCray Bros.	1974	U	1,040	S	Dg/fsh
1599	4214-7946	Exxon Corp.	Max E. Hickernell	1970	C	810	F	Qt/t
1600	4210-7948	North East Borough	Robert Rindfuss	1975	P	1,306	U	Dch/fsh
1601	4156-7949	Vic Dasconio	Robert Anderson	1976	H	1,530	S	Dv/fsh
1602	4153-7951	Gary Potts	Robert Rindfuss	1975	H	1,332	U	Qo/gr
1603	4158-7947	Stanley Phillips	Harold F. Anderson	1975	H	1,538	S	Dv/fsh
1604	4152-7951	Victor Powell	do.	1975	H	1,425	S	Dv/fsh
1605	4153-7951	Robert Miller	Max E. Hickernell	1972	H	1,350	S	Dv/fsh
1606	4153-7951	Dan Tarbell	do.	1974	H	1,300	U	Qt/gr
1607	4154-7949	Joseph Tomcho	do.	1974	N	1,370	S	Qo/gr
1608	4157-7946	Norman Troyer	do.	---	H	1,500	V	Dv/fst
1609	4154-7947	Rexford Morris	Alfred L. Burch	1966	H	1,460	H	Qt/gr
1610	4155-7946	Bargain Road Trailer Sales	do.	1970	H	1,604	H	MDcr/fsh
1611	4202-7949	J. Whitehill	Lorenze Lee Hall	1976	H	1,330	V	Qo/gr
1612	4205-7951	Gene Penberthy	Ralph C. Parmenter	1975	H	1,440	S	Dch/fsh
1613	4200-7952	Paul Vogel	Harold F. Anderson	1974	H	1,525	S	Dv/fsh
1614	4200-7952	Lawrence Vogel	do.	1974	H	1,490	S	Dv/fsh
1616	4202-7949	John Wroblewski	Ralph C. Parmenter	1977	H	1,325	V	Qt/u
1617	4152-7958	Betty Wallace	Robert Rindfuss	1972	H	1,220	V	Qo/gr
1618	4152-7958	Thomas McLaughlin	Lorenze Lee Hall	1974	H	1,210	V	Qt/clgr
1619	4159-7953	Francis O'Sullivan	Alfred L. Burch	1964	H	1,315	V	Dch/fsh
1620	4153-7955	Henry Rupert	do.	1971	H	1,288	S	Dv/fsh
1621	4153-7959	Lovewells Country Market	do.	1968	H	1,172	V	Qo/gr
1622	4153-7959	Thomas Lovewell	do.	1968	H	1,198	V	Qo/gr
1623	4155-7954	Atlas Construction Co.	do.	1972	H	1,405	S	Dv/fsh
1624	4157-7959	Happy Homes Trailer Park	do.	1972	H	1,230	S	Qo/gr
1625	4154-7959	William Anysz	Robert Rindfuss	1974	H	1,285	S	Dv/fsh
1626	4155-7957	Troyer Farms	Donald L. Hermann	1975	I	1,252	H	Dch/fsh
1627	4153-7953	Nolan Webb	Max E. Hickernell	1969	H	1,302	S	Dv/fss
1628	4153-7958	O. J. Stull	Harold F. Anderson	1973	H	1,190	V	Qo/sdgr
1629	4156-7957	G. A. Rieder	Donald L. Hermann	1972	H	1,220	V	Dch/fsh
1630	4158-7954	R. E. Petty	Robert Rindfuss	1974	H	1,534	U	Qt/c
1631	4201-8009	Erie Skeet Club	Moody Drilling Co., Inc.	1956	H	992	F	Qt/sdgr
1632	4203-8014	Robert Seth	do.	1957	H	700	F	Qb/sdgr
1633	4203-8007	D. Rogala	Robert Anderson	1977	H	922	U	Qt/sdgr
1634	4204-8013	Fred Ralph	Vernon Reed	1947	Z	610	V	Qb/gr
1635	4204-8013	do.	Alfred L. Burch	1970	Z	625	V	Qb/sdgr
1637	4157-8024	R. R. Robison	---	---	H	740	F	Qb/gr
1638	4205-8008	W. Blakesley	Vernon Reed	1946	H	715	F	Dne/sh
1639	4205-8008	Willard Johnson	---	1950	H	715	F	Qb/sd
1640	4203-8012	Edward Lunenberger	Bernard P. Kuntz	1946	H	782	F	Qb/gr
1641	4203-8008	James Di Cara	do.	1949	H	857	U	Qo/gr
1642	4158-8018	John Bair	Vernon Reed	1950	H	862	F	Qt/gr
1643	4157-8023	Richard Godfrey	John E. Gage, Jr.	1974	H	820	U	Qo/gr
1644	4159-8028	Erie County Parks Commission	Alfred L. Burch	1967	Z	590	V	Qb/sdgr
1645	4159-8028	do.	do.	1967	U	620	U	Qt/clgr
1646	4159-8028	do.	do.	1966	U	625	T	Dne/sh
1647	4152-8018	Edwin Horrigan	do.	1972	H	1,149	S	MDbv/fsh
1648	4155-7943	John Frontera	do.	1964	H	1,404	V	Qo/gr
1649	4156-7942	Martin Dewitt	do.	1969	H	1,570	S	Dv/fsh
1650	4152-7941	Dale Bunnell	do.	1966	H	1,720	S	MDcr/fsh
1651	4154-8024	B. H. Anderson	B. W. Bateman and Son	1969	H	895	U	Qt/t
1652	4156-8024	William Dunegan	do.	1969	H	825	U	Qo/gr
1653	4203-8012	Standard Oil Co.	Vernon Reed	1951	C	795	T	Qb/gr
1654	4204-8008	William Rounds	do.	1950	H	910	U	Qo/gr
1655	4203-8009	Walter Schreiber	Bernard P. Kuntz	1950	H	890	U	Qo/gr

(Continued)

Total depth below land surface (feet)	Casing		Depth(s) to water-bearing zone(s) (feet)	Static water level		Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conductance (µmho/cm at 25°C)	pH (units)	Well number
	Depth (feet)	Diameter (inches)		Depth below land surface (feet)	Date measured (mo/yr)						
49	41	12	37	31	---	300	38	---	---	---	Er-1581
65	38	8	34;62	10	5/75	20	---	---	---	---	1582
55	55	8	50	12	6/67	15	---	240	560	---	1583
65	12	8	12;17	7	8/74	5	.09	---	---	---	1584
50	20	8	20;30	10	5/75	2	.06	---	---	---	1585
98	95	8	92	68	4/75	6	---	---	---	---	1586
90	80	8	76;82	72	8/72	4	.2	100	325	---	1587
80	80	8	---	---	---	---	---	---	---	---	1588
60	20	8	12;14	4	9/71	18	---	---	---	---	1589
85	85	8	80;85	38	7/75	20	2.5	---	---	---	1590
96	96	8	91	55	12/74	5	.1	---	---	---	1591
60	28	6	40	12	8/64	5	---	---	---	---	1592
75	31	8	17;22;25	10	11/70	12	.2	---	---	---	1593
83	31	8	58;72	20	10/68	15	---	---	---	---	1594
17	17	24	---	---	---	2	---	---	---	---	1595
24	24	5	1	F	6/74	4	4	---	---	---	1596
60	31	8	23;53	36	8/72	20	---	---	---	---	1597
60	16	12	24;36	---	8/74	2	.05	---	---	---	1598
78	31	8	32	15	11/70	8	---	570	1,400	---	1599
52	33	8	40	10	4/75	12	.4	---	---	---	1600
91	24	8	26;78	41	8/76	4	.09	---	---	---	1601
33	33	8	22	6	10/75	12	.6	---	---	---	1602
55	23	8	23;50	---	---	27	---	---	---	---	1603
110	17	8	---	---	---	24	---	---	---	---	1604
90	19	6	---	11	1972	10	---	140	360	---	1605
48	48	6	44	15	10/74	20	1.3	---	---	---	1606
50	50	8	36	1	1/74	10	---	---	---	---	1607
53	28	6	34;50	6	---	20	---	---	---	---	1608
123	102	6	70;123	52	6/66	3	.04	80	240	---	1609
125	70	8	74;115	30	9/70	6	.06	---	---	---	1610
100	95	8	57;90	15	6/76	50	1.1	---	---	---	1611
60	25	6	---	10	8/75	3	.08	110	280	---	1612
70	36	8	36;60;65	---	---	8	---	---	---	---	1613
75	22	8	2;60;65;70	---	---	8	---	120	950	---	1614
50	50	6	---	10	4/77	4	.1	180	470	---	1616
52	52	8	52	39	7/72	12	12	---	---	---	1617
79	45	8	47;72	38	9/74	5	.1	110	400	---	1618
62	30	6	50	20	8/64	20	---	110	400	8.1	1619
67	17	8	16;40;50	28	5/71	4	---	---	---	---	1620
98	96	6	21	9	---	20	1.2	---	---	---	1621
55	55	8	40;51;55	27	8/68	30	2.3	140	360	---	1622
100	15	8	15;20;70	6	10/72	7	.07	---	---	---	1623
49	47	8	2;27;30;42	13	6/72	10	.3	---	---	---	1624
60	45	8	50	26	1/74	5	.14	---	---	---	1625
100	80	8	79	42	8/75	2	---	240	560	8.0	1626
120	50	6	87	45	6/69	1	---	---	---	---	1627
50	33	8	30;44;50	---	---	6	---	---	---	---	1628
55	28	8	27	14	6/72	3	.08	---	---	---	1629
70	35	8	35;57	15	5/74	7	.1	150	380	---	1630
44	44	8	---	20	8/56	20	---	---	---	---	1631
44	44	6	---	7	7/57	3	---	---	---	---	1632
86	58	8	56	28	11/77	2	.04	---	---	---	1633
31	31	---	---	---	---	---	---	280	547	6.9	1634
40	14	8	11	4	10/70	1	.03	---	---	---	1635
18	18	---	---	---	---	---	---	110	324	7.0	1637
90	---	---	---	---	---	---	---	88	903	8.0	1638
20	20	---	---	---	---	---	---	270	525	7.7	1639
35	35	---	---	---	---	---	---	200	488	7.7	1640
54	54	---	---	---	---	---	---	210	369	7.7	1641
60	60	---	---	---	---	---	---	120	440	7.7	1642
112	112	8	63;112	80	9/74	9	.6	170	420	---	1643
25	---	---	9	6	1/67	2	.1	320	800	---	1644
58	58	8	45	---	---	.1	---	---	---	---	1645
50	---	---	---	20	12/66	.1	---	---	---	---	1646
70	35	8	17;24;38	10	4/72	5	.08	170	510	---	1647
138	136	6	11;36;90;130	F	6/64	360	---	---	---	---	1648
110	25	8	26;40;92	27	7/69	20	.4	120	350	---	1649
35	15	8	20;30	20	8/66	20	1.3	85	230	---	1650
50	45	6	46	20	5/69	6	.3	200	1,700	---	1651
48	48	---	20	3	7/69	6	.6	110	280	---	1652
32	32	---	---	---	---	---	---	240	482	7.4	1653
100	100	---	---	---	---	---	---	210	407	7.8	1654
108	108	---	---	---	---	---	---	260	522	7.5	1655

Table 12.

Well location: Number	Well location: Lat-Long	Owner	Driller	Year completed	Use	Altitude of land surface (feet)	Topographic setting	Aquifer/ lithology
Er-1656	4211-7950	W. M. Luke	Ralph C. Parmenter	1920	H	1,008	S	Dg/sh
1658	4156-8028	Hugh Seeley	---	1941	H	712	F	Qb/u
1659	4157-8024	George Jones	---	---	H	750	T	Qb/gr
1660	4159-8029	S. Wilcox	---	---	H	620	F	Qb/gr
1661	4156-7938	Corry Water Supply Co.	Moody Drilling Co., Inc.	1974	P	1,420	V	Qo/sdgr
1662	4152-8008	Edinboro Waste Plant	Robert Rindfuss	1976	C	1,250	S	Dv/fsh
1663	4203-7954	Wattsburg Joint Area High School	Alfred L. Burch	1971	T	1,345	U	Qo/sdgr
1664	4201-7958	Richard Ziegler	Michael W. Burch	1976	H	1,235	V	Qo/sdgr
1665	4205-7952	Gregory Spinks	do.	1975	H	1,504	S	Dv/fsh
1666	4204-7953	Robert Austin	do.	1976	H	1,354	S	Dch/fsh
1667	4203-7958	Raymond Jonczak	do.	1977	H	1,309	V	Qo/sdgr
1668	4201-7952	Paris Bros.	do.	1977	H	1,578	H	Qt/gr
1669	4203-7959	Dennis Heberlein	do.	1977	H	1,372	H	Dv/ssh
1670	4203-7955	Atlas Homes	Alfred L. Burch	1976	H	1,305	V	Qo/sdgr
1671	4202-7955	John Shick	do.	1967	H	1,328	U	Qo/sd
1672	4202-7959	Dale Zimmerly	do.	1972	H	1,360	S	Dch/fsh
1673	4203-7956	Wattsburg Joint Area High School	do.	1969	Z	1,335	S	Qo/gr
1674	4203-7956	do.	do.	1969	U	1,335	S	Qo/sdgr
1675	4203-7956	do.	do.	1969	Z	1,345	S	Qt/gr
1676	4203-7956	do.	do.	1969	Z	1,348	S	Qt/clgr
1677	4200-8013	Lakelands Racing Association	Max E. Hickernell	1973	C	920	F	Qo/gr
1678	4209-7946	Edith Munger	Adgate Marshall	1915	H	1,470	S	Dch/sed
1679	4155-7940	Pennsylvania Fish Commission	Moody Drilling Co., Inc.	1961	R	1,390	V	Qo/gr
1680	4155-7940	do.	do.	1968	Z	1,420	V	Qo/gr
1681	4155-7940	do.	do.	1961	Z	1,388	V	Qo/gr
1682	4155-7940	do.	do.	1967	Z	1,392	V	Qo/gr
1683	4158-8030	U.S. Steel Corp.	Lininger Drilling and Pumps	1977	Z	621	F	Dg/sh
1684	4158-8030	do.	do.	1977	Z	640	F	Dne/sh
1685	4157-8030	do.	do.	1977	Z	640	F	Dg/sh
1686	4156-8031	do.	do.	1977	Z	680	F	Qt/t
1687	4158-8028	do.	do.	1977	Z	653	F	Qt/t
1688	4158-8030	do.	---	---	H	622	F	Qt/t
1689	4158-8028	do.	---	---	H	658	F	Qt/t
1690	4156-8031	Frank Talarico	Max E. Hickernell	---	H	680	F	Qb/sd
1691	4156-8012	Perry Mills	---	---	H	1,245	U	Qt/t
1692	4214-7948	Frank Mehler	Robert Anderson	1975	H	673	S	Dne/sh
1693	4208-7947	Russell Arrigo	Boyd Lee Hall	1977	H	1,425	S	Qo/sdgr
1694	4207-7947	William Penn	Ralph C. Parmenter	1976	H	1,442	H	Qt/sd
1695	4202-8004	New's Volvo	Donald L. Hermann	1971	C	1,280	U	Dch/fsh
1696	4204-7946	D. Bull	Michael W. Burch	1979	H	1,682	H	Qt/clgr
1697	4152-8026	J. R. Smith	John E. Gage, Jr.	1970	H	943	U	Qt/gr
1698	4207-7958	Richard Horton	Alfred L. Burch	1973	H	940	S	Qo/gr
1699	4200-8018	Imperial Mobile Home Park	Moody Drilling Co., Inc.	1972	P	780	F	Qb/sdgr
1700	4158-8027	Pennzoil Service Station	---	---	C	680	T	Qb/u
1701	4159-8028	Erie County Parks	---	---	H	615	S	Qt/t
1702	4159-8025	Ford Bailey	---	---	H	664	F	Qt/clgr
1703	4202-8018	Jack Northrup	---	---	H	684	F	Qb/u
1704	4201-8021	Samuel Repoff	---	---	H	693	F	Qb/u
1705	4154-8017	T. Rader	---	---	H	1,110	F	Qt/t
1706	4203-8014	Munch Fisheries	---	---	H	688	T	Qb/sdgr
1707	4204-7946	Timothy Shumac	Ralph C. Parmenter	1976	H	1,755	H	Dv/sh
1708	4155-8007	Erie County Schools	Moody Drilling Co., Inc.	1957	I	1,250	V	Qo/gr
1709	4200-7951	Walter Meyers	Lorenze Lee Hall	1974	H	1,520	S	Qt/clgr
1710	4200-7949	Floyd Parsons	McCray Bros.	1975	H	1,376	S	Dch/sh
1711	4205-8001	Carl Pepper	Ralph Wayne Grant	1975	H	1,108	S	Qo/sdgr
1712	4154-8023	Carlyle Krieg	Moody Drilling Co., Inc.	---	H	912	U	Qt/clgr
1713	4153-8024	Rudler's Auto Service	---	1952	C	855	F	Qt/t
1714	4151-7942	Allison Bell	---	---	H	1,555	S	MDcr/ss
1715	4151-7938	Robert Kraft	---	1977	H	1,677	S	MDcr/fsh
1716	4153-7937	G. E. Haenel	McCray Bros.	1974	H	1,800	S	Qt/sd
1717	4155-7942	Carroll Colonial Estates	---	---	H	1,405	V	Qt/u
1718	4152-7950	Walter Downer	Max E. Hickernell	1971	H	1,542	S	MDcr/fsh
1719	4212-7946	Edward Calvin	Alfred L. Burch	1968	H	1,108	S	Dg/sh
1720	4209-7958	Curt Hoover	---	---	Z	700	F	Dne/sh
1721	4210-7956	Rainbow Motel	---	---	C	730	F	Qb/sdgr
1722	4154-7942	A. C. Gates	---	---	H	1,382	V	Qo/sdgr
1723	4159-7950	Ralph Bacon	Alfred L. Burch	1974	H	1,284	L	Qo/u

(Continued)

Total depth below land surface (feet)	Casing		Depth(s) to water-bearing zone(s) (feet)	Static water level		Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Hardness (mg/L as $CaCO_3$)	Specific conduc-tance (μmho/cm at 25°C)	pH (units)	Well number
	Depth (feet)	Diameter (inches)		Depth below land surface (feet)	Date measured (mo/yr)						
80	---	---	---	---	---	---	---	140	443	7.7	Er-1656
25	25	---	---	---	---	---	---	98	293	6.7	1658
22	22	---	---	---	---	---	---	160	355	6.8	1659
20	20	---	---	---	---	---	---	610	1,350	7.4	1660
71	59	12	---	16	8/74	400	12	160	---	7.0	1661
60	35	8	35;54	57	1976	5	---	---	---	---	1662
57	53	8	46	23	6/71	40	4.4	---	---	---	1663
41	41	8	17;36	9	9/76	17	.8	---	---	---	1664
45	27	8	16;28	4	5/75	2	.05	---	---	---	1665
75	32	8	26;50	6	9/76	22	.4	130	320	---	1666
30	29	8	12	8	9/77	10	.5	---	---	---	1667
55	52	8	47	25	6/77	30	6	---	---	---	1668
50	43	8	31;41	F	5/77	28	.9	---	---	---	1669
64	64	6	59	F	8/66	15	---	---	---	---	1670
159	159	8	20;35;141	40	3/67	5	.04	---	---	---	1671
50	24	8	16;40	6	5/72	20	.4	---	---	---	1672
70	53	8	21;49	17	2/69	8	---	---	---	---	1673
72	72	8	20;62	F	5/69	10	---	---	---	---	1674
103	53	8	36;84	15	4/69	5	---	---	---	---	1675
50	---	---	11;27	4	2/69	1	---	---	---	---	1676
52	45	12	40	29	5/73	60	10	---	---	---	1677
98	---	---	---	---	---	---	---	160	324	7.7	1678
82	78	8	48;55;73	+4	4/61	100	---	---	---	---	1679
405	---	8	---	12	2/68	---	12	---	---	---	1680
337	260	6	42;204;241	---	---	---	---	---	---	---	1681
140	40	10	10;30	0	12/67	290	26	---	---	---	1682
63	60	2	60	43	4/77	---	---	600	5,110	6.3	1683
185	50	6	---	73	5/77	---	---	2,500	25,800	6.0	1684
150	43	6	---	21	4/77	2	---	550	9,870	7.1	1685
60	55	2	55	5	4/77	---	---	200	2,090	6.6	1686
55	50	2	48	8	5/77	---	---	120	2,110	6.7	1687
26	26	48	---	5	---	---	---	120	941	6.7	1688
28	28	48	---	24	---	---	---	98	613	6.7	1689
25	25	8	15	10	---	---	---	---	---	---	1690
25	25	36	---	---	---	---	---	---	---	8.1	1691
47	24	8	---	20	---	.1	---	---	---	---	1692
36	36	8	---	15	---	10	---	100	260	---	1693
220	220	6	---	20	7/76	5	.1	110	300	---	1694
80	15	8	---	F	---	5	---	118	---	7.9	1695
52	52	8	---	35	7/79	20	---	180	380	---	1696
41	41	6	38	10	9/70	3	.12	---	---	---	1697
50	40	8	31	F	9/73	15	---	---	---	---	1698
51	41	8	30	30	---	490	22	200	---	7.7	1699
22	22	36	---	---	---	---	---	92	---	7.3	1700
26	26	48	---	---	---	---	---	400	---	7.0	1701
27	27	36	---	---	---	---	---	260	---	7.7	1702
25	25	48	---	---	---	---	---	110	---	7.5	1703
22	22	36	---	---	---	---	---	150	---	7.3	1704
25	25	6	---	---	---	---	---	---	---	8.2	1705
26	26	36	---	---	---	---	---	160	---	7.7	1706
80	60	6	75	20	6/76	4	.08	---	---	---	1707
30	30	8	---	5	11/57	155	13	125	320	7.5	1708
120	120	8	112	40	9/74	17	.7	---	---	---	1709
160	40	6	84;96;130	40	2/75	---	---	---	---	---	1710
120	109	8	---	---	---	---	---	---	---	---	1711
140	140	6	---	---	---	.1	---	---	---	---	1712
51	---	5	---	---	---	---	---	---	---	8.5	1713
150	---	---	---	20	---	---	---	---	---	7.9	1714
122	105	6	106	30	10/77	30	10	---	---	---	1715
147	147	6	---	---	6/74	12	.5	---	---	---	1716
42	42	8	---	---	---	---	---	---	---	8.2	1717
114	---	6	85;97;108	---	---	20	---	---	---	---	1718
95	32	8	30;50;85	34	6/68	2	---	---	---	---	1719
29	29	36	---	---	---	---	---	150	---	7.4	1720
14	14	36	---	---	---	---	---	210	---	6.6	1721
79	79	6	---	---	---	---	---	120	320	---	1722
85	52	8	18;72	---	---	.1	---	---	---	---	1723

Ground-Water-Quality Data in Pennsylvania—A Compilation of Computerized [Electronic] Databases, 1979-2004

By Dennis J. Low and Douglas C. Chichester

In cooperation with the Pennsylvania Department of Environmental Protection

Data Series 150

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

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Contents

Figures

Tables

Conversion Factors, Datums, and Abbreviations

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
gallon per day (gal/d)	0.003785	cubic meter per day
	Radioactivity	
picocurie per liter (pCi/L)	0.037	becquerel per liter
	Temperature	
degree Fahrenheit (°F)	°C=5/9 (°F-32)	degree Celsius

Horizontal coordinate information is referenced to either the North American Datum (NAD 1927) or the North American Datum of 1983 (NAD 83).

Water-Quality Units

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as mass (milligrams) of solute per unit volume (liter) of water. One-thousand micrograms per liter is equivalent to 1 milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is the same as for concentrations in parts per million. Bacterial concentrations are reported in units of colonies per 100 milliliters (col/100 mL). Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C). Turbidity is reported in nephelometric turbidity units (NTU).

Radioactivity Units

A commonly used unit of measure for radioactivity is the picocurie. One Curie is the activity of one gram of radium-226, which is equal to 3.7×10^{10} atomic disintegrations per second; a picocurie is 10^{-12} Curies, which is about equal to 2.2 atomic disintegrations per minute. Activity refers to the decay of a radioactive substance, which is measured by the number of particles emitted by a radionuclide per unit of time. The rate of decay is proportional to the number of atoms of a radioactive substance present, and inversely proportional to its half life, which is the time necessary for the substance to lose half its radioactivity. Activity is defined as being equal to n x l, where n is the number of atoms of a radionuclide and l is the decay constant. The decay constant, l, is equal to the natural logarithm of 2 divided by the half-life of the radionuclide.

Ground-Water-Quality Data in Pennsylvania—A Compilation of Computerized [Electronic] Databases, 1979-2004

By Dennis J. Low and Douglas C. Chichester

Abstract

This study, by the U.S. Geological Survey (USGS) in cooperation with the Pennsylvania Department of Environmental Protection (PADEP), provides a compilation of ground-water-quality data for a 25-year period (January 1, 1979, through August 11, 2004) based on water samples from wells. The data are from eight source agencies—Borough of Carroll Valley, Chester County Health Department, Pennsylvania Department of Environmental Protection-Ambient and Fixed Station Network, Montgomery County Health Department, Pennsylvania Drinking Water Information System, Pennsylvania Department of Agriculture, Susquehanna River Basin Commission, and the U.S. Geological Survey. The ground-water-quality data from the different source agencies varied in type and number of analyses; however, the analyses are represented by 12 major analyte groups: biological (bacteria and viruses), fungicides, herbicides, insecticides, major ions, minor ions (including trace elements), nutrients (dominantly nitrate and nitrite as nitrogen), pesticides, radiochemicals (dominantly radon or radium), volatile organic compounds, wastewater compounds, and water characteristics (dominantly field pH, field specific conductance, and hardness).

A summary map shows the areal distribution of wells with ground-water-quality data statewide and by major watersheds and source agency. Maps of 35 watersheds within Pennsylvania are used to display the areal distribution of water-quality information. Additional maps emphasize the areal distribution with respect to 13 major geolithologic units in Pennsylvania and concentration ranges of nitrate (as nitrogen). Summary data tables by source agency provide information on the number of wells and samples collected for each of the 35 watersheds and analyte groups.

The number of wells sampled for ground-water-quality data varies considerably across Pennsylvania. Of the 8,012 wells sampled, the greatest concentration of wells are in the southeast (Berks, Bucks, Chester, Delaware, Lancaster, Montgomery, and Philadelphia Counties), in the vicinity of Pittsburgh, and in the northwest (Erie County). The number of wells sampled is relatively sparse in south-central (Adams, Cambria, Cumberland, and Franklin Counties), central (Centre, Indiana, and Snyder Counties), and north-central (Bradford, Potter, and Tioga Counties) Pennsylvania. Little to no data are available for approximately one-third of the state. Water characteristics and nutrients were the most frequently sampled major analyte groups; approximately 21,000 samples were collected for each group. Major and minor ions were the next most-frequently sampled major analyte groups; approximately 17,000 and 12,000 samples were collected, respectively. For the remaining eight major analyte groups, the number of samples collected ranged from a low of 307 samples (wastewater compounds) to a high of approximately 3,000 samples (biological).

The number of samples that exceeded a maximum contaminant level (MCL) or secondary maximum contaminant level (SMCL) by major analyte group also varied. Of the 2,988 samples in the biological analyte group, 53 percent had water that exceeded an MCL. Almost 2,500 samples were collected and analyzed for volatile organic compounds; 14 percent exceeded an MCL. Other major analyte groups that frequently exceeded MCLs or SMCLs included major ions (17,465 samples and a 33.9 percent exceedence), minor ions (11,905 samples and a 17.1 percent exceedence), and water characteristics (21,183 samples and a 20.3 percent exceedence). Samples collected and analyzed for fungicides, herbicides, insecticides, and pesticides (4,062 samples), radiochemicals (1,628 samples), wastewater-compounds (307 samples), and nutrients (20,822 samples) had the lowest exceedences of 0.3, 8.4, 0.0, and 8.8 percent, respectively.

Introduction

Ground-water-quality data have been collected in Pennsylvania for more than 100 years. Unfortunately, most data are confined to paper copies, and it is prohibitively expensive to compile the data. However, with the advent of computers and increased storage capacities, most recent (since about 1980) data now reside in electronic databases making access less expensive. By compiling the electronic data from local, state, and Federal agencies, it may be possible to identify areas where (1) data are sparse and further studies of ground-water quality may be needed, and (2) ground water contains analytes of concern at elevated concentrations.

In 2001, the Pennsylvania Department of Environmental Protection (PADEP) re-oriented its resource management and planning strategy to a watershed, as opposed to political boundary, approach. With this watershed-focused approach, PADEP established 35 watershed teams (fig. 1 and table 1) to address 17 indicators of environmental improvement at a watershed scale.

Pennsylvania is a physiographically and geologically diverse state. Over 200 different geologic formations or members are recognized by the Pennsylvania Topographic and Geologic Survey (PAGS). For this study, geologic formations were consolidated into 13 major aquifer categories based on dominant rock type or geolithologies (table 2). Even with this simplified categorization, however, geology extends beyond watershed and political boundaries (fig 2).

Purpose and Scope

This report provides geologic, hydrologic, and geographic information regarding electronically available ground-water-quality data in the Commonwealth of Pennsylvania on watershed and statewide scales from January 1, 1979, through August 11, 2004. This report presents ground-water-quality data from eight local, state, or Federal source agencies in a standard electronic format. The geographic distribution of the data also are presented in a standard electronic format, most commonly by watershed. Ancillary information, including local well numbers, and major geolithologic units are included by well for each source agency. More detailed information, specifically the aquifer sampled and the original scientific or data report in which the water-quality data were released, is provided for individual wells sampled as part of various U.S. Geological Survey (USGS) studies or investigations.

Nitrate nitrogen was identified as an analyte of interest to better evaluate the potential of an electronic database for visually displaying ground-water-quality data. Nitrate nitrogen was selected because (1) it is widespread in Pennsylvania, (2) it is commonly analyzed for, and (3) it has a maximum contaminant level (MCL). As a result, maps were generated summarizing nitrate nitrogen concentrations by watershed and geology.

Data-Compilation Methods

The compiled ground-water-quality data varies by (1) number of constituents, (2) frequency of sample collection, (3) source agency, and (4) geographic distribution. For example, the Borough of Carroll Valley collects water-quality data on bacteria and nutrients from selected wells within the Borough once every 10 years. The PADEP Ambient and Fixed Station Network (FSN) collects water-quality data (major ions, minor ions, trace elements, and nutrients) from across the state at individual wells. The frequency of this collection varies from one time only to multiple samples spread out over a period of years. Although the USGS collects ground-water-quality samples across the state, the geographic distribution may vary from several wells at a field research site to major river basins. A specific contaminant of concern such as arsenic may lead to a geographic distribution relating to land use or other factors. Geographic distribution of data collection also may be restricted to specific geologic formations and members.

Table 1. The 35 watersheds used by Pennsylvania Department of Environmental Protection to subdivide Pennsylvania for resource management.

Watershed number	Watershed name
1	Central Penn
2	Upper West Branch
3	Susquehannock/Genessee
4	Lower North Branch Susquehanna
5	Big Bend
6	Bradford/Tioga
7	Upper Susquehanna
8	Wyoming Valley
9	Lackawanna
10	Upper Delaware
11	Brodhead/Toby/Tunk
12	Upper Schuylkill/Middle Lehigh
13	Lower Lehigh
14	Delaware River/Tohickon Creek
15	Delaware Common Tributaries/Neshaminy
16	Middle Schuylkill
17	French/Manatawny
18	Perkiomen Creek
19	Wissahickon Creek/Schuylkill River
20	Darby/Chester/Ridley/Crum Creeks
21	Christina River/Elk/North East River/ Brandywine Creek/White Clay
22	Pennypack/Tacony
23	Lower Susquehanna East
24	Lower Susquehanna West
25	Potomac
26	Juniata
27	Kiski-Conemaugh
28	Youghiogheny
29	Monongahela
30	Ohio
31	Allegheny
32	Moraine
33	Middle Allegheny
34	Upper Allegheny
35	Lake Erie/French & Oil Creek

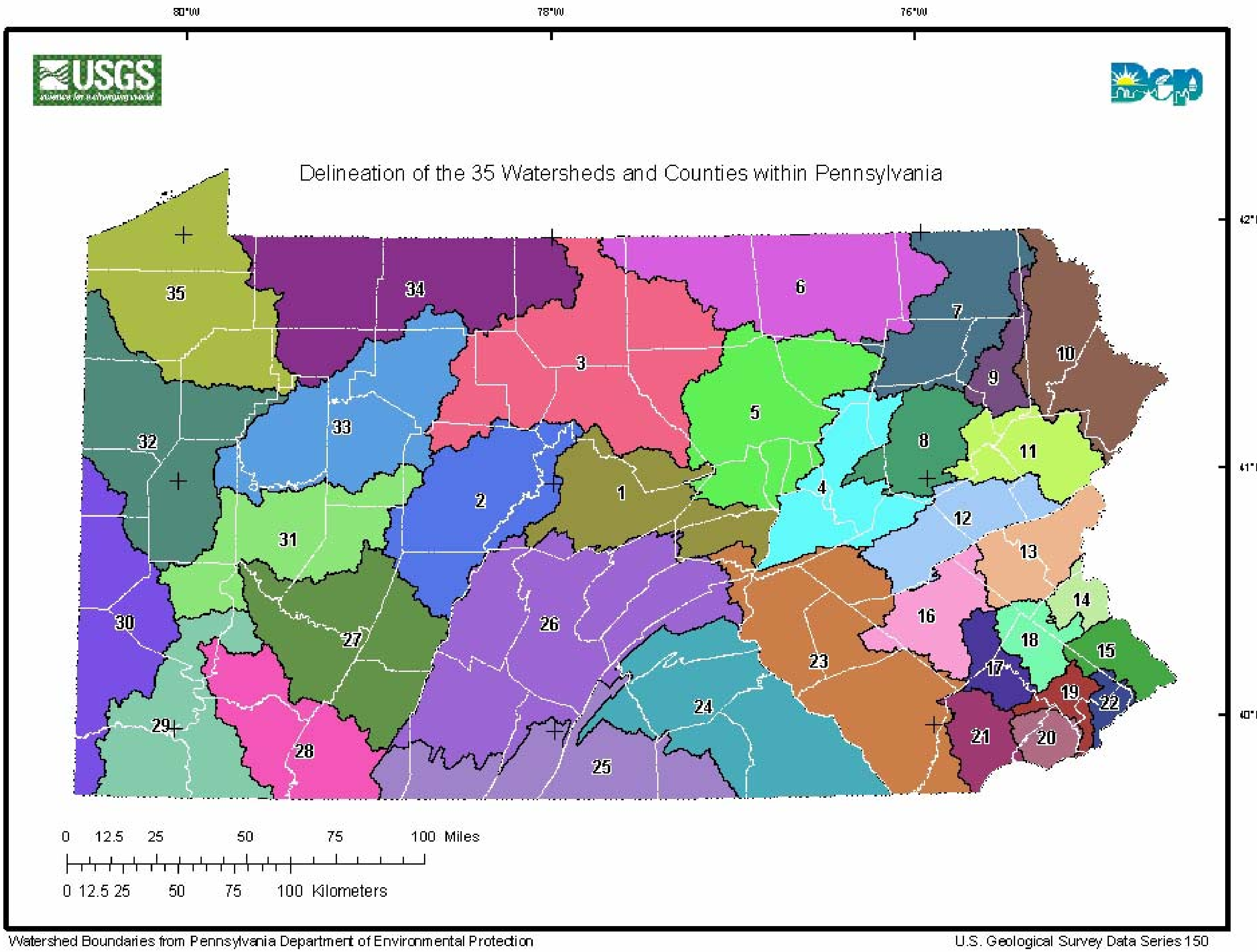

Figure 1. The 67 counties in Pennsylvania and boundaries of the 35 watersheds used by Pennsylvania Department of Environmental Protection to subdivide Pennsylvania for resource management (see table 1 for watershed names). (modified from Pennsylvania Department of Environmental Protection, 2005)

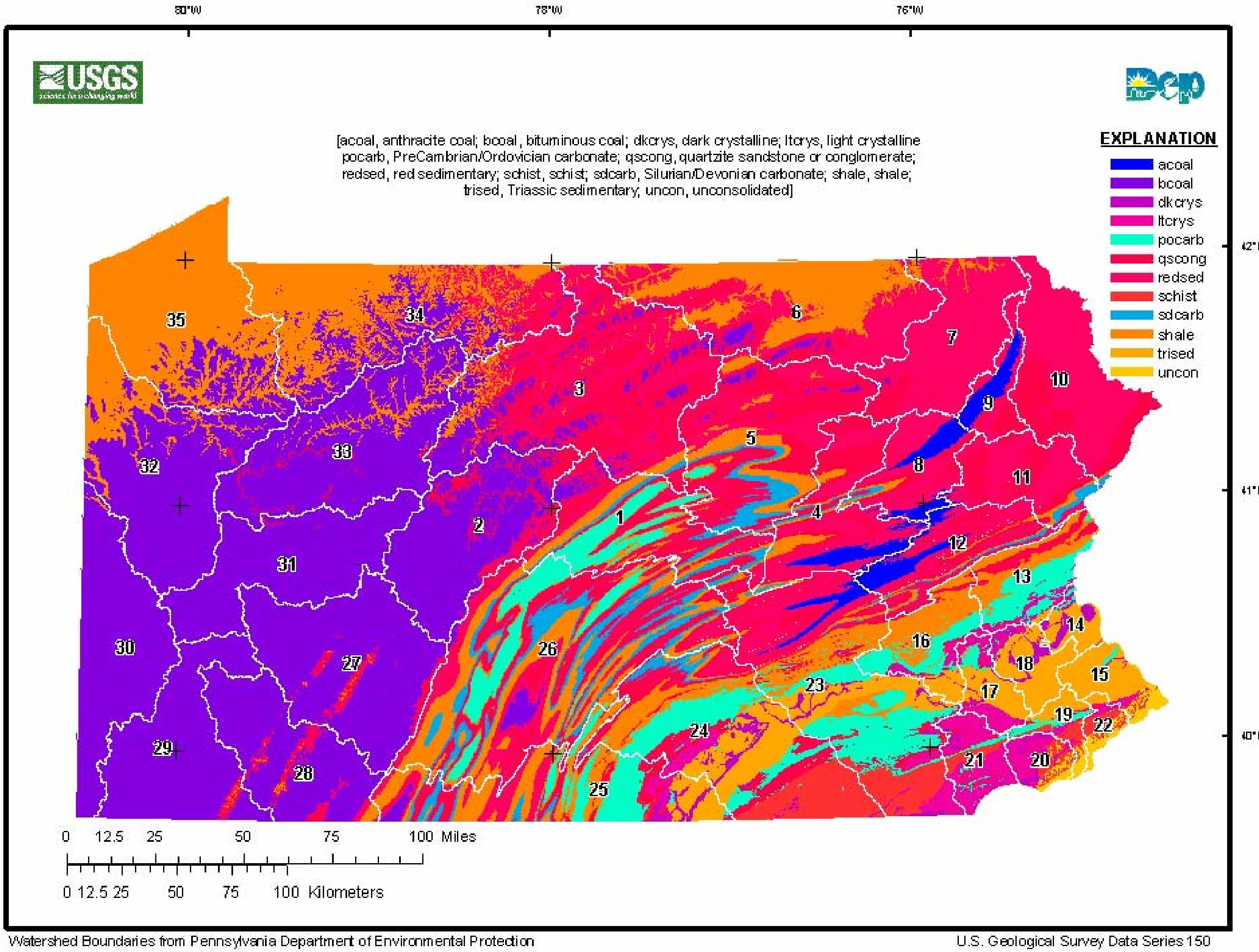

Figure 2. Dominant aquifer (excludes Glacial outwash or "ice") and boundaries of the 35 watersheds used by Pennsylvania Department of Environmental Protection to subdivide Pennsylvania for resource management.

Table 2. The 13 dominant aquifer and rock-type categories used for this data compilation with abbreviations.

Dominant aquifer	Geo-Abbreviation	Dominant rock type.
Anthracite coal	acoal	Anthracite coal bearing
Bituminous coal	bcoal	Bituminous coal bearing
Dark crystalline	dkcrys	Intrusive crystalline rocks that are dark in color (for example, diabase)
Light crystalline	ltcrys	Intrusive crystalline rocks that are light in color (for example, granite)
PreCambrian/Ordovician carbonates	pocarb	Precambrian- through Ordovician-age limestones and dolomites (with or without minor siliciclastics)
Quartzite, sandstone, or conglomerate	qscong	Quartz rich, dominantly sedimentary rocks (for example, Tuscarora Formation)
Red sedimentary	redsed	Rocks that are dominantly red in color, excludes Triassic age sediments (for example, Catskill Formation)
Schist	schist	A strongly foliated crystalline rock, formed by dynamic metamorphism, that have a dominant cleavage plane due to well developed parallelism of the minerals (for example, Marburg Schist)
Silurian/Devonian carbonates	sdcarb	Silurian- through Devonian-age limestones and dolomites (with or without minor siliciclastics)
Shale	shale	Dark, fine-grained, sedimentary rocks (for example, Hamilton Group)
Triassic sedimentary	trised	Sedimentary rocks that are Triassic in age (for example, Gettysburg Formation)
Unconsolidated	uncon	Gravels, sands, and clays along the Delaware River (for example, Trenton Gravel)
Glacial outwash	ice	Dominantly sand and gravel that were deposited by glaciers or associated fluvial action (for example, outwash)

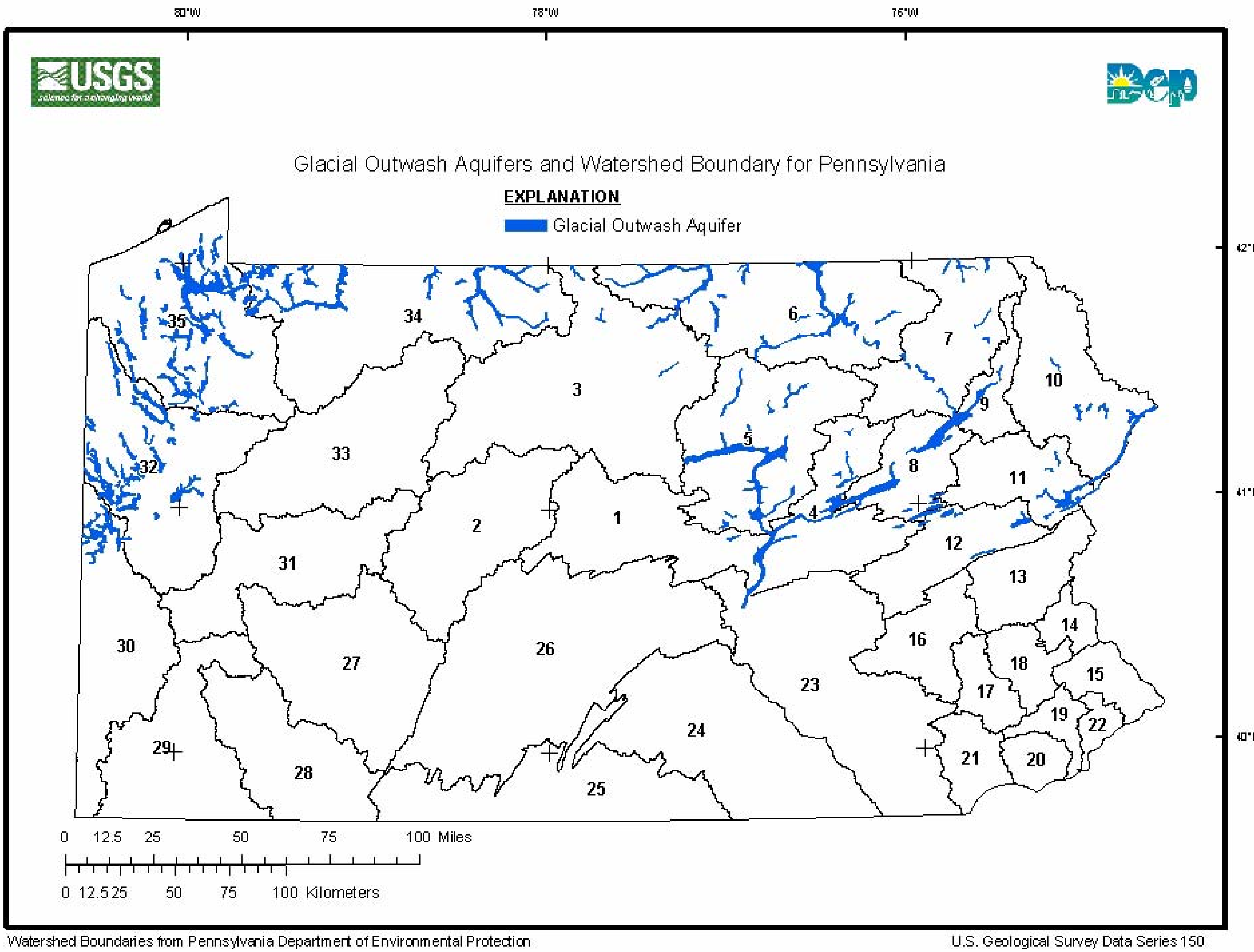

Figure 3. Glacial outwash or "ice" aquifers and boundaries of the 35 watersheds used by Pennsylvania Department of Environmental Protection to subdivide Pennsylvania for resource management. (modified from Sevon and Braun, 2000)

Data Sources

Despite the widespread use of computers and related software, electronic archival or storage of ground-water-quality data is limited when compared to what is available in hard or paper copy. Many local and county agencies as well as universities contacted for this study maintain paper copies as the final repository format for ground-water-quality data. As a result, the sources of the collected data in this study are dominated by state and Federal agencies. Information on the source of the ground-water-quality data collected for this study and reasons for data collection are presented in table 3.

About every 10 years, as part of their Act 537 Sewage Facilities Program (Carl Bower, Borough of Carroll Valley, oral commun., 2004), the Borough of Carroll Valley (CV) evaluates the effectiveness of the community's onlot septic systems. This is done by collecting water-quality samples from domestic wells for analysis of nitrate as nitrogen and bacteria (fecal and total coliform). Carroll Valley tries to obtain a representative sample from about 10 percent of the domestic wells.

Since 1984, the Chester County Health Department (CCDH) has required that recently drilled and completed domestic wells be sampled and tested for a fixed group of analytes. Although the number of analytes tested is extensive, only a small part of the data is stored electronically (water characteristics, major ions, and nutrients).

PADEP is charged with determining the ambient ground-water quality of water in Pennsylvania. PADEP addresses this effort through the FSN. The FSN consists of a large number of wells in selected basins generally in the eastern or western parts of Pennsylvania.

Since February 1, 1997, the Montgomery County Health Department (MCHD) has required that recently drilled and completed domestic wells be sampled and tested for a fixed group of analytes. These analytes include bacteria, water characteristics, major ions, minor ions, nutrients, trace elements, volatile organic compounds, and wastewater compounds.

PADEP also is responsible for assessments of ground-water quality for community and non-community water systems to determine whether ground water meets the primary drinking-water standards. One method utilized by PADEP to meet this directive is through the Pennsylvania Drinking Water Information System (PADWIS). Through PADWIS, raw (unfiltered) ground-water samples are collected from non-private wells and submitted to private water-quality labs for analysis. The resulting data are then reviewed and entered into PADWIS.

The Pennsylvania Department of Agriculture (PennAg) has long been interested in monitoring for pesticides in ground water. As a result, PennAg has sampled wells in agricultural areas to determine occurrence and distribution of pesticides in ground water; the most recent sampling was directed at an assessment of concentration trends.

The Susquehanna River Basin Commission (SRBC) issues permits for large supply wells (wells that yield more than 100,000 gallons per day). Water-quality data is a part of the data that SRBC collects.

The U.S. Geological Survey (USGS) has collected data through various water-resources and water-quality studies. Much of the water-quality data collected by the USGS was obtained from analysis of water samples from domestic wells.

Table 3. Data sources and reason(s) for data collection.

Data Sources	Source abbreviation	Reason for data collection
Borough of Carroll Valley	CV	Act 537 (sewage facilities program)
Chester County Health Department	CCDH	Permitting of domestic wells
Pennsylvania Department of Environmental Protection—Ambient and Fixed Station Network	FSN	Monitoring of ground-water quality by ground-water basin
Montgomery County Health Department	MCHD	Permitting of domestic wells
Pennsylvania Drinking Water Information System	PADWIS	Permitting of public and non-community wells (self-reporting system)
Pennsylvania Department of Agriculture	PennAg	Pesticides in ground water
Susquehanna River Basin Commission	SRBC	Permitting of public, industrial, and commercial water-supply wells
U.S. Geological Survey	USGS	Various water-resources and water-quality studies

Mandatory Latitude and Longitude in Data Files

Water-quality data collected from January 1, 1979, through August 11, 2004, were obtained from the source government agencies in a variety of electronic formats but were dominated by Microsoft Excel or .dbf4 type files (.dbf4 or dBase files are simple sequential files of fixed-length records. .dbf file formats commonly are understood by Windows spreadsheets and organizers.). Although the number of analytes varied by source agency and the objective(s) of historical studies, each data set was required to have (1) a site-specific identifier such as a local name or well number, (2) a geographic reference, and (3) an analyte of interest. The CV data set lacked latitudes and longitudes but contained street addresses and parcel numbers. The parcel and address information was combined with an available Geographic Information System (GIS) parcel coverage to assign latitudes and longitudes. The wells comprising the MCHD data set contained a mixture of latitudes, longitudes, and street addresses. The GIS parcel coverage from Montgomery County was not available; therefore, wells lacking latitudes or longitudes were removed from the data set.

Assigning a Geolithology to Wells

Utilizing previous work (Barker, 1984; Low and others, 2002), the geologic formations represented on PAGS Map 1 (Berg and others, 1980) were condensed into 13 geolithologic units (table 2), and a GIS coverage was developed. A second GIS coverage that contained attributes for the 35 watersheds was obtained from PADEP (fig. 1). On the basis of their geographic distribution, the wells in each data set were brought into the various GIS coverages and assigned a specific geolithologic unit and watershed.

Clean-up of Data Records and Bulk Processing

The data sets from MCHD and CCDH included a large segment of text embedded with quantified results. A substantial effort at hand editing was involved to separate the text from the quantified results. In many of these cases, qualitative results were converted into numeric remark codes such as “sample exceeded the MCL for lead,” or “an analyte was sampled for but not detected.”

To efficiently combine the water-quality data sets and the GIS data sets, a series of SAS Institute Inc. (SAS) programs were developed. The SAS programs not only merged the water-quality and GIS data sets by site identifier but also were written to identify which samples contained an analyte that exceeded a U.S. Environmental Protection Agency (USEPA) maximum contaminant level (MCL) or secondary maximum contaminant level (SMCL). Because of the size of some files generated by the SAS program, the data sets were exported as .dbf4 files and hand edited for possible errors prior to conversion to Microsoft Excel format where additional editing took place. Additional GIS coverages were then developed from the Microsoft Excel data files to show the distribution of wells by data source across the state and for individual major watershed.

Categories of Analytes

The source-agency data files are subdivided into 12 analyte groups described below. These analyte groups represent subfiles or folders. Some source agency files, such as the CV, consisted of two subfiles—bacteria and nutrients. Others, like the USGS, consisted of 11 subfiles. Because some source agencies such as the USGS collect a large amount of pesticide data, it was necessary to further divide this analyte group into fungicides, herbicides, and insecticides.

Analyte Group Abbreviations and Descriptions

- Micro—Bacteria, viruses, and other micro-organisms group. Total coliform and fecal coliform are the most common bacteria analyzed. Enteric and coliphage are the most common viruses analyzed. Clostridium and enterococci are some of the other micro-organisms analyzed.

    Source agency—CV: Total and fecal bacteria; 124 samples.
    Source agency—MCHD: Total, fecal, and *Escherichia coli* (*E. coli*) bacteria; 971 samples.
    Source agency—PADWIS: Total, fecal, and *E. coli* bacteria; 360 samples.
    Source agency—PennAg: Total and *E. coli* bacteria; 269 samples.
    Source agency—USGS: 11 methods or organisms including viruses; 1,264 samples.

- Field—Water characteristics group. pH and specific conductance are the most common analytes.

    Source agency—CCDH: Turbidity and pH; 833 samples.
    Source agency—FSN: lab pH, lab alkalinity, and total hardness; 10,590 samples.
    Source agency—MCHD: pH; 971 samples.
    Source agency—SRBC: 4 parameters or analytes; 681 samples.
    Source agency—USGS: 16 parameters or analytes; 8,132 samples

- Fungus—Fungicide group. Chlorothalonil and cis-1,3-Dichloropropane are the most common analytes.

    Source agency—USGS: 10 analytes (including filtered and unfiltered); 1,196 samples.

- Herb—Herbicide group. Atrazine, Alachlor, and Cyanazine are among the most common analytes.

    Source agency—USGS: 107 analytes (including filtered and unfiltered); 1,319 samples.

- Insec—Insecticide group. Carbaryl, Dieldrin, and Lindane are among the most common analytes.

    Source agency—USGS: 87 analytes (including filtered and unfiltered); 1,280 samples.

- Major—Major cations and anions group. Chloride, calcium, and iron are among the most common analytes.

    Source agency—FSN: 11 analytes; 10,591 samples.
    Source agency—MCHD: 4 analytes; 971 samples.
    Source agency—SRBC: 8 analytes; 724 samples.
    Source agency—USGS: 31 analytes (including filtered and unfiltered); 5,175 samples.

- Minors—Minor cations, anions, and trace elements group. Aluminum, arsenic, and lead are common analytes.

    Source agency—FSN: 8 analytes (trace elements); 7,675 samples.
    Source agency—MCHD: 4 analytes (trace elements); 75 samples.
    Source agency—PADWIS: 12 analytes; 36 samples.
    Source agency—SRBC: 6 analytes (trace elements); 706 samples.
    Source agency—USGS: 41 analytes (including filtered and unfiltered); 3,413 samples.

- Nuts—Nutrient group. Nitrate, nitrite, and total organic carbon are among the most common analytes.

    Source agency—CV: Nitrate; 124 samples.
    Source agency—CCDH: Nitrate; 849 samples.
    Source agency—FSN: 5 analytes; 10,594 samples.
    Source agency—MCHD: Nitrate; 971 samples.
    Source agency—PennAg: Nitrate, nitrite; 269 samples.
    Source agency—SRBC: Nitrate, orthophosphate, and total organic carbon; 707 samples.
    Source agency—USGS: 27 analytes (including filtered and unfiltered); 7,315 samples.

- Pest—Pesticide group. Atrazine, Cyanazine, and Simazine are among the most common analytes.

    Source agency—PADWIS: Carbofuran, and 2,4-D; 2 samples.
    Source agency—PennAg: 10 analytes; 273 samples.

- Radio—Radiochemicals (radionuclides) group. Radon-222 and uranium are the most common analytes.

    Source agency— PADWIS: 6 analytes; 19 samples.
    Source agency—USGS: 16 analytes (including filtered and unfiltered); 1,609 samples.

- Voa—Volatile organic compounds group. Benzene, toluene, styrene, and xylenes are among the most common analytes.

    Source agency—MCHD: 25 analytes; 971 samples.
    Source agency—PADWIS: 27 analytes; 183 samples.
    Source agency—USGS: 104 analytes (including filtered and unfiltered); 1,280 samples

- Waste—Wastewater and pharmaceuticals group. Methylene blue active substance and caffeine are among the most common analytes.

    Source agency—MCHD: Trihalomethanes; 5 samples.
    Source agency—USGS: 54 analytes (including filtered and unfiltered); 304 samples.

Formats, Naming Conventions, and Abbreviations Used in Data Files

The data format is Microsoft Excel 2003 (Excel); supporting documents are in Portable Document Format (PDF). Each folder is identified by the source agency. For example, the folder titled MCHD contains files compiled from the Montgomery County Health Department. Within each folder are a series of files. Each file is organized by analyte group. For example, the Excel file titled MCHD.Voa.xls contains the water-quality data for volatile organic compounds collected by the Montgomery County Health Department. Also included in this file are ancillary data such as local well number, site identifier (site ID), latitude, longitude, and geolithologic unit. Information regarding an exceedence of a USEPA MCL or SMCL is presented in an adjacent column and cell. Analyte results for MCHD and CCDH also contain numeric qualifiers. Data files from the USGS also contain analyte remark codes such as less than, estimated, and missing, as well as information on the study for which the samples were collected. The USGS data files also contain a seven or eight length alphanumeric code that details a specific geologic formation or unit.

MCHD.Comments.Micro.pdf is a PDF file that provides supporting information on the water-quality measurements (in this case about bacteria and viruses), including analytes, definitions, and USEPA contaminant levels on samples collected by or for the Montgomery County Health Department.

USGS.CrossReferenceNumbers is an Excel table that presents the abbreviated author and report citation for the scientific or data report in which the data were originally published. This allows the interested reader a means to locate the study and determine the purpose for which the data were collected. It is an aid in locating the complete citation listed in the Selected References, which also lists the abbreviated report citation in bold. USGS.MicroReport is an Excel file that lists the abbreviated citations for bacteria and virus studies and includes local well numbers, site IDs, latitudes, longitudes, watersheds, geolithologic units, and geologic formations.

Maps and Tables Summarizing the Ground Water-Quality Data

The maps generated for this study (accessed through hyperlinks in the Appendix) are PDF images. The 35 images titled Basin1_Wells through Basin35_Wells show the distribution of wells with available water-quality data by watershed and source agency. The 35 images titled Basin1_QWNO3 through Basin35_QWNO3 show the distribution of nitrate data (NO3) by watershed and source agency. The 12 images pre-fixed by “Statewide” show the distribution of wells with water-quality data by source agency.

Summary tables (accessed through hyperlinks in the Appendix) are included within each source-agency file. For example, SRBC.Summary.pdf (table 4) presents information on the number of (1) wells sampled by major river basin, (2) wells sampled by watershed, (3) samples collected by analyte group, and (4) samples that exceeded USEPA contaminant levels.

Statewide Summary Map

Figure 4 shows the distribution of the 8,012 wells from the eight source agencies. The greatest concentration of wells with water-quality data are in watersheds 17, 18, 21, and 23 of southeastern Pennsylvania (Chester, Lancaster, and Montgomery Counties). The part of watershed 35 that has been extensively sampled is Erie County. About half of the watersheds in Pennsylvania have fewer than 100 wells with water-quality data; watershed 9 contains no ground-water-quality data.

Summary Maps for 35 Watersheds

Figure 5 shows the distribution by county and watershed from the PDF image Basin35_Wells. Almost all 246 wells sampled for ground-water-quality data in watershed 35 were the result of USGS studies specifically related to Erie County. Similar images for all 35 watersheds can be viewed through the hyperlinks in the Appendix.

Summary Maps for Nitrate Nitrogen Concentrations in Ground Water for 35 Watersheds

Figure 6 shows the distribution of 461 wells by county in watershed 24 (from the PDF image Basin24_QWNO3). Of the 565 nutrient samples collected and analyzed, 31 samples (5.5 percent) exceeded the USEPA MCL of 10.0 mg/L for nitrate. Results were averaged for wells that were sampled more than once. About 50 percent of the wells visited and sampled are the result of USGS studies. Similar images for all 35 watersheds can be viewed through the hyperlinks in the Appendix.

Summary Tables by Source Agency

Table 4 is a summary of the ground-water-quality data collected by the SRBC and contained within the various Excel data spreadsheet files listed for the SRBC in the Appendix. Similar summary files for the other source agencies also are available through hyperlinks in the Appendix. Each summary table presents information on the number of wells sampled, the number of samples collected, the number of exceedences for USEPA MCL and SMCL analytes. The summary data are organized by PADEP watershed and major analyte group.

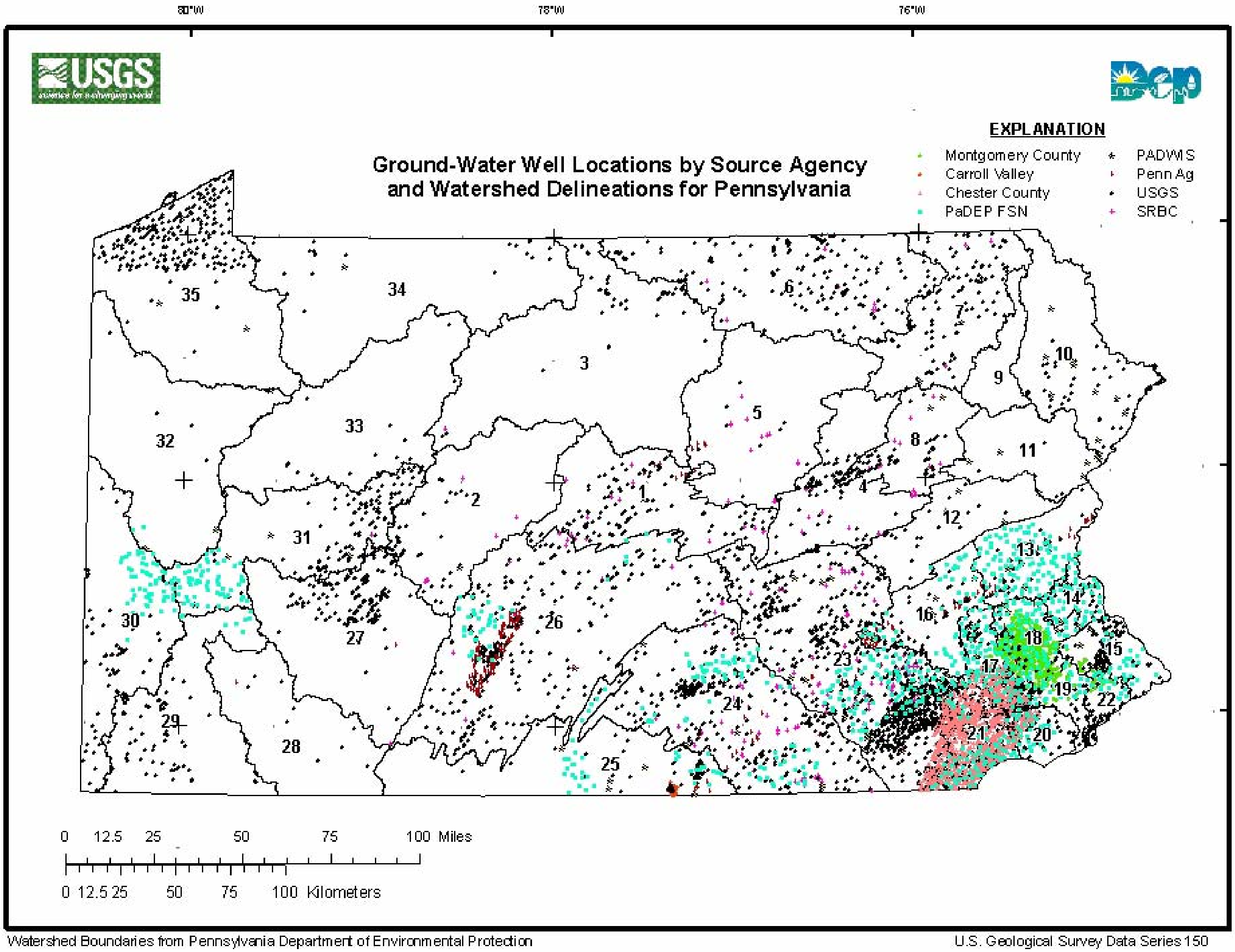

Figure 4. Well locations with ground-water-quality data compiled from eight source agencies representing the period 1979-2004 for Pennsylvania.

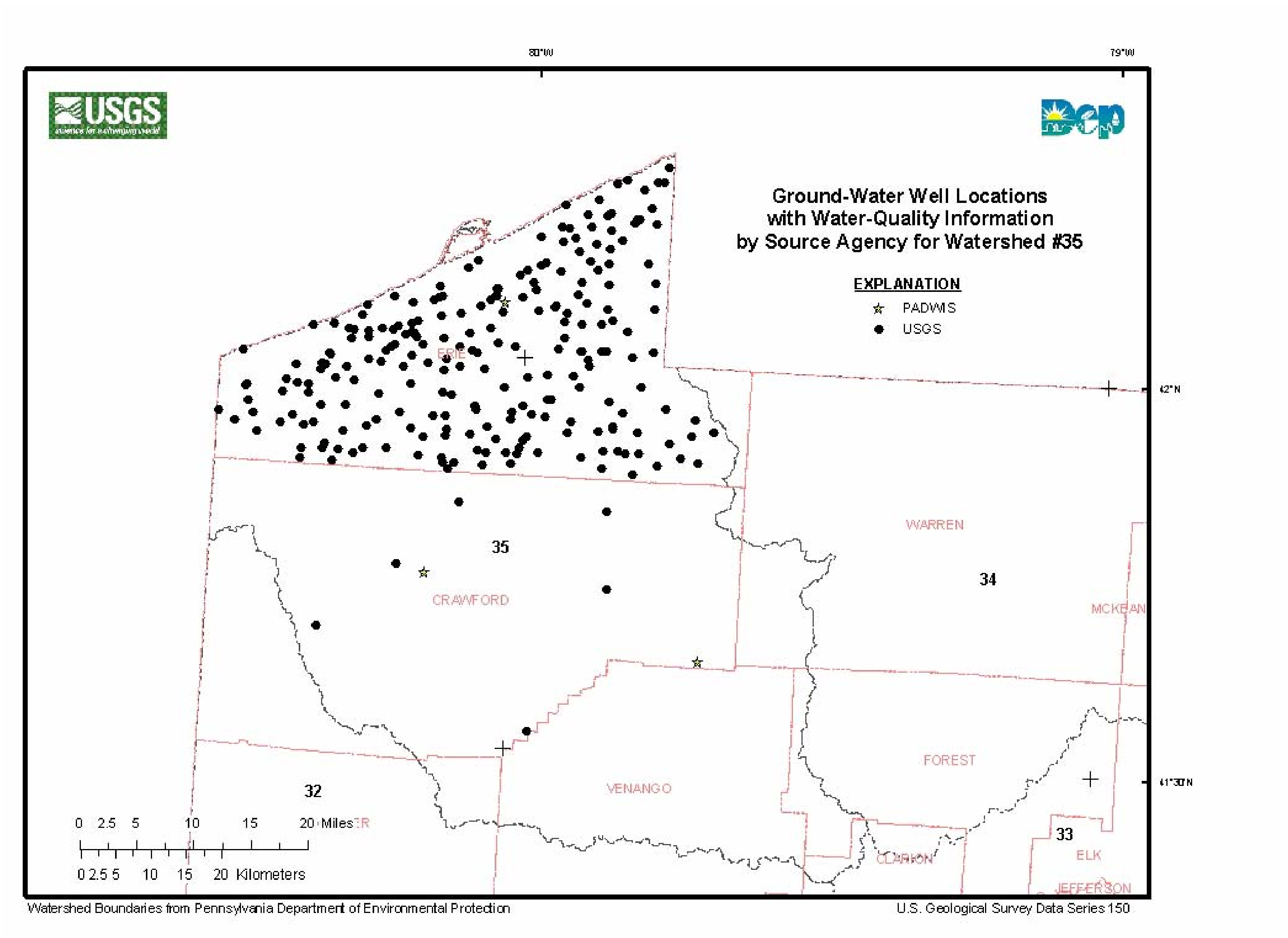

Figure 5. Well locations of water-quality data compiled from two source agencies (Pennsylvania Drinking Water Information System and U.S. Geological Survey) for Watershed Number 35, Lake Erie/French & Oil Creek, northwestern Pennsylvania.

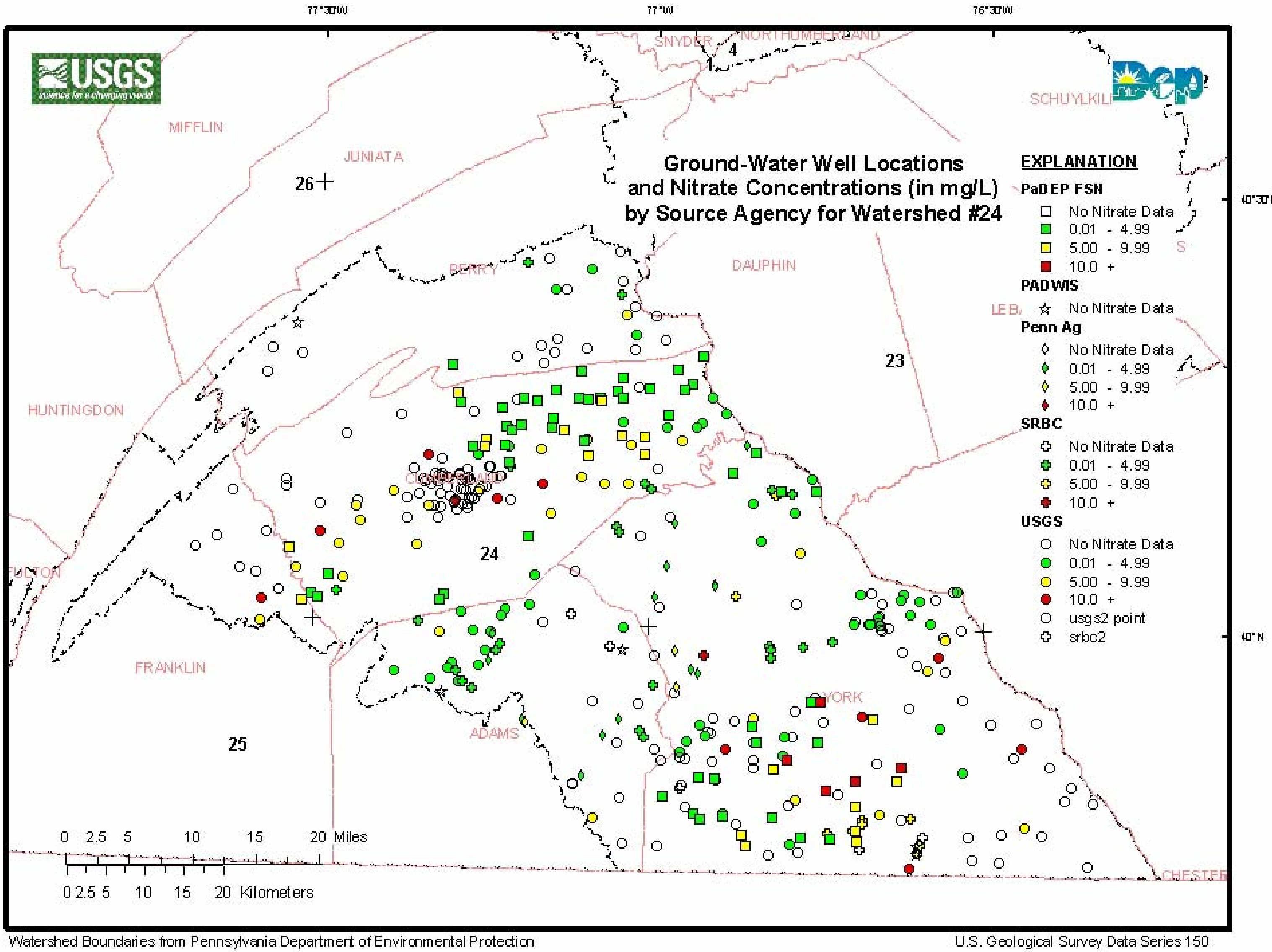

Figure 6. Ranges of concentration for nitrate nitrogen in ground water for Watershed Number 24, southcentral Pennsylvania.

Table 4. Summary table of Susquehanna River Basin Commission (SRBC) ground-water-quality studies by major river basins in Pennsylvania.

[2/ 0, number of samples collected/number of samples that exceeded a U.S. Environmental Protection Agency Maximum or Secondary Maximum Contaminant Level]

Pennsylvania Department of Environmental Protection watershed	Wells	Major ions		Minor and trace elements		Nutrients		Water characteristics (field measurements)	
Ohio and St. Lawrence River Basins									
31	1	2/	0	2/	0	2/	0	2/	0
Delaware River Basin									
12	6	13/	4	14/	4	13/	0	13/	8
Lower Susquehanna River Basin									
23	123	289/	73	278/	27	236/	34	267/	27
24	61	147/	14	145/	22	138/	3	144/	23
26	18	40/	3	39/	6	31/	3	33/	2
Upper Susquehanna River Basin									
1	23	39/	9	38/	5	36/	0	37/	1
2	10	35/	15	35/	5	28/	0	33/	7
3	1	2/	0	3/	0	2/	0	2/	0
4	14	21/	12	21/	5	21/	0	21/	7
5	24	44/	12	41/	3	41/	0	43/	10
6	17	33/	23	32/	8	28/	0	31/	0
7	3	7/	0	6/	1	7/	0	6/	1
8	28	52/	22	52/	7	49/	1	49/	17

Summary

This study, by the U.S. Geological Survey (USGS) in cooperation with the Pennsylvania Department of Environmental Protection (PADEP) Bureau of Watershed Management, provides detailed ground-water-quality data from January 1, 1979, to August 11, 2004, on 8,612 wells for 35 watersheds throughout Pennsylvania. Eight source agencies—Borough of Carroll Valley (CV), Chester County Health Department (CCDH), Pennsylvania Department of Environmental Protection-Ambient and Fixed Station Network (FSN), Montgomery County Health Department (MCHD), Pennsylvania Drinking Water Information System (PADWIS), Pennsylvania Department of Agriculture (PennAg), Susquehanna River Basin Commission (SRBC), and USGS provided the data in various electronic formats that were suitable for editing and compiling. The resulting ground-water-quality data were divided, by source agency, into 12 analyte groups—micro-organisms, major ions, minor ions and trace elements, nutrients, pesticides (USGS pesticide data were further subdivided into fungicides, herbicides, and insecticides), radiochemicals, volatile organic compounds, wastewater compounds, and water characteristics.

For each source agency, Microsoft Excel files and Portable Document Format files were created. The Excel files (for example, CV.Micro.xls) contain the edited ground-water-quality data, whereas the PDF files (for example, SRBC.Summary.pdf) contain a summary of the results by watershed and analyte group. As a result of the large number of independent studies conducted by the USGS, additional Excel files were created. These Excel files (for example, USGS.MicroReport.xls) contain an abbreviated reference to the original citation listed in Selected References. This allows the interested reader a means to locate the study and determine the purpose for which the ground-water-quality data were collected.

A series of PDF images were created to show the 35 watersheds within Pennsylvania, the 13 geolithologic units that were used to represent the complex geology of Pennsylvania, and the distribution of 8,612 wells with ground-water-quality data. An additional 35 images were created to show the distribution of the 8,612 wells by watershed, another 35 were images created to show the distribution and range of nitrate (as nitrogen) concentrations in the 35 watersheds.

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Selected References

Bolded abbreviations in parentheses at the end of a citation are used in USGS.MicroReport.xls and other similar named Excel files to identify where the water-quality data have been previously published and/or the basis for the collection of the sample.

Anderson, R.M., Beer, K.M., Buckwalter, T.F., Clark, M.E., McAuley, S.D., Sams III, J.I., and Williams, D.R., 2000, Water quality in the Allegheny and Monongahela River Basins: U.S. Geological Survey Circular 1202, 32 p. **(Circular 1202)**

Balmer, W.T., and Davis, D.K., 1996, Groundwater resources of Delaware County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 66, 67 p. **(WRR 66)**

Barker, J.L., 1984, Compilation of ground-water-quality data in Pennsylvania: U.S. Geological Survey Open-File Report 84-706, 102 p.

Becher, A.E., 1989, Geohydrology and water quality in the vicinity of the Gettysburg National Military Park and Eisenhower National Historic Site, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 89-4154, 44 p. **(WRIR 89-4154)**

Becher, A.E., 1991, Groundwater resources in and near the Anthracite basins of Schuylkill and adjacent counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 64, 59 p. **(WRR 64)**

Becher, A.E., 1996, Ground-water resources of Cambrian and Ordovician carbonate rocks in the Valley and Ridge Physiographic Province of Pennsylvania: U.S. Geological Survey Open-File Report 90-109, 134 p. **(OFR 90-109)**

Becher, A.E., and Taylor, L.E., 1981, Groundwater and geology of the Cumberland Valley, Cumberland County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 50, 95 p. **(WRR 50)**

Becher, A.E., and Taylor, L.E., 1982, Groundwater resources in the Cumberland and contiguous valleys of Franklin County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 53, 67 p. **(WRR 53)**

Berg, T.M., Edmunds, W.E., Geyer, A.R., Glover, A.D., Hoskins, D.M., MacLachlan, D.B., Root, S.I., Sevon, W.D., and Socolow, A.A., comps., 1980, Geologic map of Pennsylvania: Pennsylvania Geological Survey, 4th ser., Map 1, scale 1:250,000, 3 sheets.

Bird, P.H., 1998, Geohydrology and ground-water quality of Warwick Township, Bucks County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 97-4267, 37 p. **(WRIR 97-4267)**

Blickwedel, R.S., and Linn, J.H., 1987, Hydrogeology and ground-water quality at a land reclamation site, Neshaminy State Park, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 86-4164, 41 p. **(WRIR 86-4164)**

Blickwedel, R.S., and Wood, C.R., 1989, Relation of ground-water quality to land use in the Philadelphia, Pennsylvania-Camden, New Jersey area: U.S. Geological Survey Water-Resources Investigations Report 88-4211, 58 p. **(WRIR 88-4211)**

Buchanan, J.W., 1983, Water Resources Data Pennsylvania Water Year 1982, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA 82-2, 244 p. **(PA 82-2)**

Buchanan, J.W., Loper, W.C., Schaffstall, W.P., and Hainly, R.A., 1984, Water Resources Data Pennsylvania Water Year 1983, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA 83-2, 283 p. **(PA 83-2)**

Buckwalter, T.F., Schreffler, C.L., and Gleichsner, R.E., 1996, Geohydrology and water quality of the unconsolidated deposits in Erie County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 95-4165, 105 p. **(WRIR 95-4165)**

Cecil, L., D., 1988, Geohydrology of the Furnace Creek Basin and vicinity, Berks, Lancaster, and Lebanon Counties, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 87-4218, 38 p. **(WRIR 87-4218)**

Coll, M.B., and Siwicki, R.W., 1997, Water Resources Data Pennsylvania Water Year 1996, vol. 3, Ohio River and St. Lawrence River Basins: U.S. Geological Survey Water-Data Report PA-96-3, 204 p. **(PA 96-3)**

Coll, M.B., and Siwicki, R.W., 1998, Water Resources Data Pennsylvania Water Year 1997, vol. 3, Ohio River and St. Lawrence River Basins: U.S. Geological Survey Water-Data Report PA-97-3, 339 p. **(PA 97-3)**

Coll, M.B., and Siwicki, R.W., 1999, Water Resources Data Pennsylvania Water Year 1998, vol. 3, Ohio River and St. Lawrence River Basins: U.S. Geological Survey Water-Data Report PA-98-3, 352 p. **(PA 98-3)**

Conger, R.W., 1997, Evaluation of selected wells in Pennsylvania's observation-well program as of 1993: U.S. Geological Survey Water-Resources Investigations Report 96-4319, 73 p. **(WRIR 96-4319)**

Davis, D.K., 1989, Groundwater resources of Pike County, Pennsylvania: Pennsylvania Topographic and Geologic Survey, 4th ser., Water Resource Report 65, 63 p. **(WRR 65)**

Durlin, R.R., and Schaffstall, W.P., 1992, Water Resources Data Pennsylvania Water Year 1991, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-91-2, 358 p. **(PA 91-2)**

Durlin, R.R., and Schaffstall, W.P., 1993, Water Resources Data Pennsylvania Water Year 1992, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-92-2, 342 p. **(PA 92-2)**

Durlin, R.R., and Schaffstall, W.P., 1994, Water Resources Data Pennsylvania Water Year 1993, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-93-2, 361 p. **(PA 93-2)**

Durlin, R.R., and Schaffstall, W.P., 1996, Water Resources Data Pennsylvania Water Year 1994, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-94-2, 418 p. **(PA 94-2)**

Durlin, R.R., and Schaffstall, W.P., 1997, Water Resources Data Pennsylvania Water Year 1995, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-95-2, 518 p. **(PA 95-2)**

Durlin, R.R., and Schaffstall, W.P., 1997, Water Resources Data Pennsylvania Water Year 1996, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-96-2, 310 p. **(PA 96-2)**

Durlin, R.R., and Schaffstall, W.P., 1998, Water Resources Data Pennsylvania Water Year 1997, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-97-2, 439 p. **(PA 97-2)**

Durlin, R.R., and Schaffstall, W.P., 1999, Water Resources Data Pennsylvania Water Year 1998, vol. 1, Delaware River Basin: U.S. Geological Survey Water-Data Report PA-98-1, 405 p. **(PA 98-1)**

Durlin, R.R., and Schaffstall, W.P., 1999, Water Resources Data Pennsylvania Water Year 1998, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-98-2, 456 p. **(PA 98-2)**

Durlin, R.R., and Schaffstall, W.P., 2000, Water Resources Data Pennsylvania Water Year 1999, vol. 1, Delaware River Basin: U.S. Geological Survey Water-Data Report PA-99-1, 571 p. **(PA 99-1)**

Durlin, R.R., and Schaffstall, W.P., 2000, Water Resources Data Pennsylvania Water Year 1999, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-99-2, 444 p. **(PA 99-2)**

Durlin, R.R., and Schaffstall, W.P., 2001, Water Resources Data Pennsylvania Water Year 2000, vol. 1, Delaware River Basin: U.S. Geological Survey Water-Data Report PA-00-1, 652 p. **(PA 00-1)**

Durlin, R.R., and Schaffstall, W.P., 2001, Water Resources Data Pennsylvania Water Year 2000, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-00-2, 458 p. **(PA 00-2)**

Durlin, R.R., and Schaffstall, W.P., 2002, Water Resources Data Pennsylvania Water Year 2001, vol. 1, Delaware River Basin: U.S. Geological Survey Water-Data Report PA-01-1, 529 p. **(PA01-1)**

Durlin, R.R., and Schaffstall, W.P., 2002, Water Resources Data Pennsylvania Water Year 2001, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-01-2, 441 p. **(PA 01-2)**

Durlin, R.R., and Schaffstall, W.P., 2003, Water Resources Data Pennsylvania Water Year 2002, vol. 1, Delaware River Basin: U.S. Geological Survey Water-Data Report PA-02-1, 527 p. **(PA 02-1)**

Durlin, R.R., and Schaffstall, W.P., 2003, Water Resources Data Pennsylvania Water Year 2002, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-02-2, 536 p. **(PA 02-2)**

Durlin, R.R., and Schaffstall, W.P., 2004, Water Resources Data Pennsylvania Water Year 2003, vol. 1, Delaware River

Basin: U.S. Geological Survey Water-Data Report PA-03-1, 637 p. **(PA 03-1)**

Durlin, R.R., and Schaffstall, W.P., 2004, Water Resources Data Pennsylvania Water Year 2003, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-03-2, 563 p. **(PA 03-2)**

Fischer, J.M., Riva-Murray, K., Hickman, R.E., Chichester, D.C., Brightbill, R.A., Romanok, K.M., and Bilger, M.D., 2004, Water quality in the Delaware River Basin, Pennsylvania, New Jersey, New York, and Delaware, 1998-2001: U.S. Geological Survey Circular 1227, 38 p. **(Circular 1227)**

Galeone, D.G., and Low, D.J., 2003, Surface-water and ground-water quality in the Powell Creek and Armstrong Creek Watersheds, Dauphin County, Pennsylvania, July-September 2001: U.S. Geological Survey Fact Sheet FS-052-03, 6 p. **(FS 052-03)**

Hippe, D.J., Witt III, E.C., and Giovanitti, R.M., 1994, Hydrogeology, herbicides and nutrients in ground water and springs, and relation of water quality to land use and agricultural practices near Carlisle, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 93-4172, 66 p. **(WRIR 93-4172)**

Langland, M.J., 1996, Quality of ground water at selected sites in the Upper Mahoning Creek Basin, Pennsylvania: U.S. Geological Survey Fact Sheet 176-96, 4 p. **(FS 176-96)**

Lescinsky, J.B., Coll, M.B., and Siwicki, R.W., 1985, Water Resources Data Pennsylvania Water Year 1984, vol. 3, Ohio River and St. Lawrence River Basins: U.S. Geological Survey Water-Data Report PA-84-3, 207 p. **(PA 84-3)**

Lescinsky, J.B., Coll, M.B., and Siwicki, R.W., 1986, Water Resources Data Pennsylvania Water Year 1985, vol. 3, Ohio River and St. Lawrence River Basins: U.S. Geological Survey Water-Data Report PA-85-3, 191 p. **(PA 85-3)**

Lindsey, B.D., Breen, K.J., Bilger, M.D., and Brightbill, R.A., 1998, Water quality in the Lower Susquehanna River Basin—Pennsylvania and Maryland, 1992-95: U.S. Geological Survey Circular 1168, 38 p. (**Circular 1168)**

Lindsey, B.D., and Koch, M.L., 2004, Determining sources of water and contaminants to wells in a carbonate aquifer near Martinsburg, Blair County, Pennsylvania, by use of geochemical indicators, analysis of anthropogenic contaminants and simulation of ground-water flow: U.S. Geological Survey Scientific Investigations Report 2004-5124, 46 p. **(SIR 2004-5124)**

Lindsey, B.D., Phillips, S.W., Donnelly, C.A., Speiran, G.K., Plummer, L.N., Bohlke, J.K., Focazio, M.J., Burton, W.C., and Busenberg, Eurybiades, 2003, Residence times and nitrate transport in ground water discharging to streams in the Chesapeake Bay watershed: U.S. Geological Survey Water-Resources Investigations Report 03-4035, 201 p. **(WRIR 03-4035)**

Lindsey, B.D., Rasberry, J.S., and Zimmerman, T.M, 2002, Microbiological quality of water from noncommunity supply wells in carbonate and crystalline aquifers of Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 01-4268, 30 p. **(WRIR 01-4268)**

Loper, W.C., Behrendt, T.E., and Schaffstall, W.P., 1985, Water Resources Data Pennsylvania Water Year 1984, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-84-2, 327 p. **(PA 84-2)**

Loper, W.C., Behrendt, T.E., and Schaffstall, W.P., 1988, Water Resources Data Pennsylvania Water Year 1986, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-86-2, 330 p. **(PA 86-2)**

Loper, W.C., Behrendt, T.E., and Schaffstall, W.P., 1988, Water Resources Data Pennsylvania Water Year 1987, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-87-2, 322 p. **(87-2)**

Loper, W.C., Behrendt, T.E., and Schaffstall, W.P., 1989, Water Resources Data Pennsylvania Water Year 1988, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-88-2, 276 p. **(88-2)**

Loper, W.C., Behrendt, T.E., and Schaffstall, W.P., 1990, Water Resources Data Pennsylvania Water Year 1989, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-89-2, 289 p. **(89-2)**

Loper, W.C., Behrendt, T.E., Schaffstall, W.P., and Hainly, R.A., 1987, Water Resources Data Pennsylvania Water Year 1985, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-85-2, 361 p**. (PA 85-2)**

Loper, W.C., Durlin, R.R., and Schaffstall, W.P., 1991, Water Resources Data Pennsylvania Water Year 1991, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-90-2, 266 p. **(90-2)**

Low, D.J., and Conger, R.W., 2002, Ground-water availability in part of the Borough of Carroll Valley, Adams County, Pennsylvania, and the establishment of a drought-monitor well: U.S. Geological Survey Water-Resources Investigations Report 02-4273, 78 p. **(WRIR 02-4273)**

Low, D.J., Goode, D.J., and Risser, D.W, 2000, Hydrogeology and simulation of ground-water flow at the Gettysburg Elevator Plant Superfund Site Adams County, Pennsylvania: U.S. Geological Survey Open-File Report 00-185, 34 p. **(OFR 00-185)**

Low, D.J., Hippe, D.J., and Yannacci, Dawna, 2002, Geohydrology of southeastern Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 00-4166, 347 p. **(WRIR 00-4166)**

McAuley, S.D., 2003, MTBE concentrations in ground water in Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 03-4201, 44 p. **(WRIR 03-4201)**

McElroy, T.A., 1998, Groundwater resources of Cambria County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 67, 49 p**. (WRR 67)**

Moore, M.E., and Buckwalter, T.F., 1996, Ground-water resources data for Warren County, Pennsylvania: U.S. Geological Survey Open-File Report 94-87, 94 p. **(OFR 94-87)**

Paulachok, G.N., and Wood, C.R., 1988, Water resources of Oley Township, Berks County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 87-4065, 59 p. **(WRIR 87-4065)**

Paulachok, G.N., Wood, R.C., and Norton, L.J., 1984, Hydrologic data for aquifers in Philadelphia, Pennsylvania: U.S. Geological Survey Open-File Report 83-149, 104 p. **(OFR 83-149)**

Pennsylvania Department of Environmental Protection, 2005, eMapPA: accessed December 7, 2005, at http://www.emappa.dep.state.pa.us/emappa/viewer.htm

Reese, S.O. and Lee, J.J., 1998, Summary of groundwater quality monitoring data (1985-1997) from Pennsylvania's Ambient and Fixed Station Network (FSN) Monitoring Program—Selected groundwater basins in southwestern, southcentral, and southeastern Pennsylvania: Pennsylvania Department of Environmental Protection, Bureau of Water Supply Management, 32 p. plus Appendices. **(FSN)**

Richards, D.B., McCoy, H.J., and Gallaher, J.T., 1987, Groundwater resources of Erie County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 62, 101 p**. (WRR 62)**

Royer, D.W., 1983, Summary groundwater resources of Lebanon County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 55, 84 p. **(WRR 55)**

Royer, D.W., 1984, Summary groundwater resources of Perry County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 59, 70 p. **(WRR 59)**

Sams, III, J.I., Day, R.L., and Stiteler, J.M., 1998, Influence of land use and open-water wetlands on water quality in the Lake Wallenpaupack Basin, northeastern Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 98-4186, 56 p. **(WRIR 98-4186)**

Schreffler, C.L., McManus, B.C., and Rowland-Lesitsky, C.J., 1994, Hydrologic data for northern Bucks County, Pennsylvania: U.S. Geological Survey Open-File Report 94-381, 90 p. **(OFR 94-381)**

Senior, L.A., 1994, Geohydrology of, and nitrogen and chloride in, the glacial aquifer, Milford-Matamoras area, Pike County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 93-4109, 43 p. **(WRIR 93-4109)**

Senior, L.A., 1996, Ground-water quality and its relation to hydrogeology, land use, and surface-water quality in the Red Clay Creek Basin, Piedmont Physiographic Province, Pennsylvania and Delaware: U.S. Geological Survey Water-Resources Investigations Report 96-4288, 79 p. **(WRIR 96-4288)**

Senior, L.A., 1998, Radon-222 in the ground water of Chester County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 98-4169, 79 p. **(WRIR 98-4169)**

Senior, L.A., Sloto, R.A., and Reif, A.G., 1997, Hydrogeology and water quality of the West Valley Creek Basin, Chester County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 94-4137, 160 p. **(WRIR 94-4137)**

Senior, L.A., and Vogel, K.L., 1995, Radium and radon in ground water in the Chickies Quartzite, southeastern Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 92-4088, 145 p. **(WRIR 92-4088)**

Sevon, W.D., and Braun, D.D., 2000, Glacial deposits of Pennsylvania: Pennsylvania Topographic and Geologic Survey, 4th ser., Map 59, 1 p.

Siwicki, R.W., 2002, Water Resources Data Pennsylvania Water Year 2001, vol. 3, Ohio and St. Lawrence River Basins: U.S. Geological Survey Water-Data Report PA-01-3, 220 p**. (PA 01-3)**

Siwicki, R.W., 2003, Water Resources Data Pennsylvania Water Year 2002, vol. 3, Ohio and St. Lawrence River Basins: U.S. Geological Survey Water-Data Report PA-02-3, 285 p. **(PA 02-3)**

Siwicki, R.W., 2003, Water Resources Data Pennsylvania Water Year 2003, vol. 3, Ohio and St. Lawrence River Basins: U.S. Geological Survey Water-Data Report PA-01-3, 319 p. **(PA 03-3)**

Siwicki, R.W., 2005, Water Resources Data Pennsylvania Water Year 2004, vol. 3, Ohio and St. Lawrence River Basins: U.S. Geological Survey Water-Data Report PA-02-3, 337 p. **(PA 04-3)**

Siwiec, S.F., Hainly, R.A., Lindsey, B.D., Bilger, M.D., and Brightbill, R.A., 1997, Water-quality assessment of the Lower Susquehanna River Basin, Pennsylvania and Maryland—Design and implementation of water-quality studies, 1992-95: U.S. Geological Survey Open-File Report 97-583, 121 p. **(OFR 97-583)**

Sloto, R.A., 1987, Effect of urbanization on the water resources of Eastern Chester County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 87-4098, 131 p. **(WRIR 87-4098)**

Sloto, R.A., 1989, Selected ground-water data, Chester County, Pennsylvania: U.S. Geological Survey Open-File Report 87-217, 198 p. **(OFR 87-217)**

Sloto, R.A., 1994, Geology, hydrology, and ground-water quality of Chester County, Pennsylvania: Chester County Water Resources Authority, Water-Resource Report 2, 127 p. **(Chester Co. WRR2)**

Sloto, R.A., 2002, Geohydrology and ground-water quality, Big Elk Creek Basin, Chester County, Pennsylvania, and Cecil County, Maryland: U.S. Geological Survey Water-Resources Investigations Report 02-4057, 81 p. **(WRIR 02-4057)**

Sloto, R.A., and Davis, D.K., 1983, Effect of urbanization on the water resources of Warminster Township, Bucks County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations 82-4020, 72 p. **(WRIR 82-4020)**

Sloto, R.A., Macchiaroli, Paola, and Towle, M.T., 1996, Geohydrology of the Stockton Formation and cross-contamination through open boreholes, Hatboro Borough and Warminster Township, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 96-4047, 49 p. **(WRIR 96-4047)**

Sloto, R.A., and McManus B.C., 1996, Hydrogeology and ground-water quality of Valley Forge National Historical Park, Montgomery County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 96-4120, 35 p. **(WRIR 96-4120)**

Stoner, J.D., Williams, D.R., Buckwalter, T.F., Felbinger, J.K., and Pattison, K.L., 1987, Water resources and the effects of coal mining, Greene County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 63, 166 p. **(WRR 63)**

Taylor, L.E., 1984, Groundwater resources of the Upper Susquehanna River Basin, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 58, 136 p. **(WRR 58)**

Taylor, L.E., and Royer, D.W., 1981, Summary groundwater resources of Adams County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 52, 50 p. **(WRR 52)**

Taylor, L.E., and Werkheiser, W.H., 1984, Groundwater resources of the Lower Susquehanna River Basin, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 57, 130 p. **(WRR 57)**

Taylor, L.E., Werkheiser, W.H., DuPont, N.S., and Kriz, M.L., 1982, Groundwater resources of the Juniata River Basin, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 54, 131 p. **(WRR 54)**

Taylor, L.E., Werkheiser, W.H., and Kriz, M.L., 1983, Groundwater resources of the West Branch Susquehanna River Basin, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 56, 143 p. **(WRR 56)**

Ulanoski, J.T., Spangenberg, N.M., and Reese, S.O., 1997, Groundwater quality monitoring network—Ambient and Fixed Station Network (FSN) Monitoring Programs: Pennsylvania Department of Environmental Protection 391-3200-009/6/97, 87 p. **(FSN)**

Vogel, K.L., and Reif, A.G., 1993, Geohydrology and simulation of ground-water flow in the Red Clay Creek Basin, Chester County, Pennsylvania, and New Castle County, Delaware: U.S. Geological Survey Water-Resources Investigations Report 93-4055, 111 p. **(WRIR 93-4055)**

Unangst, Donald—Chairman, State RCWP Coordinating Committee, 1992, Conestoga Headwaters Project, Pennsylvania—Rural Clean Water Program 10-year report, 1981-1991: U.S. General Printing Office, 1992-624-121:60346, 329 p.

White, K.E., White, T.E., Druther, R.L., and Moleski, P., 1993, Water Resources Data Pennsylvania Water Year 1992, vol. 1, Delaware River Basin: U.S. Geological Survey Water-Data Report PA-92-1, 340 p. **(PA 92-1)**

Williams, D.R., Felbinger, J.K., and Squillace, P.J., 1993, Water resources and the hydrologic effects of coal mining in Washington County, Pennsylvania: U.S. Geological Survey Open-File Report 89-620, 226 p. **(OFR 89-620)**

Williams, D.R., and McElroy, T.A., 1991, Water resources data for Indiana County: U.S. Geological Survey Open-File Report 90-384, 147 p. **(OFR 90-384)**

Williams, D.R., and McElroy, T.A., 1997, Water resources of Indiana County: U.S. Geological Survey Water-Resources Investigations Report 95-4164, 105 p. **(WRIR 95-4164)**

Williams, J.H., and Eckhardt, D.A., 1987, Groundwater resources of the Berwick-Bloomsburg-Danville area, East-Central Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 61, 76 p. **(WRR 61)**

Williams, J.H., Taylor, L.E., and Low, D.J., 1998, Hydrogeology and groundwater quality of the glaciated valleys of Bradford, Tioga, and Potter Counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 68, 89 p. **(WRR 68)**

Zimmerman, T.M., Zimmerman, M.L., and Lindsey, B.D., 2002, Relation between selected well-construction characteristics and occurrence of bacteria in private household-supply wells, south-central and southeastern Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 01-4206. **(WRIR 01-4206)**

Appendix—Files of Comments, Data, and Map Images by Source

["Click" on filename in lists below to link to the file]

Borough of Carroll Valley

Comment Files	**Data Spreadsheet Files**	**Map Image Files**
Portable Document Format	Microsoft Excel Format	Portable Document Format
CV.Comments.Micro.pdf	CV.Micro.xls	Statewide_WellsCarrollValley.pdf
CV.Comments.Nuts.pdf	CV.Nuts.xls	
CV.Summary.pdf		

Chester County Health Department

Comment Files	**Data Spreadsheet Files**	**Map Image Files**
Portable Document Format	Microsoft Excel Format	Portable Document Format
CCDH.Comments.Field.pdf	CCDH.Field.xls	Statewide_WellsChesterCo.pdf
CCDH.Comments.Nuts.pdf	CCDH.Nuts.xls	
CCDH.Summary.pdf		

Pennsylvania Department of Environmental Protection Ambient and Fixed Station Network

Comment Files	**Data Spreadsheet Files**	**Map Image Files**
Portable Document Format	Microsoft Excel Format	Portable Document Format
FSN.Comments.Field.pdf	FSN.Field.xls	Statewide_WellsPaDEPFSN.pdf
FSN.Comments.Major.pdf	FSN.Major.xls	
FSN.Comments.Minor.pdf	FSN.Minor.xls	
FSN.Comments.Nuts.pdf	FSN.Nuts.xls	
FSN.Summary.pdf		

Montgomery County Health Department

Comment Files	**Data Spreadsheet Files**	**Map Image Files**
Portable Document Format	Microsoft Excel Format	Portable Document Format
MCHD.Comments.Micro.pdf	MCHD.Micro.xls	Statewide_WellsMontgomeryCo.pdf
MCHD.Comments.Field.pdf	MCHD.Field.xls	
MCHD.Comments.Major.pdf	MCHD.Major.xls	
MCHD.Comments.Minor.pdf	MCHD.Minor.xls	
MCHD.Comments.Nuts.pdf	MCHD.Nuts.xls	
MCHD.Comments.Voa.pdf	MCHD.Voa.xls	
MCHD.Comments.Waste.pdf	MCHD.Waste.xls	
MCHD.Summary.pdf		

Pennsylvania Drinking Water Information System

Comment Files	Data Spreadsheet Files	Map Image Files
Portable Document Format	Microsoft Excel Format	Portable Document Format
PADWIS.Comments.Micro.pdf	PADWIS.Micro.xls	Statewide_WellsPADWIS.pdf
PADWIS.Comments.Minor.pdf	PADWIS.Minor.xls	
PADWIS.Comments.Pest.pdf	PADWIS.Pest.xls	
PADWIS.Comments.Radio.pdf	PADWIS.Radio.xls	
PADWIS.Comments. Voa.pdf	PADWIS.Voa.xls	
PADWIS.Summary.pdf		

Pennsylvania Department of Agriculture

Comment Files	Data Spreadsheet Files	Map Image Files
Portable Document Format	Microsoft Excel Format	Portable Document Format
PennAg.Comments.Micro.pdf	PennAg.Micro.xls	Statewide_WellsPennAg.pdf
PennAg.Comments.Nuts.pdf	PennAg.Nuts.xls	
PennAg.Comments.Pest.pdf	PennAg.Pest.xls	
PennAg.Summary.pdf		

Susquehanna River Basin Commission

Comment Files	Data Spreadsheet Files	Map Image Files
Portable Document Format	Microsoft Excel Format	Portable Document Format
SRBC.Comments.Field.pdf	SRBC.Field.xls	Statewide_WellsSRBC.pdf
SRBC.Comments.Major.pdf	SRBC.Major.xls	
SRBC.Comments.Minor.pdf	SRBC.Minor.xls	
SRBC.Comments.Nuts.pdf	SRBC.Nuts.xls	
SRBC.Summary.pdf		

U.S. Geological Survey—Pennsylvania Water Science Center

Comment Files	Data Spreadsheet Files		Map Image Files
Portable Document Format	Microsoft Excel Format		Portable Document Format
USGS.Comments.Micro.pdf	USGS.Micro.xls	USGS.MicroReport.xls	Statewide_WellsUSGS.pdf
USGS.Comments.Field.pdf	USGS.Field.xls	USGS.FieldReport.xls	
USGS.Comments.Fungus.pdf	USGS.Fungus.xls	USGS.FungusReport.xls	
USGS.Comments.Herb.pdf	USGS.Herb.xls	USGS.HerbReport.xls	
USGS.Comments. Insec.pdf	USGS.Insec.xls	USGS.InsecReport.xls	
USGS.Comments.Major.pdf	USGS.Major.xls	USGS.MajorReport.xls	
USGS.Comments.Minor.pdf	USGS.Minor.xls	USGS.MinorReport.xls	
USGS.Comments.Nuts.pdf	USGS.Nuts.xls	USGS.NutsReport.xls	
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USGS.Comments.Voa.pdf	USGS.Voa.xls	USGS.VoaReport.xls	
USGS.Comments.Waste.pdf	USGS.Waste.xls	USGS.WasteReport.xls	
USGS.Summary.pdf	USGS.CrossReference Numbers.xls		

Pennsylvania Geology

Map Image Files
Portable Document Format
Statewide_Geology.pdf
Statewide_SurficialGeology.pdf

Pennsylvania Well Locations

Map Image Files
Portable Document Format
Statewide_Wells2.pdf

Pennsylvania Watersheds

Map Image Files
Portable Document Format
Statewide_Watershed.pdf
Basin1_Wells.pdf
Basin2_Wells.pdf
Basin3_Wells.pdf
Basin4_Wells.pdf
Basin5_Wells.pdf
Basin6_Wells.pdf
Basin7_Wells.pdf
Basin8_Wells.pdf
Basin9_Wells.pdf
Basin10_Wells.pdf
Basin11_Wells.pdf
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Basin33_Wells.pdf
Basin34_Wells.pdf
Basin35_Wells.pdf

Pennsylvania Watersheds and Nitrate Ranges

Map Image Files
Portable Document Format
Basin1_QWNO3.pdf
Basin2_QWNO3.pdf
Basin3_QWNO3.pdf
Basin4_QWNO3.pdf
Basin5_QWNO3.pdf
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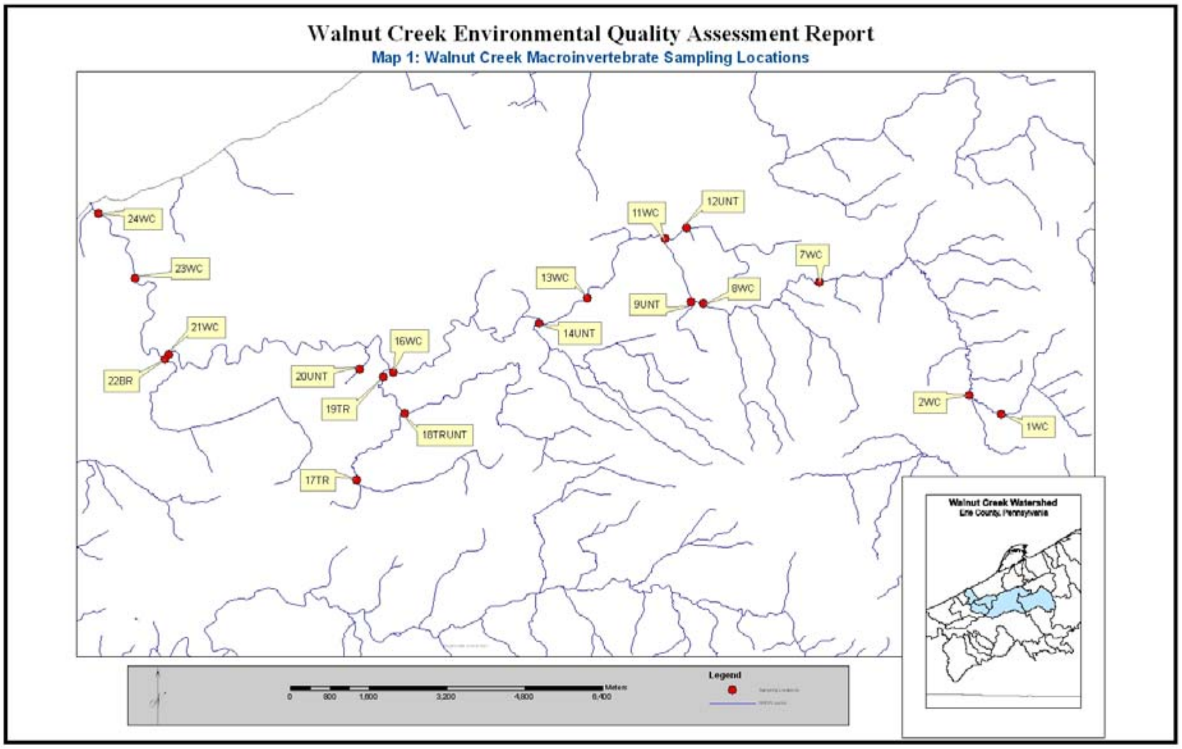
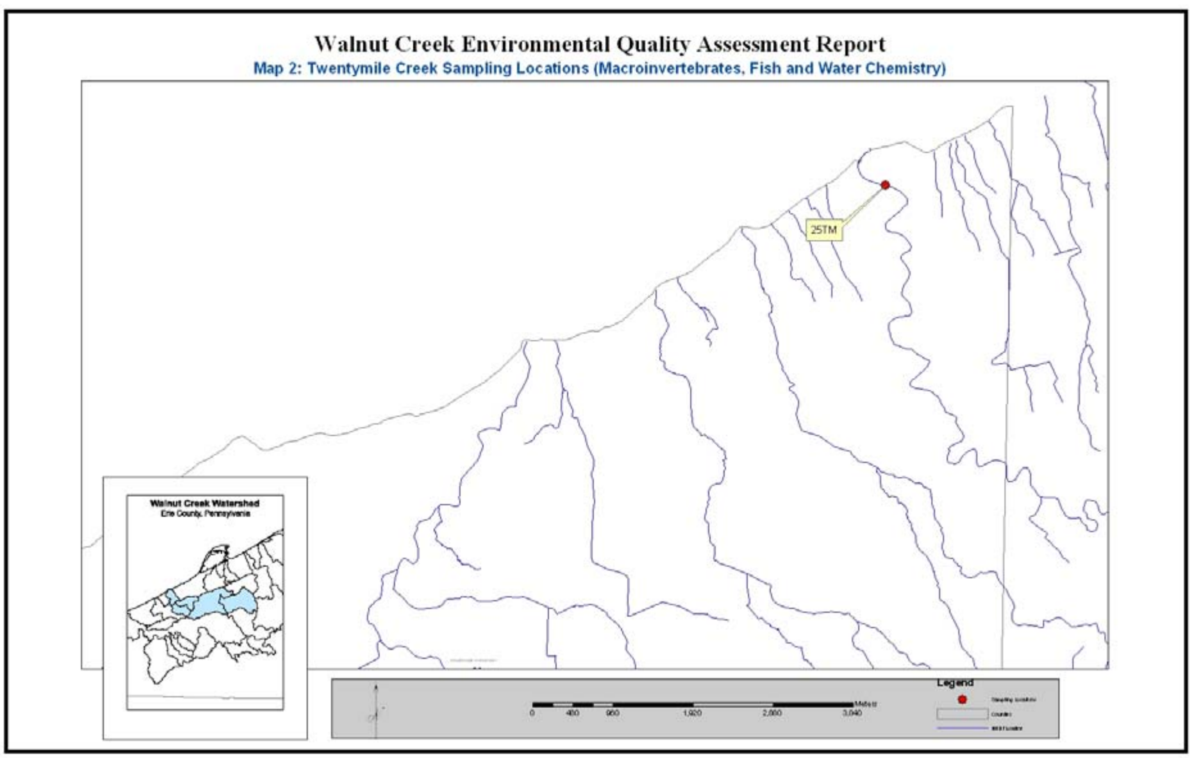
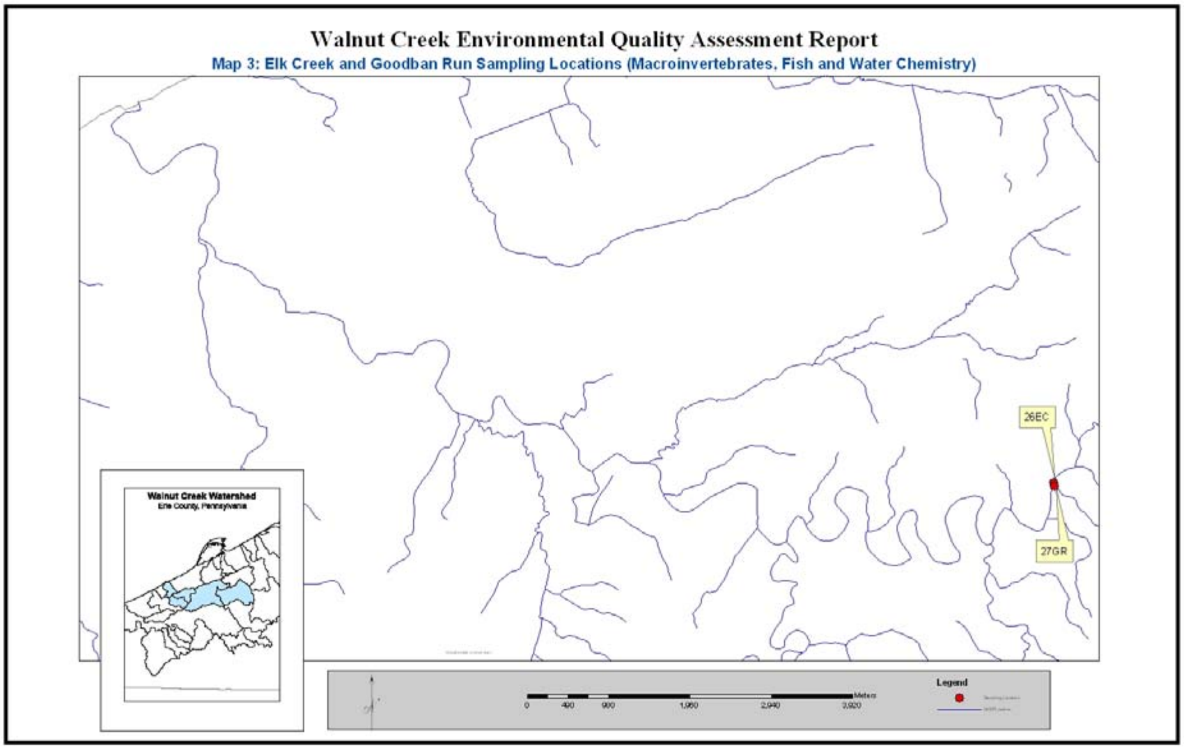
Basin35_QWNO3.pdf

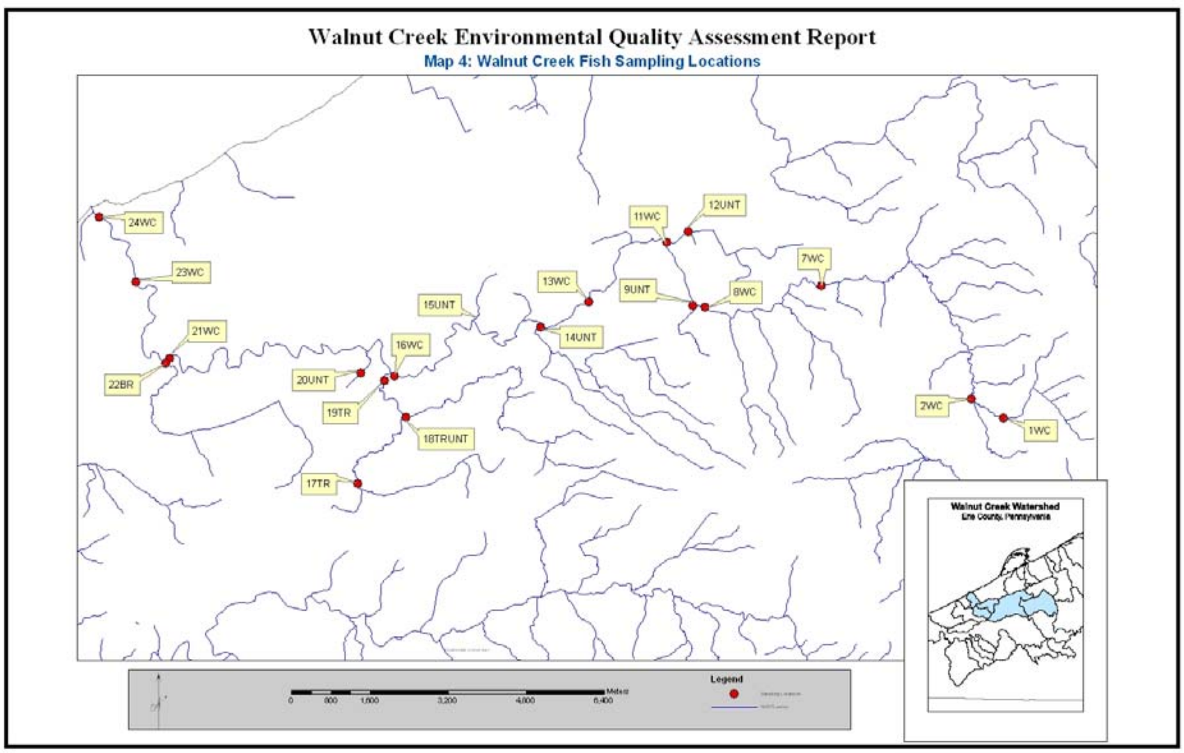
Pennsylvania Watersheds 17 and 18 Geology and Nitrate Ranges

Map Image Files
Portable Document Format
Basin17_QWNO3GEO.pdf
Basin18_QWNO3GEO.pdf


Walnut Creek Environmental Quality Assessment Report
Map 1: Walnut Creek Macroinvertebrate Sampling Locations
24WC
23WC
21WC
22BR
20UNT
16WC
19TR
18TRUNT
17TR
13WC
14UNT
11WC
12UNT
9UNT
8WC
7WC
2WC
1WC
Walnut Creek Watershed
Erie County, Pennsylvania
Legend
0
800
1,600
3,200
4,800
6,400
Meters

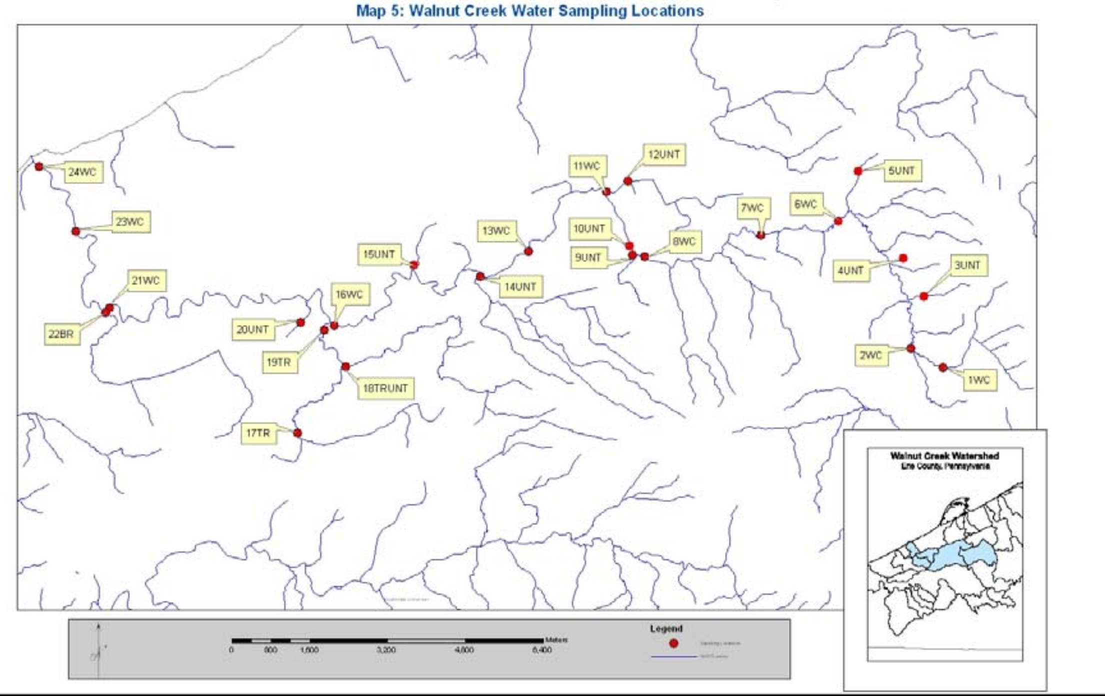

Walnut Creek Environmental Quality Assessment Report
Map 2: Twentymile Creek Sampling Locations (Macroinvertebrates, Fish and Water Chemistry)
25TM
Walnut Creek Watershed
Erie County, Pennsylvania
Legend
0
480
960
1,920
2,880
3,840
Meters


Walnut Creek Environmental Quality Assessment Report
Map 3: Elk Creek and Goodban Run Sampling Locations (Macroinvertebrates, Fish and Water Chemistry)
26EC
27GR
Walnut Creek Watershed
Erie County, Pennsylvania
0
490
980
1,960
2,940
3,920
Meters
Legend


Walnut Creek Environmental Quality Assessment Report
Map 4: Walnut Creek Fish Sampling Locations
24WC
23WC
21WC
22BR
20UNT
16WC
19TR
18TRUNT
17TR
15UNT
13WC
14UNT
11WC
12UNT
9UNT
8WC
7WC
2WC
1WC
Walnut Creek Watershed
Erie County, Pennsylvania
0
800
1,600
3,200
4,800
6,400
Meters
Legend

Walnut Creek Environmental Quality Assessment Report

Map 5: Walnut Creek Water Sampling Locations



STREAM ASSESSMENT DATA TABLES

Site #	Site Name	Drainage Area (m^2)	Latitude	Longitude
1 WC	Walnut Creek downstream of Donation Road bridge		42.0418	-80.0125
2 WC	Walnut Creek upstream of Zwilling Road bridge		42.0451	-80.0206
3 UNT	UNT Walnut Creek @ landfill (site #2)		42.0549	-80.0182
4 UNT	UNT Walnut Creek @ landfill (site #1)		42.0615	-80.0223
5 UNT	UNT Walnut Creek downstream of Footmill Road crossing		42.0775	-80.0341
6 WC	Walnut Creek downstream of Route 97/ Route 19 Interchange		42.0686	-80.0387
7 WC	Walnut Creek upstream of Cherry Street bridge		42.0654	-80.0584
8 WC	Walnut Creek at Glade Drive dead end		42.061	-80.0871
9 UNT	UNT Walnut Creek downstream of Peach Street		42.0612	-80.09
10 UNT	Drainage Pipe from Wegman's / Amish Buggy		42.0627	-80.0907
11 WC	Walnut Creek behind Millcreek Mall Cinemas		42.0728	-80.097
12 UNT	UNT Walnut Creek upstream of Peach Street		42.0749	-80.0917
13 WC	Walnut Creek upstream of Schermer Road bridge		42.0614	-80.1159
14 UNT	UNT Walnut Creek upstream of Garries Road bridge		42.0565	-80.1277
15 UNT	UNT Walnut Creek downstream of Loves Road bridge		42.0581	-80.1434
16 WC	Walnut Creek upstream of Thomas Run confluence		42.0469	-80.1635
17 TR	Thomas Run downstream of California Road bridge		42.0268	-80.172
18 TRUNT	UNT Thomas Run @ mouth		42.0392	-80.1604
19TR	Thomas Run - 1/4 mile upstream of mouth		42.046	-80.166
20 UNT	UNT Walnut Creek downstream of Asbury Park bridge		42.0473	-80.1719
21 WC	Walnut Creek upstream of Bear Run confluence		42.0491	-80.2193
22 BR	Bear Run @ mouth	3.31	42.0482	-80.2203
23 WC	Walnut Creek upstream of Route 5		42.063	-80.2281
24 WC	Walnut Creek @ mouth	38.1	42.0748	-80.2377
25 TM (REF)	Twentymile Creek @ mouth	34.7	42.2606	-79.7802
26 EC (REF)	Elk Creek upstream of Route 98		41.9861	-80.2362
27 GR (REF)	Goodban Run @ mouth	3.85	41.9857	-80.2361

Table 1. Walnut Creek watershed and reference waterway sampling locations.

TAXA	1WC	2WC	7WC	8WC	9UNT	11WC	12UNT	13WC	14UNT	16WC	17TR
Ephemeroptera (mayflies)											
Ameletidae; ***Ameletus***	5			2					3		
Baetidae; ***Acentrella***											
Baetis		64	2	24		6	1		36	5	86
Caenidae; ***Caenis***	43	9	25	1		5		1		1	1
Ephemerellidae; ***Ephemerella***	2										8
Eurylophella	7	15				1		1	4		18
Ephemeridae; ***Ephemera***			2								
Heptageniidae; ***Cinygmula***											
Epeorus	51	6							1		
Leucrocuta											
Stenacron	11			2					1	1	
Stenonema	4	9	7	4		5		2	1	3	
Isonychidae; ***Isonychia***	1					1					
Leptophlebidae; ***Paraleptophlebia***	141	4	1	7					10	1	38
Plecoptera (stoneflies)											
Chloroperlidae; ***Haploperla***	685	127	11	98		1		7	74	3	276
Sweltsa	14	6		4		7			7		
Leuctridae; ***Leuctra***	23	8	2	2				1	1		1
Nemouridae; ***Amphinemura***	20	11							1		14
Ostrocerca				1							
Prostoia	1	6									
Perlidae; ***Acroneuria***											
Agnetina									1		20
Neoperla											
Paragnetina											
Perlodidae; ***Diploperla***	41	5	4	4					4		1
Isoperla	11	1									29
Trichoptera (caddisflies)											
Hydropsychidae; ***Cheumatopsyche***	5	76	24	6		17		23	5	16	1
Diplectrona	25			3	9						
Hydropsyche	3	29	2	23	2	26		10	12	10	61
Lepidostomatidae; ***Lepidostoma***											
Limnephilidae; ***Pycnopsyche***		2									
Philopotamidae; ***Chimarra***	1	85	6			1		1	4		
Dolophilodes	2									2	
Wormaldia											
Polycentropodidae; ***Polycentropus***	1		2	17	1	2		8	8	2	1
Rhyacophilidae; ***Rhyacophila***	10	4	1						2		
Uenoidae; ***Neophylax***	23	6							1		7
Diptera (true flies)											
Ceratopogonidae; ***Bezzia***			3								19
Ceratopogon	1	1						1			
Probezzia	15	14	7	9	3	10	7	12	6	26	37
Serromyia											
Chironomidae	878	632	493	868	109	539	159	477	353	537	1648
Dolichopodidae									1		

Table 2. Total macroinvertebrate taxa list.

TAXA	1WC	2WC	7WC	8WC	9UNT	11WC	12UNT	13WC	14UNT	16WC	17TR
Empididae; ***Chelifera***	1						1	1		1	1
Clinocera			6	5					1		35
Hemerodromia	4	23				6		2	1		10
Ephydridae											2
Simuliidae; ***Prosimulium***	16	89									11
Simulium	64							6	2	2	21
Tabanidae									1	1	
Tipulidae; ***Antocha***	1	9	2	1		1	1	4		1	10
Dicranota	3		1						1	1	
Hexatoma	2			1					7		31
Molophilus		1				1					
Pseudolimnophila		2									
Tipula	1	3				2	1				
Coleoptera (aquatic beetles)											
Dytiscidae; ***Agabus***	6										
Elmidae; ***Dubiraphia***	3	1									2
Optioservus	3	145							5		77
Oulimnius											
Stenelmis		70	93	1		83	11	159		13	126
Gyrinidae; ***Dineutus***	2										
Haliplidae; ***Peltodytes***	3										
Hydrophilidae; ***Helophorus***							1				
Psephenidae; ***Ectopria***	1										1
Psephenus	8	36	8	2		16		22	7	3	25
Ptilodactylidae; ***Anchytarsus***				1							
Megaloptera (alderflies, dobsonflies)											
Corydalidae; ***Nigronia***											
Sialidae; ***Sialis***		1									
Odonata (dragonflies, damselflies)											
Macromiidae; ***Macromia***	1										
Calopterygidae; ***Calopteryx***	3										
Non-Insect Taxa											
Oligochaeta (aquatic worms)	4	14	20	5	18	22	41	57		23	2
Hydracarina (aquatic mites)		1				1					
Planariidae (flatworms)	1				3			16		1	7
Cambaridae (crayfish)	1	1									
Nematomorpha (horsehair worms)		1									
Hirundinea (leeches)							2	1			
Amphipoda (freshwater shrimp)											
Crangonyctidae; ***Crangonyx***				1		6		3		1	
Gammaridae; ***Gammarus***								1			
Talitridae; ***Hyalella***	2										
Isopoda (scuds or sowbugs)											
Asellidae; ***Caecidotea***			2	1							
Gastropoda (snails, limpets)											
Ancylidae		2	1								
Physidae							2				
Planorbidae					2		2				

Table 2. Total macroinvertebrate taxa list, continued.

TAXA	18TRUNT	19TR	20UNT	21WC	22BR	23WC	24WC	25TM	26EC	27GR
Ephemeroptera (mayflies)										
Ameletidae; ***Ameletus***										27
Baetidae; ***Acentrella***								9	10	65
Baetis	81	61		1	355	7		13	6	480
Caenidae; ***Caenis***						1		2	17	1
Ephemerellidae; ***Ephemerella***					2			13		1
Eurylophella	1				1			1		3
Ephemeridae; ***Ephemera***										
Heptageniidae; ***Cinygmula***								8		
Epeorus								10	13	2447
Leucrocuta								8		
Stenacron				1			1		4	
Stenonema					1	4		8	25	
Isonychidae; ***Isonychia***								2	1	
Leptophlebidae; ***Paraleptophlebia***	1	4		1	183		1	70		40
Plecoptera (stoneflies)										
Chloroperlidae; ***Haploperla***		137		8	1054	1	4	24	5	101
Sweltsa	20							2		11
Leuctridae; ***Leuctra***	1	1						1		10
Nemouridae; ***Amphinemura***	1	1			38	6		5	12	208
Ostrocerca										
Prostoia										3
Perlidae; ***Acroneuria***										1
Agnetina	3	7			17	2				
Neoperla								11		
Paragnetina								5		
Perlodidae; ***Diploperla***					1				1	6
Isoperla	1	10			68	1			2	33
Trichoptera (caddisflies)										
Hydropsychidae; ***Cheumatopsyche***		3		4	2	14	1	30	46	
Diplectrona					7					6
Hydropsyche	11	10		2	18	9	1	49	14	12
Lepidostomatidae; ***Lepidostoma***										1
Limnephilidae; ***Pycnopsyche***										
Philopotamidae; ***Chimarra***									39	
Dolophilodes					7			4		14
Wormaldia						1			2	5
Polycentropodidae; ***Polycentropus***	1			1				3		1
Rhyacophilidae; ***Rhyacophila***	1				3					1
Uenoidae; ***Neophylax***								2		1
Diptera (true flies)										
Ceratopogonidae; ***Bezzia***									3	
Ceratopogon										
Probezzia	18	19		9	2	9	5	3	22	3
Serromyia										1
Chironomidae	1040	471	1349	179	226	423	67	234	286	334
Dolichopodidae										
Empididae; ***Chelifera***	1	2			1					2

Table 2. Total macroinvertebrate taxa list, continued.

TAXA	18TRUNT	19TR	20UNT	21WC	22BR	23WC	24WC	25TM	26EC	27GR
Clinocera										
Hemerodromia	3	24		1	6			6	1	1
Ephydridae										
Simuliidae; ***Prosimulium***	12	8						7		172
Simulium	2	18			3	15		12	168	121
Tabanidae	2								1	
Tipulidae; ***Antocha***	2	1			2					
Dicranota		3			2				1	
Hexatoma	7	13			4			2		1
Molophilus		2			3					
Pseudolimnophila										
Tipula	1	4			1		1			
Coleoptera (aquatic beetles)										
Dytiscidae; ***Agabus***										
Elmidae; ***Dubiraphia***	2									
Optioservus	19	17			14	2	1	3	2	
Oulimnius					6					
Stenelmis	32	4		3		10	2		97	
Gyrinidae; ***Dineutus***										
Haliplidae; ***Peltodytes***										
Hydrophilidae; ***Helophorus***										
Psephenidae; ***Ectopria***		1								
Psephenus	3					1		2	24	1
Ptilodactylidae; ***Anchytarsus***										
Megaloptera (alderflies, dobsonflies)										
Corydalidae; ***Nigronia***	1									
Sialidae; ***Sialis***										
Odonata (dragonflies, damselflies)										
Macromiidae; ***Macromia***										
Calopterygidae; ***Calopteryx***										
Non-Insect Taxa										
Oligochaeta (aquatic worms)	6	4	826	3	17					5
Hydracarina (aquatic mites)	3	3			3					
Planariidae (flatworms)			39							
Cambaridae (crayfish)	1				1					
Nematomorpha (horsehair worms)	1	1								
Hirundinea (leeches)										
Amphipoda (freshwater shrimp)										
Crangonyctidae; ***Crangonyx***			37	1						2
Gammaridae; ***Gammarus***										
Talitridae; ***Hyalella***										
Isopoda (scuds or sowbugs)										
Asellidae; ***Caecidotea***					2					
Gastropoda (snails, limpets)										
Ancylidae										1
Physidae										
Planorbidae										

Table 2. Total macroinvertebrate taxa list, continued.

Table 3.
Rapid Bioassessment Protocol (RBP III) – Benthic Macroinvertebrate Metric Analysis

Metric	Biological 6	Condition 4	Scoring 2	Criteria 0
1. Taxa Richness[a]	>80%	60-80%	40-60%	<40%
2. Hilsenhoff Biotic Index (modified)[b]	>85%	70-85%	50-70%	<50%
3. Ratio EPT and Chironomid Abundances[a]	>75%	50-75%	25-50%	<25%
4. EPT Index[a]	>90%	80-90%	70-80%	<70%
5. Community Loss Index[c]	<0.5	0.5 – 1.5	1.5 – 4.0	>4.0

(a) Score is a ratio of study site to reference site x 100.
(b) Score is a ratio of reference site to study site x 100.
(c) Range of values obtained. A comparison to the reference station is incorporated in these indices.

Criteria for Characterization of Biological Condition for RBP III

% Comparison to Reference Score[a]	Biological Condition Category	Attributes
>83%	Non-Impaired	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for stream size and habitat quality.
54-79%	Slightly Impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
21-50%	Moderately Impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
<17%	Severely Impaired	Few species present. If high densities of organisms, then dominated by one or two taxa.

a) Percentage values obtained that are intermediate to the above ranges will require subjective judgment as to the correct placement. Use of the habitat assessment and physiochemical data may be necessary to aid in the decision process.

TAXA	7WC	8WC	11WC	13WC	16WC	21WC	23WC	24WC	25TM
Taxa Richness	24	26	22	23	22	13	16	10	30
Total # Individuals (sample size)	732	1093	759	816	654	214	506	84	549
Hilsenhoff Biotic Index (HBI)	5.74	5.32	5.82	5.99	6.02	5.77	5.85	5.55	4.25
Number (#) of EPT	8	10	6	5	5	3	6	3	17
Percent (%) EPT	5.6	11.6	2.1	1.5	1.5	4.7	3	7.1	33.3
% Dominant	67.3	79.4	71	58.5	82.1	83.6	83.6	79.8	42.6
Shannon Diversity	1.37	0.95	1.24	1.47	0.89	0.79	0.83	0.9	2.26
# Intolerant Taxa (<6)	13	17	13	11	11	6	10	7	22
# Mayflies	3	4	3	2	3	2	1	2	9
% Mayflies	1.4	1.4	0.9	0.4	0.8	0.9	0.8	2.4	23.5
# Stoneflies	3	5	2	2	1	1	4	1	6
% Stoneflies	3.3	10	1.1	1	0.5	3.7	2	4.8	8.7
% Shredders	0.3	0.4	0.4	0.1	0	0	1.2	1.2	1.1
% Filterer/Collectors	4.6	4.5	6.1	5.9	4.9	3.3	7.7	2.4	19.1
% Scrapers	14.9	0.8	13.8	22.5	3.1	1.9	3.4	4.8	7.8
% Predators	5.5	11.1	3.3	4.9	4.9	8.4	2.6	10.7	9.7
% Collector/Gatherers	74.7	83.3	76.4	66.5	87	86.4	85.2	81	62.3
Biological Condition Score vs 25TM	8	14	12	12	12	8	10	6	30
% Comparability to Reference vs 25TM	27%	47%	40%	40%	40%	27%	33%	20%	Reference
Biological Condition Category vs 25TM	Moderately Impaired	Moderately Impaired	Moderately Impaired	Moderately Impaired	Moderately Impaired	Moderately Impaired	Moderately Impaired	Moderately Impaired	Reference

Table 4. Macroinvertebrate community comparisons: Walnut Creek main stem sampling locations vs. Twentymile Creek sampling locations.

TAXA	7WC	8WC	11WC	13WC	16WC	21WC	23WC	24WC	26EC
Taxa Richness	24	26	22	23	22	13	16	10	25
Total # Individuals (sample size)	732	1093	759	816	654	214	506	84	802
Hilsenhoff Biotic Index (HBI)	5.74	5.32	5.82	5.99	6.02	5.77	5.85	5.55	5.37
Number (#) of EPT	8	10	6	5	5	3	6	3	11
Percent (%) EPT	5.6	11.6	2.1	1.5	1.5	4.7	3	7.1	14.2
% Dominant	67.3	79.4	71	58.5	82.1	83.6	83.6	79.8	35.7
Shannon Diversity	1.37	0.95	1.24	1.47	0.89	0.79	0.83	0.9	2.11
# Intolerant Taxa (<6)	13	17	13	11	11	6	10	7	17
# Mayflies	3	4	3	2	3	2	1	2	5
% Mayflies	1.4	1.4	0.9	0.4	0.8	0.9	0.8	2.4	6.6
# Stoneflies	3	5	2	2	1	1	4	1	4
% Stoneflies	3.3	10	1.1	1	0.5	3.7	2	4.8	2.5
% Shredders	0.3	0.4	0.4	0.1	0	0	1.2	1.2	1.5
% Filterer/Collectors	4.6	4.5	6.1	5.9	4.9	3.3	7.7	2.4	33.5
% Scrapers	14.9	0.8	13.8	22.5	3.1	1.9	3.4	4.8	21.8
% Predators	5.5	11.1	3.3	4.9	4.9	8.4	2.6	10.7	4.5
% Collector/Gatherers	74.7	83.3	76.4	66.5	87	86.4	85.2	81	38.7
Biological Condition Score vs 26EC	20	24	16	16	16	12	14	10	30
% Comparability to Reference *vs 26EC*	67%	80%	53%	53%	53%	40%	47%	33%	Reference
Biological Condition Category vs 26EC	Slightly Impaired	Non-Impaired	Slightly Impaired	Slightly Impaired	Slightly Impaired	Moderately Impaired	Moderately Impaired	Moderately Impaired	Reference

Table 5. Macroinvertebrate community comparisons: Walnut Creek main stem sampling locations vs. Elk Creek sampling locations.

TAXA	1WC	2WC	9UNT	12UNT	14UNT	17TR	18TRUNT	19TR	20UNT	22BR	27GR
Taxa Richness	48	38	8	12	30	33	30	26	4	31	36
Total # Individuals (sample size)	2154	1519	147	229	561	2628	1278	829	2251	2050	4122
Hilsenhoff Biotic Index (HBI)	3.19	4.66	6.17	6.68	4.77	4.95	5.76	4.73	7.49	2.18	1.74
Number (#) of EPT	20	15	1	0	15	10	8	6	0	12	20
Percent (%) EPT	50	19.4	6.1	0	20.5	15.7	2.3	19.3	0	67.4	72.4
% Dominant	40.8	41.6	74.1	69.4	62.9	62.7	81.4	56.8	59.9	51.4	59.4
Shannon Diversity	1.88	2.28	0.96	1.06	1.56	1.63	0.93	1.65	0.81	1.63	1.57
# Intolerant Taxa (<6)	33	24	2	4	21	18	17	16	1	20	25
# Mayflies	8	4	0	0	6	3	2	1	0	4	6
% Mayflies	10.3	2.2	0	0	3.6	2.4	0.2	0.5	0	9.1	62.7
# Stoneflies	7	7	0	0	6	6	5	5	0	5	8
% Stoneflies	36.9	10.8	0	0	15.7	13	2	18.8	0	57.5	9
% Shredders	2.2	2	0	0.9	0.4	0.6	0.2	1	0	2	5.4
% Filterer/Collectors	5.4	18.4	8.2	0	5.5	3.6	2	4.7	0	1.8	8
% Scrapers	5.2	19.1	1.4	6.6	3.6	9.8	4.5	2.7	0	1.1	61.1
% Predators	37.1	12.2	4.1	4.4	18.7	17.7	4.5	26.3	1.7	56.6	3.9
% Collector/Gatherers	50	48.3	86.4	88.2	71.7	68.2	88.6	65.4	98.3	38.4	21.6
Biological Condition Score vs 27GR	20	14	2	2	12	12	10	8	0	18	30
% Comparability to Reference vs 27GR	67%	47%	7%	7%	40%	40%	33%	27%	0%	60%	Reference
Biological Condition Category vs 27GR	Slightly Impaired	Moderately Impaired	Severely Impaired	Severely Impaired	Moderately Impaired	Moderately Impaired	Moderately Impaired	Moderately Impaired	Severely Impaired	Slightly Impaired	Reference

Table 6. Macroinvertebrate community comparisons: Walnut Creek tributaries and headwater sampling locations vs. Goodban Run sampling locations.

TAXA	1WC	2WC	7WC	8WC	11WC	13WC	16WC	21WC	23WC	24WC
Taxa Richness	48	38	24	26	22	23	22	13	16	10
Total # Individuals (sample size)	2154	1519	732	1093	759	816	654	214	506	84
Hilsenhoff Biotic Index (HBI)	3.19	4.66	5.74	5.32	5.82	5.99	6.02	5.77	5.85	5.55
Number (#) of EPT	20	15	8	10	6	5	5	3	6	3
Percent (%) EPT	50	19.4	5.6	11.6	2.1	1.5	1.5	4.7	3	7.1
% Dominant	40.8	41.6	67.3	79.4	71	58.5	82.1	83.6	83.6	79.8
Shannon Diversity	1.88	2.28	1.37	0.95	1.24	1.47	0.89	0.79	0.83	0.9
# Intolerant Taxa (<6)	33	24	13	17	13	11	11	6	10	7
# Mayflies	8	4	3	4	3	2	3	2	1	2
% Mayflies	10.3	2.2	1.4	1.4	0.9	0.4	0.8	0.9	0.8	2.4
# Stoneflies	7	7	3	5	2	2	1	1	4	1
% Stoneflies	36.9	10.8	3.3	10	1.1	1	0.5	3.7	2	4.8
% Shredders	2.2	2	0.3	0.4	0.4	0.1	0	0	1.2	1.2
% Filterer/Collectors	5.4	18.4	4.6	4.5	6.1	5.9	4.9	3.3	7.7	2.4
% Scrapers	5.2	19.1	14.9	0.8	13.8	22.5	3.1	1.9	3.4	4.8
% Predators	37.1	12.2	5.5	11.1	3.3	4.9	4.9	8.4	2.6	10.7
% Collector/Gatherers	50	48.3	74.7	83.3	76.4	66.5	87	86.4	85.2	81

Table 7. Macroinvertebrate community comparisons within the Walnut Creek watershed sampling locations.

Fish Species	1 WC	2 WC	7 WC	8 WC	9 UNT	11 WC	12 UNT	13 WC	14 UNT	15 UNT	16 WC	17 TR	18 TR UNT	19 TR	20 UNT	21 WC	22 BR	23 WC	24 WC	25 TM	26 EC	27 GR
Rainbow Trout (***Onchorhynchus mykiss)***(stocked smolts)				R+		R+		C	C					P	P		P	P	P	C	R+	P
Rainbow Trout (wild steelhead) (< 100 mm in length)									C	R+				C			A	C	C	A	P	C
Brown Trout ***(Salmo trutta)*** (Lake Run)																		R	P	R		
Brown Trout ***(Salmo trutta)*** (Wild-Reproducing)																	P					
Creek Chub ***(Semotilus atromaculatus)***	VA	C	C	A		C	A	A	P	P	A	C	A	C		A	P	P	C	C	C	C
River Chub ***(Nocomis micropogon)***							R				P					R		C	P	C	P	
Blacknose Dace ***(Rhinichthys atratulus)***	VA	C	A	A		VA	A	A	C	C	C	A	C	C		A	C	C	C	P	C	VA
Longnose Dace ***(Rhinichthys cataractae)***			P	A		C		P	P+				P+	C		C	P+	C	P+	C	C	
Redside Dace ***(Clinostomus elongatus)***		C	C			C	C															
Central Stoneroller ***(Campostoma anomalum)***		P	A	VA		VA	P	A	C	C	VA		A	C		VA	P	VA	VA	C	VA	VA
Northern Hog Sucker ***(Hypentelium nigricans)***		P	P			C		P			P+		P	P+		A		C	P	P	P	R
White Sucker ***(Catostomus commersoni)***		P+	C	P		C	P	P+	P		P		P	P+		P		P	C	P	P	C
Common Shiner ***(Notropis cornutus)***		C	P+			A		A	P		C		P	P+		A		C	P	P	C	P
Rainbow Darter ***(Etheostoma caeruleum)***	R	C	P+			A		C	A	P	VA		P+	C		P+	P	A	A	A	VA	C
Banded Darter ***(Etheostoma zonale)***																		P				
Fantail Darter ***(Etheostoma flabellare)***		P	C	P		P+		R	R	R			R	R+		P		P	P	C	P	
Johnny Darter ***(Etheostoma nigrium)***		P	R																			
Mottled Sculpin ***(Cottus bairdi)***		P	P			R		C	P	P	P	C	P	R+			C	R	R	R		
Stonecat ***(Notorus flavus)***											R							C	P	P	P	
Smallmouth Bass (yoy) ***(Micropterus dolomieu)***																			R	P	C	
Largemouth Bass (yoy) ***(Micropterus salmoides)***												R	P						R			
Yellow Perch ***(Perca flavescens)***																					R	P
Log Perch ***(Percina caprodes)***																			P			
Pumpkinseed ***(Lepomis gibbosus)***									R	R				R					P		P	P
Bluegill ***(Lepomis macrochirus)***				R			R	R+	P	P	R+							R	P	R+	P	P
Round Goby ***(Neogobius melanostomus)***																			C	P		
Total Number of Species*	**3**	**11**	**12**	**7**	**0**	**11**	**7**	**11**	**12**	**9**	**11**	**4**	**11**	**12**	**0**	**10**	**8**	**16**	**20**	**17**	**16**	**11**

* excludes stocked steelhead smolts

Table 8. General abundance of fish species collected in the Walnut Creek Watershed in 2006. Abundance estimates: Very Abundant (>100 individuals); Abundant (26-99 individuals); Common (10-25 individuals); Present (3-9 individuals); Rare (<3 individuals).

Habitat Parameter	27GR	1WC	2WC	7WC	9UNT	12UNT	14UNT	17TR	18 TRUNT	19TR	20UNT	22BR
Instream Cover (fish)	15	15	16	**10**	**9**	**6**	14	12	14	12	14	14
Epifaunal Substrate	16	15	15	**8**	**9**	**7**	16	12	13	**9**	12	13
Embeddedness	15	12	15	**10**	11	**4**	16	12	12	11	**10**	12
Velocity/Depth Regimes	16	14	14	11	13	11	16	15	15	15	15	18
Channel Alteration	15	15	16	15	**7**	**7**	20	15	20	20	11	19
Sediment Deposition	13	12	13	9	11	**5**	14	**10**	13	11	11	12
Frequency of Riffles	16	16	13	9	12	**6**	16	15	16	12	15	15
Channel Flow Status	**10**	12	16	15	11	13	11	16	16	11	15	14
Condition of Banks	11	**10**	11	13	**6**	**2**	13	11	11	**6**	12	**8**
Bank Vegetative Protection	18	13	16	14	11	**2**	19	**10**	16	18	15	16
Grazing or Other Disruptive Pressures	18	13	16	17	12	**2**	19	**9**	16	18	13	16
Riparian Vegetative Zone Width	12	12	12	14	**6**	**1**	19	**10**	16	15	**10**	16
Total Score (possible of 240)	175	159	173	145	118	66	193	147	176	158	153	178
Overall Habitat Rating	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Marginal	Poor	Optimal	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal
Percent Comparability to Reference Station	Reference	90.9%	98.9%	82.9%	67.4%	37.7%	>100%	84%	>100%	90.3%	87.4%	>100%

Table 9. Habitat assessment summary scores for tributary streams in the Walnut Creek Watershed. Station 27GR was used as the comparative reference station. Individual scores in the “marginal” and “poor” categories are listed in bold.

Habitat Parameter	25TM	26EC	8WC	11WC	13WC	16WC	21WC	23WC	24WC
Instream Cover (fish)	13	12	15	15	13	13	13	13	12
Epifaunal Substrate	13	**9**	15	15	12	12	**9**	11	**10**
Embeddedness	13	12	13	13	11	12	11	11	**10**
Velocity/Depth Regimes	15	15	14	17	15	13	18	15	14
Channel Alteration	14	17	16	13	15	16	19	16	**7**
Sediment Deposition	16	12	12	11	12	13	11	12	12
Frequency of Riffles	16	16	15	16	15	16	15	12	15
Channel Flow Status	14	12	14	12	13	12	18	11	15
Condition of Banks	**10**	15	**8**	**8**	**7**	11	**5**	**8**	**6**
Bank Vegetative Protection	12	**8**	12	**8**	14	17	12	13	**7**
Grazing or Other Disruptive Pressures	15	12	12	11	15	18	15	13	14
Riparian Vegetative Zone Width	12	12	11	**7**	12	16	15	12	**3**
Total Score (possible of 240)	162	164	157	146	154	169	161	147	125
Overall Habitat Rating	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Marginal
Percent Comparability to Reference Station	Reference	Reference	96.3%	89.5%	94.5%	>100%	98.8%	90.2%	76.7%

Table 10. Habitat assessment summary scores for the main stem of Walnut Creek. Stations 25TM and 26EC were used as comparative reference stations. Individual scores in the "marginal" and "poor" categories are listed in bold.

Station	Bedrock	Boulder (>256mm/10in)	Cobble **(64-256mm/2.5-10in)**	Gravel (2-64mm/0.1-2.5in)	Sand (0.06-2mm/gritty)	Silt (0.004-0.06mm)
27GR (reference)	0	15	42	26	10	7
1WC	0	5	40	25	22	8
2WC	0	2	40	25	25	8
7WC	0	15	25	20	25	15
9UNT	45	5	20	10	15	5
12UNT	0	0	10	25	35	30
14UNT	10	5	35	25	15	10
17TR	0	0	35	30	10	25
18TRUNT	35	0	25	10	10	20
19TR	55	1	10	9	10	15
20UNT	0	0	35	35	15	15
22BR	30	25	5	17	18	5
25TM (reference)	25	5	30	15	10	15
26EC (reference)	35	2	26	12	17	8
8WC	25	10	30	11	10	14
11WC	5	1	40	19	10	25
13WC	25	8	30	10	12	15
16WC	50	2	17	10	5	15
21WC	45	5	14	14	16	6
23WC	45	1	20	14	10	10
24WC	30	7	27	10	11	15

Table 11. Percentage of substrate types for each benthic macroinvertebrate station assessed in the Walnut Creek Watershed. Diameter of each specific particle size is listed in parenthesis (%).

Water Quality Parameters	1WC		2WC		3UNT		4UNT		5UNT		6WC		7WC		8WC		9UNT		10UNT	
	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold
Field Parameters																				
pH	7.08	-	7.93	-	8.38	-	7.24	-	7.3	-	7.45	-	7.47	-	7.82	-	7.93	-	7.64	-
Temperature (degrees C)	7.62	-	11.5	-	17.1	-	14.1	-	14.4	-	12	-	8.79	-	11	-	10.6	-	10.1	-
Alkalinity (mg/l)	40	-	68	-	150	-	140	-	75	-	130	-	100	-	120	-	125	-	80	-
Conductivity (umhos/cm)	82	-	162	-	303	-	741	-	321	-	326	-	275	-	322	-	1264	-	2709	-
Dissolved Oxygen (mg/l)	12.6	-	13.8	-	9.18	-	9.18	-	11.9	-	10.1	-	11.4	-	11.1	-	11.1	-	10.7	-
Dissolved Oxygen (%)	106	-	127	-	89.3	-	89.3	-	117	-	94	-	97.9	-	100	-	100	-	95.6	-
Laboratory Parameters																				
Fecal Coliforms (colonies/100 ml)	<20	1700	20	13000	20	3200	20	43000	140	12000	20	10000	100	2100	20	580	10	3100	20	360
pH	8	7.4	8.1	7.9	8.4	7.9	7.9	7.9	7.6	7.5	7.9	8	8	7.9	8.4	7.6	8.3	7.5	8	7.1
Alkalinity (mg/l)	45	64	92	97	100	124	118	119	63	59	107	98	106	125	92	51	189	35	271	10
Sulfate (mg/l)	13	15	12	12	102	90	69	73	17	15	21	34	22	22	23	15	90	13	23	6
Residue, Total (mg/l)	98	446	178	254	334	564	660	1404	262	344	310	1612	300	456	290	314	176	552	2544	136
Settlable Solids (ml/l)	<0.2	0.4	<0.2	0.4	<0.2	<0.2	<0.2	1.2	<0.2	1.2	<0.2	<0.80	<0.2	1.2	<0.2	0.8	<0.2	0.8	<0.2	0.4
Suspended Solids T (mg/l)	<2	254	<2	28	2	236	28	360	4	124	58	1236	12	118	<2	128	10	264	8	68
Nitrite-N (mg/l)	0.01	0.03	0.01	<0.01	<0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	<0.01	<0.01	0.01	<0.01	0.02	<0.01	<0.01
Nitrate-N (mg/l)	0.19	0.78	0.12	0.36	<0.04	0.58	0.11	0.26	0.06	0.3	0.07	0.42	0.06	0.1	<0.04	0.45	0.5	0.44	0.87	0.24
Nitrogen T (mg/l)	0.43	2.34	0.31	0.81	0.31	1.34	0.71	1.59	0.33	1.6	0.35	1.68	0.24	0.72	0.14	1.32	0.64	2.1	1.03	0.85
Total Organic Carbon TOC (mg/l)	2.9	6.87	3.1	15.7	4.39	15	7.25	7.25	5.19	16.6	3.5	16	3.42	6.88	3.03	9.57	2.35	11.6	1.54	5.07
Ammonia-N (mg/l)	<0.02	0.12	<0.02	0.1	<0.02	0.05	0.06	0.06	0.05	0.17	0.05	0.28	0.03	0.05	<0.02	0.24	<0.02	0.37	0.03	0.35
SPC @ 25 C (umhos/cm)	147	211	302	355	456	487	1052	1167	408	351	431	475	453	518	478	413	2370	328	3630	79
TDS @ 105 C (mg/l)	98	192	178	226	332	328	632	1044	258	220	252	376	288	338	290	230	1746	288	2536	68
Hardness T (mg/l)	58	82	112	126	203	218	254	320	95	96	142	226	143	168	129	95	535	93	528	23
Phosphorus T (mg/l)	0.05	0.53	0.02	0.075	0.02	0.116	0.04	0.308	0.03	0.185	0.03	0.504	0.02	0.11	0.01	0.132	<0.01	0.325	<0.01	0.076
Chloride (mg/l)	8	13.6	32.6	45.5	21.2	25.4	234	286.3	79.6	63.2	58.9	75.5	68	78.4	82.6	84.9	656	71.8	978	11.5
COD (mg/l)	23.8	37.1	24.1	33.4	25.9	67.5	25.4	56.9	20.2	55.6	19.1	54.9	28.4	24.6	16.6	41.9	32.9	38.1	37	22.1
BOD5 Inhib (mg/l)	0.66	10.9	0.69	3.3	1.4	10.4	0.82	10.3	0.68	13.8	0.84	6.8	0.7	3.9	0.45	10.6	0.46	11.3	<0.20	5.5
Turbidity (NTU)	3.43	119	1.62	34.45	2.72	65.7	9.44	494.5	2.23	76.6	16.7	1062	9.19	59.9	1.28	106.8	2.03	123.2	6.52	47.6
Iron T (ug/l)	172	5029	378	1797	172	3660	791	18600	376	4330	874	43000	907	6315	116	4642	180	11200	1413	2444
Aluminum T (ug/l)	<200	3544	<200	746	<200	1590	358	7890	<200	2430	278	21200	203	3788	<200	2614	<200	5215	380	1735
Nickle T (ug/l)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Calcium T (mg/l)	17	24	33.4	37.7	58.1	63	64.4	76.1	28.7	27.8	42.9	60.3	42.9	48.9	39.1	28.2	156	27.4	156	6.9
Copper T (ug/l)	<10	<10	<10	<10	<10	<10	<10	33	<10	<10	<10	37	<10	<10	<10	15	<10	21	<10	<10
Chromium T (ug/l)	<4	<4	<4	<4	<4	<4	<4	12	<4	<4	<4	18.3	<4	<4	<4	6.5	<4	18.4	<4	5.9
Manganese T (ug/l)	12	255	77	176	73	498	145	667	131	896	180	956	146	752	<10	168	174	976	273	142
Cadmium T (ug/l)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead T (ug/l)	<1.0	4.4	<1.0	2	<1.0	2.6	1.1	23.5	<1.0	3.8	<1.0	27.7	<1.0	3.2	<1.0	5.8	<1.0	14.7	2.5	10.4
Mercury T (ug/l)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Zinc T (ug/l)	<10	31	<10	12	<10	33	<10	113	<10	32	<10	129	<10	15	<10	58	<10	178	29	101
Magnesium T (mg/l)	3.75	5.33	6.9	7.63	13.9	14.8	21.7	31.5	5.74	6.32	8.33	18.3	8.59	11.2	7.47	6.03	35.1	6.04	33.6	1.51
Oil and Grease	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	<5.0	n/a	n/a	n/a	<5.0	<5.0	7.2	<5.0	<5.0	<5.0

Table 12. Cold-water chemistry sampling data.

Water Quality Parameter	11WC		12UNT		13WC		14UNT		15UNT		16WC		17TR		18TRUNT		19TR		20UNT	
	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold
Field Parameters																				
pH	8.78	-	7.52	-	7.81	-	8.09	-	8.07	-	8.37	-	7.9	-	8	-	8.12	-	7.77	-
Temperature (degrees C)	13.9	-	11.4	-	9.24	-	11.8	-	14.8	-	10.5	-	9.04	-	10.3	-	7.98	-	11.2	-
Alkalinity (mg/l)	82	-	114	-	120	-	92	-	156	-	106	-	98	-	96	-	112	-	222	-
Conductivity (umhos/cm)	532	-	633	-	411	-	646	-	615	-	602	-	578	-	687	-	557	-	896	-
Dissolved Oxygen (mg/l)	12.6	-	10.8	-	11.6	-	12.2	-	11.3	-	13.7	-	13.7	-	12.2	-	13.3	-	11.6	-
Dissolved Oxygen (%)	122	-	97.3	-	101	-	113	-	112	-	123	-	119	-	109	-	113	-	106	-
Laboratory Parameters																				
Fecal Coliforms (colonies/100 ml)	20	2600	60	8000	140	4600	610	3500	40	11000	80	5600	230	7000	40	4400	80	2800	<20	3600
pH	8.3	7.8	8.2	7.6	8	7.4	8.3	7.6	8.3	7.5	8.5	7.9	8.5	7.7	8.5	7.6	8.5	8	8.1	7.7
Alkalinity	103	39	196	44	120	54	106	45	187	72	117	109	109	83	121	83	126	108	222	87
Sulfate (mg/l)	29	14	46	12	33	18	26	11	52	16	33	31	24	19	25	20	28	24	49	28
Residue, Total (mg/l)	390	516	574	370	480	702	428	248	530	380	402	1084	338	364	416	1096	320	490	652	1556
Settlable Solids (ml/l)	<0.2	1.2	<0.2	0.8	<0.2	1.6	<0.2	0.8	<0.2	1.6	<0.2	8	<0.2	0.8	<0.2	1.2	<0.2	1.6	<0.2	0.4
Suspended Solids T (mg/l)	6	290	<2	264	2	138	18	72	2	158	4	632	<2	62	4	602	<2	206	<2	974
Nitrite-N (mg/l)	<0.01	0.01	<0.01	0.03	<0.01	0.03	<0.01	<0.01	<0.01	0.02	<0.01	0.02	<0.01	0.01	<0.01	0.02	<0.01	0.01	<0.01	0.04
Nitrate-N (mg/l)	0.08	0.37	0.22	0.61	0.16	0.49	0.19	0.21	0.28	0.49	0.17	0.46	0.23	0.45	0.12	0.68	0.14	0.42	2.32	0.97
Nitrogen T (mg/l)	0.3	1.73	0.37	2.98	0.32	2.03	0.35	0.94	0.42	1.91	0.28	2.41	0.36	1.36	0.26	2.67	0.42	1.15	2.37	2.11
Total Organic Carbon TOC (mg/l)	3.05	11.2	3.64	20.6	3.06	16.5	2.59	10.8	3.38	17.4	2.87	15.3	3.12	14.5	3.46	23.5	2.79	9.73	1.26	9.72
Ammonia-N (mg/l)	<0.02	0.32	<0.02	0.61	<0.02	0.39	<0.02	0.05	<0.02	0.14	<0.02	0.09	<0.02	0.1	<0.02	0.26	<0.02	0.07	<0.02	0.09
SPC @ 25 C (umhos/cm)	614	306	902	211	745	387	644	299	787	306	675	635	541	516	613	402	543	406	906	400
TDS @ 105 C (mg/l)	384	226	574	106	478	564	410	176	528	222	398	452	338	302	412	494	320	284	652	582
Hardness T (mg/l)	158	89	289	78	191	120	153	59	271	100	182	213	142	113	178	153	162	152	329	180
Phosphorus T (mg/l)	0.01	0.27	0.01	0.583	0.02	0.391	0.01	0.122	0.02	0.236	0.01	0.386	0.01	0.13	0.02	0.557	<0.01	0.152	<0.01	0.528
Chloride (mg/l)	124	60	156	27	156	74	135	58.1	123	39.8	136	127.6	89.8	99	119	64	83.2	48.4	140	54.6
COD (mg/l)	26.5	51.3	21.9	91.6	32.9	48.1	21.9	27.2	23	60.7	22.4	36.7	18.8	49.6	24.2	58.2	15.4	38.4	16.8	16.4
BOD5 Inhib (mg/l)	0.33	11.4	0.72	21.6	0.71	17.1	0.65	2	0.59	11.3	0.66	12	0.96	7.5	0.92	9.5	0.65	6.1	<0.20	5.8
Turbidity (NTU)	<1.0	111	3.2	100.9	1.27	345.8	2.49	80.45	<1	62.45	<1	193.5	<1	50.1	1.01	887.5	<1	168.2	1.25	230.6
Iron T (ug/l)	72	7120	910	7270	231	20100	223	4289	97	6648	50	18200	173	2408	146	43700	83	6144	109	58600
Aluminum T (ug/l)	<200	3760	<200	2790	<200	8791	<200	3508	<200	3486	<200	8480	<200	1619	<200	26400	<200	3600	<200	25900
Nickle T (ug/l)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	51
Calcium T (mg/l)	47.2	26.6	86.2	23.3	57.2	33.9	46.5	17.6	81.6	29.7	54.5	62.1	42.5	33.6	52.2	39.6	47.5	44.4	98.5	46.3
Copper T (ug/l)	<10	15	<10	23	<10	30	<10	<10	<10	14	<10	22	<10	<10	<10	45	<10	12	<10	66
Chromium T (ug/l)	<4	14	<4	16.4	<4	20.2	<4	<4	<4	<4	<4	15.4	<4	<4	<4	14.9	<4	5.2	<4	16
Manganese T (ug/l)	<10	615	140	383	45	685	12	220	27	814	10	833	15	502	31	1059	15	387	71	671
Cadmium T (ug/l)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	<0.2
Lead T (ug/l)	<1.0	11	<1.0	8.8	<1.0	16.6	<1.0	3.5	<1.0	4.7	<1.0	20	<1.0	2.3	<1.0	38.1	<1.0	93.2	<1.0	18.1
Mercury T (ug/l)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Zinc T (ug/l)	<10	124	<10	160	<10	160	<10	31	<10	39	<10	94	<10	15	<10	142	<10	42	<10	186
Magnesium T (mg/l)	9.79	5.43	17.9	4.79	11.7	8.67	8.81	3.55	16.3	6.3	11.1	14.1	8.7	7.1	11.6	13.1	10.6	9.9	20	15.5
Oil and Grease	5.1	<5.0	<5.0	<5.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table 12. Cold-water chemistry sampling data, continued

Water Quality Parameter	21WC		22BR		23WC		24WC		25TM		26EC		27GR	
	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold	Low-Cold	High-Cold
Field Parameters														
pH	7.6	-	8.15	-	8.12	-	8.97	-	7.68	-	8.26	-	7.28	-
Temperature (degrees C)	9.65	-	9.77	-	9.41	-	13.4	-	9.9	-	9.01	-	7	-
Alkalinity (mg/l)	90	-	130	-	120	-	110	-	60	-	90	-	35	-
Conductivity (umhos/cm)	344	-	259	-	620	-	420	-	237	-	194	-	123	-
Dissolved Oxygen (mg/l)	11.9	-	12	-	13	-	11.1	-	12	-	13.7	-	12.3	-
Dissolved Oxygen (%)	105	-	106	-	114	-	106	-	106	-	114	-	101	-
Laboratory Parameters														
Fecal Coliforms (colonies/100 ml)	60	2600	40	1800	20	1000	60	1300	<20	180	20	2100	<20	2900
pH	8.4	8.1	8.4	8.2	8.4	8.1	8.4	8.2	8.3	8.2	8.2	8	7.5	7.5
Alkalinity	125	121	177	147	135	124	132	126	77	82	88	90	34	41
Sulfate (mg/l)	37	40	45	41	41	43	42	42	25	21	21	31	21	26
Residue, Total (mg/l)	420	658	312	360	402	418	392	450	186	156	188	282	126	202
Settlable Solids (ml/l)	<0.2	2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Suspended Solids T (mg/l)	<2	240	<2	8	<2	30	<2	12	<2	<2	2	24	2	4
Nitrite-N (mg/l)	<0.01	0.02	<0.01	0.01	<0.01	<0.1	<0.01	<0.1	<0.01	<0.1	<0.01	<0.01	<0.01	0.01
Nitrate-N (mg/l)	0.22	0.42	0.38	0.58	0.27	0.38	0.31	0.5	0.2	0.21	0.31	0.55	0.38	1.02
Nitrogen T (mg/l)	0.34	1.17	0.41	0.81	0.35	0.93	0.44	0.81	0.28	0.28	0.46	0.97	0.45	1.48
Total Organic Carbon TOC (mg/l)	2.74	9.97	2.04	6.78	2.69	6.36	2.7	5.7	2.06	2.74	3.09	6.09	2.95	7.41
Ammonia-N (mg/l)	<0.02	0.04	<0.02	0.05	<0.02	0.04	0.02	0.05	<0.02	0.03	<0.02	0.06	<0.02	0.05
SPC @ 25 C (umhos/cm)	631	601	509	445	616	558	619	561	267	266	300	330	201	250
TDS @ 105 C (mg/l)	420	418	312	352	402	388	392	438	186	156	186	258	124	198
Hardness T (mg/l)	193	209	242	203	200	189	200	191	105	110	116	126	55	71
Phosphorus T (mg/l)	<0.01	0.13	<0.01	0.023	<0.01	0.044	<0.01	0.029	<0.01	<0.01	0.02	0.049	0.01	0.05
Chloride (mg/l)	112	92.4	33.6	28.5	94.8	76.8	94.4	78.5	20.1	19	27.7	27.8	26.1	31.5
COD (mg/l)	19.7	28.8	23.9	41.2	40	35	20.9	34.7	20.3	10.6	19.8	43.1	22.7	47.9
BOD5 Inhib (mg/l)	<0.20	7.5	<0.20	5	<0.20	4.2	0.57	3.5	<0.20	2.1	0.93	3.5	<0.20	3.3
Turbidity (NTU)	<1	40.6	<1	9.59	<1	20.26	<1	18.96	<1	1.26	<1	39.95	<1	23.1
Iron T (ug/l)	42	4760	89	435	42	1801	56	942	22	48	40	2002	<20	906
Aluminum T (ug/l)	<200	2210	<200	<200	<200	958	<200	440	<200	<200	<200	1476	<200	878
Nickle T (ug/l)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Calcium T (mg/l)	57	62.2	70.9	59.7	58.9	55.8	58.6	56.3	32.1	34.3	35.3	37.2	16.3	20.1
Copper T (ug/l)	<10	<10	<10	<10	<10	13	<10	<10	<10	<10	<10	<10	<10	<10
Chromium T (ug/l)	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Manganese T (ug/l)	<10	246	<10	39	<10	91	<10	46	<10	<10	<10	78	<10	26
Cadmium T (ug/l)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead T (ug/l)	<1.0	3.5	<1.0	<1.0	<1.0	3.4	<1.0	<1.0	<1.0	<1.0	<1.0	1.3	<1.0	<1.0
Mercury T (ug/l)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Zinc T (ug/l)	<10	29	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Magnesium T (mg/l)	12.3	13.1	15.8	39	12.7	12.1	13	12.1	5.9	5.91	6.72	7.94	4.92	4.92
Oil and Grease	n/a	n/a	n/a	n/a	n/a	n/a	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	n/a	n/a

Table 12. Cold-water chemistry sampling data, continued

Water Quality Parameters	1WC		2WC		3UNT		4UNT		5UNT		6WC		7WC		8WC		9UNT		10UNT	
	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm
Field Parameters																				
pH	6.51	-	6.8	-	7.02	-	6.86	-	6.82	-	7.23	-	7.65	-	8.58	-	8.16	-	7.78	-
Temperature (degrees C)	14.28	-	14.3	-	15.77	-	14.54	-	16.02	-	16.12	-	16.61	-	17.12	-	14.98	-	15.47	-
Alkalinity (mg/l)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conductivity (umhos/cm)	205	-	359	-	419	-	616	-	571	-	503	-	522	-	523	-	1725	-	1457	-
Dissolved Oxygen (mg/l)	9.89	-	8.3	-	9.45	-	8.26	-	3.59	-	7.13	-	10.11	-	13.21	-	10.06	-	9.05	-
Dissolved Oxygen (%)	96.6	-	81.2	-	95.8	-	81.3	-	66.7	-	72.7	-	103.9	-	137.6	-	100.4	-	91.2	-
Laboratory Parameters																				
Fecal Coliforms (colonies/100 ml)	500	45000	160	18000	320	15000	500	30000	360	9900	1000	37000	160	45000	260	30000	480	5200	120	500
pH	7.8	7.7	7.8	7.6	7.9	7.8	7.9	7.9	7.4	7.7	7.8	7.9	8	8	8.7	7.9	8.3	8.1	8	8.1
Alkalinity (mg/l)	79	47	141	38	115	51	116	77	102	71	152	78	147	81	121	77	222	91	233	191
Sulfate (mg/l)	18	15	14	18	105	108	54	37	29	24	33	46	34	43	36	36	83	31	155	131
Residue, Total (mg/l)	176	210	266	144	370	448	580	556	420	276	394	410	404	592	396	420	1604	360	1098	1732
Settlable Solids (ml/l)	<0.2	<0.2	<0.2	0.4	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.8	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Suspended Solids T (mg/l)	<2	<2	<2	16	2	284	6	52	<2	24	2	170	<2	350	<2	216	2	<2	4	2
Nitrite-N (mg/l)	<0.1	0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.03	0.01	0.01	<0.1	0.02	<0.1	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate-N (mg/l)	0.62	0.61	0.12	0.12	0.24	0.38	0.32	0.28	0.27	0.38	0.08	0.43	0.13	0.48	0.05	0.44	0.82	0.44	0.33	0.6
Nitrogen T (mg/l)	0.86	1.51	0.29	2.2	0.46	0.86	0.73	0.76	0.69	1.35	0.32	1.14	0.48	1.4	0.29	1.23	1.05	0.76	0.55	0.93
Total Organic Carbon TOC (mg/l)	3.94	10.6	3.44	19.4	3.83	4.13	5.68	5.15	4.93	12.3	4.26	11.9	4.65	13.8	4.13	10.2	4	5.9	5.25	7.63
Ammonia-N (mg/l)	<0.2	0.03	0.03	0.04	0.03	<0.02	0.04	<0.02	0.06	0.03	0.07	0.03	<0.02	0.04	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
SPC @ 25 C (umhos/cm)	246	219	425	196	480	366	726	344	671	482	565	367	582	372	577	361	1986	631	1667	1443
TDS @ 105 C (mg/l)	176	210	266	128	368	246	574	504	420	252	392	240	404	242	396	204	1602	360	1094	1730
Hardness T (mg/l)	101	76	163	60	225	176	225	141	162	78	208	140	190	137	172	122	527	122	364	283
Phosphorus T (mg/l)	0.169	0.222	0.024	0.14	0.024	0.128	0.051	0.176	0.041	0.153	0.037	0.176	0.023	0.226	0.013	0.164	0.018	0.045	0.015	0.023
Chloride (mg/l)	15.7	27.3	44	24.8	21.3	10.5	140.5	38	139.6	91.2	72.4	36.5	79.9	39	92.2	43	492.7	126.8	334.9	276.6
COD (mg/l)	27.2	119.1	20.6	102.9	32.7	55.2	36.5	58.4	36.9	77.6	23.6	68	22.9	76.1	27.9	109.8	48.1	40.5	54.7	80.4
BOD5 Inhib (mg/l)	1.6	1.7	1.9	17.25	<0.2	3.9	2.3	3.9	2.4	17.6	2.1	19.65	1.8	4.9	1.7	10.8	1.8	6.4	1.9	3.4
Turbidity (NTU)	1.73	38.1	3.39	4.19	5.9	162.5	10.36	310	6.85	27.8	11.23	145.8	5.91	233	<1	185.3	<1	5.37	1.84	1.15
Iron T (ug/l)	140	2850	684	230	568	10800	2680	12700	1110	1827	1350	7614	681	13400	51	11500	28	419	230	272
Aluminum T (ug/l)	<200	1560	<200	<200	225	4570	1320	6900	<200	1218	376	4165	<200	6660	<200	5807	<200	<200	<200	<200
Nickle T (ug/l)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Calcium T (mg/l)	30.4	22.5	48.8	17.7	67.2	51.9	58.7	41.7	48.7	23.6	61.6	41.6	56.2	39	51.3	35.8	157	38.8	109	87.8
Copper T (ug/l)	12	<10	<10	<10	<10	13	<10	17	<10	<10	<10	10	<10	15	<10	11	<10	<10	<10	<10
Chromium T (ug/l)	<4	<4	<4	<4	<4	5.2		8.1	<4	<4	<4	<4	<4	4.9	<4	4.4	<4	<4	<4	<4
Manganese T (ug/l)	27	100	207	50	358	162	291	168	505	153	221	259	91	361	<10	287	<10	33	147	70
Cadmium T (ug/l)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead T (ug/l)	<1.0	2.4	<1.0	<1.0	<1.0	4.6	3	8.9	<1.0	2.1	1.2	3.7	<1.0	5.9	<1.0	4.9	<1.0	<1.0	<1.0	1.7
Mercury T (ug/l)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Zinc T (ug/l)	<10	19	<10	29	<10	65	16	45	15	17	21	25	<10	51	<10	36	11	12	23	73
Magnesium T (mg/l)	6	4.85	10	3.86	13.8	11.3	18.9	8.86	9.7	4.526	13.1	8.652	12	9.55	10.7	7.976	32.7	6.087	22.1	15.5
Oil and Grease	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	<5.0	<5.0	n/a	n/a	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0

Table 13. Warm-water chemistry sampling data.

Water Quality Parameter	11WC		12UNT		13WC		14UNT		15UNT		16WC		17TR		18TRUNT		19TR		20UNT	
	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm
Field Parameters																				
PH	8.56	-	7.92	-	8.09	-	7.54	-	8.03	-	8.5	-	8.1	-	8.04	-	8.25	-	7.75	-
Temperature (degrees C)	18.16	-	16.92	-	18.36	-	16.11	-	16.41	-	17.69	-	17.5	-	16.38	-	15.36	-	15.77	-
Alkalinity (mg/l)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conductivity (umhos/cm)	711	-	1049	-	715	-	692	-	766	-	658	-	505	-	629	-	515	-	815	-
Dissolved Oxygen (mg/l)	12.72	-	9.93	-	12.95	-	8.23	-	10.41	-	12.74	-	12.13	-	10.12	-	10.95	-	10.11	-
Dissolved Oxygen (%)	135.1	-	103	-	138.1	-	84	-	106.7	-	134	-	127	-	103.5	-	109.6	-	102.3	-
Laboratory Parameters																				
Fecal Coliforms (colonies/100 ml)	370	37000	220	11000	240	18000	80	8100	500	5600	140	14000	160	30000	180	19000	280	14000	600	26000
PH	8.6	7.9	8.1	8	8.3	8	7.8	7.8	8.3	7.9	8.6	7.8	8.3	7.8	8.3	8.1	8.5	8.1	8.2	7.8
Alkalinity	126	72	238	98	140	72	162	63	251	70	127	65	150	67	157	85	158	81	240	54
Sulfate (mg/l)	43	32	55	19	41	27	21	16	56	17	40	21	29	23	31	25	32	25	52	14
Residue, Total (mg/l)	524	472	782	250	504	334	526	226	616	166	476	364	322	290	466	440	412	428	624	420
Settlable Solids (ml/l)	<0.2	0.4	<0.2	<0.2	<0.2	2.4	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	0.4	<0.2	0.4	<0.2	0.4
Suspended Solids T (mg/l)	2	246	<2	22	4	132	6	22	<2	2	<2	124	<2	48	2	114	<2	118	2	328
Nitrite-N (mg/l)	<0.01	0.02	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.03
Nitrate-N (mg/l)	<0.04	0.45	0.13	0.85	0.13	0.42	0.16	0.25	0.12	0.37	0.04	0.41	0.18	0.26	0.09	0.59	0.14	0.51	1.48	0.42
Nitrogen T (mg/l)	0.22	1.17	0.26	1.63	0.28	1.03	0.31	0.71	0.23	0.85	0.15	1.07	0.31	1.1	0.22	1.46	0.24	1.33	1.63	1.02
Total Organic Carbon TOC (mg/l)	4.02	9.66	3.04	8.95	3.21	7.98	3.57	6.57	3.43	7.24	3.22	5.4	2.33	13.5	3.54	11.8	2.77	12.2	1.29	8.18
Ammonia-N (mg/l)	<0.02	0.03	0.02	0.04	<0.02	0.03	<0.02	<0.02	<0.02	0.02	<0.02	0.03	<0.02	0.03	<0.02	0.06	<0.02	0.03	<0.02	0.06
SPC @ 25 C (umhos/cm)	764	351	1155	351	854	349	773	352	848	251	713	315	549	432	701	579	590	510	918	200
TDS @ 105 C (mg/l)	522	226	782	228	500	202	520	204	616	164	476	240	320	242	464	326	412	310	622	92
Hardness T (mg/l)	211	113	359	106	226	99	220	83	338	82	202	87	187	73	220	103	207	99	344	79
Phosphorus T (mg/l)	<0.01	0.204	0.016	0.13	0.011	0.132	0.019	0.076	0.02	0.06	<0.01	0.123	0.015	0.16	0.017	0.179	0.011	0.159	0.012	0.258
Chloride (mg/l)	151.4	44.5	213.1	36.9	172.5	46.6	147.3	59.5	109.7	25.5	140.7	47.3	72.1	79.2	120.7	119.1	79.9	92.9	135.4	19.5
COD (mg/l)	21.1	47.5	22.7	67.3	24.3	81.8	23	103.4	28.9	75.5	35.1	17.3	25	143.1	15.9	38.7	34.9	87.9	24.8	56.3
BOD5 Inhib (mg/l)	1.9	9.65	1.9	3.3	1.8	4.6	1.6	18.8	1.5	1.2	2.3	1.8	2.1	11.1	1.8	12.45	1.5	27.3	2.1	17.1
Turbidity (NTU)	<1	234.5	3.83	17.94	<1	96.8	1.34	11.18	<1	5.24	<1	91.6	<1	29.35	1.26	62.7	<1	50.15	1.08	321.5
Iron T (ug/l)	<20	11900	636	706	55	3981	315	1280	193	402	31	1758	40	2190	163	4520	76	3024	78	11500
Aluminum T (ug/l)	<200	6150	<200	331	<200	2188	<200	548	<200	203	<200	1342	<200	1480	<200	2382	<200	1578	<200	5385
Nickle T (ug/l)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Calcium T (mg/l)	62.7	33.1	109	33.2	67.8	30.3	66.8	25.2	102	25.5	60.1	27	55.7	22.3	64.6	31	60.8	30	104	23.3
Copper T (ug/l)	<10	11	<10	<10	<10	<10	<10	<10	<10	<10	<10	13	<10	<10	<10	<10	<10	<10	<10	15
Chromium T (ug/l)	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Manganese T (ug/l)	<10	364	120	47	22	205	168	93	38	32	<10	244	24	232	46	298	13	272	56	151
Cadmium T (ug/l)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead T (ug/l)	<1.0	6.1	<1.0	<1.0	<1.0	3.6	<1.0	<1.0	<1.0	<1.0	<1.0	6	<1.0	1.9	<1.0	4.8	<1.0	4.9	<1.0	3.1
Mercury T (ug/l)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Zinc T (ug/l)	<10	46	<10	13	<10	28	<10	11	<10	<10	<10	27	25	11	<10	19	<10	20	<10	47
Magnesium T (mg/l)	13.2	7.369	21.1	5.658	13.8	5.601	12.9	4.84	20.2	4.4	12.5	4.7	11.7	4.2	14.1	6.2	13.3	5.8	20.4	5
Oil and Grease	<5.0	<5.0	<5.0	<5.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table 13. Warm-water chemistry sampling data, continued.

Water Quality Parameter	21WC		22BR		23WC		24WC		25TM		26EC		27GR	
	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm	Low-Warm	High-Warm
Field Parameters														
pH	8.62	-	8.25	-	8.28	-	7.98	-	8.32	-	8.1	-	7.68	-
Temperature (degrees C)	19.35	-	15.24	-	16.2	-	16.42	-	22.33	-	19.36	-	16.82	-
Alkalinity (mg/l)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conductivity (umhos/cm)	621	-	456	-	551	-	558	-	347	-	330	-	298	-
Dissolved Oxygen (mg/l)	11.18	-	10.46	-	12.24	-	11.53	-	10.26	-	9.96	-	8.84	-
Dissolved Oxygen (%)	121.6	-	104.4	-	124.8	-	118.2	-	118.2	-	108.4	-	90.6	-
Laboratory Parameters														
Fecal Coliforms (colonies/100 ml)	80	18000	100	11000	140	24000	80	16000	<20	14000	280	54000	260	51000
pH	8.6	8	8.4	8.1	8.4	8	8.3	7.9	8.2	7.9	8.3	8	8.1	7.8
Alkalinity	125	62	193	83	132	66	131	65	104	55	91	94	57	39
Sulfate (mg/l)	44	24	52	24	49	24	48	23	35	25	27	30	38	28
Residue, Total (mg/l)	446	406	378	206	402	496	434	612	202	288	212	466	214	148
Settlable Solids (ml/l)	<0.2	0.4	<0.2	0.4	<0.2	0.8	<0.2	3.2	<0.2	0.8	<0.2	1	<0.2	<0.2
Suspended Solids T (mg/l)	<2	204	<2	30	<2	310	<2	418	6	224	8	208	22	4
Nitrite-N (mg/l)	<0.01	<0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate-N (mg/l)	<0.04	0.47	0.32	0.64	<0.04	0.52	0.05	0.5	0.11	0.5	0.48	0.67	0.85	1.23
Nitrogen T (mg/l)	0.15	1.21	0.38	1.39	0.15	1.42	0.19	1.64	0.22	1.39	0.75	1.68	1.17	1.67
Total Organic Carbon TOC (mg/l)	3.13	5.52	1.66	10.3	2.66	8.88	2.72	11.3	1.98	9.52	3.06	7.77	3.36	7.03
Ammonia-N (mg/l)	<0.02	0.03	<0.02	0.02	<0.02	0.04	<0.02	0.04	0.02	<0.02	0.02	<0.02	0.03	<0.02
SPC @ 25 C (umhos/cm)	649	317	536	274	616	321	622	294	358	215	368	391	350	242
TDS @ 105 C (mg/l)	446	202	378	176	402	186	434	194	196	64	204	258	192	144
Hardness T (mg/l)	194	95	253	116	212	109	205	108	148	87	122	167	96	67
Phosphorus T (mg/l)	<0.01	0.17	<0.01	0.121	0.01	0.217	0.01	0.283	<0.01	0.143	0.011	0.148	0.023	0.058
Chloride (mg/l)	115	45.8	33.3	18.7	93	42.9	92.6	38.8	29.3	15	41.7	47.1	48.5	28
COD (mg/l)	21.2	72.4	10.1	151.5	20.8	55.9	23.2	156.6	23.6	58.2	16.9	71	34.1	46.2
BOD5 Inhib (mg/l)	2	8.3	1.9	11.35	1.7	23.4	1.5	2.2	2.2	18.1	2.3	22.2	1.9	14.8
Turbidity (NTU)	<1	119.7	<1	23.55	<1	188.8	<1	199.5	<1	96.8	<1	47.85	1.34	10.37
Iron T (ug/l)	37	8650	46	2180	33	14100	36	9702	<20	4108	30	3604	270	479
Aluminum T (ug/l)	<200	4390	<200	919	<200	6700	<200	6912	<200	2512	<200	1900	<200	323
Nickle T (ug/l)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Calcium T (mg/l)	55.9	27.8	73.9	34.6	61.2	32	59.6	32.1	46	26	35.4	52.9	29	19.8
Copper T (ug/l)	<10	11	<10	<10	23	15	<10	<10	<10	<10	<10	<10	<10	<10
Chromium T (ug/l)	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Manganese T (ug/l)	<10	314	<10	154	<10	494	<10	501	<10	186	<10	222	<10	13
Cadmium T (ug/l)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead T (ug/l)	<1.0	7.1	<1.0	1.3	<1.0	9.5	<1.0	12.8	<1.0	2.9	<1.0	3.3	<1.0	<1.0
Mercury T (ug/l)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Zinc T (ug/l)	<10	50	<10	15	15	69	<10	50	<10	21	<10	17	<10	<10
Magnesium T (mg/l)	13.1	6.26	16.5	7.1	14.2	7.1	13.6	6.7	8.1	5.3	8.2	8.5	5.8	4.3
Oil and Grease	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0

Table 13. Warm-water chemistry sampling data, continue

APPENDIX D STREAM CORRIDOR ASSESSMENT

Stream channel modification, floodway encroachment and non-point sources of pollution are evident throughout the Walnut Creek watershed. Some modifications are necessary for road and railway crossings, navigation, and stream improvements, like providing bank stabilization and fish habitat improvement. Other conditions appear to have negative environmental impacts. These conditions can create dangerous flooding problems and are causing detrimental impacts to the health and diversity of the aquatic biota.

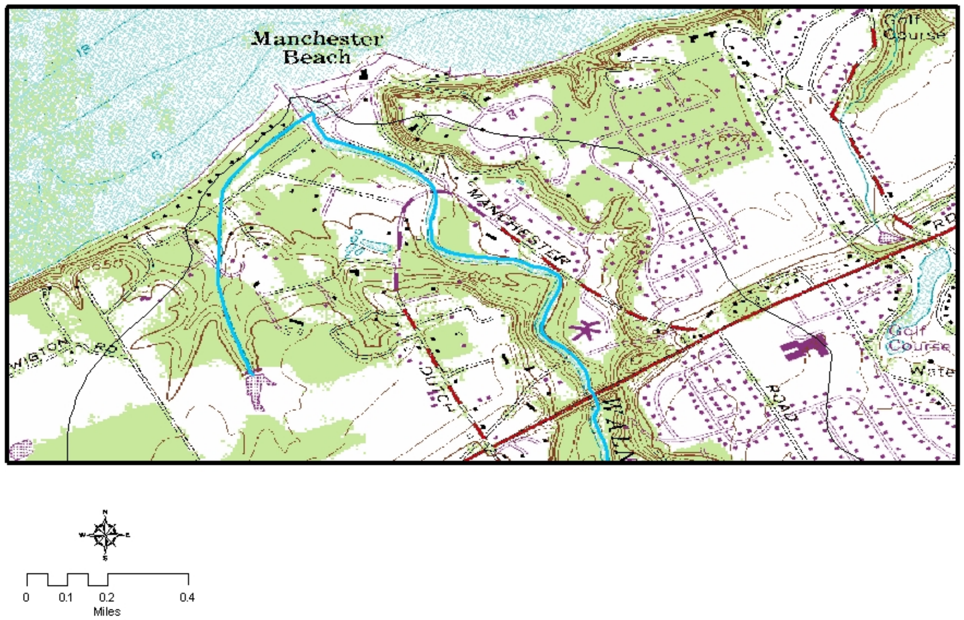
DEP staff conducted a walking survey of portions of Walnut Creek, using the Stream Corridor Assessment (SCA) survey protocols, developed by the State of Maryland - Department of Natural Resources, as a guide. These protocols are intended as a rapid assessment tool to identify potential environmental problems, such as:

- Erosion Sites
- Inadequate Stream Buffers
- Fish Migration Blockages
- Exposed or Discharging Pipes
- Channelized Stream Sections
- Trash Dumping Sites
- In or Near Stream Construction
- Unusual Conditions

Several sections of Walnut Creek, representative of the sub-watersheds, were surveyed. The observations are intended as a *general* assessment of the primary impacts observed within the stream corridor. This assessment should not be considered as an exhaustive survey of all impacts to Walnut Creek, but rather an inventory of the most common, obvious, impact types.

The conditions were photographed and are displayed to provide a tour of the Walnut Creek basin. The order of the photographs is traversing from the mouth of Walnut Creek upstream. Each photo represents a site considered as an individual and discreet “point” impact to the stream.

Walnut Creek Watershed



The following photos document the stream corridor assessment of **subwatershed 1**. Within this survey segment were also several other types of impacts, either too numerous to count or of a “non-point” type. These included: unmitigated erosional features, lack of sufficient riparian buffer zone, small storm water outfalls, uncontrolled highway and parking lot runoff, encroaching residential construction.

Photo 1 – Channel Alteration / Inadequate Buffer at the mouth of Walnut Creek

Photo 2 – Exposed Pipe, PFBC Manchester Facility

Photo 3 – Erosion Site, PFBC Manchester Facility

Photo 4 – Channel Alteration at 24 WC

Photo 5 – Erosion Site, PFBC Manchester Facility

Photo 6 – Channel Alteration for habitat improvement/ potential fish barrier, PFBC Manchester Facility

Photo 7 – Channel Alteration, Downstream Manchester Road Bridge

Photo 8 – Channel Alteration, Manchester Road Bridge

Photo 9 - Garbage deposited along the high water mark of Walnut Creek at 23WC

Photo 10 - Garbage deposited along the high water mark of Walnut Creek at 23WC

Photo 11 – Water Withdrawals / Encroachments , Upstream Manchester Rd. Bridge

Photo 12 – Water Withdrawal/Inadequate Buffer, Upstream Manchester Rd. Bridge

Photo 13 – Pipe Outfall, Upstream Manchester Rd. Bridge

Photo 14 – Unusual Condition / Unidentified Seep, Upstream Manchester Rd. Bridge

Photo 15 – Inadequate Buffer, Upstream Manchester Rd. Bridge

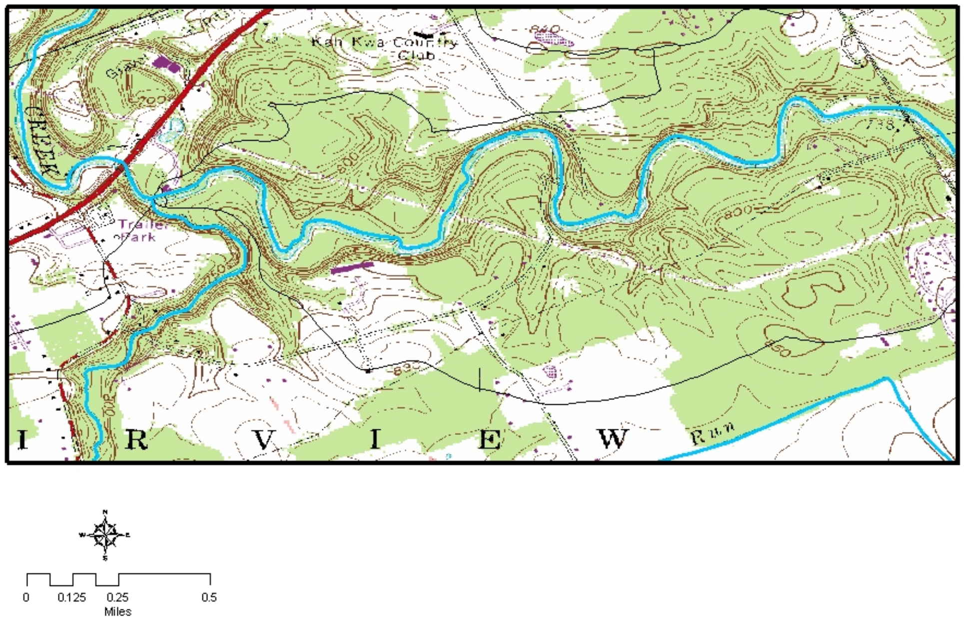
Photo 16 – Water Withdrawal / Inadequate Buffer Upstream Manchester Rd. Bridge

Photo 17 – Channel Alteration, Upstream Manchester Rd. Bridge

Photo 18 – Sedimentation, Downstream U.S. Highway 5 Bridge

Photo 19 – Channel Alteration / Sedimentation, Downstream U.S. Highway 5 Bridge

Walnut Creek Watershed



The following map depicts the second stream section surveyed as part of this assessment. The section is approximately 2.0 miles in length, between the CSXT Railroad bridge crossing, and the Millfair Road Bridge Crossing

Photo 20 – Channel Alteration / Sedimentation, Downstream CSXT RR Bridge

Photo 21 – Channel Alteration, Downstream CSXT RR Bridge

Photo 22 – Sedimentation, Downstream CSXT RR Bridge

Photo 23 – Sedimentation, Downstream CSXT RR Bridge

Photo 24 – Channel Alteration / Sedimentation, Downstream CSXT RR Bridge

Photo 25 – Erosion / Sedimentation, Downstream CSXT RR Bridge

Photo 26- Sedimentation, Downstream Elevated CSXT RR Bridge

Photo 27 – Sedimentation / Debris Jam, Downstream Elevated CSXT RR Bridge

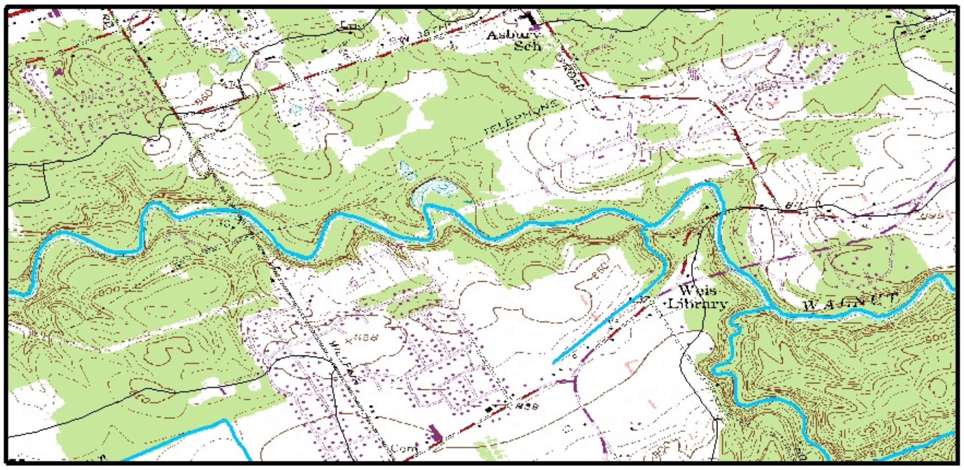
Photo 28 - Sedimentation/Debris Jam, Upstream Elevated CSXT RR Bridge

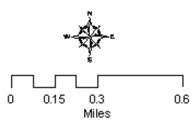
Photo 29 – Sedimentation, Upstream Elevated CSXT RR Bridge

Photo 30 – Inadequate Buffer, Upstream Elevated CSXT RR Bridge

Photo 31 – Sedimentation, Upstream Elevated CSXT RR Bridge

Walnut Creek Watershed





The following map depicts the third stream section surveyed as part of this assessment. The section is approximately 2.0 miles in length, between The Millfair Road Bridge Crossing, and approximately 0.75 miles upstream from the Old Sterrettania Road Bridge Crossing

Photo 32 – Inadequate Buffer, Downstream Millfair Road Bridge

Photo 33 – Channel Alteration, Downstream Millfair Road Bridge

Photo 34 – Channel Alteration 20UNT

Photo 35 – Channel Alteration / Pipe Outfall, Downstream Millfair Road Bridge

Photo 36 – Channel Alteration, Upstream Millfair Road Bridge

Photo 37 – Pipe Outfall, Upstream Millfair Road Bridge

Photo 38 – Unusual Condition / Unidentified Seep, Upstream Millfair Road Bridge

Photo 39 Erosion Site, Upstream Millfair Road Bridge

Photo 40 – Exposed Pipe, Upstream Millfair Road Bridge

Photo 41 – Channel Alteration, Upstream Millfair Road Bridge

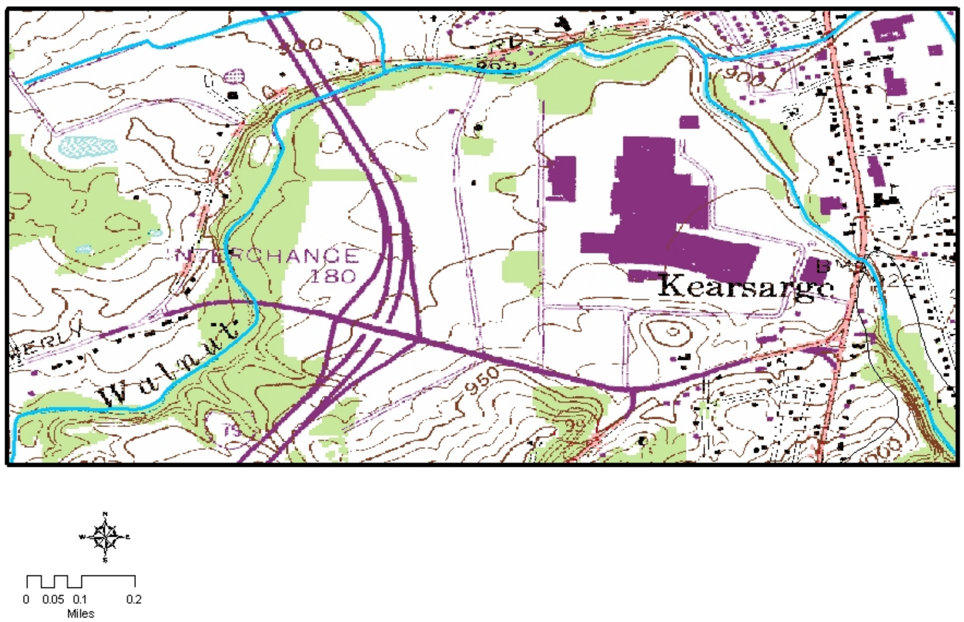
Photo 42 – Channel Alteration, Upstream Millfair Road Bridge

Photo 43 – Pipe Outfall, Upstream Old Sterritania Road Bridge

Photo 44 Channel Alteration, Upstream Old Sterritania Road Bridge

Photo 45 Lake of Riparian Buffer at 17TR

Walnut Creek Watershed



The following depicts the fourth stream section surveyed as part of this assessment. The section is approximately 1.75 miles in length from downstream of the Interstate 79 Bridge Crossing to the Peach Street Bridge Crossing.

Photo 46 – Channel Alteration, Downstream Peach Street Bridge Crossing

Photo 47 – Channel Modification/No buffer (12UNT)

Photo 48 – Pipe Outfall, Downstream Peach Street Bridge Crossing

Photo 49 – Inadequate Buffer, Downstream Peach Street Bridge Crossing

Photo 50 – Pipe Outfall, Downstream Peach Street Bridge Crossing

Photo 51 Erosion Site, Downstream Peach Street Bridge Crossing

Photo 52 Erosion site 9UNT

Photo 53 – Channel Alteration, Downstream Peach Street Bridge Crossing

Photo 54 – Fill Material, Downstream Peach Street Bridge Crossing

Photo 55 – Channel Alteration, Downstream Peach Street Bridge Crossing

Photo 56 – Erosion Site, Downstream Peach Street Bridge Crossing

Photo 57 – Erosion Site, Downstream Peach Street Bridge Crossing

Photo 58 – Pipe Outfall, Downstream Peach Street Bridge Crossing

Photo 59 – Pipe Outfall, Downstream Peach Street Bridge Crossing

Photo 60 – Fill, Downstream Peach Street Bridge Crossing

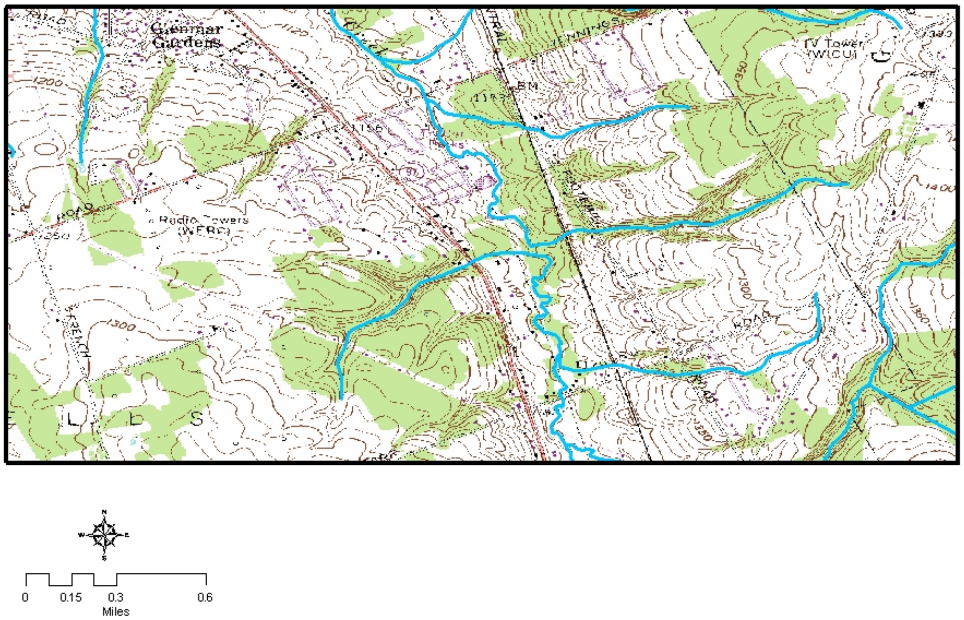
Photo 61 – Channel Alteration, Upstream Interstate 79 Bridge Crossing

Photo 62 – Pipe Outfall, Interstate 79 Bridge Crossing

Photo 63 – Inadequate Buffer / Erosion Site, Downstream Interstate 79 Bridge Crossing

Photo 64 - Obstructions to Fish Passage (15UNT).

Walnut Creek Watershed



The following depicts the fifth stream section surveyed as part of this assessment. The section includes the Peach Street Bridge Crossing to the headwaters area.

Photo 65 – Erosion Site / ATV Crossing

Photo 66 – Erosion Site / ATV Crossing

Photo 67 - Loss of Riparian Habitat / Stream Channelization (12UNT)

Photo 68 – Unusual Condition – iron staining within Walnut Creek tributary (12UNT)

Photo 69 Erosion site at 13WC

Photo 70 – Fill / Debris

Photo 71 – Channel Alteration

Photo 72 - Channel Alteration

Photo 73 – Inadequate Buffer / Erosion Site

Photo 74 – Pipe Outfall

Photo 75 – Pipe Outfall

Photo 76 – Pipe Outfall

Photo 77 – Exposed Pipe

Photo 78 – Exposed Pipe / Channel Alteration

Photo 79 – Channel Alteration / Inadequate Buffer

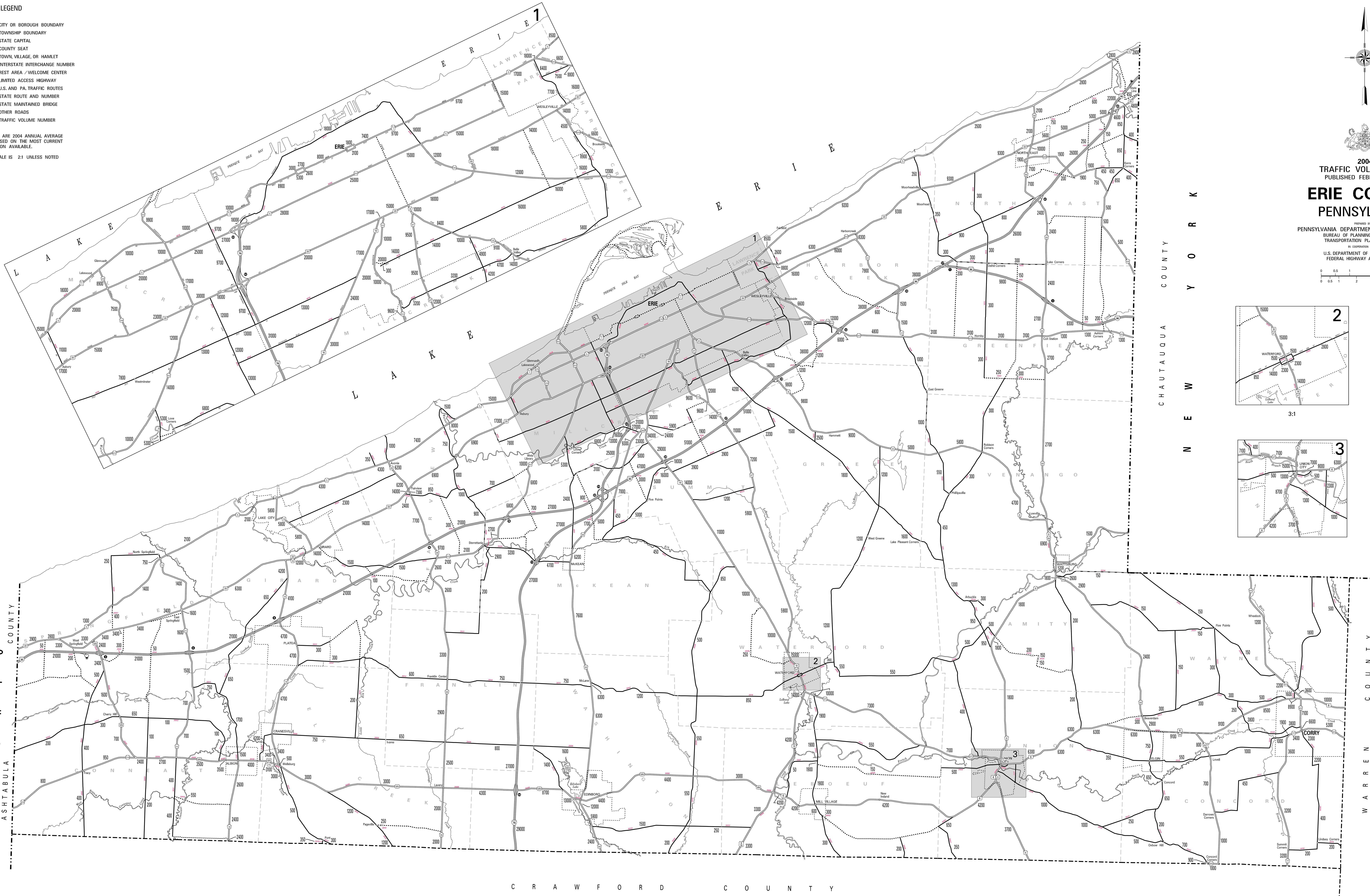
Photo 80 – Channel Alteration / Inadequate Buffer

LEGEND

- CITY OR BOROUGH BOUNDARY
- TOWNSHIP BOUNDARY
- STATE CAPITAL
- COUNTY SEAT
- TOWN, VILLAGE, OR HAMLET
- INTERSTATE INTERCHANGE NUMBER
- REST AREA / WELCOME CENTER
- LIMITED ACCESS HIGHWAY
- U.S. AND PA. TRAFFIC ROUTES
- 1010 STATE ROUTE AND NUMBER
- STATE MAINTAINED BRIDGE
- OTHER ROADS
- 12500 TRAFFIC VOLUME NUMBER

VOLUMES SHOWN ARE 2004 ANNUAL AVERAGE DAILY TRAFFIC BASED ON THE MOST CURRENT COUNT INFORMATION AVAILABLE.

ENLARGEMENT SCALE IS 2:1 UNLESS NOTED OTHERWISE.



2004

TRAFFIC VOLUME MAP

PUBLISHED FEBRUARY 2006

ERIE COUNTY

PENNSYLVANIA

PREPARED BY THE

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
BUREAU OF PLANNING AND RESEARCH
TRANSPORTATION PLANNING DIVISION

IN COOPERATION WITH THE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

0 0.5 1 2 3 Miles
0 0.5 1 2 3 4 5 Kilometers

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TYPE 4 – 25

2006

GENERAL HIGHWAY MAP
ERIE COUNTY
PENNSYLVANIA

PREPARED BY THE
PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
BUREAU OF PLANNING AND RESEARCH
GEOGRAPHIC INFORMATION DIVISION
IN COOPERATION WITH THE
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

Scale 1:65,000
0 0.5 1 2 3 Miles
0 0.5 1 2 3 4 5 Kilometers

POPULATION OF COUNTY (2000 Census).......280,843
AREA OF COUNTY (SQ. MI.)....................................804
(SQ. KM.)............................... 2,082

POLYCONIC PROJECTION – NAD 83 DATUM

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Susceptibility Analysis of Drinking Water Sources to Contamination

Appendix. The parameters used in these matrices include time of travel (TOT), persistence, and quantity. ***Although some of these parameters will be set, the parameters for quantity and the "potential for release" should be discussed and reflect local public concern***. The changes in the threshold values for the parameters must be consistent with setting high, medium and low values for the resulting factors and must apply to the entire group of potential contaminant sources (i.e. Volatile organic chemicals).

The time of travel (TOT) to the drinking water intake from a source of a potential contaminant is measured in terms of short, medium, or long. For groundwater sources, Wellhead Protection (WHP) areas I, II, and III are synonymous with short, medium, or long TOT, respectively. For surface water intakes, the definitions of the segmented delineations are based on TOT (zone delineations: A = 5 hours, B = 25 hours, and C represents the remainder of the watershed). Accordingly, the TOT for Zones A, B and C are short, medium and long, respectively.

The persistence of a potential contaminant will be measured as high, medium or low. This will be based on the contaminant ability to move in the environment and is determined on the adsorption and/or half-life (or rate of removal). If the contaminant has been known to contaminate water supply sources with concentrations greater than the MCL or in significant concentrations it will have a high to medium persistence. For ground water sources, the soils and geologic materials ability to remove the contaminant will be factored in as well. This will be based on the clay content and the hydraulic conductivity of the material.

Quantity will be measured as high, medium and low. Low quantities are those that are clearly on a domestic scale and can be categorized as non-reportable or non-regulated releases, volumes or events. Medium quantities are those that can be categorized as reportable releases, regulated minimum volumes, or events, or equivalent, up to 10X such a quantity, or those quantities that are associated with commercial- or industrial-sized operations and distribution. High quantities are those that are clearly associated with commercial- or industrial-sized operations and distribution, with a minimum 10X a reportable release, regulated minimum volume, event, or the equivalent.

The sensitivity of a drinking water source is most critical in a groundwater source where the aquifer and overlying geologic materials above are expected to provide some treatment of infiltrating water. Surface water sources are highly susceptible because of short travel times of contaminants and limited processes for mitigation of contaminants other than dilution, settling, oxidation, and volatilization. By definition, there is a higher susceptibility of contamination by potential sources within Zone I (Zone A) than Zone II (Zone B). Determining the potential for impact of a contaminant source on a drinking water source is related to the properties of the contaminant of concern, the amount that could be released, the distance or travel time of the contaminant and contaminant concentration reduction that can be expected. Some of these factors are represented in a practical way in the rank of significance of the identified contaminant types ranked in the previous section. If the potential or existing potential sources of contamination are considered to be of a high density, their potential impact should be analyzed cumulatively.

One of the more important considerations in the susceptibility analysis is the potential for release of the contaminant of concern. This would include containment measures for stored potential contaminants. Of primary concern is the level of treatment, monitoring and quality assurance of any treatment process before release of a contaminant. This is the purpose of most permitting programs related to water quality and can be a measure of drinking water source susceptibility. If the activity or a contaminant potentially released from that facility or activity is not regulated, susceptibility can be related to the use of best management practices established voluntarily or as accepted practice. The definition of Best Management Practices here is broader then for agriculture and is the combination of practices accepted in the industry or supported by the department to protect surface and groundwater from contamination. This will include pollution prevention measures. Another tool for determining the potential for release of a contaminant is the establishment and implementation of emergency management plans to protect against release.

1. Susceptibility Analysis of Groundwater Sources to Contamination

The first step is to assess the potential for contamination of the drinking water source, if all the contaminant were released from the potential contaminant source without consideration of any source protection (See Flowchart 1). Factors controlling the potential for contamination from a release are the fate and transport of the contaminant, the amount of contaminant of concern that might be released and the time of travel (or distance) to the drinking water source. The relative value for this potential is determined from Matrix A and Matrix B.

Groundwater sources of drinking water have the benefit of a level of protection from contamination relative to their integrity and the vulnerability of their source aquifer. This defines the sensitivity of the groundwater sources to contamination. Factors related to the integrity of the well are the construction standards, depth of the well, pumping rate, and the rate of infiltration and movement of the groundwater. If the aquifer is confined, the drinking water source should be well protected from man-induced contamination. Site-specific factors that increase aquifer sensitivity such as sinkholes can be included in site-specific assessments. The potential for impact can be assessed by considering the intrinsic sensitivity of the drinking water source (Flowchart 2) and the potential for contamination, or the value from Matrix B. The potential for release is determined from the potential for release table and is based upon the following factors:

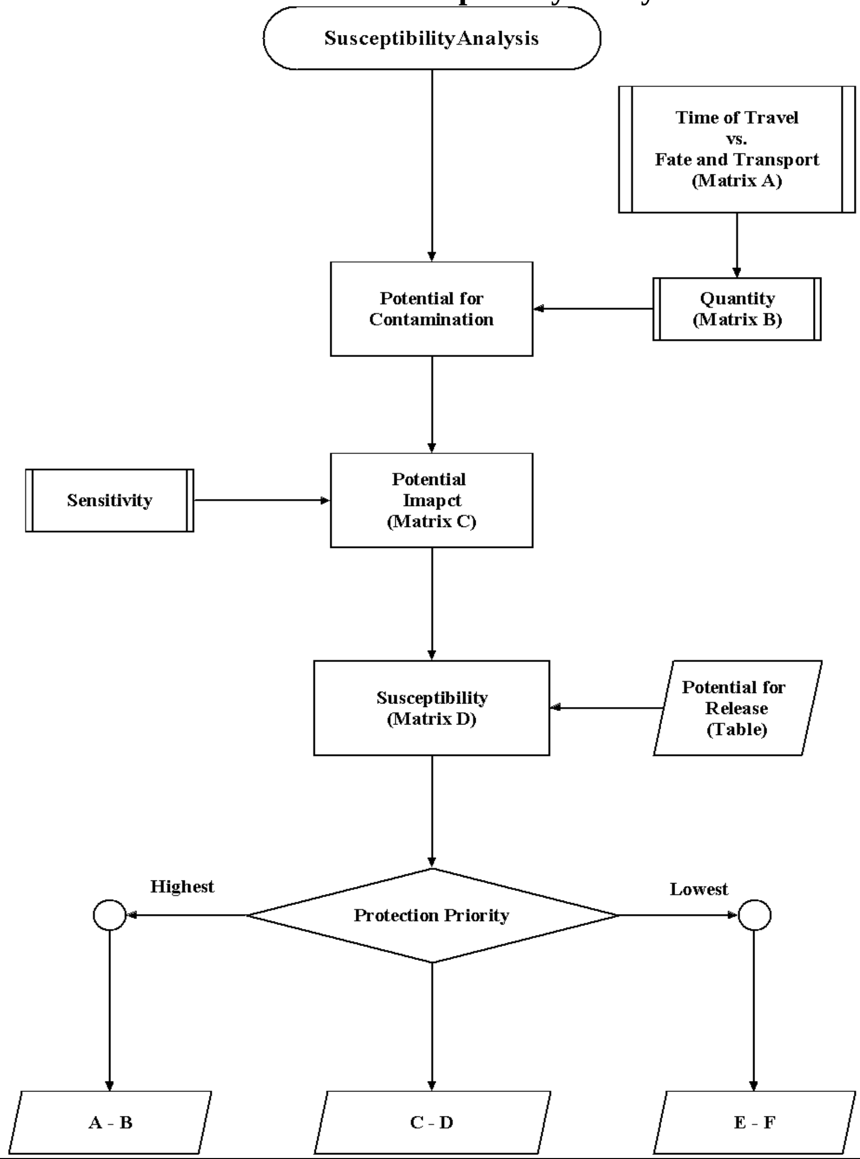
- Containment
- Regulatory control of the potential source of contamination
- Compliance
- Best Management Practices &/or Emergency Response Plan

If there were no control on the potential for release of the contaminant, the potential for release would be high. By relating the potential for impact described above to the potential for release, the susceptibility rating is determined from Matrix D. A potential source of contamination with a high potential for impact and a high potential for release would have a high susceptibility rating or priority.

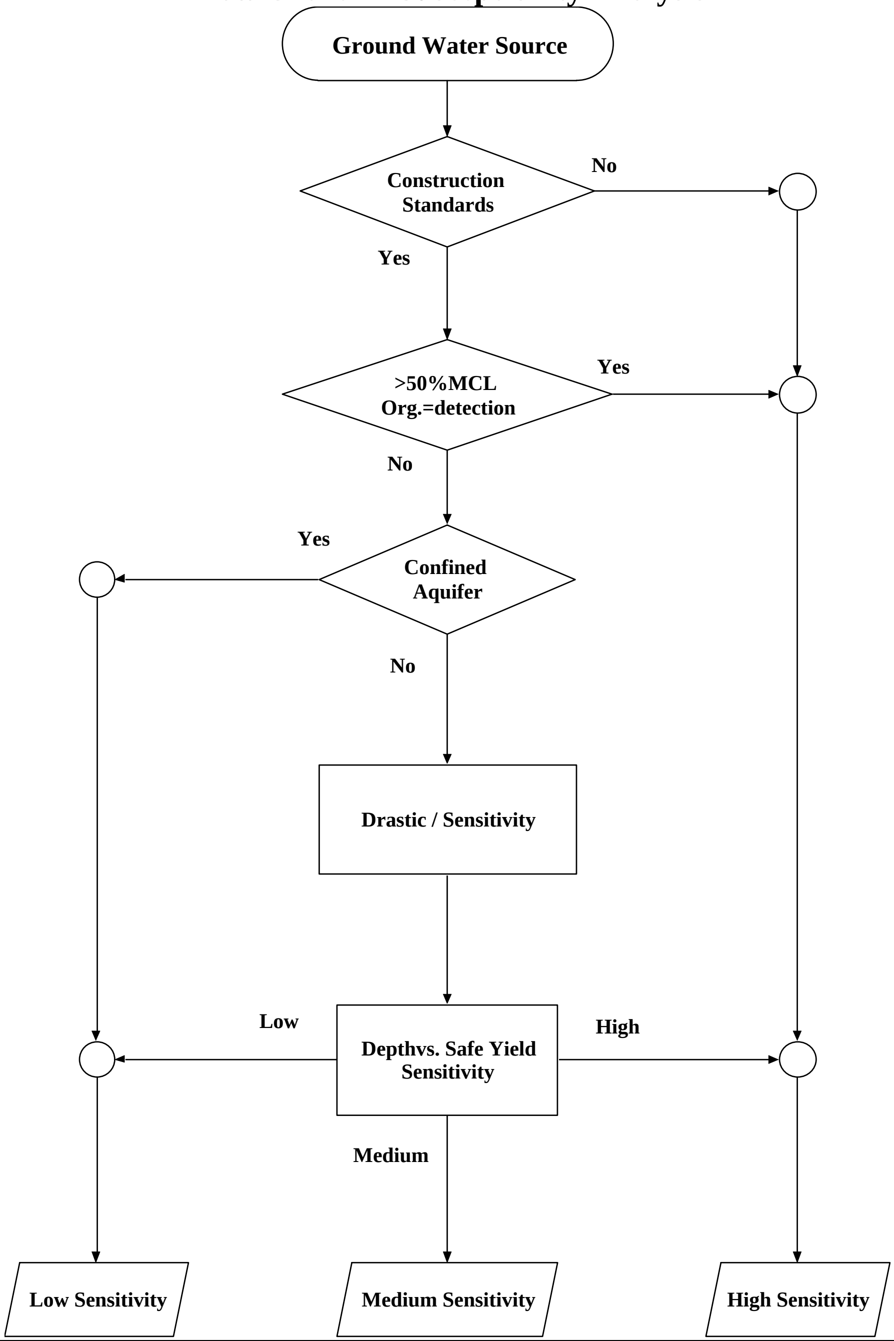
2. Susceptibility Analysis of Surface Water Sources to Contamination

The susceptibility analysis for a surface water source of drinking water would not be substantially different from an analysis of a groundwater source except for the limited protection and resulting high sensitivity of surface water sources to contamination. Large reservoirs with at least a one-month detention time at high flows could offer a medium sensitivity to upstream or distant potential sources of contamination.

Flow Chart 1 - Susceptibility Analysis



Flow Chart 2 - Susceptibility Analysis



Potential for Contamination
Matrix A (Step 1)
Time of Travel (TOT) vs. Fate & Transport (persistence)

\ Persistence **TOT **	High	Medium	Low
Short	High	High	Medium
Medium	High	Medium	Low
Long	Medium	Low	Low

Matrix B (Step 2)
Matrix A vs. Quantity

\ Quantity **Matrix A Result**	High	**Medium**	**Low**
High	High	High	Medium
Medium	High	Medium	Low
Low	Medium	Low	Low

Potential Impact
Matrix C
Potential for Contamination vs. Sensitivity

\ Sensitivity **Potential for Contamination ** **(from Matrix B)**	**High**	**Medium**	**Low**
High	High	High	Medium
Medium	High	Medium	Low
Low	Medium	Low	Low

Potential for Release

**Potential for Release Control Practice **	**Low**	*Medium*	**Medium-High**	**High**
Regulated Containment &/or ERP	X			
Unregulated Containment / no ERP		X		
Regulated Discharge in Compliance			X	
“ “ *Not in Compliance*				X
NPS w/ Best Management Practices		X		
BMPs Not Operating			X	
No Control Practices				X

(ERP = Emergency Response Plan, NPS = Non-Point Source, BMP = Best Management Practice)

Susceptibility Rating
Matrix D

Potential for Release vs. Potential Impact

\ *Potential Impact* **(from Maxtrix C)** **Pot. For Release ** **(from Table)**	*High*	**Medium**	**Low**
High	A	B	C
Medium High	B	***C***	D
Medium	C	***D***	E
Low	D	E	F

Walnut Creek Stream Flow Measurements

US 5 Bridge					**FLOW**	**IN CFS :**	**29.0617**
Walnut Creek					"	**" GPM :**	**13043.75**
10/16/06					"	**" MGD :**	**18.78**
Width(W)	Depth(D)	Velocity(V)		Wi	Di	Vi	Qi
0	0.4	0.2		*	*	*	*
2.624672	2.4	0.45		2.62	1.40	0.33	1.1942
5.249344	2.6	0.6		2.62	2.50	0.53	3.4449
7.874016	2.6	0.55		2.62	2.60	0.58	3.9239
10.498688	2.7	0.5		2.62	2.65	0.53	3.6516
13.12336	2.8	0.5		2.62	2.75	0.50	3.6089
15.748032	2.8	0.4		2.62	2.80	0.45	3.3071
18.372704	2.7	0.5		2.62	2.75	0.45	3.2480
20.997376	2.5	0.45		2.62	2.60	0.48	3.2415
23.622048	1.8	0.4		2.62	2.15	0.43	2.3983
26.24672	0.7	0.25		2.62	1.25	0.33	1.0663
28.871392	0.2	0.2		2.62	0.45	0.23	0.2657

US 5 Bridge Walnut Creek 10/30/06					**FLOW**	**IN CFS :**	**73.9878**
					"	**" GPM :**	**33207.92**
					"	**" MGD :**	**47.82**
Width(W)	Depth(D)	Velocity(V)		Wi	Di	Vi	Qi
0	0.6	0.8		*	*	*	*
1.924759467	0.6	0.95		1.92	0.60	0.88	1.0105
3.849518933	2.7	1		1.92	1.65	0.98	3.0965
5.7742784	3.1	0.95		1.92	2.90	0.98	5.4423
7.699037867	2.9	1.4		1.92	3.00	1.18	6.7848
9.623797333	3	1.1		1.92	2.95	1.25	7.0976
11.5485568	3.1	1.25		1.92	3.05	1.18	6.8979
13.47331627	3.2	1.1		1.92	3.15	1.18	7.1240
15.39807573	3.4	1.2		1.92	3.30	1.15	7.3045
17.3228352	3	1.1		1.92	3.20	1.15	7.0831
19.24759467	2.8	1.2		1.92	2.90	1.15	6.4191
21.17235413	2.7	1.3		1.92	2.75	1.25	6.6164
23.0971136	2.4	1.1		1.92	2.55	1.20	5.8898
25.02187307	1.3	0.75		1.92	1.85	0.93	3.2937
26.94663253	0.6	0.75		1.92	0.95	0.75	1.3714
28.871392	0.6	0.5		1.92	0.60	0.63	0.7218

US 5 Bridge
Walnut Creek
10/30/06

					FLOW	**IN CFS :**	**71.1093**
					"	**" GPM :**	**31916.00**
					"	**" MGD :**	**45.96**
Width(W)	Depth(D)	Velocity(V)		Wi	Di	Vi	Qi
0	0.6	0.47		*	*	*	*
1.804462	2.9	0.95		1.80	1.75	0.71	2.2420
3.608924	3.2	0.8		1.80	3.05	0.88	4.8157
5.413386	2.9	1.1		1.80	3.05	0.95	5.2284
7.217848	3	1.1		1.80	2.95	1.10	5.8555
9.02231	3	1		1.80	3.00	1.05	5.6841
10.826772	3.1	1		1.80	3.05	1.00	5.5036
12.631234	3.2	1		1.80	3.15	1.00	5.6841
14.435696	3.4	0.9		1.80	3.30	0.95	5.6570
16.240158	3.4	1.05		1.80	3.40	0.98	5.9818
18.04462	2.9	1		1.80	3.15	1.03	5.8262
19.849082	2.8	1.1		1.80	2.85	1.05	5.3999
21.653544	2.6	1.1		1.80	2.70	1.10	5.3593
23.458006	1.9	1		1.80	2.25	1.05	4.2630
25.262468	1.8	0.85		1.80	1.85	0.93	3.0879
27.06693	0.9	0.5		1.80	1.35	0.68	1.6443
28.871392	0.6	0.4		1.80	0.75	0.45	0.6090

US 5 Bridge
Walnut Creek
11/1/06

				FLOW	**IN CFS :**	**71.1093**	
				"	**" GPM :**	**31916.00**	
				"	**" MGD :**	**45.96**	
Width(W)	Depth(D)	Velocity(V)		Wi	Di	Vi	Qi
0	0.6	0.47		*	*	*	*
1.804462	2.9	0.95		1.80	1.75	0.71	2.2420
3.608924	3.2	0.8		1.80	3.05	0.88	4.8157
5.413386	2.9	1.1		1.80	3.05	0.95	5.2284
7.217848	3	1.1		1.80	2.95	1.10	5.8555
9.02231	3	1		1.80	3.00	1.05	5.6841
10.826772	3.1	1		1.80	3.05	1.00	5.5036
12.631234	3.2	1		1.80	3.15	1.00	5.6841
14.435696	3.4	0.9		1.80	3.30	0.95	5.6570
16.240158	3.4	1.05		1.80	3.40	0.98	5.9818
18.04462	2.9	1		1.80	3.15	1.03	5.8262
19.849082	2.8	1.1		1.80	2.85	1.05	5.3999
21.653544	2.6	1.1		1.80	2.70	1.10	5.3593
23.458006	1.9	1		1.80	2.25	1.05	4.2630
25.262468	1.8	0.85		1.80	1.85	0.93	3.0879
27.06693	0.9	0.5		1.80	1.35	0.68	1.6443
28.871392	0.6	0.4		1.80	0.75	0.45	0.6090

US 5 Bridge Walnut Creek 11/3/06							
				FLOW	**IN CFS :**	**85.0432**	
				"	**" GPM :**	**38169.95**	
				"	**" MGD :**	**54.96**	
Width(W)	Depth(D)	Velocity(V)		Wi	Di	Vi	Qi
0	0.6	0.9		*	*	*	*
1.698317176	0.6	0.9		1.70	0.60	0.90	0.9171
3.396634353	2.9	1		1.70	1.75	0.95	2.8235
5.094951529	3.2	1.3		1.70	3.05	1.15	5.9568
6.793268706	3.3	1		1.70	3.25	1.15	6.3475
8.491585882	3.3	1.1		1.70	3.30	1.05	5.8847
10.18990306	3.7	1.3		1.70	3.50	1.20	7.1329
11.88822024	3.7	1.3		1.70	3.70	1.30	8.1689
13.58653741	3.7	1.2		1.70	3.70	1.25	7.8547
15.28485459	3.8	1		1.70	3.75	1.10	7.0056
16.98317176	4.1	1.1		1.70	3.95	1.05	7.0438
18.68148894	3.1	1		1.70	3.60	1.05	6.4196
20.37980612	2.9	1.2		1.70	3.00	1.10	5.6044
22.07812329	2.8	1.1		1.70	2.85	1.15	5.5662
23.77644047	2.8	1.3		1.70	2.80	1.20	5.7063
25.47475765	2	1.1		1.70	2.40	1.20	4.8912
27.17307482	1.7	1.1		1.70	1.85	1.10	3.4561
28.871392	0.7	1.7		1.70	1.20	1.40	2.8532

US 5 Bridge Walnut Creek 11/4/06					**FLOW**	**IN CFS :**	**45.5049**
					"	**" GPM :**	**20423.97**
					"	**" MGD :**	**29.41**
Width(W)	Depth(D)	Velocity(V)		Wi	Di	Vi	Qi
0	0.5	0.8		*	*	*	*
1.924759467	0.5	0.4		1.92	0.50	0.60	0.5774
3.849518933	2.2	0.37		1.92	1.35	0.39	1.0004
5.7742784	2.9	0.67		1.92	2.55	0.52	2.5522
7.699037867	3.1	0.57		1.92	3.00	0.62	3.5801
9.623797333	2.9	0.55		1.92	3.00	0.56	3.2336
11.5485568	3	0.84		1.92	2.95	0.70	3.9462
13.47331627	3	1.03		1.92	3.00	0.94	5.3990
15.39807573	3.25	1.04		1.92	3.13	1.04	6.2254
17.3228352	3.3	1.08		1.92	3.28	1.06	6.6818
19.24759467	2.7	0.95		1.92	3.00	1.02	5.8609
21.17235413	2.3	1		1.92	2.50	0.98	4.6916
23.0971136	1.9	0.87		1.92	2.10	0.94	3.7793
25.02187307	1.65	0.4		1.92	1.78	0.64	2.1694
26.94663253	0.6	0.25		1.92	1.13	0.33	0.7037
28.871392	0.4	0.25		1.92	0.50	0.25	0.2406
30.79615147	1.7	1.1		1.92	1.05	0.68	1.3642
32.72091093	0.7	1.7		1.92	1.20	1.40	3.2336

US 5 Bridge Walnut Creek 11/28/06					**FLOW**	**IN CFS :**	**28.1445**
					"	**" GPM :**	**12632.10**
					"	**" MGD :**	**18.19**
Width(W)	Depth(D)	Velocity(V)		Wi	Di	Vi	Qi
0	0.3	0.12		*	*	*	*
1.698317176	0.3	0.16		1.70	0.30	0.14	0.0713
3.396634353	2.7	0.35		1.70	1.50	0.26	0.6496
5.094951529	2.8	0.5		1.70	2.75	0.43	1.9849
6.793268706	2.6	0.45		1.70	2.70	0.48	2.1781
8.491585882	2.7	0.45		1.70	2.65	0.45	2.0252
10.18990306	2.8	0.45		1.70	2.75	0.45	2.1017
11.88822024	2.8	0.55		1.70	2.80	0.50	2.3776
13.58653741	2.8	0.55		1.70	2.80	0.55	2.6154
15.28485459	2.8	0.61		1.70	2.80	0.58	2.7581
16.98317176	3	0.4		1.70	2.90	0.51	2.4872
18.68148894	2.9	0.44		1.70	2.95	0.42	2.1042
20.37980612	2.5	0.6		1.70	2.70	0.52	2.3844
22.07812329	2.1	0.5		1.70	2.30	0.55	2.1484
23.77644047	1.7	0.5		1.70	1.90	0.50	1.6134
25.47475765	0.8	0.07		1.70	1.25	0.29	0.6050
27.17307482	0.3	0.01		1.70	0.55	0.04	0.0374
28.871392	0.3	0		1.70	0.30	0.01	0.0025