

in cooperation with the Chester County Water Resources Authority

U.S. Geological Survey Cooperative Water-Resources Programs in Chester County, Pennsylvania

INTRODUCTION

Since 1969, the U.S. Geological Survey (USGS) has had a cooperative water-resources investigation program with Chester County to measure and describe the water resources of the County. Generally, the USGS provides one-half of the program funding, and local cooperators are required to provide matching funds. Cooperation has been primarily with the Chester County Water Resources Authority (CCWRA), with participation from the Chester County Health Department and funding from the Chester County Board of Commissioners. Municipalities and the Red Clay Valley Association also have provided part of the funding for several projects. This report describes how the long-term partnership between the USGS and Chester County, Pa., provides the County with the information that it needs for sound water-resources management.

The CCWRA was created in 1961, primarily for land acquisition and planning for flood-control and water-supply projects. With the backing of the Brandywine Valley Association, the CCWRA started its first cooperative project with the USGS in 1969. It was a study of the water-quality condition of Chester County streams with an emphasis on benthic macroinvertebrates and stream chemistry.

The kinds of projects and data collection conducted by the USGS have changed with the needs of Chester County and the mission of the CCWRA. Chester County is experiencing rapid population growth (it had the tenth-highest rate of growth in the nation from 1980 to 1990). This growth places considerable stress on water resources and has caused the CCWRA to broaden its focus from flood control to water-supply planning, water quality, and ground-water and surface-water management. The results of USGS studies are used by the CCWRA and other County agencies, including the Planning Commission, Health Department, and Parks and Recreation Department, for conducting day-to-day activities and planning for future growth. The results also are used by the CCWRA to provide guidance and technical assistance to municipalities, water suppliers, industrial dischargers, watershed and conservancy associations and other civic organizations, state and Federal agencies, river basin commissions, and the private sector.

The cooperative water-resources program, which is described in the following sections, benefits not only the citizens of Chester County but also serves the interests of the Federal Government. Innovative studies conducted in Chester County provide methods and interpretations that often can be used nationwide, and the headwaters of several interstate drainages lie within the County. Major program thrusts include collection of surface-water, ground-water, and water-quality data and interpretive studies. The use of this information also is described.

FLOOD-WARNING NETWORK

As part of the cooperative program between the USGS and Chester County, a system of streamflow-measurement stations is maintained with telephone access for real-time stage (depth) monitoring as well as near-real-time access via the World Wide Web for monitoring stream stage and discharge. With this system, County emergency management personnel and CCWRA can monitor rising and cresting floods in key watersheds throughout the County. This information provides the basis for alerting emergency response personnel of potential and existing flood conditions. Streamflow is monitored continuously by the USGS at 14 sites in Chester County. Three of the stations also are equipped with rain gages (fig. 1). Eleven of the 14 streamflow-measurement stations are

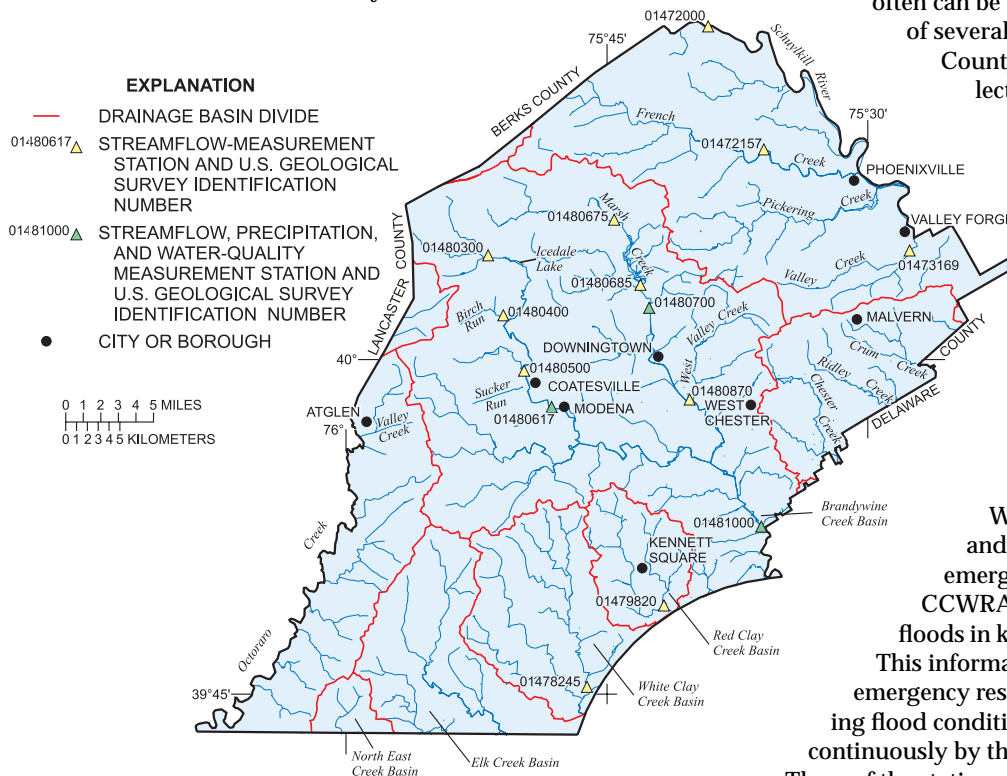


Figure 1. Location of streamflow-measurement stations and water-quality monitors in Chester County.

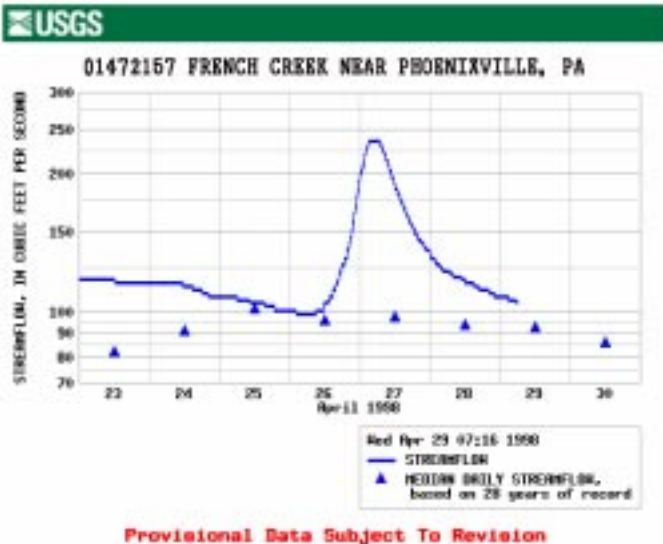


Figure 2. Example of near-real-time streamflow data from the USGS Pennsylvania District Web site (<http://pa.water.usgs.gov>).

equipped with data-collection platforms. These platforms broadcast hydrologic data to a satellite that relays the data to the USGS District office in Lemoyne, Pa. These data are available on the Internet within a few hours of being collected. A streamflow hydrograph obtained directly from the USGS Pennsylvania District Web site is shown in figure 2. The hydrograph shows an increase in streamflow caused by rainfall starting on April 26, 1998. Land line telemetry that provides instantaneous values of stream stage also is available at several of the streamflow-measurement stations and is used by County and municipal emergency management coordinators during severe weather events to ascertain local flooding conditions. The CCWRA provides all or part of the funding for eight sites: French Creek near Phoenixville (USGS station number 01472157), Birch Run near Wagontown (01480400), West Branch Brandywine Creek at Coatesville (01480500), West Branch Brandywine Creek at Modena (01480617), Valley Creek at Pennsylvania Turnpike Bridge near Valley Forge (01473169), East Branch Brandywine Creek below Downingtown (01480870), West Branch Brandywine Creek near Honeybrook (01480300), and Brandywine Creek at Chadds Ford (01481000).

Data from the flood-warning network are used by Chester County to provide early warning of floods as well as to provide flood statistics (recurrence interval) and a quantitative basis for flood plain mapping. Streamflow data from the network are published by the USGS in annual water-data reports and also are available on the District Web site.

DATA FOR RESERVOIR MANAGEMENT

Data from several streamflow-measurement stations operated by the USGS are used by Chester County and water suppliers for managing streamflows and reservoir releases. Streamflow and water-temperature data collected by the USGS throughout the Brandywine Creek watershed are used to determine when reservoir releases are required, how much release is necessary, and how much release occurs, and also to insure that interstate water-management requirements are fulfilled. These releases are needed to provide adequate flow of water for aquatic life, to meet the needs of downstream water suppliers, and to meet permit requirements. Adequate stream-

flow during droughts is critical to downstream users in New Castle County, Del., who obtain 70 percent of their public supply from streams in the Christina River Basin that originate in Chester County.

DROUGHT-MONITORING NETWORK

Chester County has the only county-wide water-level observation-well network in Pennsylvania. Since 1973, water levels have been measured monthly in a network of 23 wells. Monthly drought-warning and drought-emergency water levels (triggers) have been determined statistically for all but three of the wells in the network using methods described by Schrefler (1997). Data from the network are used by Chester County officials and other agencies to make decisions about when to declare drought watches, warnings, and emergencies. Low streamflow data for the 14 streamflow-measurement stations in Chester County and CCWRA's own network of 29 rain gages also are used to help make these decisions.

SURFACE-WATER-QUALITY MONITORING

Except during the winter, surface-water quality is monitored on the West Branch Brandywine Creek at Modena (01480617), on the East Branch Brandywine Creek below Downingtown (01480870), and on the Brandywine Creek at Chadds Ford (01481000). Temperature, pH, specific conductance (related to dissolved solids), and dissolved oxygen are measured hourly, and fecal coliform bacteria are measured biweekly. These data are used to assess stream health and to determine trends and detect problems in stream-water quality. Minimum daily dissolved-oxygen concentrations for 1972-97 for the East Branch Brandywine Creek below Downingtown are shown in figure 3. Dissolved-oxygen concentrations of less than 5 milligrams per liter (the minimum concentration needed to support a healthy aquatic environment) were fairly common before 1989 but are relatively infrequent from 1989 to 1997.

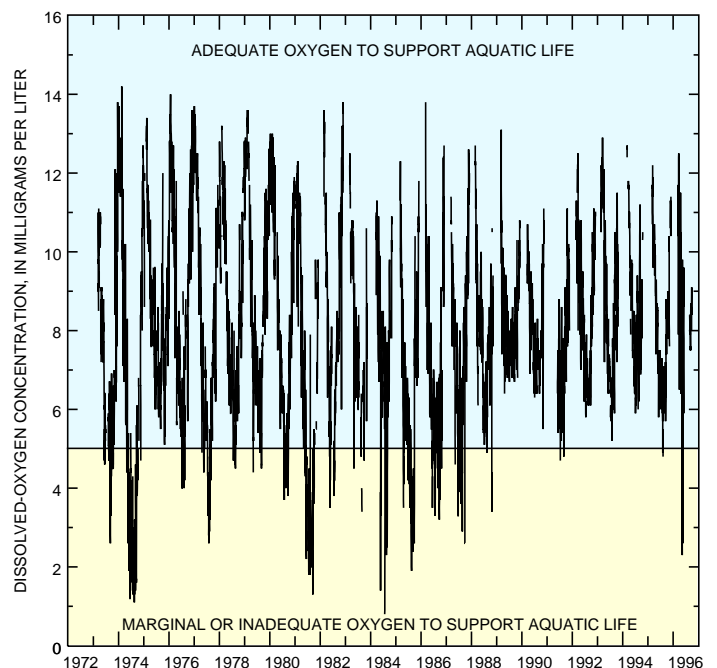


Figure 3. Minimum daily dissolved-oxygen concentration for the East Branch Brandywine Creek below Downingtown, Pa. (U.S. Geological Survey station number 01480870).

GROUND-WATER QUALITY

Since 1925, water from numerous wells in Chester County has been sampled and analyzed by the USGS for inorganic constituents, nutrients, metals and other trace constituents, pesticides, volatile and semivolatile organic compounds, and radionuclides. Some sampling has been targeted toward industrial areas, landfills, and agricultural areas. For example, figure 4 shows the distribution of volatile organic compounds in ground water in Chester County. Results of USGS sampling have been beneficial to local residents and to the Chester County Health Department by locating local areas of ground-water contamination and have contributed to several sites in Chester County being placed on the National Priorities (Superfund) List. Also, sampling helped to identify the Chickies Formation as a source of elevated, naturally occurring radium and radon in ground water.

STREAM AND GROUND-WATER CHARACTERIZATION

Since about 1970, benthic invertebrates and stream water chemistry are sampled annually at 51 different sites in Chester County to determine relative stream quality (health) and long-term changes in stream quality. The sampling network currently (1998) consists of 43 sites on the major streams in the County. Each fall, benthic invertebrates are sampled (fig. 5) at 25 of the sites, and a diversity index (a statistic that describes community structure of benthic invertebrates) is calculated for each site. A low-flow water sample is collected for laboratory analysis for selected constituents, and bottom sediments are periodically sampled and analyzed for polychlorinated biphenyls (PCB's) and organochlorine insecticides (including DDT).

The diversity indices for Valley Creek at Atglen for 1971-96 are shown in figure 6. The substantial improvement (increase) in diversity from 1971 to 1989, which is typical of most streams



Figure 5. U.S. Geological Survey personnel collecting benthic invertebrates from Pickering Creek near Phoenixville, Pa.

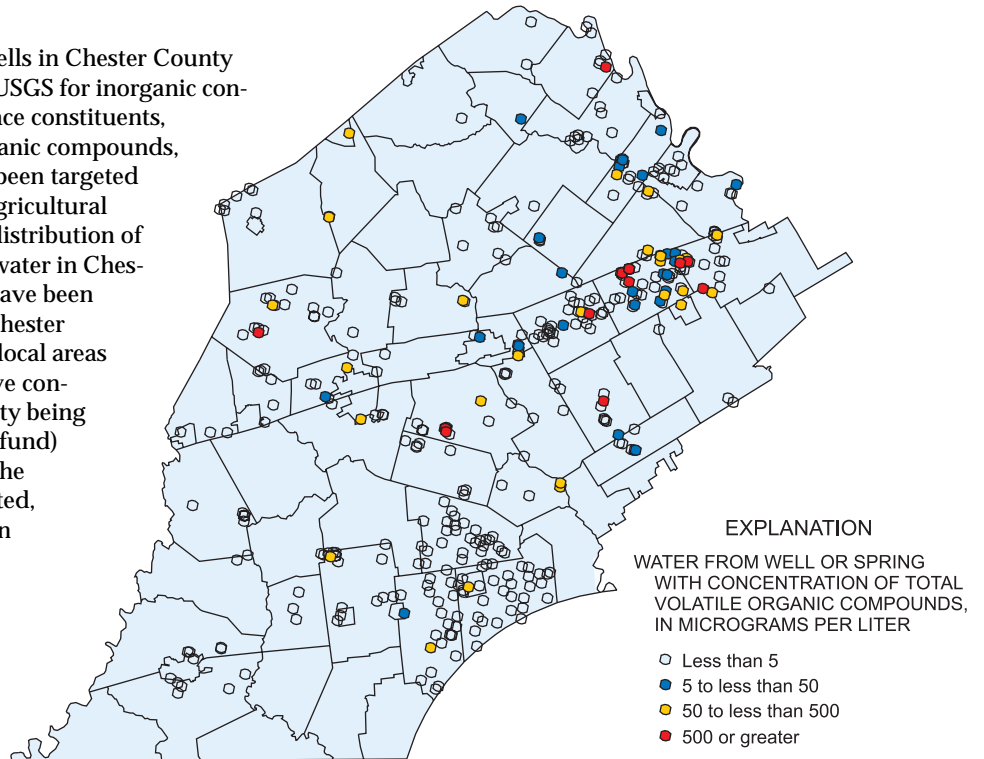


Figure 4. Concentrations of total volatile organic compounds in water from wells and springs in Chester County, 1980-96.

in Chester County, is at least partly the result of decreased concentrations of organochlorine insecticides in bottom sediments (Hardy and others, 1995).

Since 1981, the USGS has been mapping the elevation and shape of the water table (for unconfined aquifers) and the potentiometric surface (for confined aquifers) in Chester County. Areas of Chester County where the water table or potentiometric surface has been mapped are shown on figure 7. These maps can be compared to water table or potentiometric-surface maps prepared at some later time to assess changes caused by increased ground-water withdrawals and reduced recharge related to urbanization. They also can be used to determine the direction of ground-water (and, where present, contaminant) flow. These maps are frequently used by municipalities and developers to evaluate ground-water conditions for water supply and resource-protection requirements.

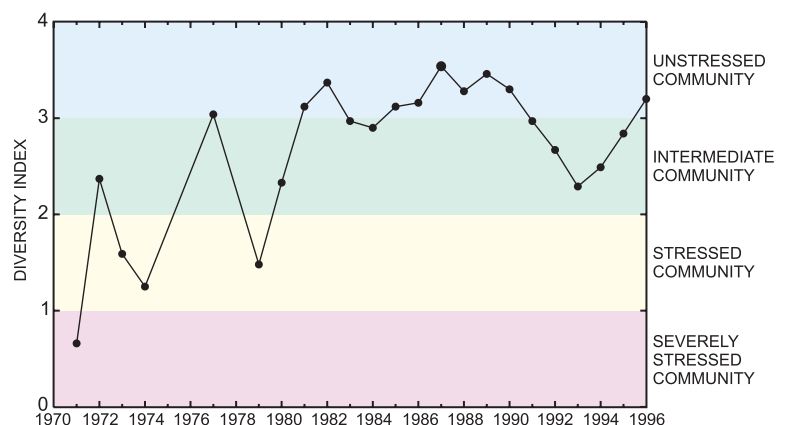


Figure 6. Brillouin's Diversity Index of benthic macroinvertebrates for Valley Creek at Atglen, Pa., 1971-96.

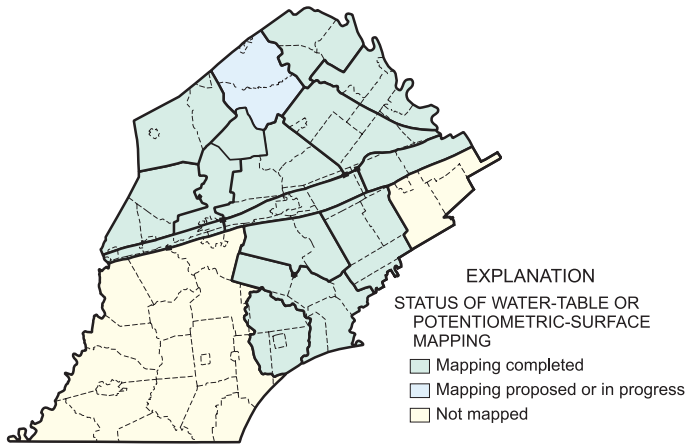


Figure 7. Areas in Chester County, Pa., where the water table or potentiometric surface has been mapped by the U.S. Geological Survey.

INTERPRETIVE STUDIES

In addition to data collection and monitoring, the USGS, in cooperation with Chester County and local entities, has conducted many interpretive studies of the water resources of Chester County. These studies, which interpret the data collected for the study and long-term-monitoring data, have evaluated peak flows of streams, ground-water flow and quality, the effects of urbanization on water resources, chemical and biological quality of streams, and water use.

Computer-based models of peak streamflow are used for stormwater management and to design reservoirs for flood control. Models of the West Branch Brandywine Creek developed by the USGS (Sloto, 1982a; 1988a) were used by the CCWRA to select a site for a new multi-purpose reservoir (Chambers Lake). Sloto (1985) modeled the peak flows of Sucker Run and showed that flood-control structures could reduce 100-year peak discharges for the West Branch Brandywine Creek by 41 percent. Sloto also showed that flood-control structures in Sucker Run would increase flooding of the Brandywine Creek below its confluence with Sucker Run. A peak-flow model of Valley Creek (Sloto, 1988b) was used to illustrate how increased impervious land area would cause an increase in peak streamflows (fig. 8).

Comprehensive evaluations of the ground-water resources of Chester County were prepared by McGreevy and Sloto (1977) and by Sloto (1994). Computer models have been developed to simulate ground-water flow in the Pickering Creek Basin (McGreevy and Sloto, 1980), the Valley Creek Basin (Sloto, 1990), and the Red Clay Creek Basin (Vogel and Reif, 1993). Sloto (1994, p. 53) used the model of the Pickering Creek Basin to illustrate the effects of increased ground-water withdrawals on streamflow in Pickering Creek.

Three studies have described the effects of urbanization and land use on water resources or provide background data for future studies of the effects of urbanization. Sloto (1987) described the effect of urbanization on the quality and quantity of surface water and ground water of eastern Chester County. Senior (1996) studied ground-water quality and its relation to hydrogeology, land use, and surface-water quality in the Red Clay Creek Basin. This study showed how nitrate concentration is increasing with time in the base flow of the West Branch

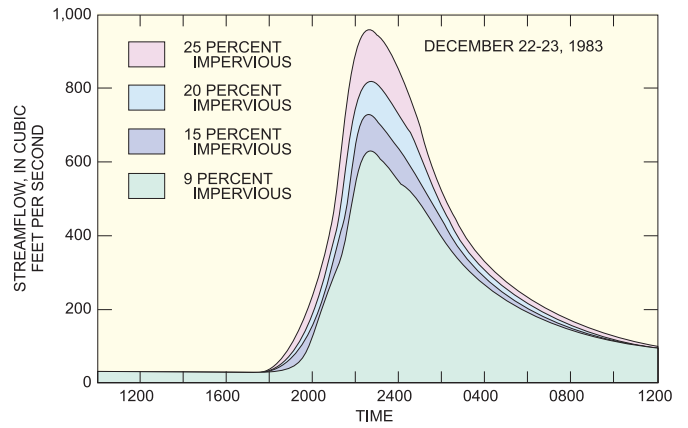


Figure 8. Simulated hydrographs of the flow of Valley Creek at the confluence with the Schuylkill River for storm of December 22-23, 1983, showing the effects of increased impervious area in the Valley Creek Basin (from Sloto, 1988b, fig. 18).

Red Clay Creek. Senior and others (1997) also studied the hydrogeology and water quality of the West Valley Creek Basin to provide baseline data prior to additional urbanization. Gaining and losing stream reaches identified in this study are shown in figure 9. Any contaminants in streamflow in the losing reaches will move downward to the water table.

Several USGS reports describe the biological and chemical quality of streams. Murphy and others (1982) evaluated the results of water-quality monitoring in the Brandywine Creek Basin from 1973 to 1978. Lium (1977) prepared a report on the limnology of the major streams in Chester County. Moore (1987) determined benthic-macroinvertebrate indices and discussed water-quality trends for selected streams. Hardy and others (1995) related land use, concentrations of organochlorine compounds, and trends in benthic-macroinvertebrate communities in selected streams. These studies show that changes in the biota can indicate water-quality problems that cannot be observed on the basis of chemical analyses alone.

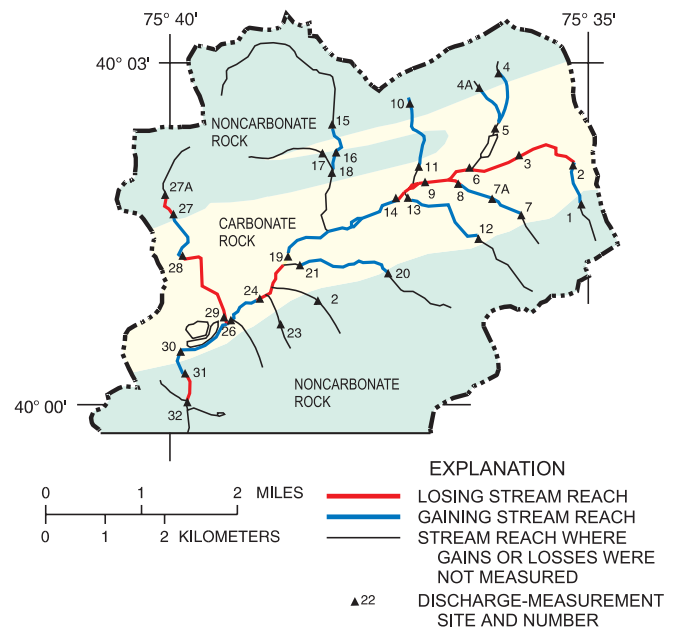


Figure 9. Location of losing and gaining stream reaches and discharge-measurement sites, October 1990, West Valley Creek Basin, Pa. (modified from Senior and others, 1997).

NEW STUDIES

Several studies are currently being conducted by the USGS in cooperation with Chester County. A study of radon in ground water will provide information on county-wide geographic and geologic distribution of radon and identify those geologic units that have the highest ground-water radon activities. Low-flow frequency is being computed for stream sites in Chester County where flow has been measured. A new study will investigate the effects of land application of treated sewage effluent (spray irrigation) on ground water and surface water in New Garden Township. Trends in benthic-macroinvertebrate diversity from 1981 to 1996 will be evaluated to update earlier studies. A study of the Elk Creek Basin will develop a water budget, make estimates of ground-water availability, and describe the chemical quality of ground water. Hydrologic data collected by the USGS in Chester County is being compiled into a CD-ROM along with an index to provide greater access and use of the data by consultants, engineers, researchers, and planners.

The USGS is cooperating with Chester County and several state, regional, and Federal agencies in a study of the Christina River Basin, which includes the White Clay, Red Clay, and Brandywine Creek Basins (fig. 1) in Chester County, Pa., and New Castle County, Del. Streamflow, nutrient, and sediment data will be collected to estimate total loads of nitrate, phosphorus, and sediment from point and nonpoint sources and to estimate concentrations and loads of these constituents from various land uses. These data will be used to calibrate a watershed model of the basin for these constituents. The watershed model will simulate the hydrodynamics, chemical reactions, and sediment transport in the stream and the delivery of non-point-source contaminants to the stream. This study will provide the basis for a Christina River Basin watershed-management plan to protect sources of water supply and preserve ecological resources.

APPLICATION OF HYDROLOGIC DATA AND RESULTS OF STUDIES TO COMPREHENSIVE PLANNING AND LAND-USE MANAGEMENT

The data, results, and products developed by the USGS in the cooperative water-resources investigation program with Chester County have created a base of water-resources knowledge that is being increasingly incorporated into land-use planning and management at all levels of government. Many USGS documents are cited in municipal ordinances as authoritative sources of information and resource data. USGS data and products are frequently used by watershed associations in watershed-management studies and activities. Water-resources management goals and policies for Chester County were defined in "Landscapes," the County's comprehensive planning policy document. These policies are being carried forward in a county-wide water-resources management and water-supply planning effort, which will be based on the scientific foundation of nearly 40 years of water-resources data and understanding developed through the cooperative program. This new plan will provide County and local land planners and municipal decisionmakers with the water-resources data and understanding necessary to make informed land-use management decisions to accommodate growth while preserving the integrity of Chester County's natural resources.

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