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SIMULATION OF STREAMFLOW AND WATER QUALITY IN THE WHITE CLAY CREEK SUBBASIN OF THE CHRISTINA RIVER BASIN, PENNSYLVANIA AND DELAWARE, 1994-98

by Lisa A. Senior and Edward H. Koerkle

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In cooperation with the

DELAWARE RIVER BASIN COMMISSION,

DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL, *and the*

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CONVERSION FACTORS, DATUMS, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	4,047	square meter
square mile (mi^2)	2.590	square kilometer
	Volume	
million gallons (Mgal)	3,785	cubic meter
cubic foot (ft^3)	0.02832	cubic meter
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second
inch per hour (in/h)	0.0254	meter per hour
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram
pound per hour (lb/h)	0.4536	kilogram per hour
ton, short (2,000 lb)	0.9072	megagram
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Application rate	
pound per acre (lb/acre)	1.121	kilogram per hectare
pound per acre per year [(lb/acre)/yr]	1.121	kilogram per hectare per year
ton per acre (ton/acre)	2.242	megagrams per hectare
ton per acre per year [(ton/acre)/yr]	2.242	megagrams per hectare
	Temperature	
degree Fahrenheit (°F)	°C=5/9 (°F-32)	degree Celsius

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29); horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Abbreviated water-quality units used in report:

L, liter
mg/L, milligrams per liter
µg/L, micrograms per liter
mL, milliliter
µS/cm, microsiemens per centimeter at 25 degrees Celsius

SIMULATION OF STREAMFLOW AND WATER QUALITY IN THE WHITE CLAY CREEK SUBBASIN OF THE CHRISTINA RIVER BASIN, PENNSYLVANIA AND DELAWARE, 1994-98

By Lisa A. Senior and Edward H. Koerkle

ABSTRACT

The Christina River Basin drains 565 square miles (mi^2) in Pennsylvania, Maryland, and Delaware. Water from the basin is used for recreation, drinking-water supply, and to support aquatic life. The Christina River Basin includes the major subbasins of Brandywine Creek, White Clay Creek, and Red Clay Creek. The White Clay Creek is the second largest of the subbasins and drains an area of 108 mi^2. Water quality in some parts of the Christina River Basin is impaired and does not support designated uses of the streams. A multi-agency water-quality management strategy included a modeling component to evaluate the effects of point and nonpoint-source contributions of nutrients and suspended sediment on stream water quality. To assist in non point-source evaluation, four independent models, one for each of the three major subbasins and for the Christina River, were developed and calibrated using the model code Hydrological Simulation Program—Fortran (HSPF). Water-quality data for model calibration were collected in each of the four main subbasins and in smaller subbasins predominantly covered by one land use following a nonpoint-source monitoring plan. Under this plan, stormflow and base-flow samples were collected during 1998 at two sites in the White Clay Creek subbasin and at nine sites in the other subbasins.

The HSPF model for the White Clay Creek Basin simulates streamflow, suspended sediment, and the nutrients, nitrogen and phosphorus. In addition, the model simulates water temperature, dissolved oxygen, biochemical oxygen demand, and plankton as secondary objectives needed to support the sediment and nutrient simulations. For the model, the basin was subdivided into 17 reaches draining areas that ranged from 1.37 to 13 mi^2. Ten different pervious land uses and two impervious land uses were selected for simulation. Land-use areas were determined from 1995 land-use data. The predominant land uses in the White Clay Creek Basin are agricultural, forested, residential, and urban.

The hydrologic component of the model was run at an hourly time step and primarily calibrated using streamflow data from two U.S. Geological Survey (USGS) streamflow-measurement stations for the period of October 1, 1994, through October 29, 1998. Additional calibration was done using data from two other USGS streamflow-measurement stations with periods of record shorter than the calibration period. Daily precipitation data from two National Oceanic and Atmospheric Administration (NOAA) gages and hourly precipitation and other meteorological data for one NOAA gage were used for model input. The difference between simulated and observed streamflow volume ranged from -0.9 to 1.8 percent for the 4-year period at the two calibration sites with 4-year records. Annual differences between observed and simulated streamflow generally were greater than the overall error. For example, at a site near the bottom of the basin (drainage area of 89.1 mi^2), annual differences between observed and simulated streamflow ranged from -5.8 to 14.4 percent and the overall error for the 4-year period was -0.9 percent. Calibration errors for 36 storm periods at the two calibration sites for total volume, low-flow-recession rate, 50-percent lowest flows, 10-percent highest flows, and storm peaks were within the recommended criteria of 20 percent or less. Much of the error in simulating storm events on an hourly time step can be attributed to uncertainty in the hourly rainfall data.

The water-quality component of the model was calibrated using data collected by the USGS and state agencies at three USGS streamflow-measurement stations with variable water-quality monitoring periods ending October 1998. Because of availability, monitoring data for suspended-solids concentrations were used as surrogates for suspended-sediment concentrations, although suspended solids may underestimate suspended sediment and affect apparent accuracy of the suspended-sediment simulation. Comparison of observed to simulated loads for up to five storms in 1998 at each of the two nonpoint-source monitoring sites in the White Clay Creek Basin indicate that simulation error is commonly as large as an order of magnitude for suspended sediment and nutrients. The simulation error tends to be smaller for dissolved nutrients than for particulate nutrients. Errors of 40 percent or less for monthly or annual values indicate a fair to good water-quality calibration according to recommended criteria,

with much larger errors possible for individual events. The accuracy of the water-quality calibration under stormflow conditions is limited by the relatively small amount of water-quality data available for the White Clay Creek Basin.

Users of the White Clay Creek HSPF model should be aware of model limitations and consider the following if the model is used for predictive purposes: streamflow and water quality for individual storm events may not be well simulated, but the model performance is reasonable when evaluated over longer periods of time; the observed flow-duration curve for the simulation period is similar to the long-term flow-duration curve at White Clay Creek near Newark, Del., indicating that the calibration period is representative of all but highest 0.1 percent and lowest 0.1 percent of flows at that site; relative errors in streamflow and water-quality simulations are greater for smaller drainage areas than for larger areas; and calibration for water-quality was based on sparse data.

INTRODUCTION

The Christina River Basin (fig. 1), which includes White Clay Creek (drainage area of 108 mi^2), Red Clay Creek (54 mi^2), and Brandywine Creek (327 mi^2), drains approximately 565 mi^2 in southeastern Pennsylvania, northern Delaware, and a small part of northeastern Maryland. The Christina River and its tributaries provide drinking water for more than 40 percent of the residents of Chester County, Pa., and more than 50 percent of the residents of New Castle County, Del.

Stream waters of the Christina River Basin are used for public water supply and recreation and to support aquatic life. Some of these uses are threatened because water quality has been impaired by point and nonpoint sources of pollution. Causes of impairment have been identified as sediment, nutrients, and bacteria (Greig and others, 1998). In addition, some agricultural areas of the basin are undergoing urbanization, and the effects of land-use changes on water quality and quantity are unknown. The states of Delaware and Pennsylvania need tools to evaluate alternative approaches for addressing existing water-quality and water-quantity problems and for forecasting future conditions.

A 5-year water-quality management strategy for the Christina River Basin, starting in 1995, was conceived and directed by the Delaware Department of Natural Resources and Environmental Control (DNREC), Pennsylvania Department of Environmental Protection (PADEP), Chester County Conservation District (CCCD), Water Resources Agency of New Castle County, Chester County Water Resources Authority, New Castle County Conservation District, Delaware River Basin Commission (DRBC), U.S. Environmental Protection Agency (USEPA), watershed groups, and other concerned organizations, groups, and individuals. To assist with the water-quality management process, the U.S. Geological Survey (USGS) developed a nonpoint-source monitoring plan and constructed a hydrologic and water-quality model of the basin to estimate sediment and nutrient contributions from nonpoint sources. USGS conducted the Christina River Basin nonpoint-source monitoring and modeling in cooperation with DRBC, DNREC, and PADEP.

A widely used computer model, Hydrological Simulation Program—Fortran (HSPF), was selected to meet the water-resources planning and management needs for the Christina River Basin. The watershed modeling program, HSPF, can be used to simulate the delivery of nonpoint-source contaminants to main-stem streams. The model can simulate hydrologic processes, physical transport of nonpoint-source contaminants, and in-stream chemical reactions. This model also can be used to evaluate options for managing contaminants from nonpoint and point sources and provide a comprehensive method of calculating nonpoint-source loads to meet total maximum daily load requirements. Data required for this watershed model include concentrations of contaminants of interest over a range of hydrologic conditions from various land-use areas that are expected to differ in contribution of nonpoint-source contaminants and hydrologic response.

The nonpoint-source water-quality sampling plan, executed by USGS and cooperating agencies in 1997-98, provided streamflow, nutrient, and suspended solids data that were used to (1) estimate concentrations and loads of the selected constituents from various land uses in the Christina River Basin; and (2) calibrate an HSPF model for each major subbasin for these selected constituents. Each of the four major subbasins in the Christina River Basin was modeled separately because HSPF can be applied only to free-flowing, non-tidal streams, and the lower reaches of the Christina River and its tributaries, Brandywine Creek, White Clay Creek and Red Clay Creek, are tide-affected. Nonpoint-source water-quality and streamflow data were collected at four main-stem sites on the lower free-flowing reaches of the Christina River

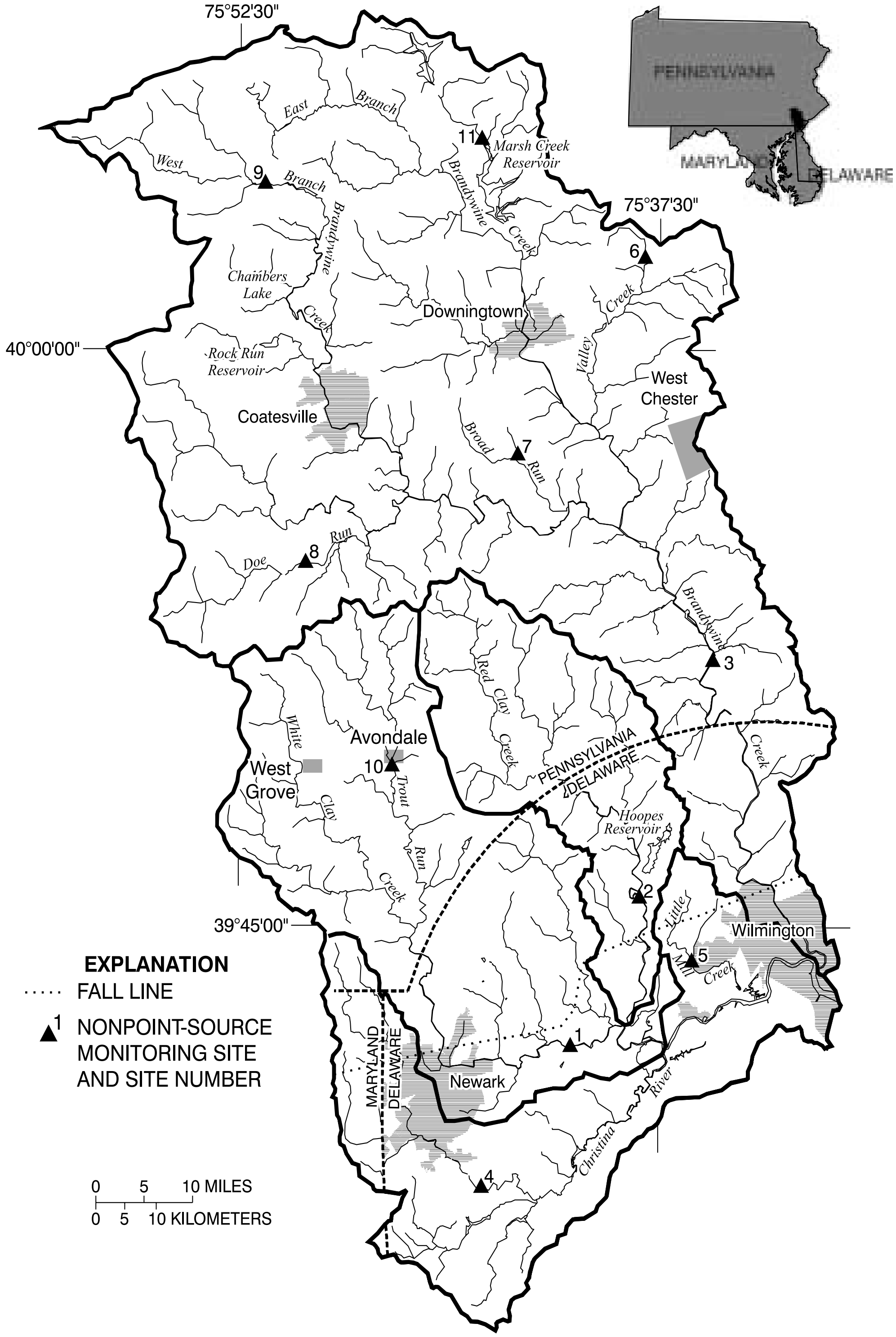


Figure 1. Location of the Christina River Basin and its four major stream basins and water-quality monitoring sites, Pennsylvania, Delaware, and Maryland.

on Brandywine, White Clay, and Red Clay Creeks, and at seven subbasin sites throughout the Christina River Basin selected principally for land-use characterization (fig. 1; table 1). All sites were equipped for continuous streamflow recording and automated water-quality sampling. Six sites were at existing USGS streamflow-measurement stations (gages), one site (01480095) was at a discontinued streamflow-measurement station recommissioned for the study, and four new streamflow / water-quality sites (01480878, 01480637, 014806318, and 01478137) were constructed (table 1).

The HSPF model for the second largest of the subbasins, the White Clay Creek Basin, was developed after the model for Brandywine Creek (Senior and Koerkle, 2003) and is discussed in this report. Model input parameters affecting suspended-sediment and nutrient contributions from selected land uses were calibrated for the Brandywine Creek model and transferred to the White Clay Creek model, where applicable. The HSPF model can provide a method of calculating nonpoint-source loads to meet total maximum daily load (TMDL) requirements under a range of flow conditions. Currently, TMDL assessments are ongoing in the Christina River Basin.

Purpose and Scope

This report describes the development of an HSPF model constructed for the White Clay Creek subbasin of the Christina River and the subsequent simulation of streamflow and water quality for the White Clay Creek for the calibration period October 1, 1994, through October 29, 1998. The main objective of modeling was to create a tool to estimate nonpoint-source loads of selected constituents over a range of hydrologic conditions. The model was used to simulate streamflow, water temperature, and the concentration of suspended sediment and the nutrients, nitrate, ammonia, and orthophosphate, on an hourly basis. Additionally, the model was used to simulate water-temperature, dissolved oxygen, biochemical oxygen demand, and plankton as secondary objectives needed to support the sediment and nutrient simulations. Explanation of model construction for the White Clay Creek Basin includes a description of the model structure, spatial segmentation, and parameterization. Data used for model input and calibration are described. Calibration results, analysis of the model's sensitivity to parameter-value variation, and model limitations are discussed for simulations of streamflow and water-quality constituents. Examples of model applications are given, including quantification of nonpoint-source loads from selected areas of the White Clay Creek Basin.

Table 1. *Nonpoint-source water-quality and streamflow monitoring sites, Christina River Basin, Pennsylvania and Delaware (See figure 1 for location of sites)*

Type of nonpoint-source water-quality sampling site	Site number on map	Location	U.S. Geological Survey streamflow-measurement station number	Drainage area (square miles)
Overall basin main-stem site				
White Clay Creek	1	White Clay Creek near Newark, Del.	01479000	89.1
Red Clay Creek	2	Red Clay Creek near Woodale, Del.	01480000	47.0
Brandywine Creek	3	Brandywine Creek at Chadds Ford, Pa.	01481000	287
Christina River	4	Christina River at Cooch's Bridge, Del.	01478000	20.5
Single land-use basins				
Urban	5	Little Mill Creek near Newport, Del.	[1]01480095	5.24
Residential - sewered	6	Unnamed tributary to Valley Creek at Highway 30 at Exton, Pa.	[2]01480878	1.47
Residential - unsewered (septic systems)	7	Little Broad Run near Marshallton, Pa.	[2]01480637	1.37
Agricultural - row crop	8	Doe Run above tributary at Springdell, Pa.	[2]014806318	11.7
Agricultural - livestock	9	West Branch Brandywine Creek near Honey Brook, Pa.	01480300	18.7
Agricultural - mushroom	10	Trout Run at Avondale, Pa.	[2]01478137	1.37
Forested	11	Marsh Creek near Glenmoore, Pa.	01480675	8.57

[1] Streamflow-measurement station restarted for study.

[2] New streamflow-measurement station constructed for study.

Previous Studies

Data on water quality and stream invertebrates collected at several sites in the White Clay Creek Basin as part of a long-term monitoring effort in Chester County, Pa., were evaluated for the period 1969-80 by Moore (1987) and published for the period 1981-94 by Reif (1999). Moore (1987) determined that the trend in benthic-invertebrate indices indicated an improvement in water quality in the White Clay Creek for the period studied. An assessment of trends in biological and water-chemistry data at these sites for the period 1981-97 was done by Reif (2002). Reif (2002) determined that biological monitoring data in the White Clay Creek indicated degraded stream quality because of water quality and habitat conditions. Nutrient concentrations in the White Clay Creek were elevated over those in many nearby basins and were higher in the East Branch than the Middle and West Branches of the White Clay Creek. Numerous biological and chemical studies of the upper East Branch White Clay Creek have been done by scientists at the Stroud Water Research Center, London Grove, Pa.

Acknowledgments

Water-use data were obtained with the assistance of Gerald Kauffman of the Water Resources Agency, Robert Struble of the Brandywine Valley Association, and Craig Thomas of the Chester County Water-Resources Authority. Water-quality data for PADEP monitoring sites in Pennsylvania were provided by William Goman of PADEP. Information about agricultural uses was obtained from Daniel Greig and others at the Chester County Conservation District and the New Castle County Conservation District. Overall guidance for the project was provided by the modeling technical committee of the Christina River Basin Water-Quality Management group, including David Pollison of DRBC, Richard Greene and Hassan Mirsajadi of DNREC, William Goman of PADEP, Janet Bowers of Chester County Water Resources Authority, Gerald Kauffman of Water Resources Agency, and Larry Merrill of USEPA. In addition to those mentioned above, those who helped identify the need for the project include Nancy Goggin and Jennifer McDermott of DNREC, and Niki Kasi and Russell Wagner of PADEP.

DESCRIPTION OF STUDY AREA

The White Clay Creek drains areas in southeastern Pennsylvania and northern Delaware. The headwaters of White Clay Creek are in Chester County, Pa., and the stream flows south into New Castle County, Del., where it is tributary to the Christina River (fig. 1). The largest population centers in the basin are the city of Newark, Del., and the boroughs of Avondale and West Grove, Pa.

Physical Setting

The White Clay Creek Basin encompasses 108 mi^2 in the Piedmont and Coastal Plain Physiographic Provinces of southeastern Pennsylvania and northern Delaware (Berg and others, 1989). The topography of the Piedmont Physiographic Province is characterized by gently rolling uplands dissected by narrow valleys, whereas the topography of the Coastal Plain Physiographic Province is characterized by nearly flat terrain. Elevation of the land surface ranges from near sea level to about 550 ft above sea level. Most of the basin is in the Piedmont Physiographic Province, which is underlain predominantly by metamorphic rocks of igneous and sedimentary origin. A small part in the southern end of the basin, south of the Fall Line (fig. 1), is in the Costal Plain Physiographic Province, which is underlain by unconsolidated sediments. The Fall Line marks the boundary between uplands underlain by crystalline rocks of the Piedmont and relatively flat terrain underlain by sediments of the Coastal Plain.

Climate

The White Clay Creek Basin has a modified humid continental climate. Winters are mild to moderately cold and summers are warm and humid. Normal mean annual air temperatures for 1971-2000 at National Oceanic and Atmospheric Administration (NOAA) weather stations is 51.5°F (10.8°C) at Coatesville, Pa. (National Oceanic and Atmospheric Administration, 2000a), and 54.8°F (12.7°C) at Newark, Del. (National Oceanic and Atmospheric Administration, 2000b) (fig. 1). Normal mean temperature (1971-2000) for January, the coldest month, is 28.6°F (-1.9°C) and 32.5°F (0.3 °C) at Coatesville and Newark, respectively; normal mean temperature (1971-2000) for July, the warmest month, is 73.5°F (23.1°C) and 76.4°F (24.7°C) at Coatesville and Newark, respectively. Normal mean annual precipitation (1971-2000) is 49.02 in. at Coatesville and 45.35 in. at Newark. Precipitation is distributed fairly evenly throughout the year. In southeastern Pennsylvania and northern Delaware, snowfall occurs mainly in the months of December through March.

Geology

The White Clay Creek Basin is underlain by Paleozoic-age and older metamorphosed sedimentary and igneous rocks. The metasediments include schist, quartzite, and carbonate rocks. The Paleozoic-age and older rocks have been folded, faulted, and metamorphosed several times during their history, resulting in a structurally complex assemblage. The primary structural trends are east-northeast. In the southernmost part of the basin, south of the Fall Line (fig. 1), these rocks are overlain by Cretaceous-age and quaternary-age sands and gravels of the Coastal Plain. These Coastal Plain sediments were deposited on the older bedrock, forming beds that thicken to the southeast.

Soils

Five soil associations and 15 soil series are found in the White Clay Creek Basin (fig. 2) (Kunkle, 1963; Matthews and Lavoie, 1970). In general, the soils have developed in place and are derived from the underlying bedrock. Most of the soils are developed on schist, gneiss, and quartzite, with the exception of the Hagerstown-Conestoga-Guthrie association, which is developed on carbonate rocks (such as limestone), and soils south of the Fall Line, which are developed on unconsolidated Coastal Plain sediments. Soils south of the Fall Line in the White Clay Creek Basin include the Elsinboro-Delanco-Urban, Sassafras-Falsington-Matapeake, and Aldino-Keyport-Mattapex-Urban associations (fig. 2).

The principal soil association is Glenelg-Manor-Chester, which overlies about 80 percent of the White Clay Creek Basin. Soils in this association generally are gently to moderately sloping and well drained. Surface permeabilities range from 0.6 to 2.0 in/h in most soils except in the Aldino, Hagerstown, and Manor series. Permeabilities in these three series, which are limited in extent, range from 2.0 to 6.3 in/h.

Hydrology

The metamorphosed sedimentary and igneous rocks that underlie most of the White Clay Creek Basin form fractured-rock aquifers. The competent bedrock is overlain by weathered rock, saprolite, and soil. The bedrock and overlying materials are recharged by precipitation. Ground water flows through the secondary openings (fractures) in fractured-rock aquifers and discharges locally to streams and springs. The sands and gravels of the Coastal Plain in the southern tip of the basin also are recharged by precipitation. Recharge to these sedimentary beds may discharge locally to streams and also may recharge the individual beds that dip to the southeast. Ground water in the Coastal Plain sands and gravels flows through primary openings (pore spaces).

Approximately 40 percent of the annual input of precipitation to the White Clay Creek Basin was discharged as streamflow during the 1994-98 period. The remaining precipitation was lost to evapotranspiration and withdrawals. Streamflow volume averaged about 65 percent base flow (ground-water discharge) and 35 percent surface runoff based on the average of several streamflow separation techniques in the HYSEP (Sloto and Crouse, 1996) hydrograph separation program. Year-to-year variations in relative amounts of base flow and surface runoff were as large as 15 percent.

Stream gradients range from about 30 ft/mi to 10 ft/mi in the White Clay Creek Basin. Generally, stream gradients are lower in reaches underlain by the Coastal Plain sediments than in reaches underlain by crystalline bedrock. Channel bottoms in reaches with gradients greater than about 15 ft/mi and in forested areas primarily are exposed bedrock, sand, and gravel. Channel bottoms in lower gradient reaches (less than 15 ft/mi) tend to be covered with sands and gravel.

Three low-head dams are situated on White Clay Creek. One is on the upper east branch in the town of Avondale, Pa. The two other dams are on the main stem at streamflow measurement station 01478650 White Clay Creek at Newark and downstream of the city of Newark about midway between the “at Newark” (01478650) and the “near Newark” (01479000) streamflow-measurement stations. No active regulation occurs at these dams.

Land Use

Land use in the White Clay Creek Basin in 1993-95 (Greig and others, 1998) was predominantly agricultural, forested, and residential, with lesser amounts of open and urban land, including industrial and commercial uses (fig. 7). From data compiled for 1993-95, estimated land use in the

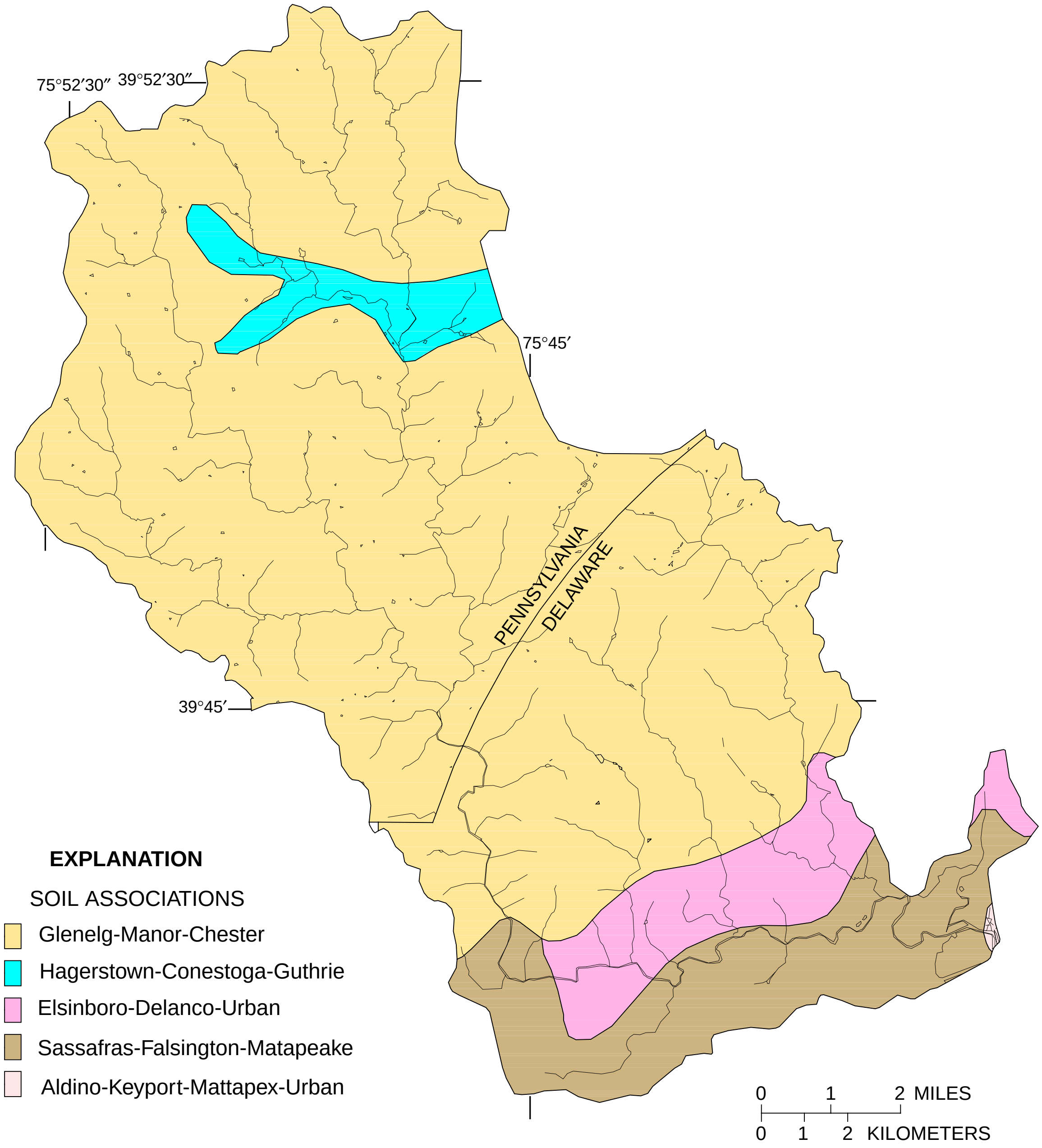


Figure 2. Mapped soil associations in the White Clay Creek Basin, Pennsylvania and Delaware. (The Fall Line is approximately coincident with the contact between Glenelg-Manor-Chester soil association and the adjacent soils to the south.)

basin is about 36 percent agricultural, 25 percent forested, 25 percent residential, 8 percent urban / commercial, 5 percent open / vacant space, and 1 percent other.

Water Use

Water use in the White Clay Creek Basin consists of withdrawals and discharges of surface water and ground water for residential, commercial, and industrial consumptive and non-consumptive uses. Typically, water from a surface-water intake or ground-water well is withdrawn, used as needed, and returned to the source as waste flow minus consumptive losses. Waste flows return to surface waters through wastewater treatment facilities and industrial discharges. Wastewater in non-sewered areas is discharged to on-lot septic systems, and return flow enters the ground-water system. In the less urbanized parts of the basin, ground water is the primary supply from wells on individual properties. In Pennsylvania, public water suppliers mainly serve the boroughs of Avondale and West Grove, parts of London Grove Township near West Grove, and along a corridor following a distribution line from Octoraro Reservoir, which is west of White Clay Creek in the Susquehanna River Basin. Of these, the Avondale, West Grove, and London Grove systems largely rely on ground water for supply. In Delaware, the entire White Clay Creek drainage is served by public water systems that primarily rely on surface-water sources.

In the Christina River Basin, impaired water quality has been linked to water-use processes such as wastewater treatment, industrial discharges, and septic systems (Greig and others, 1998). The effects of these processes on streamflow and water quality in the White Clay Creek can vary depending on their location and volumes.

DESCRIPTION OF MODEL

The numerical model HSPF includes a set of computer codes for algorithms used to simulate the hydrologic response of land areas to precipitation and flow through stream channels in a basin. The algorithms used to simulate these processes are described in detail by Bicknell and others (1997). The rainfall-driven simulation of streamflow includes responses from pervious and impervious land areas and routing of water in the stream channel. Pervious and impervious land areas are assigned hydrologic-response parameters on the basis of land use and other characteristics, such as slope. Streamflow routing is controlled by channel characteristics of model reaches. The HSPF model can be used to simulate free-flowing streams and well-mixed reservoirs but cannot be used to simulate tidal streams.

The HSPF model structure requires dividing the basin into multiple elements whose number and size reflect the range of selected hydrologic characteristics and the scope of available input data. A first step in structuring the model is segmenting the basin. Segmentation commonly is delimited by differences in climatological or physical characteristics that would determine specific hydrologic response to precipitation. When little differences are apparent in physical characteristics, segmentation may be determined by the number and location of precipitation stations available for input. The basin also is subdivided into characteristic pervious (PERLND) and impervious (IMPLND) land-use types. Within each segment, each PERLND and IMPLND is assigned hydrologic-response parameters. These parameters control the partitioning and magnitude of hydrologic outputs in response to input precipitation. The stream channel is then partitioned into reaches (RCHRES). A model reach (RCHRES) generally is delimited by major flow inputs (tributaries, discharges), calibration locations (streamflow gages, water-quality sites), and time-of-travel considerations. Each model reach receives flow from land draining to that reach and from upstream model reaches. Runoff, interflow, and ground water from each PERLND and IMPLND is directed to a model reach. Point-source withdrawals and discharges can be specified for the model reaches where they are located. The overall model structure, including assignment of time-series data (meteorological, streamflow, point-source withdrawals and discharges), reach connections, land-area to reach relations, channel characteristics, and hydrologic-response parameters, are described in the user control input (UCI) file.

The hydrologic response of PERLNDs and IMPLNDs is handled by their respective modules. The water budget, or predicted total runoff, for pervious land is simulated using the PWATER section of the PERLND module. Total runoff is the sum of base flow (ground-water discharge to streams), interflow, and surface runoff. The hydrologic processes modeled by PWATER include infiltration of precipitation, interception by plant materials, evapotranspiration, surface runoff, interflow, and ground-water flow. Precipitation may be evaporated from, move through, and (or) remain in storage in surface interception, surface detention, interflow, upper soil zone, lower soil zone, and active ground water. Predicted total runoff for impervious land is simulated using the IWATER section of the IMPLND module. The hydrologic processes modeled by IWATER include retention, routing, and evaporation of water from impervious areas.

Runoff derived from snowfall, snow accumulation, and snow melt is simulated using the SNOW module. Meteorological data are used to determine when precipitation is rain or snow, calculate an energy balance for the snow pack, and determine the effect of heat fluxes on the snow pack.

The routing of water in the stream channel is simulated by the HYDR section of the RCHRES module. Routing is based on kinematic-wave or storage-routing methods, where flow is assumed to be unidirectional. HYDR calculates rates of outflow and change in storage for a free-flowing reach or completely mixed reservoir. RCHRES inflows include runoff from PERLND and IMPLND land areas draining to that reach, water from upstream RCHRES, precipitation falling directly on the RCHRES surface area, and other discharges to the reach. RCHRES outflows include flow to the downstream reach, withdrawals from the reach, and evaporation. A series of reaches are used to represent the actual network of stream channels.

For each RCHRES, a relation between depth, surface area, volume, and outflow (discharge) is specified in an F-TABLE. When available, data for the F-TABLE’s were derived from stage-discharge ratings for stream-gaging stations at RCHRES endpoints. For reaches that do not end at a stream-gaging station, data for the F-TABLE were generated using the computer program XSECT (D. Shiffer, U.S. Geological Survey, written commun., March 2000). XSECT calculates depth-discharge relations for a hypothetical stream channel, assuming a trapezoidal shape and using specified stream length, stream slope, channel width, channel depth, floodplain slope, Manning’s n for the stream channel, and Manning’s n for the floodplain.

The water-quality component of HSPF simulates contributions from pervious and impervious land areas and accounts for chemical reactions in the stream reaches. The model includes algorithms to describe the transport of constituents from the land to the stream reach, chemical reactions affecting constituents in the reach, sediment exchange between channel bed and water column, and the temperature of runoff to, and water in, a reach. Contributions of constituents from land areas may vary by land-use category in the model. Water-quality simulation requires a calibrated hydrologic model.

Water temperature, dissolved oxygen, and carbon dioxide in surface runoff, interflow, and ground-water outflows from pervious land areas are simulated in the PWTGAS section of the PERLND module and from impervious land in the IWTGAS section of the IMPLND module. Water temperature in each reach is simulated by the HTRCH section of the RCHRES module and includes heat transported by PERLND and IMPLND outflows and point-source discharges. The main heat-transfer processes considered are transfer by advection, where water temperature is treated as a thermal concentration, and transfer across the air-water interface. Heat gain and loss by radiation also is simulated. Meteorological data, such as air temperature and wind speed, are used in the simulation of stream temperature. In-stream dissolved oxygen concentrations are simulated by the OXRX section of the RCHRES module, that includes advection, aeration, and consumption of oxygen by biochemical oxygen demand.

The simulation of sediment and nutrients includes transport of sediment and nutrients from land areas and transport within the stream channel. Sediment release from pervious areas is simulated in the SEDMNT module. Sediment available for transport is generated by detachment associated with rainfall. Detached sediment is transported to the stream as washoff. Scour also may be simulated for pervious areas. Sediment release for impervious areas is simulated in the SOLIDS module. Buildup of solids on impervious areas is transported to the stream in surface runoff. Sediment transport in the stream channel is simulated in the SEDTRN module. The channel simulation includes scour and deposition of bed material but not bank material.

The transport of nutrients from the land to the stream is simulated in the PQUAL module for pervious areas and IQUAL module for impervious areas. For pervious areas, nutrients associated with soil are transported with sediment in surface runoff. Nutrients also enter the stream in interflow and ground-water discharge. For impervious areas, nutrients accumulate on the surface and are washed into the stream during storm events. Once in the stream, the transport and chemical interactions of nutrients are simulated by the NUTRX, OXRX, PLANK modules. The NUTRX module includes physical transport and inorganic chemical reactions affecting nutrients. The OXRX module includes processes affecting dissolved oxygen and biochemical oxygen demand, constituents that affect reactions involving nutrients. The PLANK module simulates the role of phytoplankton and benthic algae in the stream and includes uptake and release of nutrients.

DATA FOR MODEL INPUT AND CALIBRATION

HSPF requires a large amount of data to characterize effectively the hydrologic and water-quality response of the watershed to precipitation and other inputs (Donigian and others, 1984). Data used in creating and defining the model structure and parameters were derived principally from spatial analysis of basin characteristics and previously published information. Spatial data analyzed for model construction include land use, land-surface slope, and soil associations. Time-series input for streamflow and water-quality simulation include meteorologic, precipitation quality, water-use, and discharge quantity and quality data. Calibration data consisted of observed streamflow for the hydrologic simulation and observed water temperatures and laboratory analyses of grab and composite stream samples for the water-quality simulation.

Time-series data for model input and model output were processed and stored in the binary format Watershed Data Management (WDM) database. The WDM format is the standard format for input to and output from HSPF. The computer programs ANNIE (Flynn and others, 1995), IOWDM (Lumb and others, 1990), METCMP (U.S. Geological Survey, in preparation), WDMUtil (U.S. Environmental Protection Agency, 1999), and GenScn (Kittle and others, 1998) were used in the processing of WDM time-series data. Parameter and model-structure data were processed independently of the time-series data and are defined in the UCI, an ASCII text file (Appendix 3).

Model-Input Data

The types, resolution, and quantity of the data needed for input are determined by (1) the hydrologic and water-quality processes to be included in the model, (2) the time step selected for simulation, (3) the length of the simulation period, and (4) the spatial scale of interest. For example, simulation of streamflow requires time-series inputs of precipitation, potential evaporation, withdrawals from streams, and discharges to streams, and when snowmelt is simulated, additional meteorological data are needed.

The White Clay Creek model was run on a 1-hour time step. Time-series data available only at time intervals greater than hourly required disaggregation. Daily-to-hourly disaggregation of meteorological data, except for potential evapotranspiration, was completed with METCMP, and monthly-to-hourly disaggregation of water-use data was done by the HSPF model at the time of simulation. Daily potential evapotranspiration data were disaggregated to hourly data at the time of simulation. For the simulation period of October 1, 1994, through October 1998, about 4 years of reported or estimated hourly values were needed for the time-series input data sets.

Simulation of stream-water quality requires, in addition to estimates of chemical-input parameters for pervious and impervious land areas, time-series inputs of water-temperature data and constituent concentrations for point-source discharges. An observed water-temperature time-series may be supplied as input. Because only a limited amount of recorded water-temperature data were available for the White Clay Creek Basin, water temperature was simulated. The simulation of water temperature requires input of additional meteorological data, including solar radiation, cloud cover, wind speed, and air and dewpoint temperatures. Inputs from point sources include water chemistry, temperature, and rate of discharge. Point-source discharge data, typically available as monthly or yearly values, were disaggregated to an hourly time step during simulation.

Meteorologic Data

Simulation of mean hourly streamflow in HSPF required inputs of hourly precipitation and potential evapotranspiration. The hourly precipitation data were derived from daily precipitation data collected at the NOAA meteorological stations, Coatesville 2 W and Newark University

Farm (fig. 3). These stations were selected because their corresponding Thiessen polygons included 85 percent of the basin and because of their proximity to the long north-south axis of White Clay Creek Basin. The Thiessen polygons of other nearby stations included no more than 7 percent of the basin area. Because hourly data were not available from the Coatesville and Newark NOAA stations, daily data from these stations were disaggregated using hourly precipitation data from Wilmington, Del., Airport, the nearest NOAA station with hourly data. Daily precipitation totals were recorded at 2400 at Coatesville 2 W and at 1600 the following day at Newark University Farm. Data from the Newark University Farm station was shifted back 24 hours to minimize the differences in the reporting time of daily observations that otherwise would result in an apparent lag in the hydrograph response to precipitation.

A network of nine rain gages was operated at the same time that the single land-use subbasin streamflow recording stations were operated. Data from these rain gages were originally intended to be used as input to the HSPF model. However, the short period of record and transient status of these

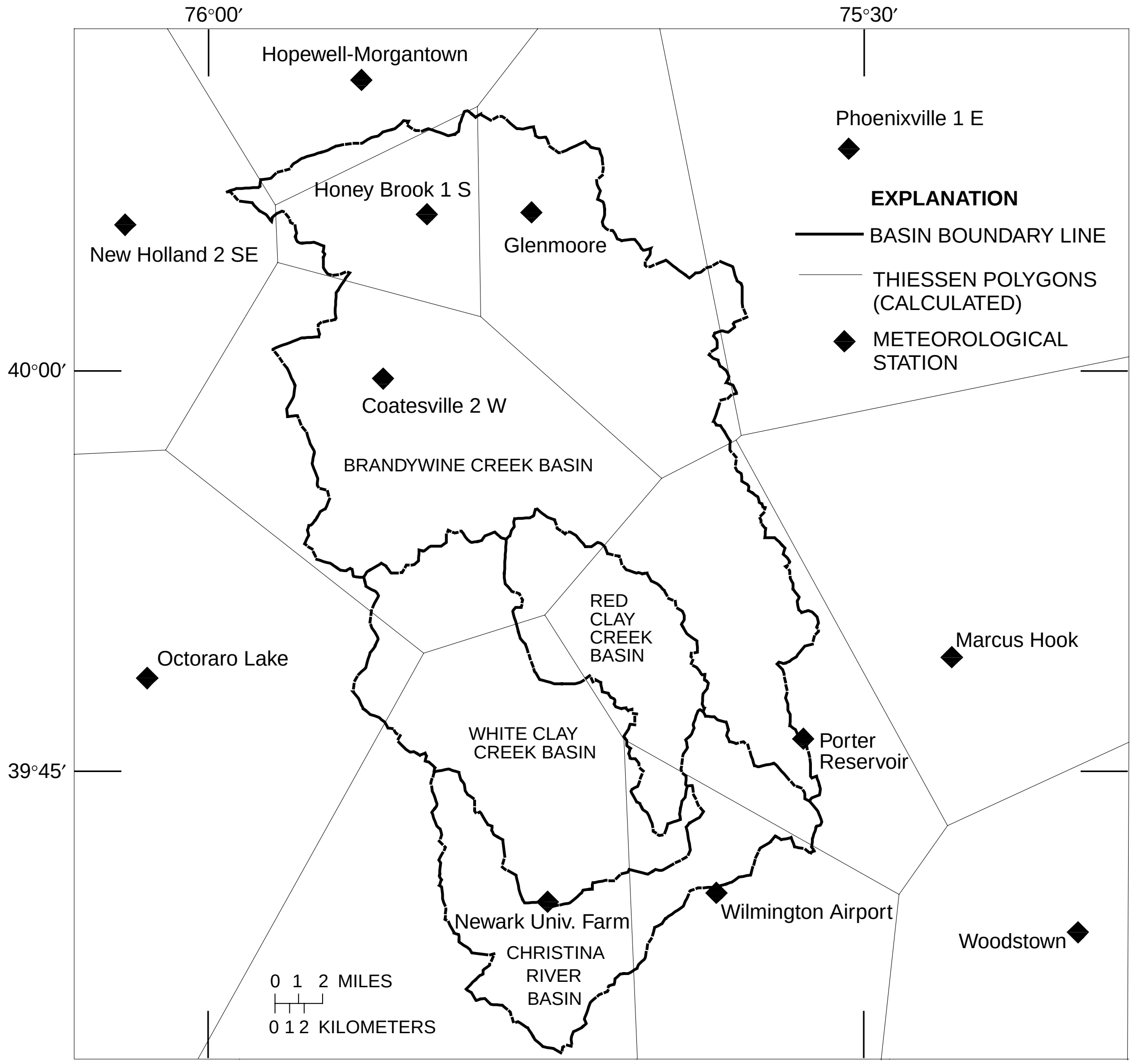


Figure 3. Location of National Oceanic and Atmospheric Administration meteorological stations and calculated Thiessen polygons in the vicinity of the White Clay Creek Basin and other parts of the Christina River Basin, Pennsylvania, Delaware, and Maryland.

rain gages precluded their use for the longer model calibration period and for modeling alternate time-period scenarios. Data from these gages were used, where possible, to resolve questions concerning precipitation during the storm event sampling period.

The 1994-98 period of simulation spanned relatively wet, dry, and normal years of precipitation. For example, the long-term (1971-2000) “normal” annual precipitation at the Newark University Farm NOAA station is 42.6 in. (Delaware State Climatologist, 2001). In comparison, 1995 and the 10-month period simulated in 1998 were within 10 percent of normal, 1996 was about 40 percent wetter, and 1997 was about 13 percent drier (table 2).

Comparison of the period-of-simulation precipitation totals shows considerable difference (table 2) between raingages. For the 4-year, 29-day period, the Coatesville 2W station reported 20 percent more precipitation than the Newark University Farm station. The difference between precipitation from the Coatesville 2 W and Newark University Farm stations is distributed evenly across the simulation period and appears to result from a consistent recording bias (fig. 4). Further comparison to NOAA raingages outside the White Clay Creek Basin shows precipitation totals for the period to be greater at Coatesville 2 W than at adjacent raingages. Although some disagreement in total precipitation can be expected, a review of numerous raingage network studies in the eastern United States showed that annual differences at adjacent gages averaged 5 percent or less (Winter, 1981) and that those differences tend to decrease over longer periods of record. Conversely, the monthly distribution of precipitation (fig. 5) shows that differences of 30 percent or more between the two raingages used for model input were not unusual.

Because of the unusually large differences between precipitation totals at Coatesville and Newark University Farm, a weighting factor of 0.85 was applied to the Coatesville precipitation record. This factor (table 2) was empirically derived as a result of completing a satisfactory water balance for the White Clay Creek Basin and minimizing the apparent bias in recorded rainfall at Coatesville 2 W relative to surrounding raingages.

Potential evapotranspiration at the Wilmington, Del., Airport gage, just southeast of the basin (fig. 3) was used for model input. The Wilmington, Del., Airport gage was the nearest gage to the basin that had meteorological data needed to calculate potential evapotranspiration. The daily estimates of potential evapotranspiration for Wilmington were calculated by the Northeast Regional Climate Center using a Penman-Monteith method described by DeGaetano and others (1994). Monthly totals of potential evapotranspiration are shown in figure 6. Daily estimates of potential evapotranspiration were disaggregated to an hourly time step during the simulation run.

Snow simulation was included in the White Clay Creek model. Annual snowfall during the simulation period averaged about 36 in. at Coatesville 2 W and 10 in. at Newark University Farm. The greatest snowfall was in the winter of 1995-96. Simulation of this snow cover and snow melt that accounts for the delay between precipitation and runoff was expected to result in more accurate streamflows. A caveat to this assumption is that periods cold enough to have substantial snowfall also are more likely to suffer from poor observed streamflow record because of channel ice at stream-gaging locations. Snow simulation requires data on precipitation, air temperature, solar radiation, dewpoint, and wind speed. Precipitation input data were from the Coatesville and Newark NOAA stations. Inputs of hourly air temperatures,

Table 2. *Raingage weighting factors and annual and total precipitation at two meteorological stations (Data from National Oceanic and Atmospheric Administration.)*

Raingage	Weighting factor	Precipitation, in inches (unweighted)					
		[1]1994	1995	1996	1997	[2]1998	Total
Coatesville 2 W	0.85	7.8	47.2	75.1	39.3	42.6	212.0
Newark Univ. Farm	1.00	5.9	40.6	60.5	36.9	32.2	176.1

[1] Precipitation for October 1 through December 31.

[2] Precipitation for January 1 through October 29.

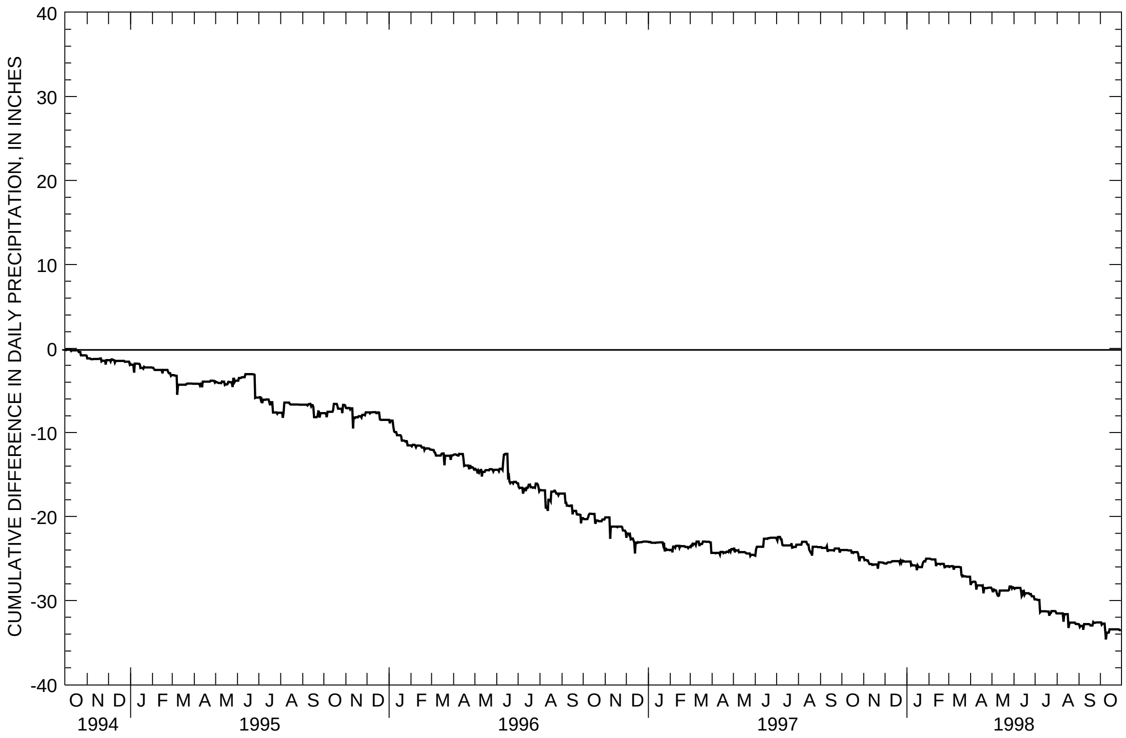


Figure 4. Cumulative difference in daily precipitation at National Oceanic and Atmospheric Administration meteorological stations Newark University Farm and Coatesville 2 W for the period October 1, 1994, through October 29, 1998.

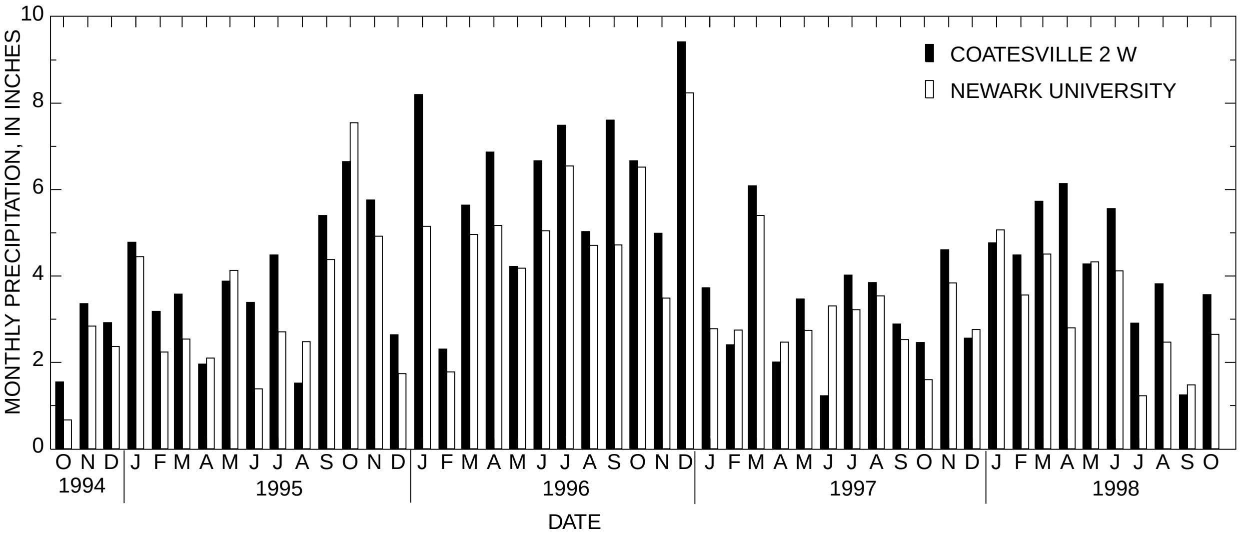


Figure 5. Monthly precipitation measured at the National Oceanic and Atmospheric Administration Coatesville 2 W, Pennsylvania, and Newark University Farm, Del., meteorological stations.

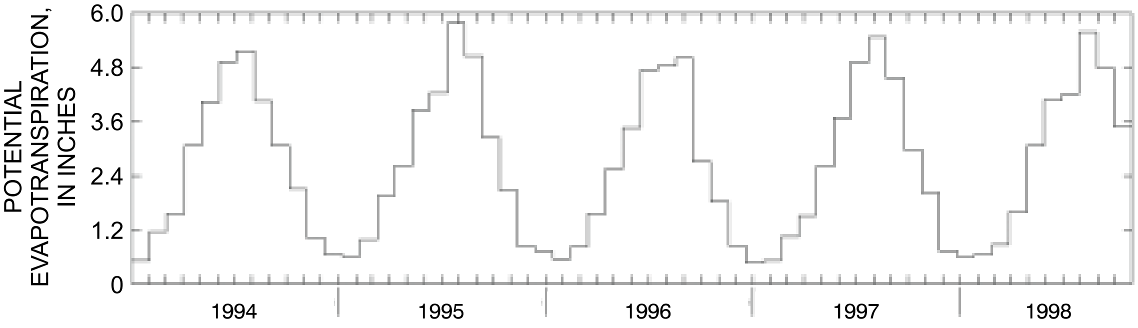


Figure 6. Monthly estimates of potential evapotranspiration for Wilmington Airport, Del.

solar radiation, dewpoints, and wind speed came from data collected at the Wilmington, Del., Airport NOAA station.

Meteorologic data required for the simulation of stream water temperature are air temperature, dewpoint, wind speed, cloud cover, and solar radiation. Hourly air temperature, dewpoint, windspeed, and cloud cover from the Wilmington, Del., Airport station were used for model input. Hourly estimates of solar radiation for Wilmington, Del., were calculated by the Northeast Regional Climate Center using a method described by DeGaetano and others (1993).

Water-Use Data

Simulation of streamflow and water quality requires information about stream withdrawals and discharges. Stream-water withdrawal and discharge data were obtained from the Chester County Water Resources Authority, the Water Resources Agency at the University of Delaware, and DNREC, who compiled water-use information from various sources, including PADEP, DNREC, and users. Much of these data are reported on a monthly or annual basis and, in many cases, were available for only 1, 2, or 3 years of the October 1994-98 simulation period. Where at least 1 year of acceptable monthly withdrawal data were available, missing information from the remaining years were estimated with data copied from the most recent year prior to the missing period. Where data were fragmented, averages of available data were used to estimate missing data. Where no monthly or annual withdrawal data were available, monthly data were estimated with values equal to 75 percent of permitted withdrawal maximums. Missing discharge data were estimated using the same method as withdrawals. The discharges and withdrawals included in the simulation are presented in table 3. Isolated single-family residential discharges were not included in the streamflow simulation.

Monthly-to-hourly disaggregation of water-use data was done by the HSPF model at the time of simulation. Inputs from point sources include water-quality constituent loads, discharge temperature, and rate of discharge. Point-source discharge-quality data, typically available as monthly or yearly values, were disaggregated to an hourly time step by dividing monthly or yearly values by the number of time steps in those periods during simulation. This approach to disaggregation results in constant hourly inputs for each month, which may not represent actual hourly discharges, but was used for lack of other data.

Table 3. *Surface-water withdrawals and discharges to White Clay Creek included in Hydrological Simulation Program—Fortran (HSPF) model of basin*

[Mgal/d, million gallons per day; DW, drinking water; IND, industrial; IRR, irrigation; STP, sewage treatment plant; GWC, ground-water control; --, unknown]

Subbasin	Name	Type	Flow volume (Mgal/d)	
			Capacity or flow limit	[1]1994-98 Average
Withdrawals				
East Branch	Loch Nairn Golf Course	IRR	0.058	0.022
East Branch	Laurel Valley Farms	IND	.032	.012
Main stem	Papermill Water Treatment Plant	DW	--	1.96
Main stem	Curtis Paper	IND	1.0	.028
Main stem	MBNA Louviers	--	.29	.025
Main stem	MBNA Deerfield Golf Course	IRR	.23	.090
Pike Creek	3 Little Bakers Golf Course	IRR	.24	.078
Mill Creek	Delcastle Golf Course	IRR	.26	.053
Main stem	United Water - Stanton Water Treatment Plant	DW	--	17.28
Discharges				
West Branch	Avon Grove School District - wastewater treatment	STP	.02	.002
Middle Branch	West Grove Borough Authority - wastewater treatment plant	STP	.25	.208
East Branch	Avon Grove Trailer Court - wastewater treatment plant	STP	.0113	.006
East Branch	Stone Barn Restaurant / Apartments - wastewater treatment	STP	.01	.006
East Branch	Chatham Acres - wastewater treatment plant	STP	.015	.007
East Branch	Chadds Ford Investment Co. - wastewater treatment plant	STP	.013	.008
East Branch	Tojo Mushrooms Inc. - processing wastewater	IND	.078	.001
East Branch	Hewlett Packard Co. - ground water remediation[2]	GWC	.144	.006
East Branch	Avondale Borough Sewer Authority - wastewater treatment plant	STP	.65	.351
East Branch	Francis Hamilton Oates - wastewater treatment plant	STP	.0012	.0002
Main stem	FMC Corp	IND	.03	.008

[1] Averages used in model simulations.

[2] Ground-water withdrawal discharged to stream.

Spatial Data

Spatial data input to the HSPF model are used primarily to define the structure and “fixed” characteristics of the model. The principal structural unit of the HSPF model is the hydrologic response unit (such as PERLND and IMPLND). Hydrologic-response units for the basin were determined from analysis of digital spatial data consisting of land use, elevation, geology, soil associations, and sanitary-sewer service areas. The digital spatial data were compiled from multiple sources by the Water Resources Agency for New Castle County (Greig and others, 1998) and were processed with a geographic information system (GIS) for model input. Non-digital data such as information regarding the location of specific agricultural practices also were used. Fifteen land-use categories were delineated in the original digital database. These categories were combined and reclassified into 10 pervious and 2 impervious land-use categories that were assumed to have distinct hydrologic and nonpoint-source water-quality signatures (table 4). The spatial distribution of the simplified pervious land-use categories is shown in fig. 7. Areas of undesignated land use were considered to have characteristics of areas with open land use. Impervious areas were estimated as a proportion of selected pervious areas, including residential, urban, and sewered open lands, based on percentages given in Greig and others (1998).

Agricultural land use, principally in the northern part of the basin, was divided into three characteristic subtypes for the model. Agricultural-livestock land use identifies relatively small acreage farms with high animals-per-acre densities, rowcrops, and limited pasture areas. Small acreage dairy operations typify this land-use type. About 16 percent of agricultural land in the White Clay Creek Basin is in this category. Agricultural-rowcrop land use identifies farms with lower animals-per-acre densities (commonly beef cattle or horses) and substantial pasture and crop acreage. About 70 percent of agricultural land in the White Clay Creek Basin is of this type. Agricultural-mushroom land use identifies land used in the production of mushrooms and accounts for the remaining 14 percent of agricultural lands. Mushroom growing, which involves the preparation and use of large amounts of manure-based compost, is more prevalent in the White Clay Creek and adjacent Red Clay Creek Basin than elsewhere in the Christina River Basin. Because digital spatial data describing the distribution of the three agricultural subtypes were not available, the distribution of these land-use types were estimated from knowledge of the watershed and information from the CCCD.

Forested land is distributed primarily along stream channels. The density of forest cover tends to increase from north to south and attains highest density along the main stem of White Clay Creek from the confluence of the middle and east branches to just north of Newark (fig. 7; fig. 1).

Residential land use is divided into two types: sewered and non-sewered. Sewered residential areas tend to have higher housing densities and are in or near urban / suburban areas. Non-

Table 4. *Land-use categories used in model of White Clay Creek Basin*

Land-use category for model		Description of land use
Pervious (PERLND)	residential-septic	Includes all residential land not within a sewer service area
	residential-sewer	Includes all residential land within a sewer service area
	urban	Includes commercial, industrial, institutional, and transportation uses
	agricultural-livestock	Predominantly mixed agricultural activities of dairy cows, row crop, pasture, and other livestock operations
	agricultural-rowcrop	Predominantly row crop cultivation (corn, soybean, alfalfa), may include some hay or pasture
	agricultural-mushroom	Mushroom growing activities including compost preparation, mushroom house operations, and spent compost processing
	open	Recreational and other open land not used for agriculture
	forested	Predominantly forested land
	wetlands / water	Wetlands and open water
	undesignated	Land use not defined
Impervious (IMPLND)	residential	Impervious residential land
	urban	Impervious commercial, industrial, and other urban land

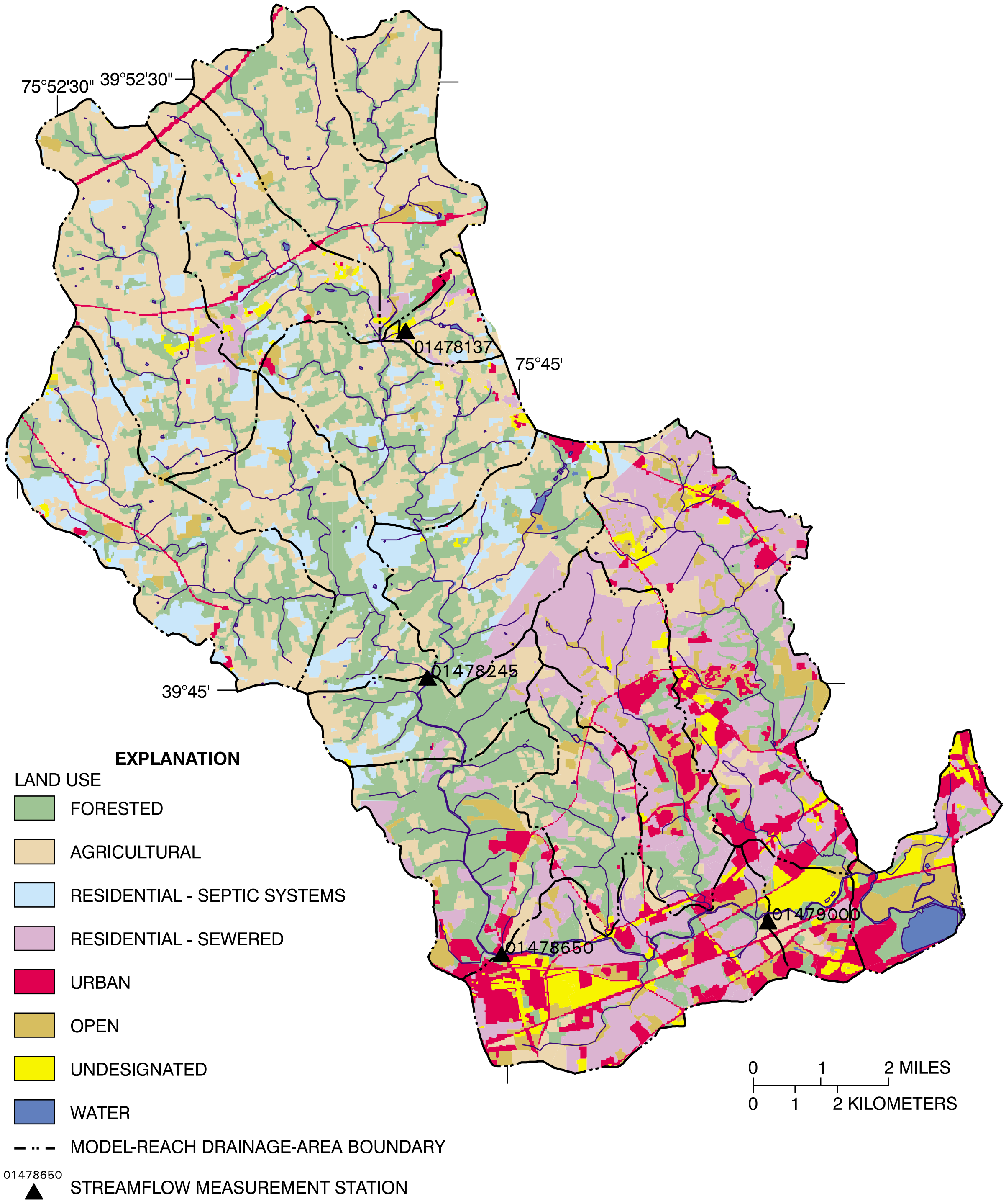


Figure 7. Generalized 1995 land-use map for the White Clay Creek Basin, Pennsylvania and Delaware.

sewered residential areas tend to have lower densities and are more rural. The southern end of the basin, Pike Creek subbasin, and Mill Creek subbasin have the largest concentration of residential land use (figs. 7 and 8). Urban land use in the White Clay Creek Basin is concentrated in the southern part of the basin around Newark (fig. 7; fig. 1). Other urban use is in small boroughs and along major roadways.

Model-Calibration Data

Observed streamflow and water-quality data are needed to calibrate the hydrologic and water-quality components of the HSPF model, respectively. These data are available at streamflow-measurement stations and water-quality monitoring sites established in the basin for this study and for other purposes. The period of record and frequency of observations differ among these gages and monitoring locations. In general, fewer water-quality data are available than streamflow data.

Hydrologic Data

Data from USGS streamflow-measurement (gaging) stations operating in the White Clay Creek Basin during the 1994-98 simulation period were used for the hydrologic calibration (table 5; fig. 8) (Durlin and Schaffstall, 1998, 1999; James and others, 1996, 1997, 1998, 1999). Three of the four stations listed in table 5 were used for primary model calibration. Station 01478245, White Clay Creek near Strickersville, was not a primary calibration point because the period of record is 22 months shorter than the period of simulation. One of the four stations (01478137) was established in a small subbasin of the White Clay Creek specifically for a 1-year period of limited storm monitoring.

During the coldest periods, freezing temperatures resulted in stream channel icing at the calibration sites and, thus, affected streamflow data. During the 1995-96 winter, only estimated daily streamflows were available during parts of December, January, and February at the White Clay Creek near Newark site and during 2-day periods in each of January and February at the White Clay Creek at Newark site. Ice affected streamflow also was reported for part of February 1997 at the “near Newark” site. Hourly streamflow values for these periods are considered poor, and published daily streamflows are reported as estimated.

Streamflow data at all the sites were recorded at time steps smaller than the 1-hour time step used in the model. Because of the shorter time steps, no disaggregation was needed for the streamflow data. However, periods of missing data and periods of poor-quality data because of freezing conditions are numerous in the hourly streamflow record. During periods of relatively steady base flow, missing data were interpolated. During periods of rapidly changing flow (generally stormflow), missing data were estimated by linear regression. A regression equation was generated using data that bounded the period of missing record from the nearest upstream or downstream gaging station. Poor-quality data due to freezing conditions were more problematic in that data from nearby stations usually were affected similarly. As a result, these data were used as recorded except in the instances where data from a nearby streamflow-measurement station were not ice affected. In these cases, estimated daily values were pro-rated using hourly values from the nearby station.

Table 5. *Streamflow-measurement stations in the White Clay Creek Basin, Pennsylvania and Delaware*

U.S. Geological Survey station identification number	Station name	Drainage area (square miles)	Period of record
01478137	Trout Run at Avondale, Pa.	1.34	7/97 - 9/98
01478245	White Clay Creek near Strickersville, Pa.	59.2	8/96 - current
01478650	White Clay Creek at Newark, Del.	69.0	3/94 - current
01479000	White Clay Creek near Newark, Del.	89.1	11/31 - 9/36 6/43 - 9/57 10/59 - current

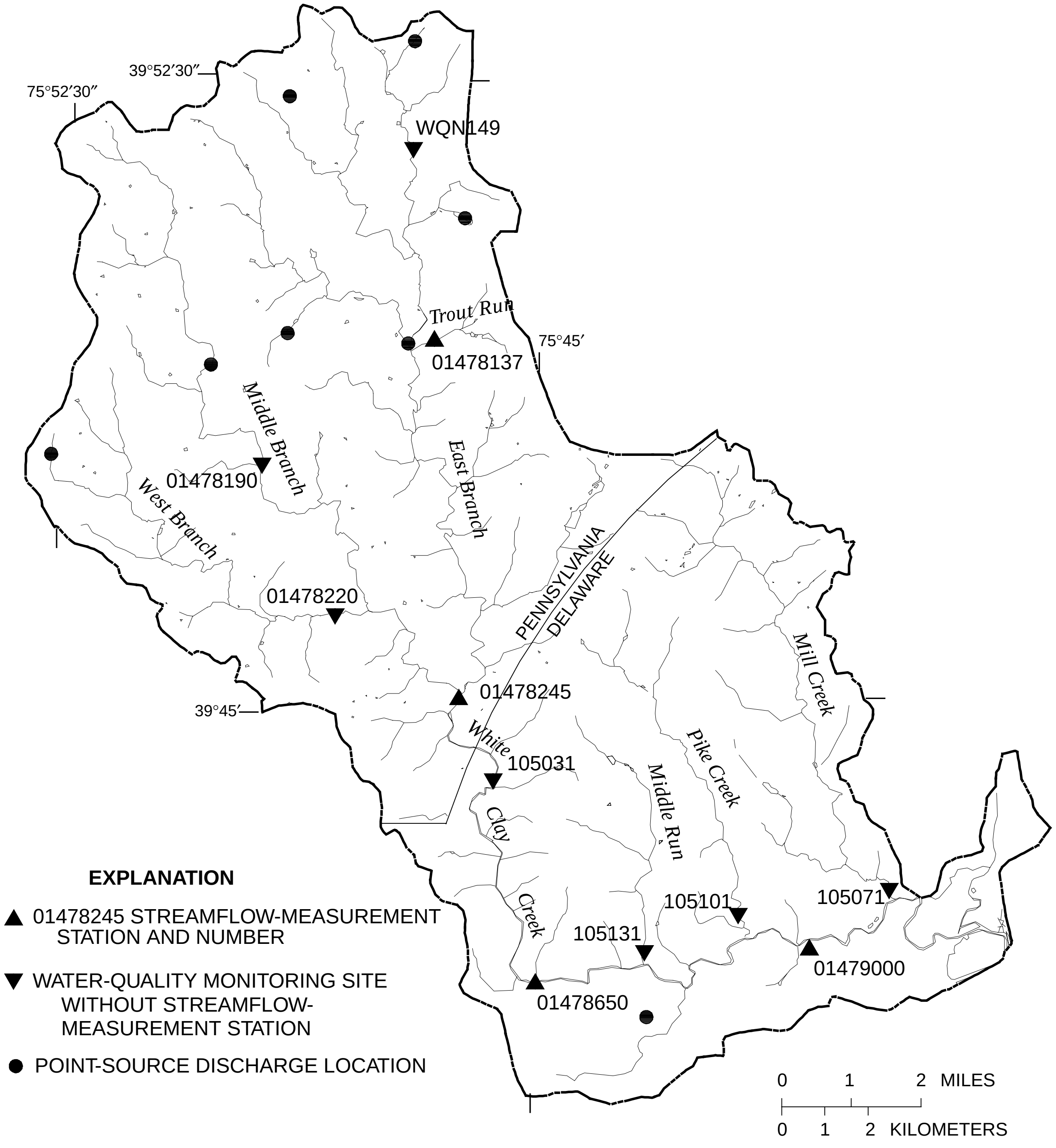


Figure 8. Location of streamflow-measurement stations and water-quality monitoring sites, White Clay Creek Basin, Pennsylvania and Delaware.

Observed snowfall at the Coatesville 2 W and Newark NOAA stations were used for calibration of the SNOW parameters. Total snow accumulation for the simulation period was 143 in. at Coatesville 2 W (about 7 mi north of the basin) decreasing to just over 41 in. at Newark. Given an average water equivalent estimate of 8 in. of snow to 1 in. of rain, snowfall accounted for about 18 in. or 8.5 percent of total rainfall (212.0 in.) at Coatesville 2 W and 5 in. or 3 percent of total rainfall (176.1 in.) at Newark for the simulation period. Snow accumulation was greatest in the year 1996 and accounted for half of the simulation-period snowfall at Coatesville 2 W and for three quarters of the snowfall at Wilmington Airport. The days of snowfall and days that snow covered the ground at the Coatesville 2 W gage for the years 1995-98 are listed in table 6. Snow was on the ground for all of January and 2 weeks of February 1996. In 1995 and 1997, snow cover of 2 in. or greater lasted no longer than 2 weeks.

Table 6. *Days of snowfall and snow-on-ground at the National Oceanic and Atmospheric Administration Coatesville 2 W meteorological station, 1995-98*

Calender year	Days of snowfall (maximum in inches[1])		Days of snow-on-ground (maximum in inches[1])		Days of greater than two inches[1] of snow on ground
1995	10	(9.1)	16	(10)	13
1996	27	(22.8)	52	(29)	39
1997	21	(11.4)	23	(11)	6
[2]1998	7	(1.4)	2	(1)	0

[1] Inches of snow, not inches of water equivalent.
[2] Through October 1998.

Water-Quality Data

Water-quality data collected at stream-monitoring sites were used for model calibration. Water-quality data for the simulation period 1994-98 were collected by PADEP, DNREC, and USGS as part of several monitoring efforts in the White Clay Creek Basin (fig. 8). The period of record at monitoring sites varied from 1 to 4 or more years (table 7), and the sampling frequency varied from hourly or less for storms to annually. The constituents analyzed as part of these monitoring efforts varied.

Two of the monitoring programs were designed specifically to assist in the current assessment of water quality in the White Clay Creek Basin: (1) a monthly and then bi-monthly monitoring conducted by DNREC and PADEP from 1996 to 1998; and (2) a hydrologically based sampling scheme was implemented by USGS, PADEP, and DNREC in 1998. The monthly and bi-monthly monitoring included analyses for metals, nutrients, suspended solids, and other constituents in samples collected at seven stream sites in the White Clay Creek Basin and was done to support an assessment of water quality during low-flow conditions and to target point-source contributions. The hydrologically-based sampling scheme included analyses for nutrients, suspended solids, and organic carbon at two sites in the White Clay Creek Basin and was done to support an assessment of these constituents under base-flow and stormflow conditions throughout the year and assist in the evaluation of nonpoint-source contributions to the stream.

The nonpoint-source water-quality monitoring in 1998 was designed to provide data on the seasonal concentrations and loads of nutrients and suspended solids under various hydrologic conditions for the whole basin and for small areas predominantly covered by one land use. Samples were collected quarterly during base-flow conditions and for up to six storms at the nonpoint-source monitoring sites, which included two sites in White Clay Creek Basin, 01478137 Trout Run at Avondale (small-basin site), and 01479000 White Clay Creek near Newark (whole-basin site), and nine other sites elsewhere in the Christina River Basin (table 1). Continuous data collected at the nonpoint-source monitoring sites included streamflow and water temperature. Samples collected in Trout Run, the small subbasin predominantly covered by one land use (table 7), were used to provide information about the relation between mushroom agricultural land use and water quality. Samples collected at the White Clay Creek near Newark, Del., site (01479000) provided information about the water quality of the whole White Clay Creek Basin. The predominant land uses in the small-basin sites elsewhere in the Christina River Basin (table 1) include various types of agricultural, residential, forested, and urban land use. Data from the small-basin sites in the Brandywine Creek Basin were used to calibrate model parameters for selected land uses and these parameters were transferred to the White Clay Creek model.

Table 7. *Water-quality monitoring sites in the White Clay Creek Basin during 1994-98*

[--, no data; WQN, Water Quality Network; P, Pennsylvania Department of Environmental Protection; D, Delaware Department of Natural Resources and Environmental Control; U, U.S. Geological Survey; Temp, water temperature; TSS, total suspended solids]

U.S. Geological Survey station identification number	State site number	Drainage area (square miles)	Location (predominant land use of nonpoint-source monitoring site)	Monitoring agency	Period of record	Chemical analyses
Monthly and bi-monthly monitoring sites						
--	WQN179	--	East Branch White Clay Creek near London Grove, Pa.	P	1995-98	Nutrients, TSS
01478265	WQN149	59.2	White Clay Creek near Strickerville, Pa.	P	1995-98	Nutrients, TSS
--	105031	--	White Clay Creek at Chambers Road	D	1995-98	Nutrients, TSS
--	105131	--	Middle Run	D	1995-98	Nutrients, TSS
--	105101	--	Pike Creek	D	1995-98	Nutrients, TSS
01479000	105151	89.1	White Clay Creek near Newark, Del.	D	1994-98	Nutrients, TSS
--	105071	--	Mill Creek	D	1995-98	Nutrients, TSS
Base flow and stormflow nonpoint-source monitoring small and whole basin sites						
01478137	--	1.31	Trout Run at Rt. 41 at Avondale, Pa. (agricultural-mushroom growing)	U, P, D	1998	Nutrients, TSS
01479000	--	89.1	White Clay Creek near Newark, Del. (mixed-whole basin)	U, P, D	1998	Nutrients, TSS
Annual biological monitoring sites						
01480653	--	11.30	East Branch at Avondale	U	1970-current	Nutrients
01478190	--	9.94	Middle Branch at Wickerton	U	1970-97	Nutrients
01478220	--	9.92	West Branch at Chesterville	U	1970-97	Nutrients
01478230	--	25.5	Middle Branch near Avondale	U	1998-current	Nutrients

The stormflow events and base-flow periods were selected as representative of the range of seasonal and hydrologic conditions in the basin. Timing for the six stormflow events was as follows: two storms in mid to late winter (February 4-5 and March 8-9, 1998), one storm in early spring after pre-planting tillage (May 2-3, 1998), one storm in late spring / early summer after planting of crops (June 12-13, 1998), one storm in midsummer (July 8-9, 1998), and one storm in fall after harvest (October 8-9, 1998). Sampling was delayed because of dry conditions in the fall of 1997. No samples were collected from frozen-ground runoff and snowmelt events because of the mild winter of 1998. Sampled storms resulted from precipitation events that ranged from about 0.4 to 3.3 in. For Brandywine Creek at Chadds Ford, Pa., a nearby station with a long period of record, these precipitation events resulted in peak flows with a 1-year or less recurrence interval. Base flow was sampled in January, April, July, and September 1998.

Base-flow and stormflow samples collected from January to October 1998 were analyzed for concentrations of dissolved and total nitrogen and phosphorus species and suspended solids (table 8). Other constituents, such as dissolved organic carbon (DOC), chlorophyll *a* and pheophytin, and properties, such as biochemical oxygen demand (BOD), also were measured to better understand and simulate the chemical processes involving the fate and transport of nutrients. Chloride was measured to provide data on the concentrations of a conservative solute. Samples collected at the monitoring site 01479000 White Clay Creek near Newark, Del., also were analyzed for total organic carbon, chemical oxygen demand (COD), and dissolved and total concentrations of copper, lead, and zinc, as requested by DNREC for their use. Stormflow samples were collected by USGS and the University of Delaware. Base-flow samples were collected by PADEP and by DNREC. DNREC's laboratory in Dover, Del., performed all laboratory chemical analyses. Results of laboratory analyses for all stormflow and base-flow samples are listed in Appendix 1.

Table 8. *Selected constituents in nonpoint-source monitoring samples determined by laboratory chemical analysis, Christina River Basin, Pennsylvania and Delaware*

[mg/L, milligrams per liter; EPA, U.S. Environmental Protection Agency; µs/cm, microsiemens per centimeter; STDMTD, Standard Methods (American Public Health Association, 1995)]

Constituent	STORET code	Method[1]	Reporting limit (mg/L)
Required constituents or properties for all samples			
Ammonia nitrogen, dissolved	00608	EPA 350.1	0.002
Ammonia nitrogen, total	00610		
Kjehldahl nitrogen, dissolved	00623	EPA 351.2	.05
Kjehldahl nitrogen, total	00625		
Nitrite plus nitrate nitrogen, dissolved	00631	EPA 353.2	.05
Orthophosphorus, dissolved	00671	EPA 365.1	.005
Phosphorus, dissolved	00666	EPA 365.1	.005
Phosphorus, total	00665		
Chloride	00940	EPA 325.2	1
Specific conductance	90095	EPA 120.1	1 µS/cm
Total suspended-solids concentration	80154	EPA 160.2	1
Biological oxygen demand (BOD_{20})	00308	EPA 405.1	2.4
Dissolved organic carbon	00681	EPA 415.1	1
Chlorophyll *a*[2]	32211	92 STDMTD 10200H	.001
Pheophytin	32218	92 STDMTD 10200H	.001

[1] Specifications for analytical method, reporting limit, holding time, sample volume and preservation provided by the Delaware Department of Natural Resources and Environmental Control laboratory.

[2] First storm sampling event, all grab sampling events.

Two types of samples, discrete and composite, were collected by an automatic sampler during storms. Discrete samples, collected at fixed-time intervals during the storm event, represent instantaneous concentrations. Composite samples represent mean concentrations and can be used to estimate loads for a storm event. The automatic sampler was programmed prior to each storm to start sampling at a pre-determined change in stage, and collect one series of fixed-interval discrete samples and another series of flow-weighted aliquots (250 mL each) for the composite sample. The fixed-interval series consisted of up to six 2-L samples, collected from 1.5 to 3 hours apart. The flow-weighted series consisted of up to 48 250-mL samples. The intake for the automatic sampler was set in mid stream and stage was determined by a transducer set in the stilling well and linked to the automatic sampler. Streams were assumed to be well mixed. The automatic sampler was programmed to collect a sample at fixed-time intervals and after each time that a pre-determined flow volume, calculated using an established rating between stage and streamflow, had passed by the monitoring site. Composite samples were obtained by mixing the series of flow-weighted aliquots collected over the sampling period that was limited by the number of available sample bottles and the pre-determined flow-weighting volume. Because the automatic sampler was programmed in advance of storms for which the intensity and duration were unknown, the amount of the actual storm periods covered by samples varied.

The measured concentration of constituents in discrete storm samples was, in general, related to streamflow (figs. 9-10). The concentration of total suspended solids, total ammonia plus organic-nitrogen (Kjehldahl nitrogen), and total phosphorus tended to increase with increasing streamflow whereas the concentration of dissolved nitrite plus nitrate decreased with increasing streamflow. The concentration-streamflow relation was not discernible in all cases. Almost no relation between constituent concentrations and streamflow is apparent for orthophosphate or dissolved ammonia.

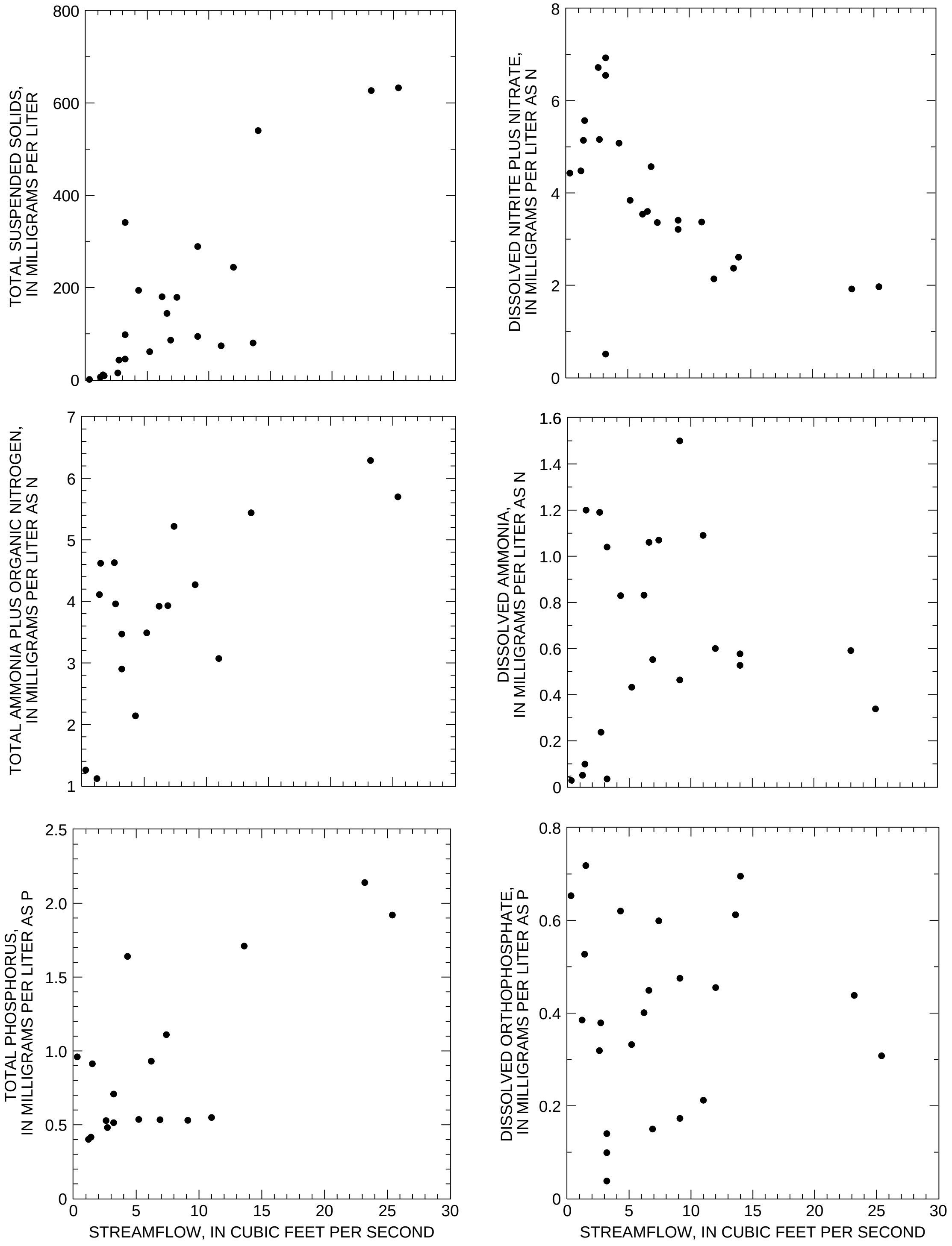


Figure 9. Relation between water-quality constituents and streamflow for stormflow and base-flow samples collected in 1998 at streamflow-measurement station 01478137, Trout Run at Avondale, Pa.

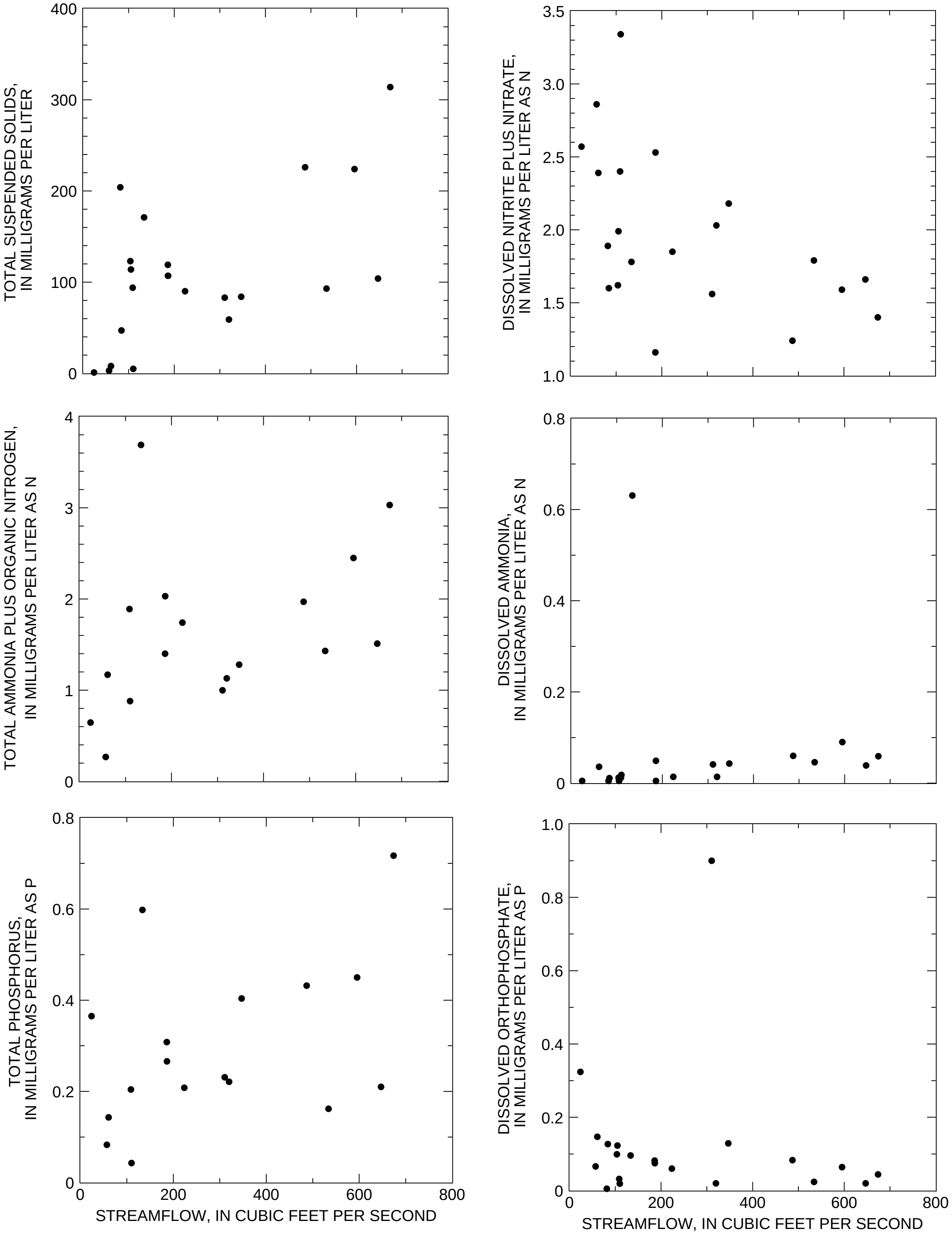


Figure 10. Relation between water-quality constituents and streamflow for stormflow and base-flow samples collected in 1998 at streamflow-measurement station 01479000, White Clay near Newark, Del.

Concentrations of suspended solids and nutrients in stream samples differed at the two White Clay Creek monitoring locations and in relation to hydrologic conditions. Base-flow concentrations are controlled primarily by ground-water discharge and stormflow concentrations by runoff and interflow processes. The distribution of constituent concentrations at the two nonpoint-source monitoring sites are shown in figures 11-13. Under stormflow and base-flow conditions, concentrations of suspended solids, nitrate plus nitrite, ammonia, and total phosphorus generally were higher at the site in the predominantly mushroom agricultural subbasin (01478137 Trout Run at Avondale) than at the whole-basin site (01479000 White Clay Creek near Newark) that drains an area of mixed land uses. Elsewhere in the Christina River Basin, concentrations of suspended solids, nitrate, and total phosphorus under base-flow and stormflow conditions were greater at sites in predominantly agricultural basins than at sites in basins with other predominant land uses and were greater in the predominantly non-sewered residential subbasin than at the sites in the predominantly forested and sewered residential subbasins (Senior and Koerkle, 2003). Concentrations of suspended solids were higher by as much as three orders of magnitude in stormflow samples compared to base-flow samples. Concentrations of nitrate generally were greater in base-flow samples.

Other water-quality data used for model calibration include continuous water temperature at one USGS streamflow-measurement station, 01478137 Trout Run at Avondale, Pa., and intermittent observed water temperature and dissolved oxygen concentrations at the streamflow-measurement stations, 01478245 White Clay Creek near Strickersville, Pa., 01478650 White Clay Creek at Newark, Del., and 01479000 White Clay Creek near Newark, Del. The intermittent water temperature and dissolved oxygen data were collected as part of PADEP and DNREC monitoring programs.

SIMULATION OF STREAMFLOW

Streamflow in the White Clay Creek Basin was simulated for the period October 1, 1994, to October 29, 1998, or just over 4 years. Donigian and others (1984) suggest a 3-year to 5-year simulation period as optimal for HSPF because a variety of climatic conditions will be included.

The White Clay Creek Basin was divided into three segments for the model. Segments of the basin area were defined primarily on the basis of spatial distribution of precipitation and soil types. Within each segment, the hydrologic response of land areas was assumed to differ principally by land use. From north to south, the segments were numbered 7, 5, and 8 (fig. 14). The segment areas are bounded approximately by Thiessen polygons generated for the NOAA meteorological gages in and near the Christina River Basin (boundary between segments 7 and 5) and by the Fall Line (contact between soils developed on crystalline rocks and unconsolidated sediments of the Coastal Plain and boundary between segments 5 and 8). Each segment receives precipitation input from one of the two NOAA gages, Coatesville 2 W and Newark University Farm (figs. 4 and 14). The land-based hydrologic response in each segment was characterized spatially by sub-dividing the area into a total of 12 land-use categories that consist of 10 pervious and 2 impervious land-use types (table 9). These simplified land-use categories represent the predominant land uses in the basin. Initial hydrologic-response parameters were assigned to the land-use categories and were modified as needed during model calibration. Parameters do not vary within a segment but may vary from segment to segment.

The amount of impervious land was calculated from the residential and urban pervious land uses using factors modified from Water Resource Agency for New Castle County values in Greig and others (1998). Because the HSPF model simulates no infiltration in impervious areas and some runoff from impervious areas, such as roofs and roads, does infiltrate to soils and the ground-water system through adjacent pervious areas, the amount of effective impervious area is expected to be lower than the impervious areas estimated by land-use maps or in Greig and others (1998). For the model, amounts of impervious land estimated by land-use maps were reduced to account for some infiltration in adjacent pervious areas and these reduced amounts of impervious land are

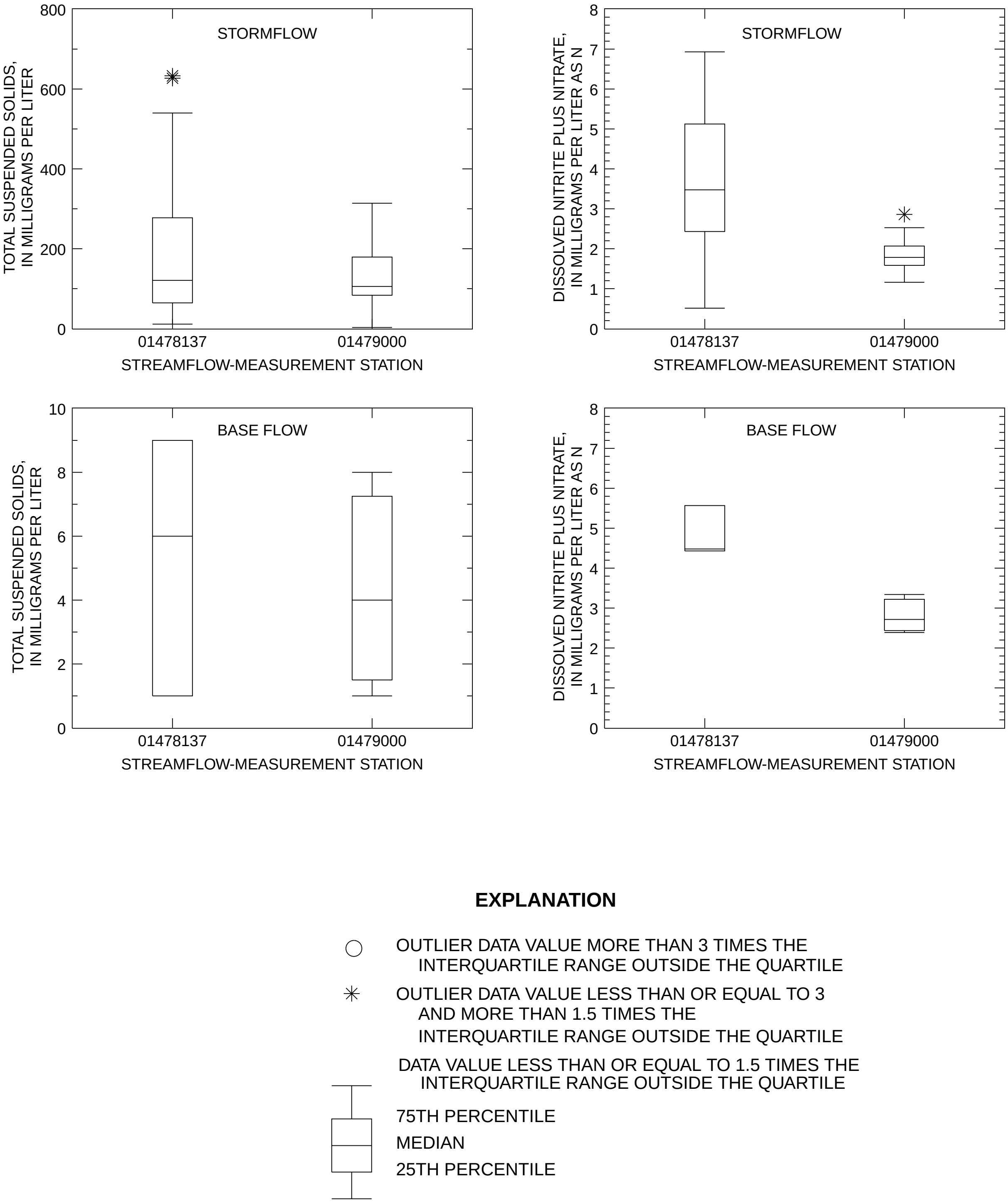


Figure 11. Distribution of concentrations of suspended solids and nitrate plus nitrite in samples collected under stormflow and base-flow conditions during 1998 at two monitoring sites in the White Clay Creek Basin, 01478137 Trout Run at Avondale, Pa., and 01479000 White Clay Creek near Newark, Del.

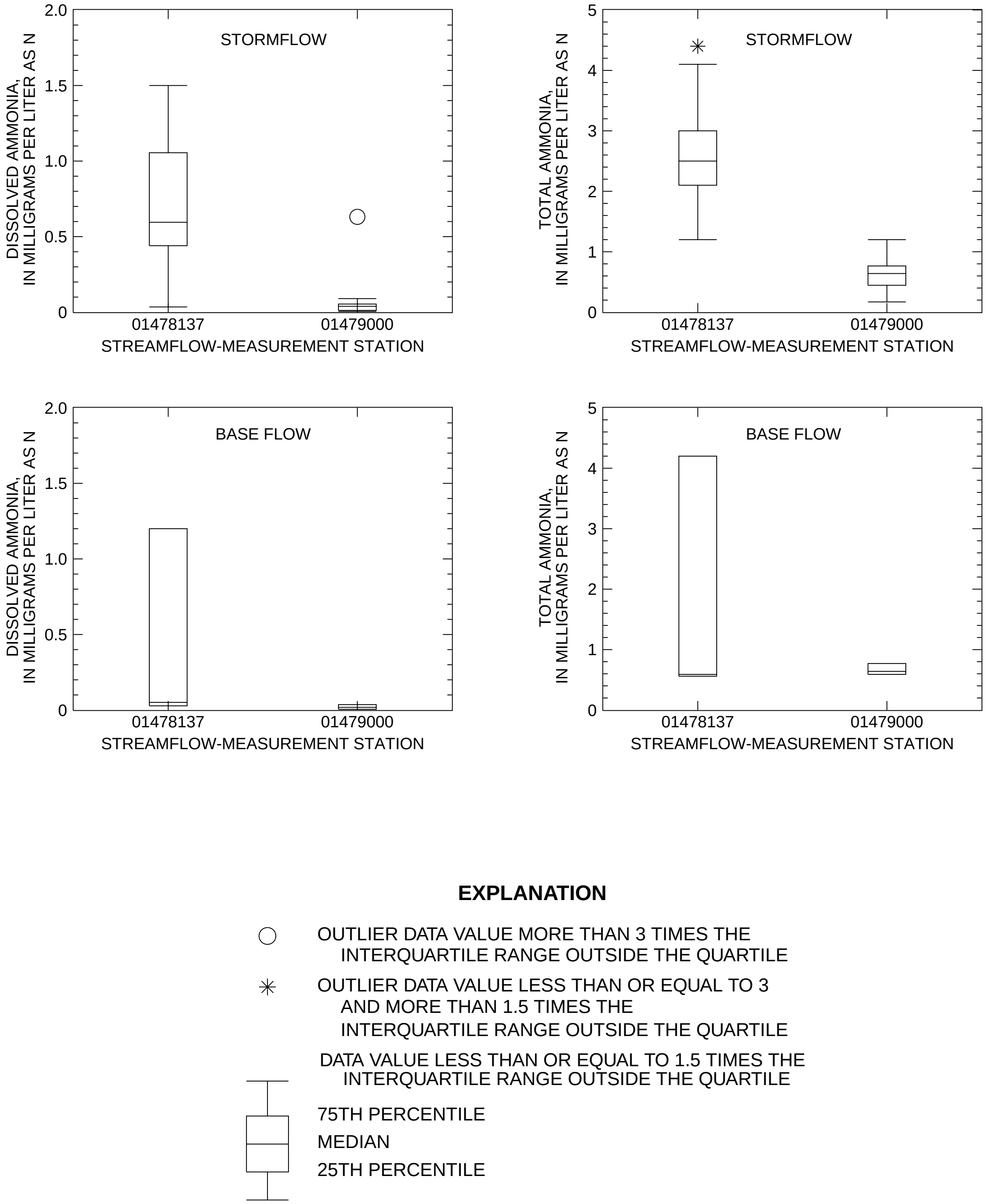


Figure 12. Distribution of concentrations of dissolved and total ammonia in samples collected under stormflow and base-flow conditions during 1998 at two monitoring sites in the White Clay Creek Basin, 01478137 Trout Run at Avondale, Pa., and 01479000 White Clay Creek near Newark, Del.

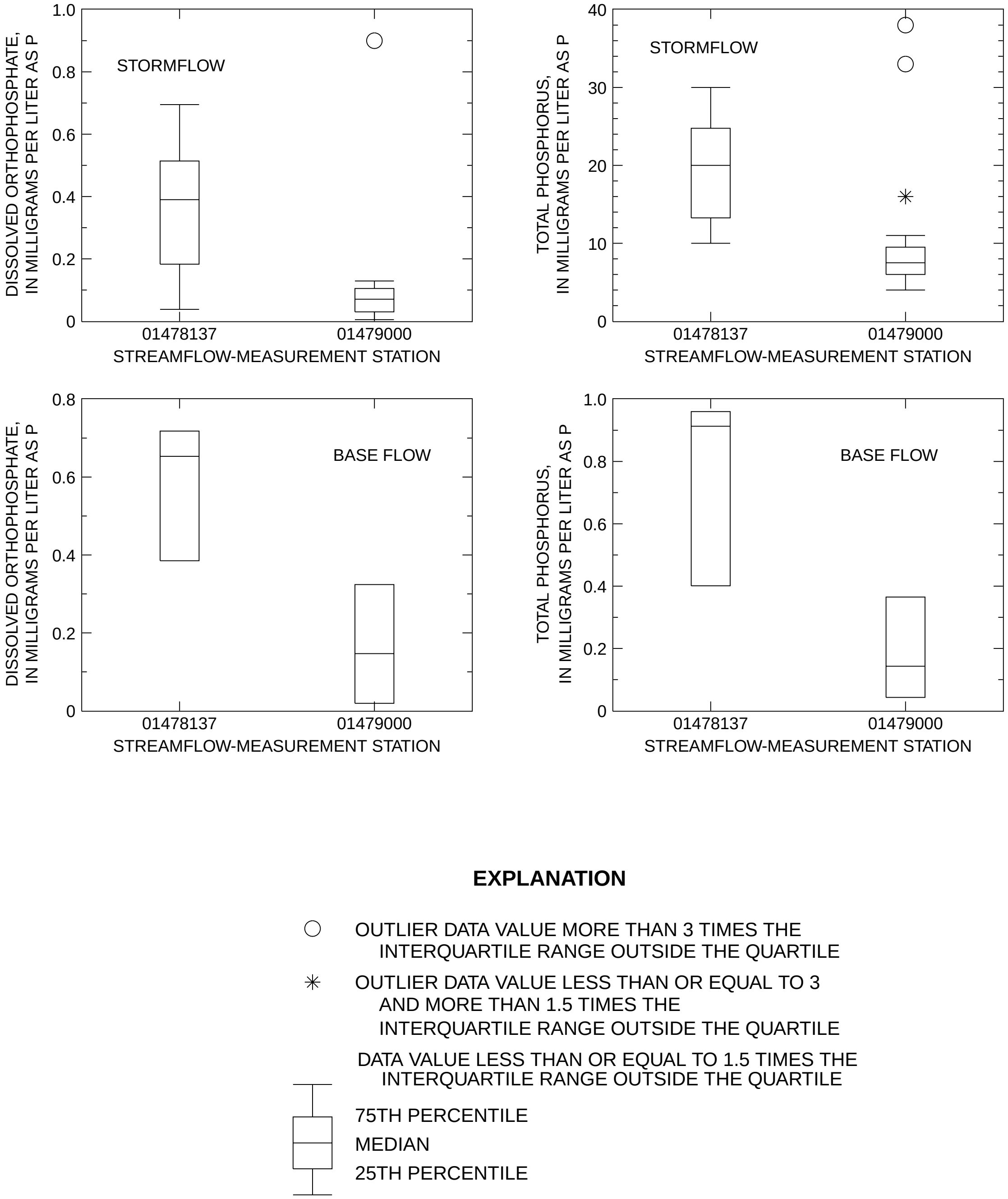


Figure 13. Distribution of concentrations of dissolved orthophosphate and total phosphorus in samples collected under stormflow and base-flow conditions during 1998 at two monitoring sites in the White Clay Creek Basin, 01478137 Trout Run at Avondale, Pa., and 01479000 White Clay Creek near Newark, Del.

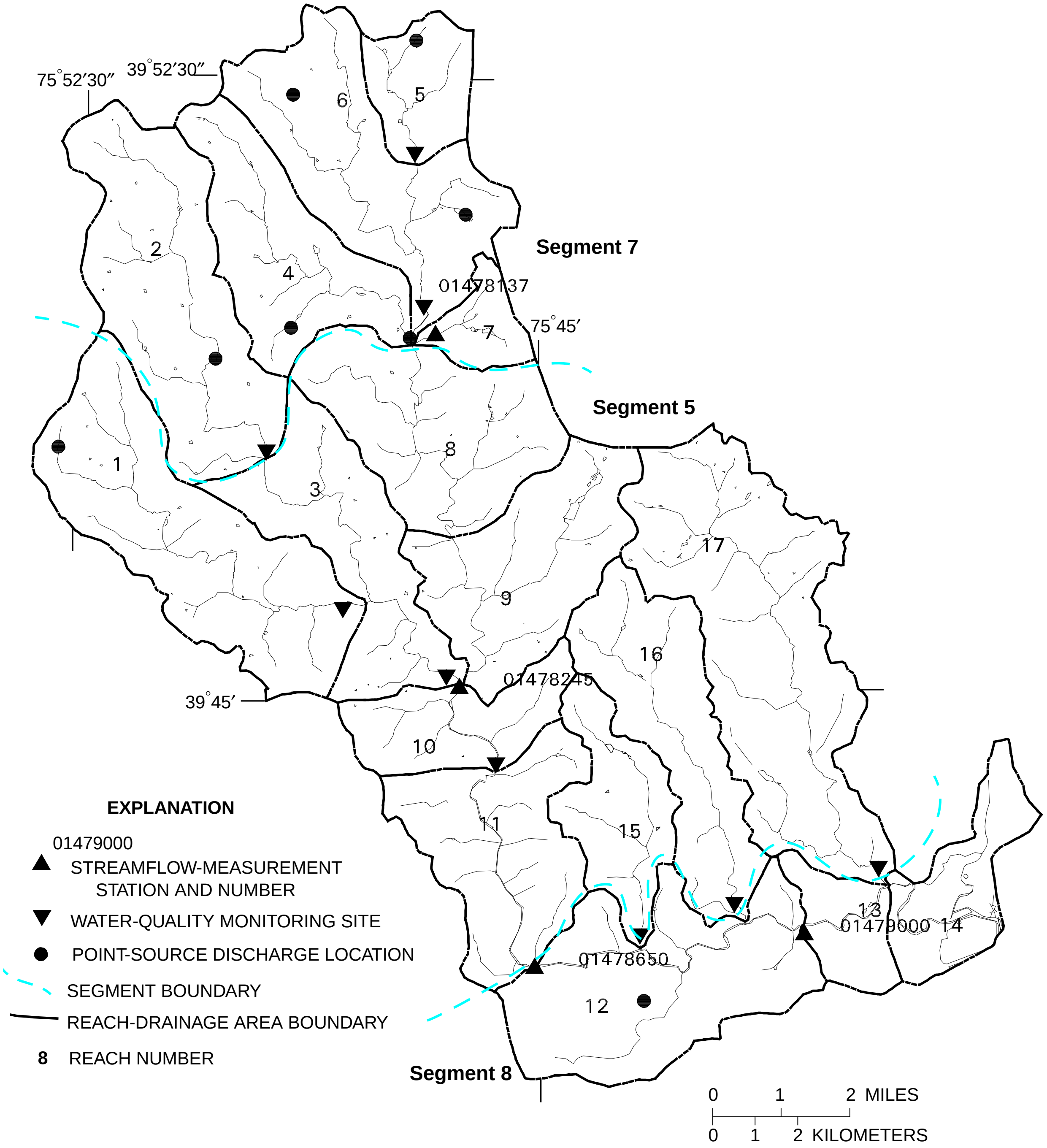


Figure 14. Location of segments, reach-drainage areas, and stream reaches (RCHRES) delineated for HSPF model of the White Clay Creek Basin, Pennsylvania and Delaware.

Table 9. *Reach number, length, drainage area, and percentage of land-use category in reach drainage area for the White Clay Creek model*

[mi, miles; mi^2, square miles]

Reach number	Reach length (mi)	Reach drainage area (mi^2)	Segment number	Land-use category (percentage of reach drainage area)											
				Residential - septic	Residential- sewer	Urban	Agricultural - livestock	Agricultural - row crop	Agricultural - mushroom	Forested	Open	Wetland.water	Undesignated	Impervious - residential	Impervious - urban
1	7.33	10.23	5	15.6	0	1.0	10.4	36.2	5.2	26.1	2.1	0.1	0.7	1.8	1.0
2	6.57	9.51	7	11.3	1.8	.8	15.9	47.5	0	17.7	1.1	.2	.9	2.0	.8
3	7.18	6.35	7	16.4	0	0	9.0	33.5	2.2	35.9	.6	.5	0	1.9	0
4	6.02	6.20	7	6.8	2.6	1.3	11.5	40.2	5.8	23.5	2.4	.5	2.1	1.9	1.5
5	2.49	2.65	7	1.5	0	0	14.7	52.1	7.5	23.0	.8	0	.4	0	0
6	6.16	8.57	7	1.5	.8	1.3	13.4	47.3	6.8	21.8	2.9	.2	2.1	.5	1.3
7	1.75	1.37	7	5.8	5.1	1.5	0	5.8	56.2	17.5	0	1.5	2.9	2.9	1.5
8	4.09	7.47	5	11.6	.5	.5	0	20.1	30.3	32.4	1.2	.5	.8	1.5	.5
9	4.46	6.85	5	17.5	7.2	.7	6.6	22.9	3.2	31.7	2.3	1.6	.6	5.0	.7
10	1.67	3.58	5	11.2	4.5	0	5.3	21.8	0	53.1	.3	.6	.3	3.1	0
11	4.02	6.53	5	1.2	8.1	4.3	0	15.5	0	54.8	7.0	.8	.3	3.7	4.3
12	5.28	8.76	8	0	24.1	10.2	0	9.4	0	10.7	9.8	.9	10.2	10.4	14.4
13	2.21	2.08	8	0	6.7	14.4	0	11.1	0	11.5	7.2	1.4	27.4	2.9	17.3
14	2.97	3.41	8	0	10.6	11.4	0	0	0	14.1	21.7	14.4	10.6	4.7	12.6
15	4.08	3.89	5	0	14.4	1.8	0	29.6	0	42.2	3.3	0	.5	6.2	2.1
16	5.85	6.65	5	0	38.9	6.2	0	8.4	0	12.9	9.2	0	1.4	16.7	6.3
17	9.76	13.00	5	.5	33.9	6.6	1.1	8.7	1.1	11.7	10.2	0	4.1	15.1	7.1
Total	81.89	107.1		6.5	11.1	3.4	5.8	25.3	4.9	24.8	4.9	.9	2.9	5.5	4.0

considered to be the effective impervious areas. This type of modification has been employed in HSPF models in other study areas (Zarriello, 1999). The percentage of effective impervious land was estimated as 10 percent in residential areas without sewers, 30 percent in residential areas with sewers, 50 percent for urban and commercial areas, and 10 percent for undesignated lands in sewered areas. The computed impervious areas for each land use based on these percentages were included in the model as IMPLNDs.

Seventeen reaches (RCHRES) were specified for the White Clay model (fig. 14). Reach lengths ranged from 1.67 to 9.76 mi; the median length was 4.46 mi. The length of a reach was determined by features related to its hydrologic characteristics and to calibration requirements. One model reach is in the West Branch, two reaches were in the Middle Branch, six reaches were in the East Branch, and five reaches were in the main stem below the confluence. There is one model reach each for Middle Run, Pike Creek, and Mill Creek. The land area draining directly to each reach ranged from 1.37 to 13 mi^2 (table 9).

Snowfall, snow accumulation, and snow melt were simulated in the White Clay model because hydrologic and meteorologic records indicated substantial snow, ice, and freezing temperatures during the winter of 1995-96 in the upper basin.

Assumptions

The simulation of streamflow in the White Clay Creek Basin was done under the following assumptions: (1) actual inputs of hourly precipitation would be estimated reasonably well by disaggregated 24-hour precipitation data; (2) the average precipitation over a given segment would be represented adequately by weighted data from a single precipitation gage; and (3) a simplified set of PERLNDs and IMPLNDs would not unduly limit a satisfactory hydrologic calibration of the White Clay model.

Model Calibration

Model calibration was done over the full range of observed streamflows, although special attention was given to simulating higher streamflows because transport of most nonpoint-source constituents is greatest at high flows. The period of calibration was October 1, 1994, to October 29, 1998, and included years with precipitation that were greater than, less than, and similar to normal values. The hydrologic component of the HSPF model for the White Clay Creek Basin was calibrated using HSPEXP (Lumb and others, 1994); an expert system, GenScn (Kittle and others, 1998); and the calibration guidelines in Donigian and others (1984). The basin model was calibrated at gaged locations in downstream order. For example, streamflow from the drainage area in the most upstream segment (segment 7) was calibrated at the streamflow-measurement station 01478137 Trout Run at Avondale (fig. 14) first. Then, streamflow from the drainage area in the next segment downstream (segment 5) was calibrated at streamflow-measurement station 01478650 White Clay Creek at Newark.

Prior to calibration, initial values of the hydrologic parameters were determined. Initial values were derived from known watershed characteristics where possible, from the HSPFParm database (Donigian and others, 1999), and from published sources such as Donigian and Davis (1978) and the USEPA, Office of Water (2000a). During calibration with HSPEXP, simulated streamflow is compared to observed streamflow through statistical and graphical methods and suggestions are given as to which parameter(s) needs to be modified. HSPEXP also includes default statistical criteria for determination of a satisfactory hydrologic calibration (table 10). The criteria are maximum allowable differences (errors) between observed and simulated streamflow expressed as percent error. These criteria are not fixed in HSPEXP and can be modified depending on the users' needs. Donigian and others (1984) offer the following error criteria for calibration: annual and monthly values less than 10 percent difference (very good); 10 to 15 percent difference (good); 15 to 25 percent difference (fair). Calibrated hydrologic parameter values are listed in the White Clay Creek UCI in Appendix 3.

Calibrated model error statistics (table 10) were all less than the default HSPEXP criteria. Because of incomplete data for the full simulation period, HSPEXP did not produce statistics for Trout Run at Avondale (01478137) and White Clay Creek near Strickersville (01478245). For these two sites, graphical comparison of observed and simulated cumulative differences in streamflow and comparison of flow duration curves were the primary methods used in calibration. Using criteria suggested by Donigian and others (1984) to evaluate simulated total annual streamflows at White Clay Creek near Newark, Del., the calibrated White Clay Creek model can be considered 'very good' except for 1995, which was 'good'.

Calibration of selected storms consisted of comparing stormflow volume, average simulated peak flows, and recession rates with observed data. Thirty-six storms were selected from the simulation period. Storms were selected using the following criteria: (1) total storm precipitation equal to 1 in. or more and over a broad area of the basin so that most or all segments of the basin exhibited a hydrologic response to the storm; and (2) all storms during which water-quality data were collected. From the selected storms, the statistics for total storm volume, error in storm peaks, and error in summer storm volume were calculated (table 10).

Table 10. *Calibration errors for HSPF simulated streamflow at two streamflow-measurement stations, 01478650 White Clay Creek at Newark, Del., and 01479000 White Clay Creek near Newark, Del., for the period October 1, 1994, through October 29, 1998*

Calibration site (streamflow-measurement station number)	Calibration criteria[1], in percent						
	Total volume	Low flow recession rate	50-percent lowest flows	10-percent highest flows	Storm peaks	Seasonal volume error	Summer storm volume error
	10.0	0.03	10.0	15.0	20.0	30.0	50.0
	Calibration errors for streamflow simulated by White Clay Creek model[2], in percent						
01478650	1.8	-.01	8.1	-3.0	.4	7.3	-11.8
01479000	-.9	0	4.5	-4.6	13.7	12.1	-11.5

[1] Default criteria for satisfactory hydrologic calibration in HSPEXP.

[2] Errors calculated as [(Simulated - Observed) / Observed] × 100.

Time-series comparisons of simulated and observed hourly streamflow show streamflow simulation errors generally are linked to seasonal and flow conditions. At White Clay Creek near Newark (01479000), periods of over simulation tend to occur in the winter and spring months or when base flows are high (fig. 15), and periods of under simulation tend to occur in the summer and fall months or when base flows are low. The winter months of 1995-96, which had substantial snowfall and snowmelt, also are a period of greater simulation error. Trout Run at Avondale (01478137) (fig. 16), which has the smallest drainage area, trends from undersimulated streamflow in the fall of 1997 to oversimulated streamflow in the spring

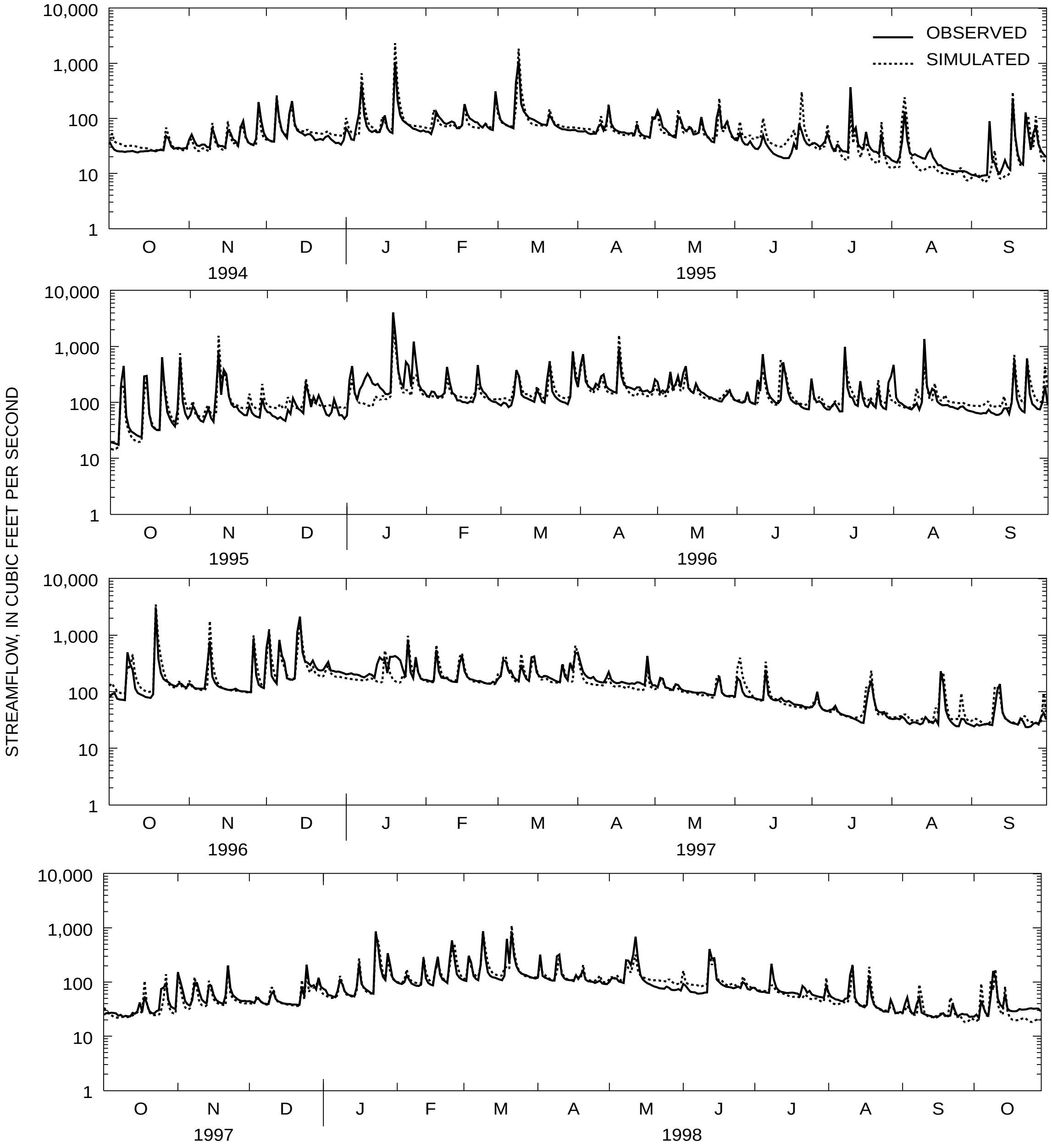


Figure 15. Simulated and observed streamflow at streamflow-measurement station 01479000, White Clay Creek near Newark, Del., October 1, 1994, through October 29, 1998.

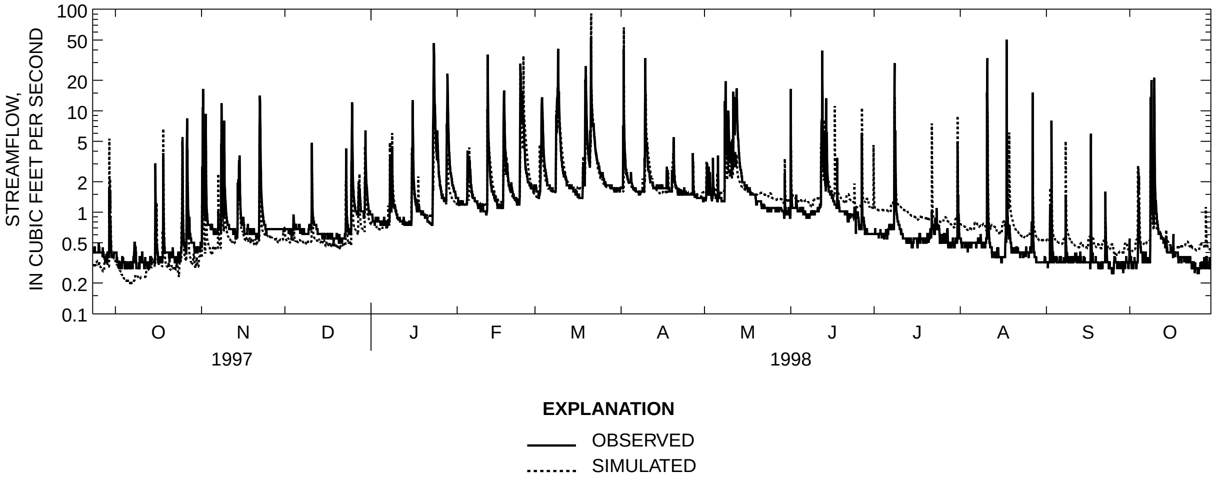


Figure 16. Simulated and observed hourly mean streamflow at streamflow-measurement station 01478137, Trout Run at Avondale, Pa., September 23, 1997 through October 29, 1998.

and summer of 1998, the period for which observed streamflow is available. Oversimulation is evident in both base flow and stormflow.

Flow-duration curves of simulated and observed hourly streamflow for the streamflow-measurement sites on the main stem of White Clay Creek show generally good agreement (figs. 17 and 18). Overall, the simulations represent streamflow reasonably well. Durations of the highest flows, those that transport the bulk of nonpoint-source constituents, are well simulated, except for the highest 0.06 percent of flows that are undersimulated at the White Clay Creek near Newark and White Clay Creek at Newark, Del., sites. White Clay Creek near Strickersville, Pa., has the highest 0.4 percent of flows oversimulated. Low flows exhibit minor to moderate undersimulation. The lowest 10 percent of flows are undersimulated at White Clay Creek near Newark, Del., and White Clay Creek near Strickersville, Pa.

The flow-duration curves for streamflow at the small-basin site, 01478137 Trout Run at Avondale, Pa. (fig. 18), show considerably greater simulation error than those for the streamflow at main-stem sites. However, because the period of record is shorter at the small-basin site (1+ year) than at the main-stem sites, the flow-duration curve at Trout Run cannot be compared directly with the other sites. With the exception of the highest 0.03 percent, the highest 10 percent and lowest 5 percent of the flows are undersimulated. The undersimulation of high flow may result from underestimation of the effective impervious area, which is specified as less than 5 percent in the model. The undersimulation of low flow is more moderate and may result in part from a retention effect related to the existence of ponds in the upper half of the drainage basin.

The model performance in simulating hourly and daily streamflow was evaluated at three water-quality monitoring sites for 1998, the year of nonpoint-source water-quality monitoring, and at one monitoring site for the calibration period of 1994-98. Statistical measures of the hourly and daily streamflow comparison are listed in table 11. Correlation and model-fit efficiency coefficients for the site draining a smaller area (01478137 Trout Run at Avondale) are lower than those for the sites draining larger areas (01478245 White Clay Creek near Strickersville and 01479000 White Clay Creek near Newark), indicating a poorer model fit for the smaller site. The magnitude of mean errors relative to mean flow also are greater for sites draining smaller areas than larger areas. Unlike the flow-duration comparisons, the statistics for one-to-one comparison of observed and simulated values (table 11) are affected by errors in the timing of storms. Because errors in the timing of precipitation and consequent storms commonly occur in shifts on the order of hours, not days, they result in lower values of correlation and model-fit efficiency coefficients for hourly stream-

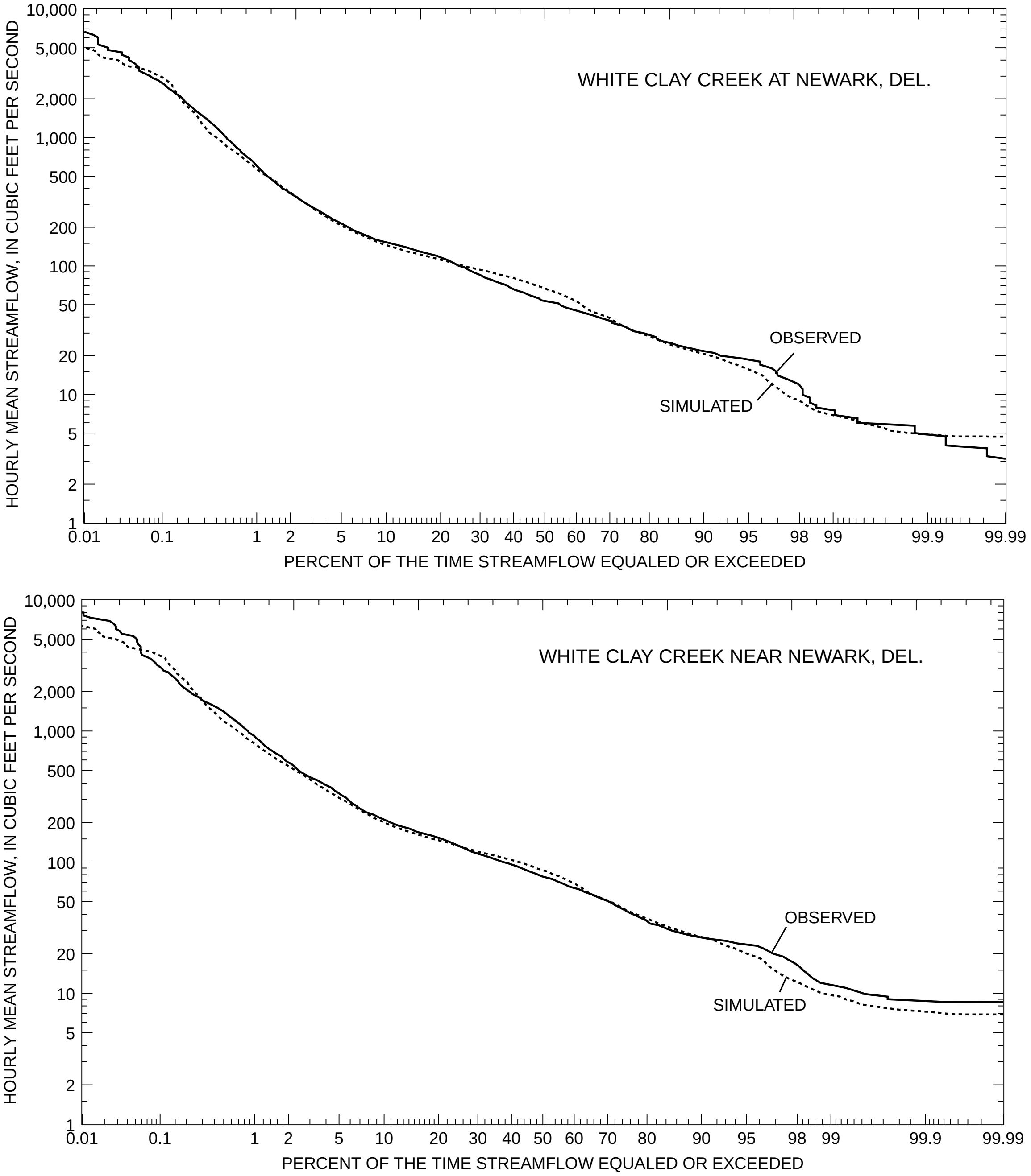
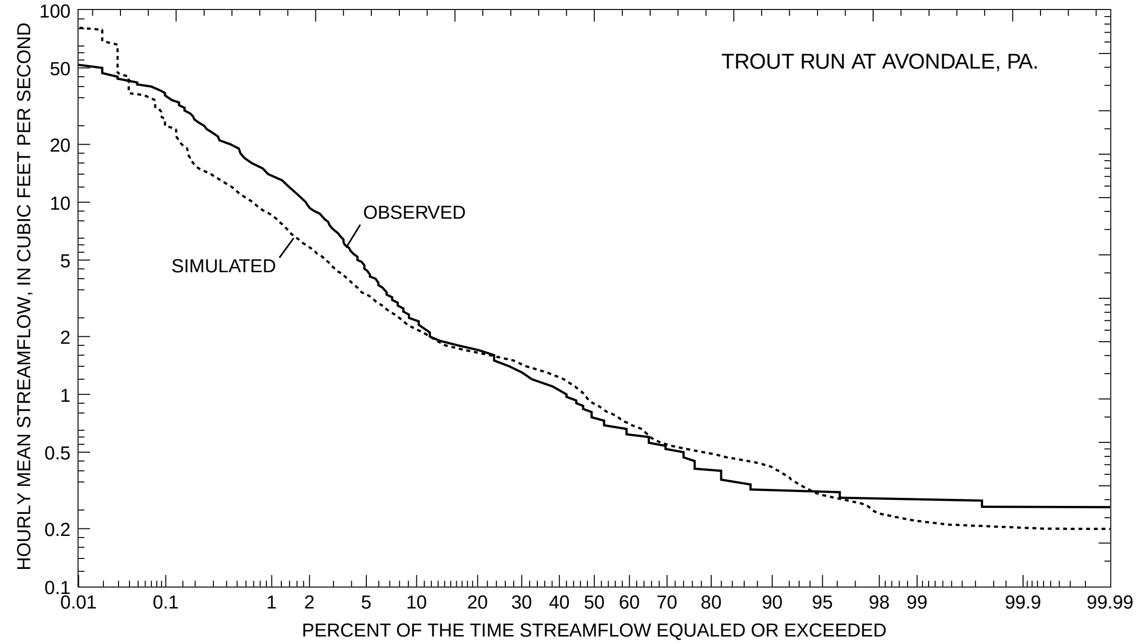


Figure 17. Duration curves of simulated and observed hourly mean streamflow at streamflow-measurement stations 01478650, White Clay Creek at Newark, Del. (top), and 01479000, White Clay Creek near Newark, Del. (bottom), October 1, 1994 through October 29, 1998.



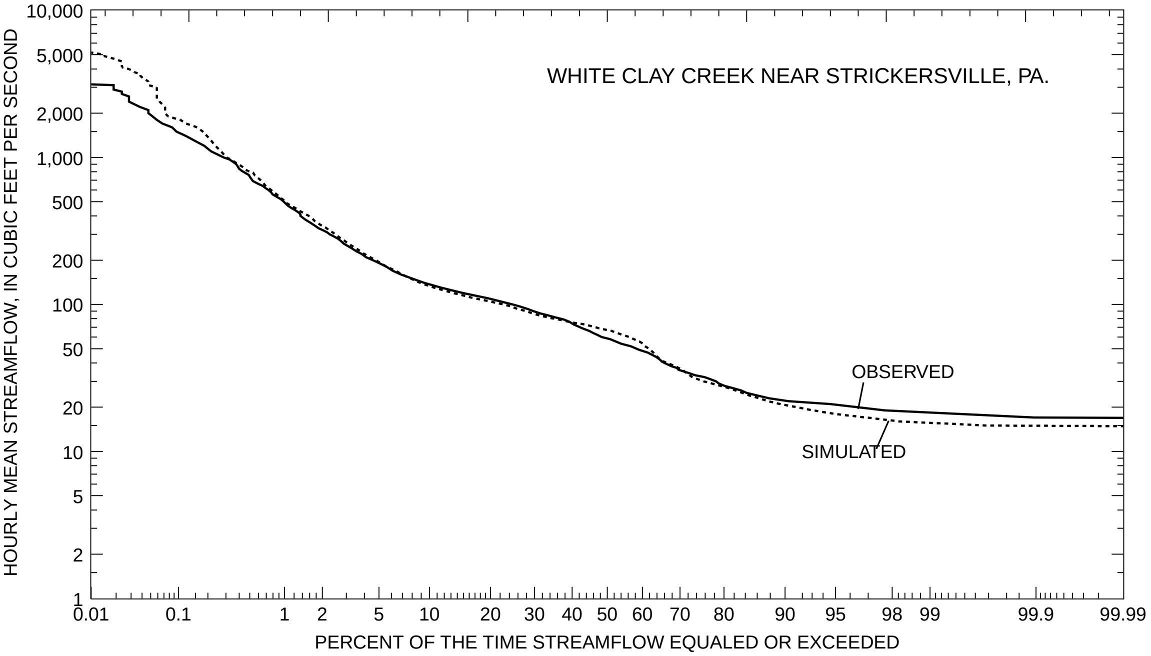


Figure 18. Duration curves of simulated and observed hourly mean streamflow for streamflow-measurement stations 01478137, Trout Run at Avondale, Pa., for the period September 23, 1997, through October 29, 1998 (top), and 01478245, White Clay Creek near Strickersville, Pa., for the period August 2, 1996, through October 29, 1998 (bottom).

Table 11. *Statistics for comparison of observed and simulated hourly and daily mean streamflow at two nonpoint-source water-quality monitoring sites and one other monitoring site during the January - October 1998 nonpoint-source monitoring period and at one water-quality monitoring site during the October 1994 - October 1998 calibration period in the White Clay Creek Basin*

Site	Type of mean values	Number of values	Streamflow, in cubic feet per second				Correlation coefficient	Model Fit efficiency
			Mean observed	Mean simulated	Mean error	Mean absolute error[1]		
Nonpoint-source monitoring period, January - October 1998								
Trout Run[2]	hourly	7,248	1.70	1.59	0.105	0.607	0.69	0.18
Trout Run	daily	302	1.70	1.59	.105	.495	.88	.51
Strickersville[3]	hourly	7,248	67.40	69.38	-1.973	15.754	.83	.68
Strickersville	daily	302	67.40	69.38	-1.973	14.149	.88	.78
Near Newark[4]	hourly	7,248	106.68	106.65	.033	26.387	.85	.69
Near Newark	daily	302	106.68	106.65	.033	22.293	.90	.79
Calibration period, October 1994 - October 1998								
Near Newark[4]	hourly	35,760	123.87	122.64	1.231	37.880	.80	.56
Near Newark	daily	1,490	123.87	122.64	1.231	33.036	.86	.70

[1] Mean absolute error = sum [|(simulated - observed)|/number of values].
[2] Nonpoint-source monitoring site 01478137 Trout Run at Avondale, Pa.
[3] Pennsylvania Department of Environmental Protection monitoring site 01478245 White Clay Creek near Strickersville, Pa.
[4] Nonpoint-source monitoring site 01479000 White Clay Creek near Newark, Del.

flow compared to those for daily streamflow (table 11). Errors in timing of precipitation on the order of hours affect simulated stormflow in small drainage areas to a greater extent than simulated stormflow in large drainage areas because the time to peak for storms generally increases with basin size. The evaluation indicates that the model fit efficiency and correlation coefficients are similar and generally slightly better for 1998 than the calibration period of 1994-98 at the one site, 01479000 White Clay Creek near Newark, where record was available. Model-fit efficiency coefficients greater than 0.97 indicate an excellent calibration (Martin and others, 2000; James and Burgess, 1982). Simulated and observed streamflow statistics, given in inches, for White Clay Creek near Newark, Del., are listed by year and for the 5-year period of simulation in table 12.

A plot of cumulative errors for White Clay Creek near Newark, Del. is presented in figure 19. Periods of good agreement between simulated and observed streamflow are displayed as a horizontal line with minor y-axis (vertical) fluctuations. Periods of poor agreement appear as larger vertical displacements. The y-axis value lists the total difference between simulated and observed streamflow volumes, in inches, from the beginning of the simulation period to the corresponding date on the x-axis scale. The most rapid changes in cumulative error occurred during the winter of 1995-96 when snowfall accumulation and snowmelt were greatest. Snow was on the ground at Coatesville 2 W meteorological station from mid-December through January during which period the model did not simulate sufficient runoff. The winters of 1994-95 and 1996-97 also were periods of substantial changes in cumulative error. Other than these periods, the cumulative error shows minimal variation (1 percent or less) across the simulation period.

Table 12. *Observed and simulated streamflow volume and difference for 01479000 White Clay Creek near Newark Del., 1994-98*

Year	Streamflow volume, in inches			Percent difference[1]
	Simulated	Observed	Simulated - observed	
[2]1994	1.86	1.79	0.07	3.9
1995	13.55	11.84	1.71	14.4
1996	31.01	32.91	-1.90	-5.8
1997	16.74	17.36	-.62	-3.6
[3]1998	13.52	13.51	.01	.1
Total (1994-98)	76.68	77.41	-.73	-.9

[1] [(Simulated - Observed) / Observed] ×100.
[2] For October 1 through December 31.
[3] For January 1 through October 29.

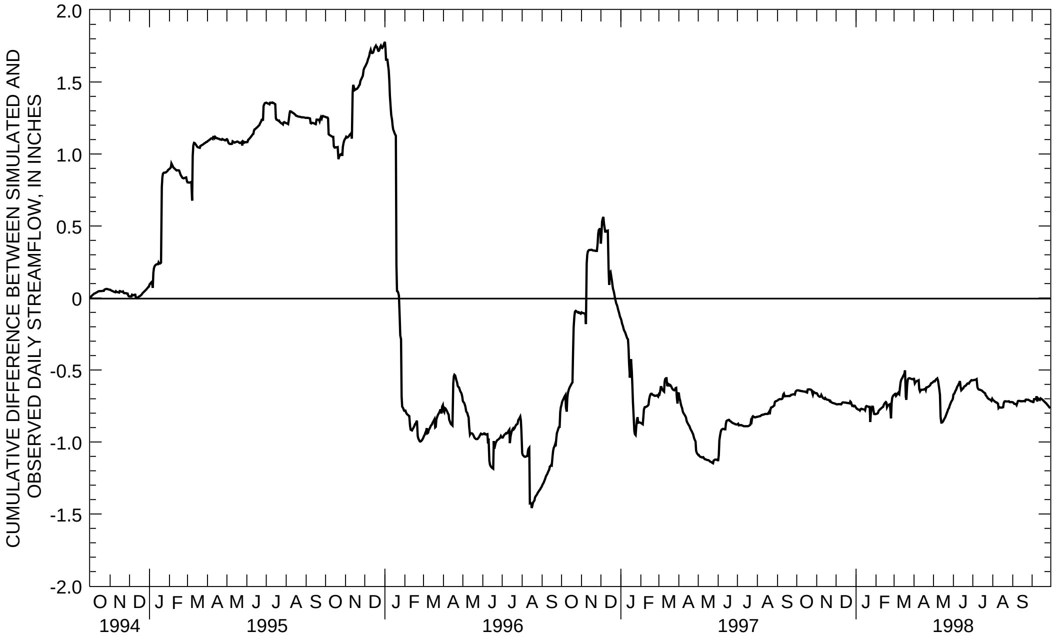


Figure 19. Cumulative difference between simulated and observed daily total streamflow at 01479000 White Clay Creek near Newark, Del.

Water in an HSPF model reach can be subdivided into surface runoff (SURO), interflow (IFWO), and active ground-water flow (AGWO). These components represent the volumes of water discharged to the stream from a pervious land segment (PERLND). Impervious land segments (IMPLNDs), by definition, have only a surface runoff (SURO) pathway. Ground-water flow (AGWO) discharged to a stream is referred to as base flow in this report. For the 4-year, 29-day period of simulation of streamflow at White Clay Creek near Newark, Del., the SURO was 17.7 in. (23 percent of total flow), IFWO was 11.4 in. (15 percent of total flow), and AGWO was 49.1 in. (63 percent of total runoff). Percentages of AGWO calculated by HSPF were compared to percentages of base flow determined by commonly used fixed-interval or local-minimum base-flow-separation techniques (Sloto and Crouse, 1996; Pettyjohn and Henning, 1979). Because of differences in methodology, the fixed-interval and local-minimum methods are only roughly equivalent to AGWO. The base-flow-separation techniques do not determine interflow as a separate component and it is likely that the techniques result in dividing the amount of IFWO, interflow calculated by HSPF, between the amounts of base flow and stormflow. The fixed-interval and local-minimum methods calculated 64.2 and 62.2 percent of total flow as base flow, respectively, which agrees well with simulated AGWO at White Clay Creek near Newark, Del.

The partitioning of PERLND water among SURO, IFWO, and AGWO affects the stream hydrograph and, consequently, the simulation of nonpoint-source constituent transport (Fontaine and Jacomino, 1997). The monthly contributions from SURO, IFWO, and AGWO for the calendar years 1995, 1996, and 1997 at the most downstream calibration point, 01479000 White Clay Creek near Newark, are presented in figure 20. In 1996, the wettest year, SURO accounted for 25 percent of the total flow. In 1997, the driest year, SURO accounted for 16 percent of the total flow. In 1995, SURO accounted for 32 percent of the total flow.

Overall, the calibration of the hydrologic component of the HSPF model for the White Clay Creek Basin generally is balanced over the full range of observed streamflows, even though more emphasis was placed on high-flow simulation. The White Clay Creek model simulates streamflow better at sites draining relatively larger areas, such as the main-stem sites, than at the site draining a relatively smaller area, Trout Run. Errors in hourly stormflow simulation are due in part to errors in hourly rainfall estimated by disaggregating daily values and commonly are relatively greater at sites

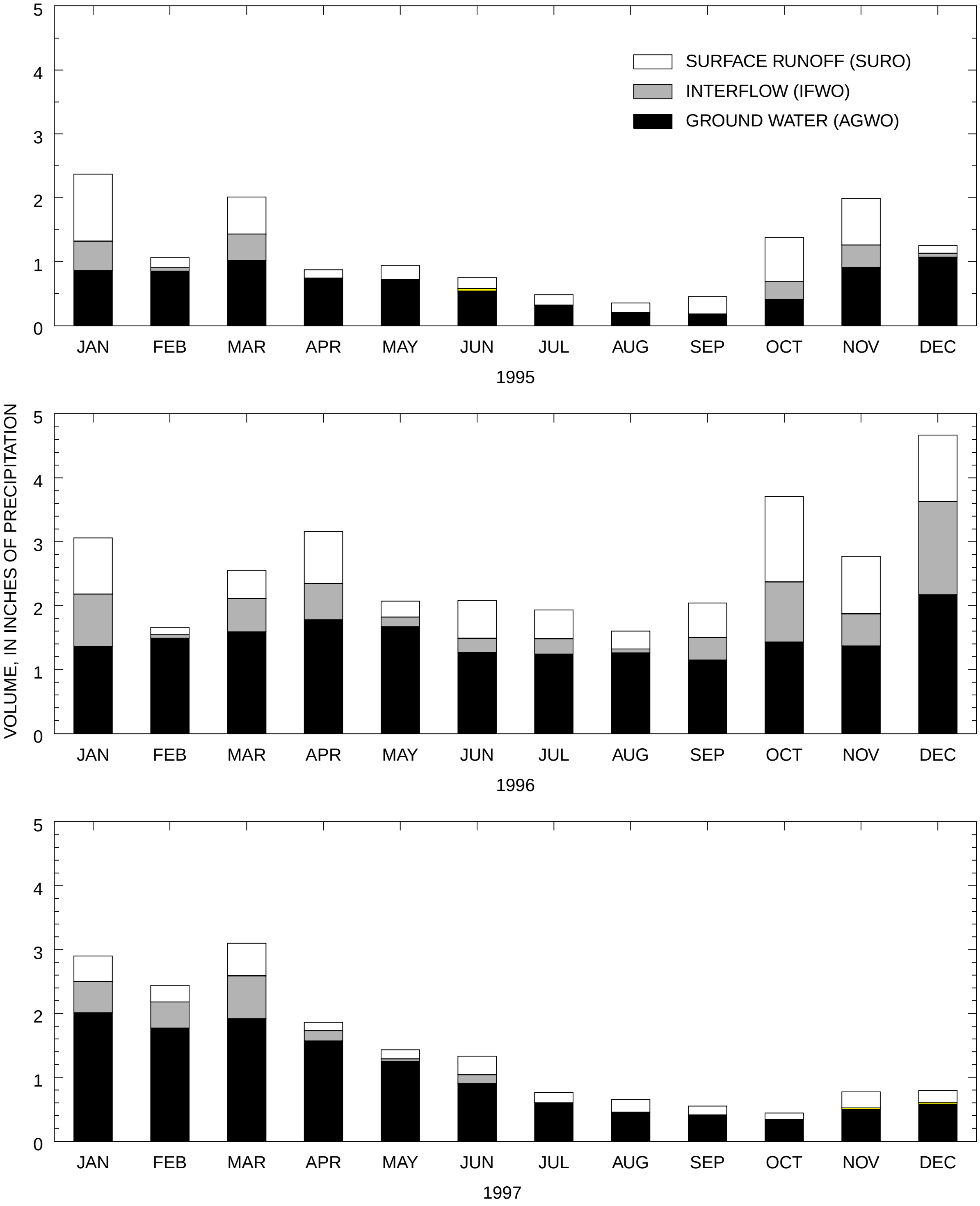


Figure 20. Simulated surface runoff, interflow, and base-flow contribution from pervious land segments (PERLNDs) at the most downstream calibration site in the White Clay Creek Basin, 01479000 White Clay Creek near Newark, Del.

draining smaller areas (less than 10 mi^2) than at sites draining larger areas (more than 10 mi^2). As calibrated, the hydrologic component of the model has limitations for the application of simulating water-quality under stormflow conditions. These limitations, related primarily to the regionalization of distant point source precipitation data and differences in spatial scale relative to the calibration sites, tend to increase the range and magnitude of errors in the simulated hydrologic responses to individual storm events at the nonpoint-source water-quality monitoring site in the small Trout Run subbasin relative to errors at the main-stem sites. Because of the dependence of certain water-quality characteristics on streamflow conditions, limitations in the hydrologic simulations will affect water-quality simulations, particularly during stormflow conditions at sites draining relatively small areas.

Model Sensitivity Analysis

A sensitivity analysis was performed to examine the influence of altering the value of selected input parameters on streamflow volume simulated by the White Clay Creek HSPF model. For the analysis, the value of parameters were varied one at a time. To a large extent, the relative sensitivities of the model results to changes in individual parameters are determined by the algorithm in which they are used. However, relative sensitivities also are influenced by the calibrated values of other parameters because of various degrees of interdependence. IMPLND and RCHRES parameters were not included in the sensitivity analysis because they have minimal influence on streamflow volumes. Variations in the timing of stormflows are affected most by varying IMPLND and RCHRES parameters.

Selected PERLND parameter values were doubled and halved while holding all other parameters constant prior to running a simulation. In some instances, limitations on the range of allowable values prevented doubling or halving the values. The lower zone evapotranspiration (LZETP) and ground-water recession (AGWRC) parameters are two examples. In addition, the AGWRC parameter was only decreased because its calibrated value is close to the maximum allowable value. Sensitivity analysis was completed for White Clay Creek near Newark, Del. The response of simulated runoff characteristics is listed in table 13.

Total runoff volume shows the greatest sensitivity to lower-zone storage (LZSN) and, to a lesser degree, upper-zone storage (UZSN) and lower-zone evapotranspiration (LZETP). LZSN controls the volume of water available for evapotranspiration, UZSN controls the loss of potential runoff to infiltration and a part of evapotranspiration, and LZETP controls the rate of evapotranspiration. Water directed to evapotranspiration is lost from the total runoff volume. Infiltration (INFILT) and interception (CEPSC) affect total runoff volume to a smaller degree.

The 10-percent highest flows are sensitive primarily to the infiltration rate (INFILT) and ground-water recession constant (AGWRC) and secondarily sensitive to lower-zone storage (LZSN) and upper-zone storage (UZSN). The 50-percent lowest flows are sensitive primarily to AGWRC and secondarily sensitive to INFILT and LZSN. INFILT is the most important parameter control the partitioning of precipitation to surface runoff or infiltration to the ground-water system. Runoff accounts for much of the volume in the 10-percent highest flows. Ground-water discharge to streams generally accounts for some of the volume in the 10-percent highest flows and most of the volume in the 50-percent lowest flows at White Clay Creek near Newark, Del. Therefore, changes in the ground-water recession constant AGWRC will affect both the 10-percent highest and 50-percent lowest flows.

Seasonal runoff volumes are most sensitive to changes in AGWRC and INFILT. Seasonal runoff volume refers to the differences between summer (June, July, and August) runoff volumes and winter (December, January, and February) runoff volumes. The AGWRC determines how rapidly stream base flow diminishes over time after recharge to ground-water storage. Ground-water storage is controlled, in part, by infiltration and water loss to lower-zone storage and evapotranspiration. Recharge to ground-water storage typically exhibits seasonality. Stream base flow modeled with relatively high ground-water recession rates shows or even amplifies the seasonality in ground-water storage, whereas, base flow modeled with relatively low ground-water recession rates suppresses seasonal fluctuations in ground-water storage. INFILT influences seasonal runoff volumes by determining in part the amount of water lost to evapotranspiration, a highly seasonal process. Seasonal runoff volumes show secondary sensitivity to LZSN, CEPSC, and UZSN.

Table 13. *Sensitivity of modeled runoff characteristics at White Clay Creek near Newark, Del. (01479000), to variations in selected PERLND parameters.*

[ET, evapotranspiration; AGWRC, ground-water recession rate; INFILT, infiltration; LZSN, lower-zone storage; CEPSC, interception storage; UZSN, upper-zone storage; SLUR, slope of overland flow; NSUR, Manning's n for overland flow; INTFW, interflow; IRC, interflow recession rate; LZETP, lower-zone evapotranspiration]

Parameter	Multiplier	Runoff errors (in percent)						Total volume for simulation period[1], in inches			
		Total runoff volume	50-percent low flow	10-percent high flow	Seasonal runoff volume	Summer storm volume	Average storm peak	Total runoff	Surface runoff	Interflow	Total ET
Calibrated value	1	1.0	-4.5	4.6	-12.1	11.5	-13.7	76.68	17.73	11.17	101.9
AGWRC	.75	-1.6	59.3	-24.9	-37	21.5	-16.1	78.69	17.69	11.11	101.1
INFILT	2	-.3	-21.7	22.4	-28.6	-.6	17.1	77.68	13.55	6.66	100.6
INFILT	.5	1.8	16.8	-18.1	-5	19	-54	76.1	24.84	14.65	103.1
LZSN	2	12.5	12.7	19.4	-23.9	-5.7	5.2	67.77	15.85	8.04	127.9
LZSN	.5	-8.1	-4.9	-13.9	-12.7	40.7	-35	83.7	20.11	16.33	97.16
CEPSC	2	3.2	2.9	3.5	-3.7	15.4	-14.9	74.98	17.94	11.6	103.7
CEPSC	.5	-.4	-9.1	5.4	-17.1	9.9	-12.5	77.76	17.59	10.89	100.8
UZSN	2	4.4	-6.9	15.5	-13.8	9.5	4.1	74.05	15.68	8.93	104
UZSN	.5	-3.4	-.7	-10	-16	6.8	-36.2	80.07	20.57	14.94	99.03
SLSUR	2	1	-4	3.8	-12.1	11.8	-16.1	76.72	18.25	10.91	101.9
SLSUR	.5	1.1	-5	5.5	-12.3	11.3	-10.1	76.64	17.17	11.45	102
NSUR	2	1.1	-5.5	6.4	-12.5	10.3	-6.6	76.60	16.58	11.77	102
NSUR	.5	.9	-3.6	3	-12	12.4	-19.6	76.75	18.72	10.69	101.9
INTFW	2	.9	-3.9	4.6	-11.4	9.9	6.4	76.80	14.25	15.70	101.8
INTFW	.5	1.2	-5.	3.5	-13.9	13.3	-37.4	76.51	22.78	4.5	102.1
IRC	2	1	-7.6	11.9	-12.6	12.9	-9	76.67	17.73	11.17	101.9
IRC	.5	1	-3.6	1.4	-12.1	12.1	-17.3	76.69	17.73	11.17	101.9
LZETP	1.25	3.9	1.1	7.2	-12.8	11	-11.3	74.41	17.39	10.59	105.1
LZETP	.75	-2.4	-10.7	1.5	-11.5	12.4	-17.3	79.3	18.14	11.9	98.36

[1] Simulation period of October 1, 1994 - October 29, 1998.

Summer storm volumes are primarily sensitive to LZSN. LZSN generally is not considered as having much influence over storm volumes. However, because HSPEXP calculates storm volumes over whole 24-hour increments, storm volumes for short duration events, which are more prevalent in the summer, will include more base flow. These base-flow periods are affected by the LZSN. In addition, HSPEXP analysis is limited to 36 storms, and the choice of storms affects the analysis. Eleven of the 36 storms selected for analysis were from the drier than average 1997-98 period that coincided with available water-quality data. Storms from this period tend to be smaller with the result that HSPEXP calculated storm volumes of which a larger proportion is base flow. Summer storm volumes showed secondary sensitivity to INFILT, which directly influences the partitioning of water to infiltration and storm runoff, and to AGWRC and CEPSC.

Stormflow peaks were most sensitive to INFILT. INFILT controls partitioning of potential surface runoff to infiltration or surface runoff and surface runoff determines stormflow peaks. Stormflow peaks were secondarily sensitive to LZSN, UZSN, and INTFW. All three had approximately equal sensitivities. LZSN and UZSN affect partitioning of surface runoff and infiltration. INTFW diverts surface runoff into interflow storage. In addition to these PERLND parameters, stormflow peaks also is affected by IMPLND parameters, if sufficient IMPLND area exists, and by RCHRES storages as defined in the F-Tables. As with storm volumes, the choice of storms selected for inclusion into HSPEXP has a substantial effect on the reported stormflow-peaks statistics.

Model Limitations

The final calibration of the hydrologic component of the HSPF model for White Clay Creek satisfies most of the recommended calibration criteria, but has limitations. These limitations can be classified as either errors in the input and calibration data or errors in the model structure. Errors in the input data may result from the measurement, interpolation, and extrapolation of precipitation and other climatic data, discharge data, and withdrawal data. Errors in calibration data include those involved in the measurement of observed streamflow data. Measurement errors result from equipment malfunction, incorrect data transcription, and other problems. Specific information required to evaluate measurement errors is generally unavailable. Interpolation errors can occur when data are disaggregated to smaller time steps. Extrapolation errors can occur when spatial variations and timing in data are lost by applying localized data to large areas.

Precipitation data can contain a number of errors. Measurement errors, while known in general, are not specifically known for the rain gages used for the White Clay Creek model. These errors may include malfunctioning equipment, incorrect calibration, poor snow-catch accuracy, and environmental influences (Winter, 1981). Extrapolation and interpolation errors in the precipitation data include applying data from two raingages to the entire 108-mi^2 basin and disaggregating daily precipitation data to hourly data. Precipitation data from NOAA meteorological stations in areas adjacent to the raingages selected for the model show departures as great as 15 percent over the simulation period whereas individual storms exhibit departures as much as several hundred percent. Thus, storms with substantial precipitation may appear to result in little or no streamflow response or vice versa. Disaggregation of daily precipitation values to hourly values ignores spatial variations in timing by applying the hourly timing of precipitation at the Wilmington, Del., airport meteorological station to the entire White Clay Creek Basin. Additionally, daily precipitation totals at the Newark University Farm meteorological station do not represent the same 24-hour period as the Wilmington data. Daily measurements from this gage are read at a different hour than the Wilmington and Coatesville gages. Disaggregation errors show as timing shifts in storm hydrographs. The overall effect of these errors on the White Clay Creek HSPF model is an increase in the average error as the period of simulation is decreased. Other climatic data such as air temperature, solar radiation, and wind speed are subject to measurement, extrapolation, and timing errors but are less important factors than precipitation in the streamflow simulation.

Measurement errors in observed streamflow are known and corrected in some instances but unknown and roughly estimated in other instances, such as ice-affected streamflow record. In many cases, corrections are limited to daily values, and hourly data are left uncorrected or missing. Periods of missing hourly streamflow record were filled with estimated data for the model in order that HSPEXP would calculate statistics. However, the errors associated with these estimated data are unknown. The USGS (Durlin and Schaffstall, 1999) rates periods of estimated record as poor and states that errors greater than 15 percent can be expected. Errors in observed streamflow data can be expected to affect the statistics used for calibration evaluation and, if severe, lead to incorrect selection of parameter values.

Errors in the model structure are due mainly to limited resolution of PERLND, IMPLND, and RCHRES spatial characteristics and incorrectly specified model parameters. In general, spatial errors result from the loss of local variation in spatial characteristics. Lack of data resolution and the need to limit the complexity of the model structure are the primary reasons for this loss. For example, in the White Clay Creek model, the number of pervious land-use categories has been limited to 10. In actuality, more than 10 distinct land-use categories exist. Further, each of these PERLND categories is assigned individual calibration parameters that are selected to represent a composite average for that category. Because of this spatial averaging, the model has limited capability to resolve responses from land uses with limited areal extent or that differ greatly from the average.

Many HSPF parameters are not expressed in terms of known physical behavior, making selection of parameter values somewhat ambiguous and leading to incorrect specification. For example, the parameter AGWRC is not defined in terms of established ground-water hydrologic characteristics. Also, in the case of the parameter INFILT, published soil permeability values cannot be used directly but only as a guide. The goal during calibration is to select parameters that most accurately model the basin's hydrologic processes as evaluated by streamflow response. However, an acceptable streamflow response can be produced with more than one combination of parameters.

SIMULATION OF WATER QUALITY

Suspended sediment and nutrients were simulated for the White Clay Creek Basin. The simulation included delivery of suspended sediment and nutrients from pervious and impervious land areas to stream reaches and transport and chemical reactions in the stream reaches. The instream simulation of nutrients requires information about stream temperature and dissolved oxygen. Because environmental data describing stream temperature and dissolved oxygen were not available for most reaches, both stream temperature and dissolved oxygen also were simulated using the model. Stream temperature is an important variable in determining water quality because temperature affects saturation levels of dissolved oxygen and rates of chemical reactions. Dissolved oxygen concentrations affect the extent of chemical reactions involving nutrients, such as nitrification. In HSPF, the simulation of water quality is based on and is an extension of the hydrologic simulation.

The simulation of water quality was undertaken with the following assumptions: (1) land-based contributions of sediment and nutrients could be simulated by a simplified set of land-use categories; (2) water quality could be represented by the condition where chemical transformation of nutrients are simulated explicitly in the stream channel but not in land processes; (3) the contribution of sediment from bank erosion in the stream channel can be estimated by sediment from pervious land areas; and (4) suspended-solids data could be used as a surrogate for estimating suspended-sediment concentrations and loads.

Model Calibration

Each land-use category is assigned parameters that affect ground-water and interflow temperature, sediment release, and nutrient contributions from land areas. Stream reaches are assigned parameters that affect the simulation of stream temperature, sediment transport, bed erosion and deposition, and chemical reactions in the stream channel. Individual parameters were adjusted until the simulated water quality was an acceptable match to observed water quality. The computer program GenScn (Kittle and others, 1998), a graphical interface to HSPF, was used for the water-quality calibration. Parameters for land-use categories that were not specifically monitored in the White Clay Creek Basin were taken from the calibrated HSPF model for the adjacent Brandywine Creek Basin (Senior and Koerkle, 2003). The land-use categories calibrated in the Brandywine model using observed data were residential with septic systems, residential with sewers, mixed animal and crop agricultural, row crop agricultural, and forested.

Suggested guidelines to evaluate sediment and water-quality calibration, including the nutrients nitrogen and phosphorus, in the HSPF model are given in percentage differences between observed and simulated monthly or annual values (table 14) (Donigian and others, 1984). Comparison of loads, rather than instantaneous concentrations, are considered more appropriate when evaluating water-quality simulations of nonpoint-source constituents (Donigian and others, 1984). Comparison of instantaneous concentrations may result in larger apparent differences between observed and simulated values than comparison of loads because of the effect of even small lags (errors) in the timing of storm events. In addition, simulation errors usually are larger for water-quality concentrations than for streamflow.

Table 14. *Suggested criteria to evaluate water-quality calibration for an Hydrological Simulation Program–Fortran (HSPF) model (from Donigian and others, 1984)*

[<, less than]

Quality of calibration	Very Good	Good	Fair
Constituent	Difference between observed and simulated monthly or annual values, in percent		
Sediment	<15	15-25	25-35
Water quality (includes nitrogen and phosphorus)	<20	20-30	30-40

Water-quality calibration included stormflow and base-flow conditions. Because the hydrologic part of the model is integral to simulation of water quality, only well-simulated storms ideally would be used for calibration of suspended sediment and nutrients simulations. In all cases, however, the simulated storm hydrograph does not replicate the observed storm hydrograph well, especially with respect to peak flows. Therefore, simulated concentrations of suspended sediment, nitrate, ammonia, and phosphorus cannot be expected to exactly replicate observed concentrations for all storms. Calibration was considered satisfactory when the general pattern of observed streamflow and suspended sediment and nutrient concentrations was simulated and when, for better simulated storms, simulated concentrations and loads of suspended sediment and nutrients were within an order of magnitude of observed concentrations and loads. Individual storm errors considerably larger than the recommended criteria of 40 percent or less for monthly or annual values for fair to good water-quality calibration may occur and have little effect on the overall calibration (Donigian and others, 1984). Calibrated values for water-quality parameters are given in the UCI file for the White Clay Creek model (Appendix 3).

Monthly and annual load data were not available to assess calibration errors. Simulated and observed load data for two to six storms in 1998 were used to provide rough estimates of calibration accuracy. Loads were calculated from measured discharge and constituent concentrations in flow-weighted composite samples collected during storms. However, these limited data do not provide a long-term measure of the accuracy of the model and may include one or more poorly simulated storms or questionable laboratory analyses, which can have a large effect on the apparent accuracy of the model. The calibration error, calculated as (simulated minus observed) divided by observed for the total flow volume and constituent load for up to six storms, is listed in table 15. Calibration errors for individual storms at the six monitoring

Table 15. *Calibration errors in flow volume and constituent loads for monitored storms in 1998 at streamflow-measurement stations 01478137 Trout Run at Avondale, Pa., and 01479000 White Clay Creek near Newark, Del.*

Monitoring site	Number of storms	Calibration error for storm simulations in 1998, in percent[1]						
		Streamflow volume	Suspended sediment load	Nitrate load	Dissolved ammonia load	Particulate ammonia load	Dissolved orthophosphate load	Particulate phosphorus load[2]
Trout Run at Avondale	5	-34	-75	-39	-89	30	-63	[3] -89
White Clay Creek near Newark	5	-11	-45	-19	48	-11	43	-45

[1] Percent calibration error = 100 x (simulated - observed)/observed.

[2] One fewer storm was available for comparison because total phosphorus was not analyzed in the October 1998 storm.

[3] March 1998 storm excluded for a total of three storms evaluated.

sites are listed and discussed in more detail in subsequent sections describing calibration of suspended sediment, nitrogen, and phosphorus simulation. Generally for these storms, loads of suspended sediment, nitrogen, and phosphorus were undersimulated when streamflow was undersimulated and oversimulated when streamflow was oversimulated. Dissolved constituents, such as nitrate and dissolved orthophosphate, usually were simulated better than particulate constituents, such as suspended sediment and adsorbed orthophosphate.

Water Temperature

Simulated stream water temperature was calibrated against observed instantaneous water-temperature data from the three main stem sites on the White Clay Creek. The water-temperature data were collected during streamflow measurement and water-quality sampling events. About 1 year of continuous water-temperature data also were collected at Trout Run at Avondale, Pa. Because of the relatively short period of record, these data were used for model validation rather than for calibration. Comparison of simulated hourly mean and observed instantaneous water temperature at the main stem sites (fig. 21) shows a good correlation between simulated and observed water temperature over the entire range of sampled temperatures. Errors in the simulated water temperatures, excluding any overall bias, are within plus or minus 3°C for 93 percent of the observed temperatures at White Clay Creek near Newark, Del.; and for 98 percent of the observed temperatures at White Clay Creek at Newark, Del., and White Clay Creek near Strickersville, Pa. Simulated water temperatures at White Clay Creek near Strickersville, Pa., are positively biased about 1°C. Because water temperature affects the rate of chemical reactions and biological processes involving nutrients in the stream, errors in the temperature simulation will affect calibration of the nutrient simulation to some degree.

At the small-basin site, Trout Run at Avondale, Pa., errors in simulated hourly mean water temperatures are greater than errors in simulated hourly mean water temperatures at the main stem sites. Simulation errors for the water temperature range from lower than observed in winter to greater than observed in summer, as shown for simulated and observed daily mean water temperatures in figure 22. These errors likely result from the parameter values used in the water-temperature simulation. These parameters were calibrated for the Strickersville, Pa., site where streamflow volumes are considerably greater and where the effects of this greater thermal mass influenced parameter selection. Another feature of the model simulation is that during the lowest streamflows, simulated temperatures begin to show greatly increased variance in daily maximum and minimums. This effect appears to be related to the reduced volume to surface area ratio of water in the RCHRES allowing more rapid heating and cooling.

Suspended Sediment

Calibration of suspended sediment concentrations and loads in the stream is done by adjusting parameters affecting soil detachment, soil washoff, and soil scour processes for pervious land surfaces, solids build up and washoff processes for impervious land surfaces, and sediment transport in the channel, including deposition on and scour of the channel bottom controlled by setting shear stress regimes. Sediment in streams may be derived from land areas, streambanks, and beds. For the calibration, no net erosion of streambeds was assumed to occur over the simulation period and therefore the principal sources of sediment were assumed to be land areas and streambanks. Because the HSPF model does not include the process of bank erosion, sediment from streambanks was estimated by simulating scour in pervious land areas. Simulated concentrations of suspended sediment were compared to data collected by USGS in 1998 at the White Clay Creek monitoring sites as well as data collected by PADEP at a site in Pennsylvania and by DNREC at sites in Delaware.

Instantaneous concentrations of suspended solids were measured for up to six storms and four base-flow periods in 1998. Reported concentrations of suspended solids (nonfilterable material) were considered estimates of suspended-sediment concentrations. Suspended-solids concentrations are not always accurate estimates of suspended-sediment concentrations and tend to be biased low, especially for conditions when sand-sized particles represent more than 25 percent of suspended sediment (Gray and others, 2000). When suspended solids are used as a surrogate for suspended-sediment concentrations, the resulting errors in load computations can be as large as several orders of magnitude (U.S. Geological Survey, 2000). As noted earlier, only well-simulated storms (simulation error less than 20 percent for storm peaks, for

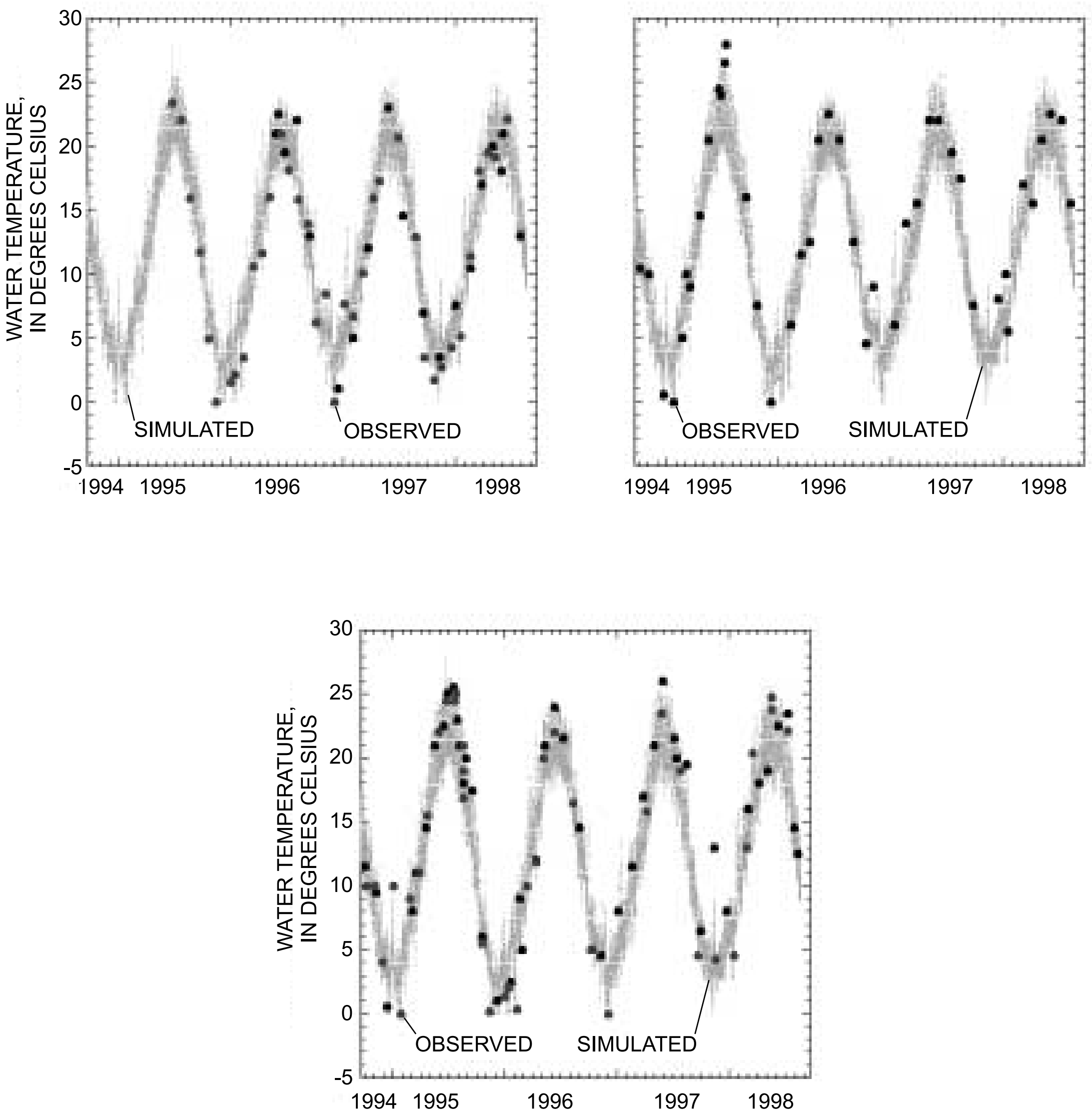
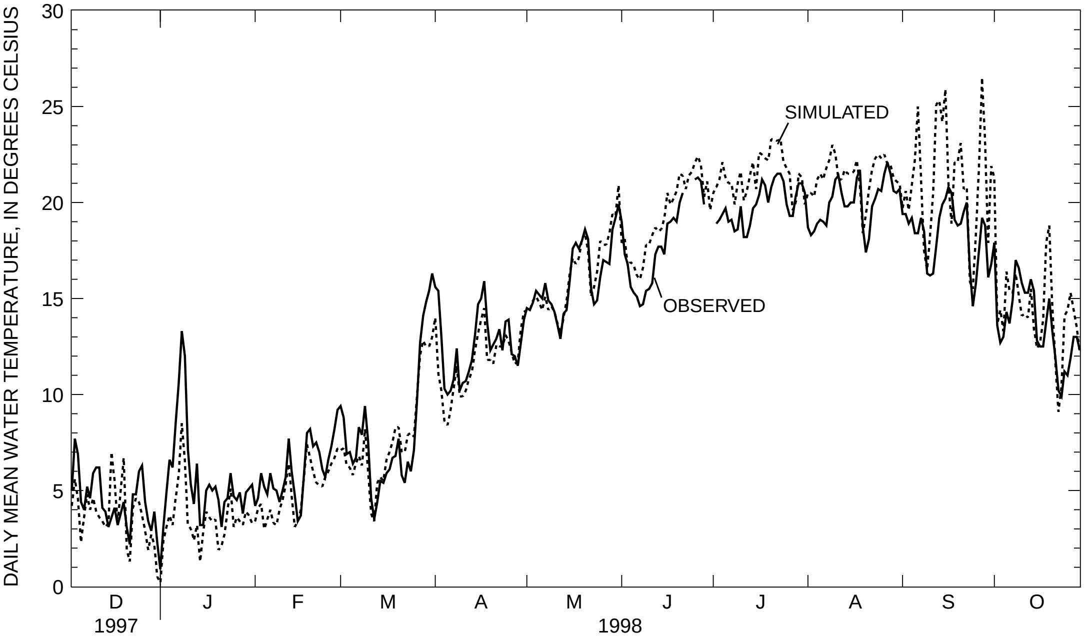


Figure 21. Simulated hourly mean and observed instantaneous water temperature at streamflow-measurement stations (A) 01478265 White Clay Creek near Strickersville, Pa., (B) 01478650 White Clay Creek at Newark, Del., and (C) 01479000 White Clay Creek near Newark, Del.



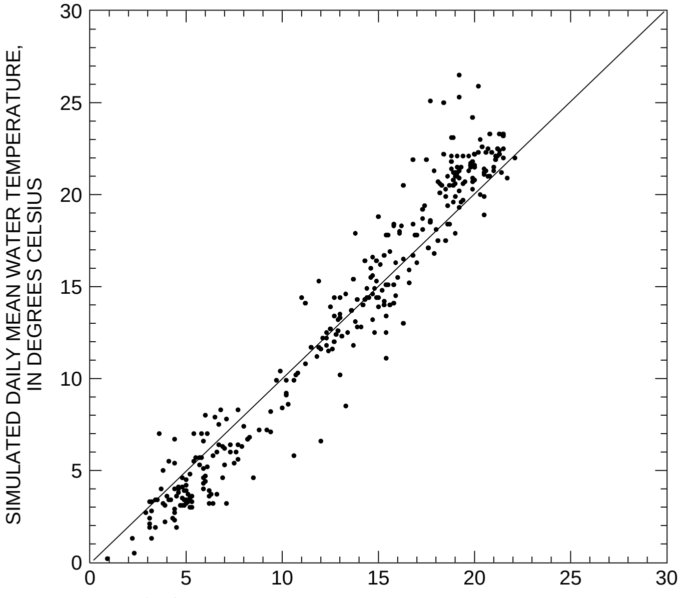


Figure 22. Simulated and observed daily mean water temperature at streamflow-measurement station 01478137 Trout Run at Avondale, Pa., December 1997 to October 1998.

example) would, ideally, be used for calibration of suspended sediment. In most cases, storms were not well simulated. Observed and simulated streamflow and sediment concentrations at the two storm monitoring sites in the basin, 01478137 Trout Run at Avondale, Pa., and 01479000 White Clay Creek near Newark, Del., are shown in figures 23 and 24 for storms sampled in 1998. No instantaneous samples were collected for analysis during the May 1998 storm at White Clay Creek near Newark (fig. 24). Of the five storms monitored at each site, streamflow is best simulated during the March 1998 storm, although both streamflow and suspended-sediment concentrations are somewhat undersimulated.

Composite samples collected during storms at the two nonpoint-source monitoring sites in the White Clay Creek Basin in 1998 allow comparison of simulated and observed loads for the periods monitored. Peak flows were greatest in the March and June storms and least in the February and May storms (table 16). Simulated loads were calculated from the simulated hourly mean flow and constituent concentrations for the approximate period of composite sampling. Observed loads were calculated from storm discharge and constituent concentrations in flow-weighted composite storm samples. The error in simulated loads includes any error in streamflow simulation. Comparison of simulated and observed data indicate that flow and concentrations of suspended sediment tend to be undersimulated at the Trout Run and White Clay Creek near Newark sites. Undersimulation of sediment is more pronounced in the June, July, and October storms than for storms earlier in 1998 and is particularly severe for the July storm, for which simulated streamflow did not replicate the observed stormflow. At the Trout Run site, the overall difference between cumulative simulated and observed streamflow was -34 percent and the overall differences between cumulative simulated and observed suspended-sediment load was -75 percent (table 16). At the White Clay near Newark site, the overall difference between cumulative simulated and observed streamflow was -11 percent and the overall difference between cumulative simulated and observed suspended-sediment load was -45 percent (table 16).

Table 16. *Simulated and observed streamflow and suspended sediment loads for storms sampled in 1998 at two nonpoint-source monitoring sites in the White Clay Creek Basin, 01478137 Trout Run at Avondale, Pa., and 01479000 White Clay Creek near Newark, Del.*

[ft^3/s, cubic feet per second]

Dates of storm sampling	Observed peak discharge[1] (ft^3/s)	Streamflow (millions of cubic feet)			Suspended sediment load (tons)		
		Simulated	Observed	Percentage difference[2]	Simulated	Observed	Percentage difference[2]
Trout Run at Avondale, Pa.							
February 4-5	4.04	0.17	0.22	-24	0.30	0.87	-65
March 8-9	41.	1.04	1.46	-29	10.73	13.49	-20
June 11-13	39.4	.60	.87	-31	1.62	15.01	-89
July 8-9	29.6	.33	.49	-33	.41	14.90	-97
October 8-10	21.2	.40	.78	-49	.27	8.86	-97
Total - all storms		2.53	3.82	-34	13.33	53.12	-75
White Clay Creek near Newark, Del.							
March 8-9	1,360	48.2	50.1	-4	334.9	340.3	-2
May 1-2	131	12.8	12.1	6	24.6	50.0	-51
June 11-13	690	22.9	24.9	-8	55.4	178.1	-69
July 8-9	355	7.2	19.5	-63	2.7	137.9	-98
October 8-9	193	12.0	9.3	28	13.6	80.9	-83
Total - all storms		103.1	115.9	-11	431.2	787.2	-45

[1] Peak mean hourly discharge during period of composite sampling.

[2] 100 x (simulated - observed)/observed.

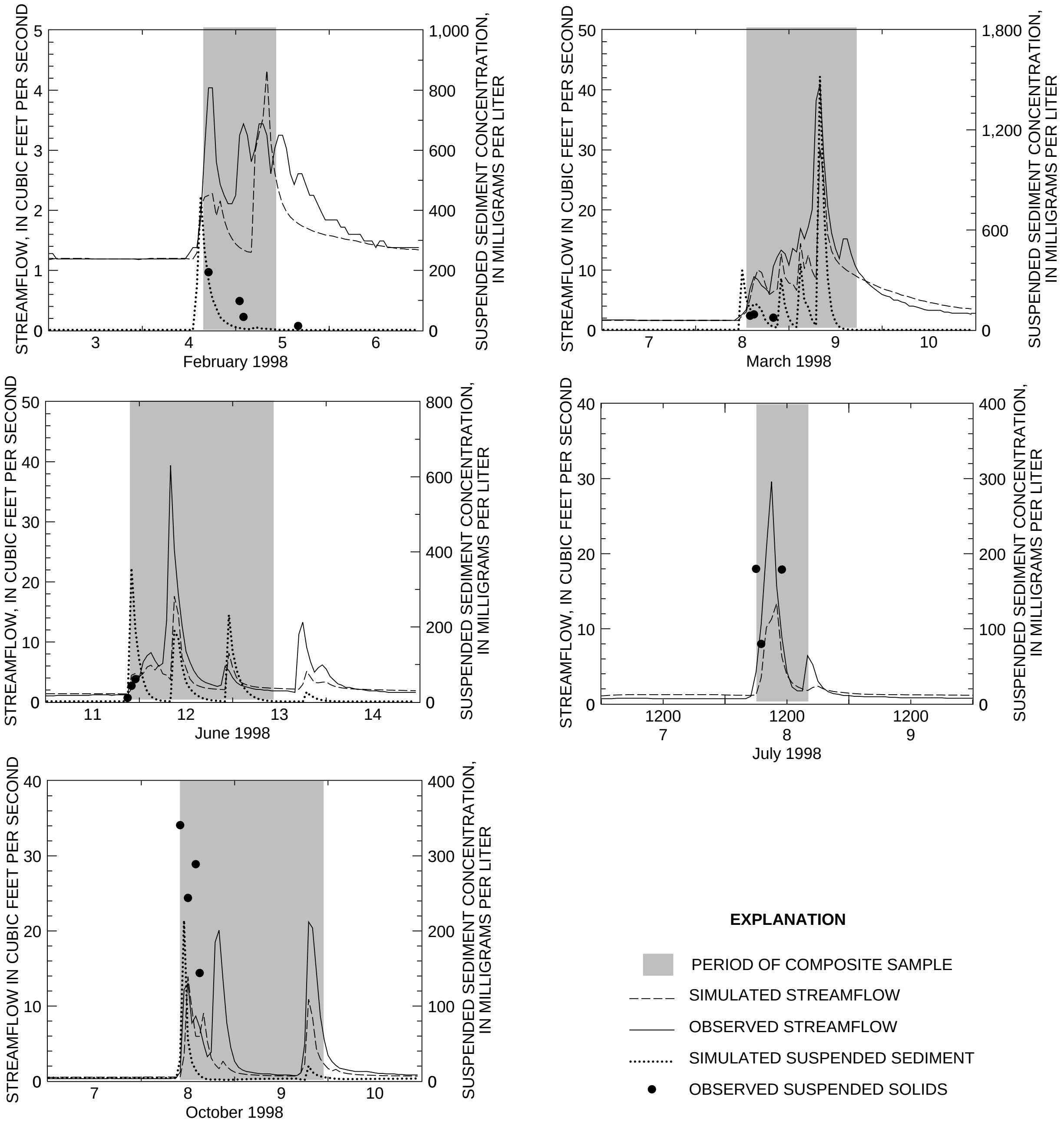


Figure 23. Simulated and observed streamflow and concentrations of suspended sediment during five storms in 1998 at streamflow-measurement station 01478137, Trout Run at Avondale, Pa. (Observed suspended solids concentrations are assumed to estimate suspended sediment concentrations.)

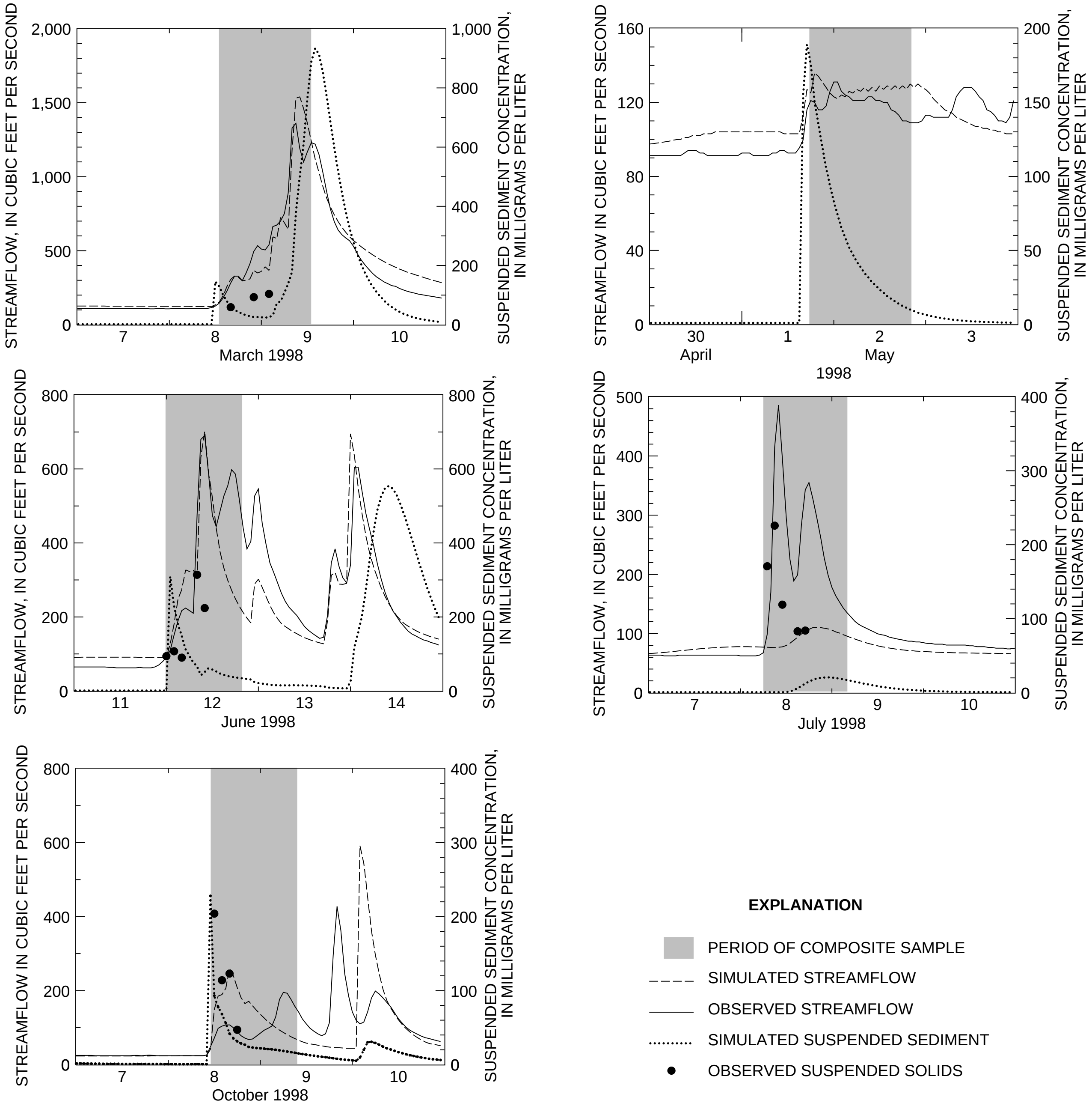


Figure 24. Simulated and observed streamflow and concentrations of suspended sediment during five storms in 1998 at streamflow-measurement station 01479000, White Clay Creek near Newark, Del. (Observed suspended solids concentrations are assumed to estimate suspended sediment concentrations. Instantaneous samples were not collected during the May 1998 storm at this station.)

The error in the water-quality component of the load simulation can be estimated by adjusting for the error in streamflow simulation as follows, although this approach does not account for a nonlinear relation between flow and concentration:

$$\text{percentage error in water-quality component of load} = 100 \times ([(L_S/L_O) / (Q_S/Q_O)] - 1), \qquad (1)$$

where

L_S is simulated load,
L_O is observed load,
Q_S is simulated streamflow, and
Q_O is observed streamflow.

Using this approach, the error in the suspended-sediment component of the cumulative load is -62 percent at Trout Run and -38 percent at White Clay near Newark.

Simulated concentrations of suspended sediment under base-flow conditions generally were within a factor of 10 (one order of magnitude) of observed concentrations at the two monitoring stations (fig. 25). For these base-flow samples, streamflow was well simulated, as shown in figure 25. The largest differences between simulated and observed base flow were -40 percent at Trout Run and -21 percent at White Clay Creek near Newark, and therefore, the error in simulating streamflow under base-flow conditions is less than the error in simulating suspended-sediment concentrations under base-flow conditions.

Instantaneous loads, calculated from streamflows measured at gages and concentrations of suspended solids measured in grab samples, also were used to evaluate model calibration. Stream samples collected by PADEP and DNREC for analysis of suspended solids provide estimates of suspended sediment concentrations at two streamflow-measurement stations, 01478245 White Clay Creek at Strickersville, Pa., and 01479000 White Clay Creek near Newark, Del., for part of the 1994-98 period. Twenty-five samples were collected by PADEP at White Clay Creek at Strickersville, Pa., from August 1996 through August 1998 and 40 grab samples were collected at White Clay Creek near Newark, Del., by DNREC from October 1994 through November 1998.

Suspended-sediment loads were calculated by multiplying streamflow and suspended-sediment (or total suspended solids) concentration. Most simulated suspended-sediment loads were within an order of magnitude of observed loads and, in general, are only moderately well simulated (fig. 26). Differences between simulated and observed suspended-sediment concentrations and loads were greater than differences between observed and simulated streamflow; these differences may be amplified by errors in the timing and magnitude of storms or in sampling a poorly-mixed stream under high-flow conditions. The average difference between simulated hourly mean and observed instantaneous and streamflows was 2 percent at White Clay Creek at Strickersville, Pa., and 16 percent at White Clay Creek near Newark, Del. The relation between streamflow and sediment concentration is not linear. For example, a simulated streamflow of 686 ft^3/s at White Clay Creek near Newark was more than three times greater than the observed flow of 162 ft^3/s, but the simulated suspended-sediment concentration of 81.9 mg/L associated with the simulated flow of 686 ft^3/s was only about two times greater than the observed suspended-solids concentration of 45 mg/L associated with the observed flow of 162 ft^3/s. Using data for those occurrences when the absolute difference between observed and simulated streamflow was less than or equal to 20 percent (streamflow calibration considered “fair”) and excluding a single high outlier near Newark, the net difference between the sum of simulated and observed streamflows and sediment loads was -4 and 4 percent, respectively, at Strickersville and -5 and 84 percent, respectively, near Newark. At these sites, sediment loads are oversimulated to various degrees. The presence of two low-head dams that allow settling of sediment upstream of the White Clay Creek near Newark site is a possible explanation of the oversimulation at that site. Although data on monthly and annual loads of suspended sediment are not available, the sum of instantaneous sediment loads provides an estimate of the adequacy of the sediment calibration as at least “good” at Strickersville and less than “fair” near Newark using guidelines described by Donigian and others (1984).

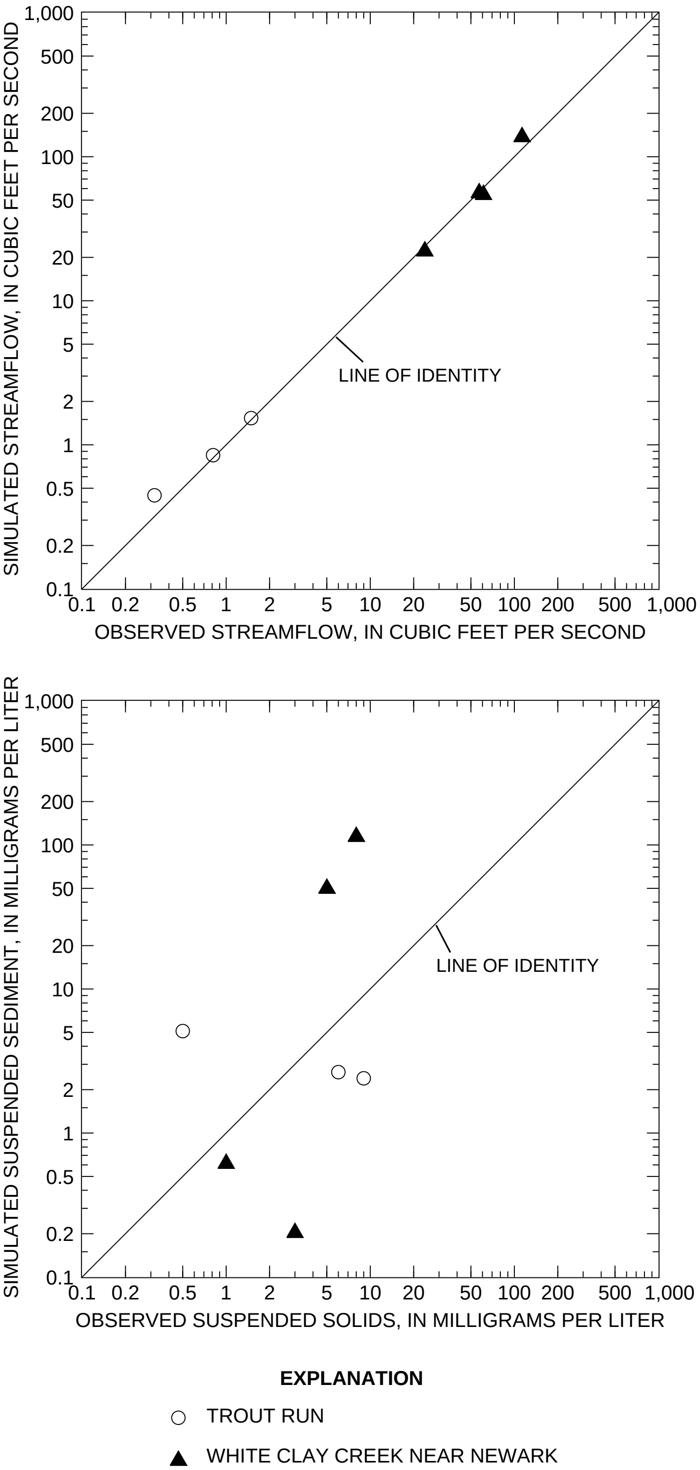


Figure 25. Simulated and observed streamflow and concentrations of suspended sediment under base-flow conditions in 1998 at two monitoring sites in the White Clay Creek Basin, 01478137 Trout Run at Avondale, Pa., and 01479000 White Clay Creek near Newark, Del.

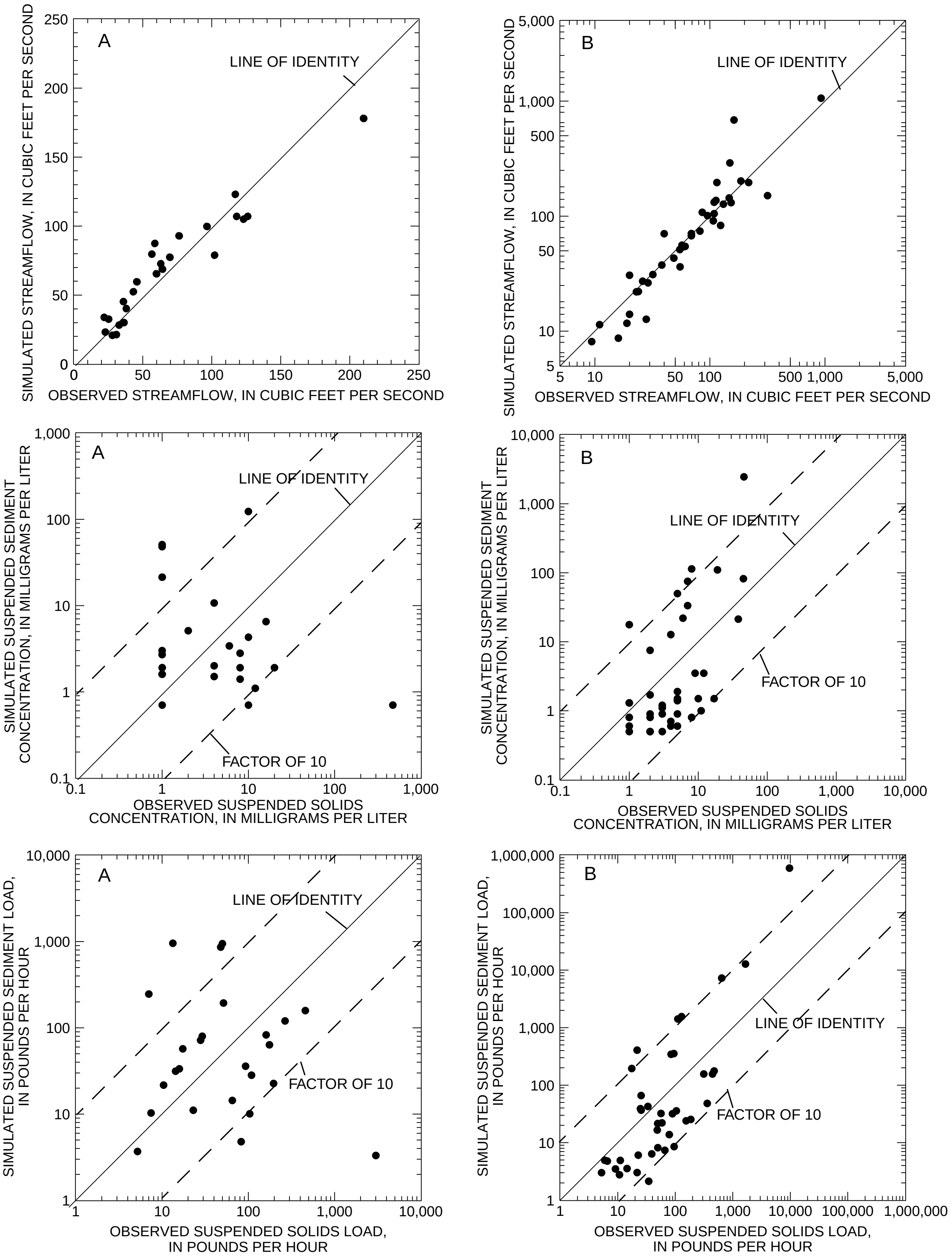


Figure 26. Simulated and observed streamflow and suspended-sediment (solids) concentrations and loads at streamflow-measurement stations (A) 01478245, White Clay Creek near Strickersville, Pa., and (B) 01479000, White Clay Creek near Newark, Del.,1994-98. (Observed suspended solids data from Pennsylvania Department of Environmental Protection and Delaware Department of Natural Resources and Environmental Control.)

In summary, the quality of the suspended-sediment calibration ranges from less than ‘fair’ (more than 35 percent error) to ‘very good’ (less than 15 percent error) for individual storms using criteria from Donigian and others (1984). Simulated instantaneous suspended-sediment loads at two long-term fixed time-interval sites generally were within one order of magnitude of observed loads. These results indicate the range of variability that might be expected in simulating individual storms or instantaneous values. Comparison of observed and simulated suspended-sediment concentration duration curves in the adjacent Brandywine Creek Basin (Senior and Koerkle, 2003) suggests that over relatively long time periods (5 years or more) the model results are statistically similar to observed data.

Simulated yields of sediment vary with precipitation from year to year and differ by land use (table 17). Sediment yields were greatest in the wettest year, 1996 and least in the driest year, 1997. Simulated yields of sediment by land use (tables 17 and 18) are within the ranges reported for equivalent land-use types by Dunne and Leopold (1978, p. 520-522). Part of the sediment yield was estimated to occur from streambank erosion. Erosion from streambanks was estimated by simulating scour, a process dependent on surface runoff and therefore related to potentially erosive flow conditions in streams. The average simulated amount of sediment removed by scour for the years 1995-97 differed among land uses and ranged from 0 to 18 percent of the total sediment yield. The highest percentages of sediment yield produced by scour were in urban and sewered residential land uses (median values of 10 and 6 percent, respectively), and the lowest were in forested and wetland land uses (median values of 0 percent). In areas of agricultural land use, the range of simulated scour (bank erosion) was about 2 to 4 percent of total sediment yield for 1995-97 and is consistent with estimates obtained elsewhere. In a study of sediment sources in two agricultural basins in the United Kingdom, bank erosion was estimated to contribute about 10 percent or less of the sediment yield (Russell and others, 2001).

Dissolved Oxygen and Biochemical Oxygen Demand

Dissolved oxygen and biochemical oxygen demand (BOD) must be simulated in order to simulate nutrient transport and transformations in the stream. The simulation of dissolved oxygen included the effects of air and water temperature, reaeration, and algal activity (photosynthesis and respiration). Oxygen concentrations were simulated in land-surface runoff and were fixed in interflow and ground water. In order to reproduce the temporal pattern of diurnal fluctuations in dissolved-oxygen concentrations observed at three continuous monitoring sites on the Brandywine Creek, simulation of plankton was needed (Senior and Koerkle, 2003). Similar fluctuations in dissolved oxygen were assumed to occur in White Clay Creek, and therefore, simulation of phytoplankton and benthic algae (periphyton) was included in the water-quality modeling for White Clay Creek. Although BOD and chlorophyll *a* were not main constituents of interest, the comparison of simulated and observed results is provided to help evaluate the dissolved-oxygen simulation. The simulation of BOD from nonpoint sources included transport of BOD from land to streams and instream processes of BOD decay, settling, and advection. For the simulation of BOD from nonpoint sources, concentrations of BOD in the sediment (soil), interflow, and ground water were fixed in estimated amounts that differed by land use. Estimates of BOD in soil, interflow, and ground water were derived from an HSPF model of the Pautuxent River Basin in northeastern Maryland (Stephen D. Preston, U.S. Geological Survey, written commun., 1995).

Table 17. *Observed annual precipitation and simulated annual sediment yields by land use for three segments of Hydrological Simulation Program—Fortran (HSPF) model for White Clay Creek Basin, 1995-97*

		Year			
	Segment	**1995**	**1996**	**1997**	**1995-97 average**
Observed precipitation (inches)[1]	7	40.11	63.75	33.37	45.74
Simulated annual sediment yield (pounds per acre per year), by land-use category[2]					
Residential - unsewered	7	.204	.66	.021	.295
Residential -sewered	7	.273	.813	.029	.372
Urban	7	.506	.923	.046	.492
Agricultural - animal/crop	7	1.91	4.42	.153	2.16
Agricultural - row crop	7	1.82	4.3	.142	2.09
Agricultural - mushroom	7	2.81	5.38	.438	2.88
Forested	7	.025	.169	.004	.066
Open	7	.271	.747	.024	.347
Wetlands/water	7	.004	.018	.001	.008
Undesignated	7	.31	.769	.029	.369
Impervious - residential	7	.197	.191	.193	.194
Impervious - urban	7	.776	.757	.765	.766
Observed precipitation (inches)	5	40.62	60.48	36.91	46.00
Simulated annual sediment yield (pounds per acre per year), by land-use category[2]					
Residential - unsewered	5	.22	.234	.020	.158
Residential -sewered	5	.338	.357	.030	.242
Urban	5	.584	.617	.055	.419
Agricultural - animal/crop	5	2.64	2.95	.339	1.98
Agricultural - row crop	5	2.51	2.92	.313	1.91
Agricultural - mushroom	5	3.11	3.88	.514	2.50
Forested	5	.074	.081	.006	.054
Open	5	.360	.363	.032	.252
Wetlands/water	5	.007	.009	.001	.006
Undesignated	5	.336	.349	.028	.238
Impervious - residential	5	.215	.199	.199	.204
Impervious - urban	5	.847	.791	.792	.810
Observed precipitation (inches)	8	40.62	60.48	36.91	46.00
Simulated annual sediment yield (pounds per acre per year), by land-use category[2]					
Residential - unsewered	8	.227	.13	.011	.123
Residential -sewered	8	.37	.213	.018	.200
Urban	8	.537	.335	.0289	.300
Agricultural - animal/crop	8	2.12	1.19	.131	1.15
Agricultural - row crop	8	1.99	1.09	.114	1.07
Agricultural - mushroom	8	2.57	2.56	.222	1.78
Forested	8	.04	.026	.002	.023
Open	8	.335	.186	.0154	.179
Wetlands/water	8	.005	.003	.0003	.003
Undesignated	8	.323	.178	.014	.172
Impervious - residential	8	.212	.2	.199	.204
Impervious - urban	8	.838	.794	.792	.808

[1] Precipitation input to segment 7 = 0.85 x precipitation recorded at Coatesville.

[2] In pervious areas, unless noted.

Table 18. *Observed average annual precipitation and simulated average annual sediment yield for pervious and impervious land areas by land use in three segments of Hydrological Simulation Program–Fortran (HSPF) model for White Clay Creek Basin, 1995-97*

	1995-97 Average			
	Segment 7	**Segment 5**	**Segment 8**	**Average of all segments**
Observed precipitation (inches)	[1]45.74	46.00	46.00	45.91
Simulated average annual sediment yield (tons per acre per year), by land-use category[2]				
Residential - unsewered	.295	.158	.123	.192
Residential -sewered	.372	.242	.200	.271
Urban	.492	.419	.300	.404
Agricultural - animals/crops	2.16	1.98	1.15	1.76
Agricultural - row crop	2.09	1.91	1.07	1.69
Agricultural - mushroom	2.88	2.50	1.78	2.39
Forested	.066	.054	.023	.047
Open	.347	.252	.179	.259
Wetlands/water	.008	.006	.003	.005
Undesignated	.369	.238	.172	.260
Impervious - residential	.194	.204	.204	.201
Impervious - urban	.766	.810	.808	.795

[1] Precipitation for segment 7 = 0.85 x precipitation at Coatesville 2 W.

[2] In pervious areas, unless noted.

Dissolved-oxygen concentration data collected intermittently at two monitoring sites at streamflow-measurement stations 01478265 White Clay Creek near Strickersville, Pa., and 014790000 White Clay Creek near Newark, Del., were used to evaluate the dissolved-oxygen simulation. Concentrations of dissolved oxygen at White Clay Creek at Strickersville appeared well simulated during warmer months but frequently were undersimulated in winter months (fig. 27). Conversely, concentrations of dissolved oxygen at White Clay Creek near Newark, Del., appeared well simulated during cooler months but frequently were oversimulated in summer months (fig. 27). Differences between observed and simulated concentrations of dissolved oxygen at White Clay Creek at Strickersville, Pa., during winter months may be due to algal activity and (or) measurement error as indicated by observed values exceeding saturation concentrations. At 0°C, the concentration of dissolved oxygen at saturation is 14.6 mg/L (American Public Heath Association, 1995). Supersaturation may occur during the day because of photosynthesis, although photosynthesis typically is not as active during cold mid-winter conditions as warmer times of the year. Dissolved-oxygen concentrations greater than 15 mg/L have been recorded during cold periods in 1994-98 when water temperatures were less than 4°C by continuous water-quality monitors at sites on the nearby Brandywine Creek, and commonly, the maximum daily dissolved-oxygen concentrations occur near midday (unit values from 1994-98 at USGS streamflow-measurement stations 01480617, 01480700, and 01481000). Most measurements at White Clay Creek at Strickersville were made in the late morning (around 11 a.m.) when photosynthesis may begin to increase concentrations of dissolved oxygen in the stream. The diurnal fluctuation in concentrations of dissolved oxygen attributed to processes of algal photosynthesis and respiration becomes more pronounced in the summer months than at other times of the year. Differences between observed and simulated concentrations of dissolved oxygen at White Clay Creek at Newark, Del., during summer months may indicate undersimulation of respiration processes. Most measurements at White Clay Creek near Newark were made in the morning (between 7 and 9 a.m.) when dissolved-oxygen concentrations may still be depleted from night-time respiration. Differences between observed and simulated concentrations of dissolved oxygen at the two monitoring sites range from 0 to 5 mg/L but generally are less than 2 mg/L (fig. 28).

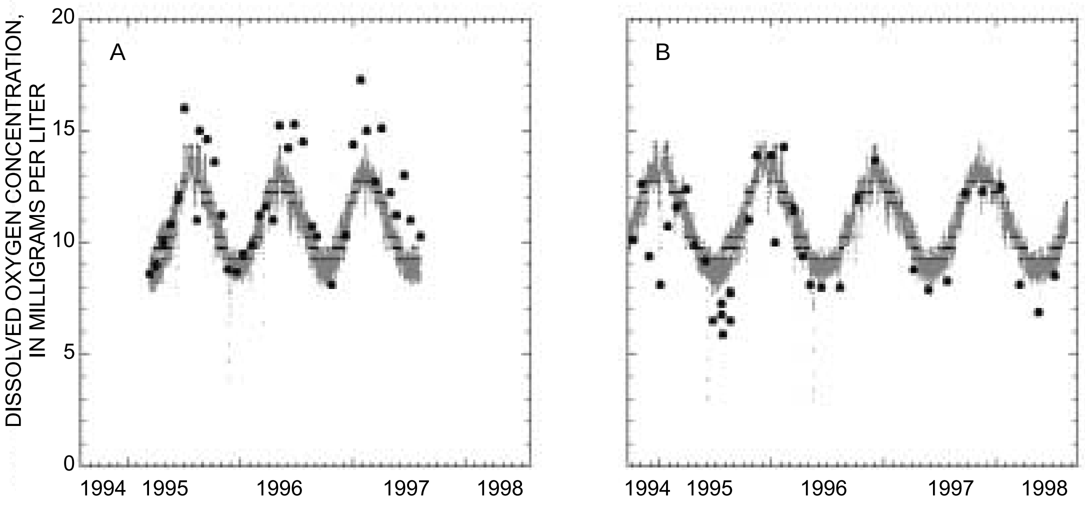


Figure 27. Simulated hourly mean and observed instantaneous concentrations of dissolved oxygen in relation to time at streamflow-measurement stations (A) 01478265 White Clay Creek at Strickersville, Pa., January 1995 through August 1998, and (B) 01479000 White Clay Creek near Newark, Del., October 1994 through September 1998.

The simulation of phytoplankton was evaluated using chlorophyll *a* concentration data collected under base-flow conditions in 1998 as part of the nonpoint-source monitoring and under a range of hydrologic conditions at the streamflow-measurement station 01479000 White Clay Creek near Newark, Del., as part of state monitoring efforts. Evaluation of the limited data collected and simulated results under base-flow conditions indicates that the model tends to undersimulate chlorophyll *a* concentrations at both sites but to various degrees. Simulated chlorophyll-*a* concentrations under base-flow conditions are less than observed concentrations at the Trout Run site by as much as an order of magnitude and are either very similar to or less than observed concentrations at the White Clay Creek near Newark site (fig. 29A). For the larger amount of data collected under state monitoring, many data were reported at 1 µg/L, the lowest level of detection. For observed concentrations greater than 1 µg/L, the model simulates most chlorophyll *a* concentrations within an order of magnitude of observed values (fig. 29B). Undersimulation of chlorophyll *a* concentrations may result in undersimulation of the magnitude of diurnal fluctuations in dissolved-oxygen concentrations.

BOD concentration data from the analysis of grab and composite samples collected at three monitoring sites, Trout Run at Avondale, White Clay Creek near Newark, and White Clay Creek near Strickersville, were used to evaluate the BOD simulation. Simulated BOD concentrations and loads appear to be undersimulated during stormflow and base-flow conditions. Comparison of simulated and observed BOD loads for storms in 1998 at the two nonpoint-source monitoring sites, Trout Run and White Clay Creek near Newark (table 19) indicate that overall BOD loads are undersimulated by about a factor of four. Simulated and observed loads were calculated for BOD in a manner similar to those loads calculated for other water-quality constituents, described in the section on suspended sediment. The error in simulated loads includes any error in streamflow simulation. Comparison of simulated and observed BOD concentrations under base-flow conditions at the same two nonpoint-source monitoring sites (fig. 30) indicates that BOD commonly is undersimulated by as much as an order of magnitude or more. At White Clay Creek near Strickersville, BOD loads also are

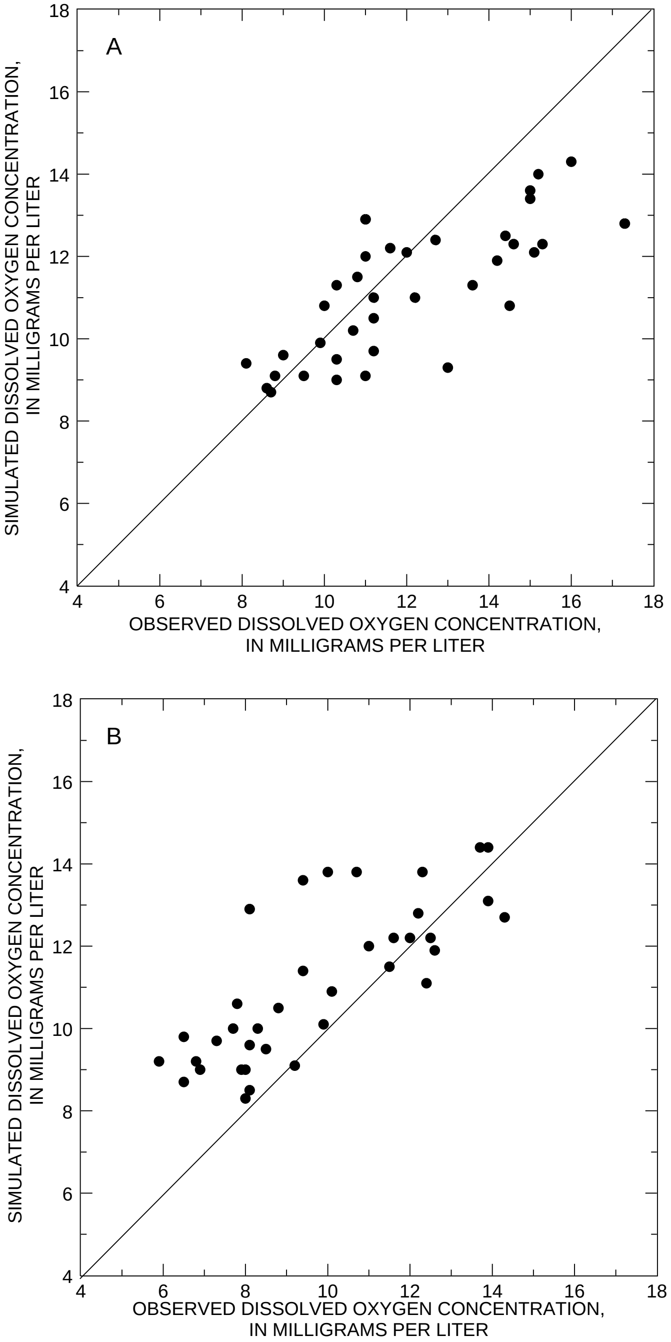


Figure 28. Relation between simulated hourly mean and observed instantaneous concentrations of dissolved oxygen at streamflow-measurement stations (A) 01478245 White Clay Creek at Strickersville, Pa., January 1995 through August 1998, and (B) 01479000 White Clay Creek near Newark, Del., October 1994 through September 1998.

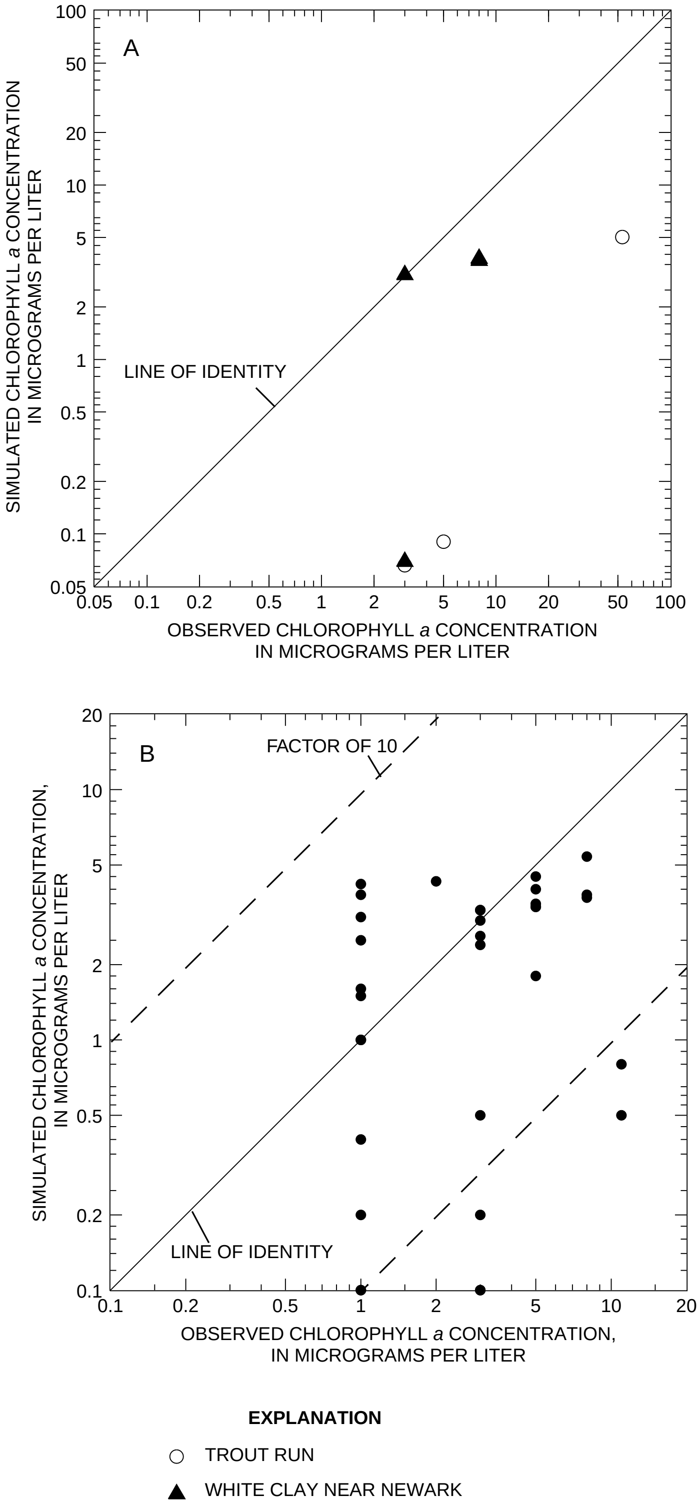


Figure 29. Simulated and observed concentrations of chlorophyll *a* (A) in base-flow samples collected in 1998 at 01478137 Trout Run at Avondale, Pa. and 01479000 White Clay Creek near Newark, Del., and (B) monthly samples collected by DNREC 1994-98 at 01479000 White Clay Creek near Newark, Del.

Table 19. *Simulated and observed streamflow and loads of biochemical oxygen demand for storms sampled in 1998 at two nonpoint-source monitoring sites in the White Clay Creek Basin, 01478137 Trout Run at Avondale, Pa., and 01479000 White Clay Creek near Newark, Del.*

[ft^3/s, cubic feet per second; BOD, biochemical oxygen demand]

Dates of storm sampling	Observed peak discharge[1] (ft^3/s)	Streamflow (millions of cubic feet)			BOD load (tons)		
		Simulated	Observed	Percent difference[2]	Simulated	Observed	Percent difference[2]
Trout Run at Avondale, Pa							
February 4-5	4.04	0.17	0.22	-24	0.02	0.08	-80
March 8-9	41.	1.04	1.46	-29	.21	.61	-66
June 11-13	39.40	.60	.87	-31	.06	.15	-60
July 8-9	29.6	.33	.49	-33	.04	.20	-81
October 8-10	21.2	.40	.78	-49	.03	.39	-93
Total - all storms		2.53	3.82	-34	.35	1.44	-76
White Clay Creek near Newark, Del.							
March 8-9	1,360	48.2	50.1	-4	5.78	44.17	-87
May 1-2	131	12.8	12.1	6	.85	14.51	-94
June 11-13	690	22.9	24.9	-8	3.36	8.40	-60
July 8-9	355	7.2	19.5	-63	.09	10.12	-99
October 8-9	193	12.0	9.3	28	1.16	4.78	-76
Total - all storms		103.1	115.9	-11	11.24	81.97	-86

[1] Peak mean hourly discharge during period of composite sampling.

[2] 100 x (simulated-observed)/observed.

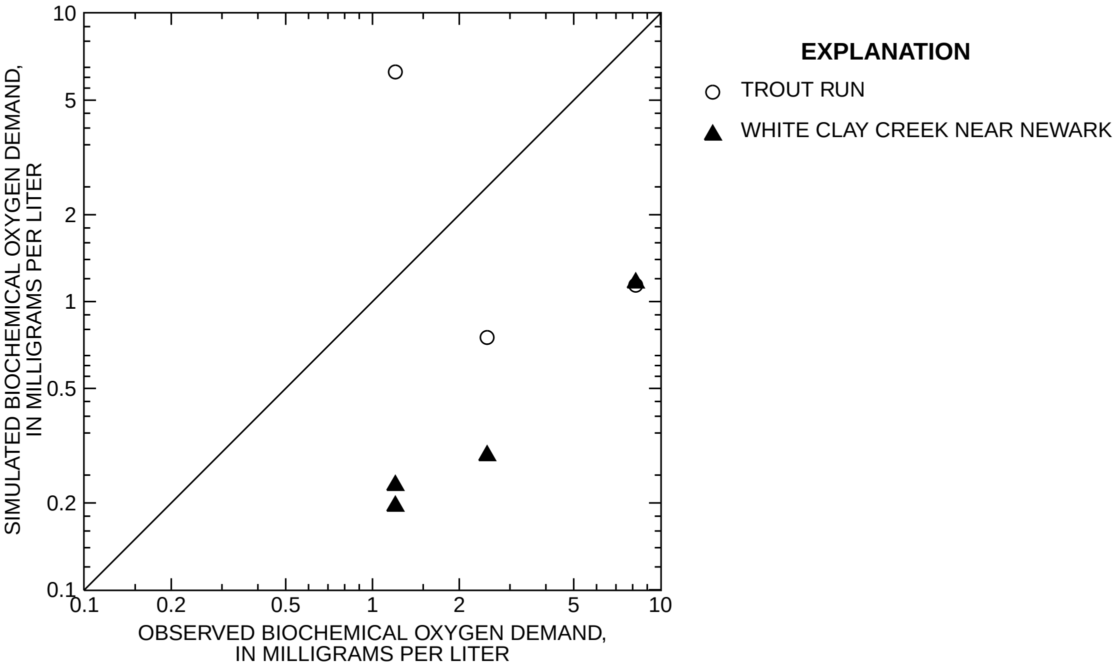


Figure 30. Simulated and observed concentrations of biochemical oxygen demand in base-flow samples collected in 1998 at two monitoring sites in the White Clay Creek Basin, 01478137 Trout Run at Avondale, Pa., and 01479000 White Clay Creek near Newark, Del.

undersimulated by as much as an order of magnitude under primarily base-flow conditions (fig. 31). Some samples collected in 1998 for BOD analysis under base-flow conditions were reported as less than the detection level of 2.4 mg/L and are shown as 1.2 mg/L (0.5 times the detection level) in figure 30. Underestimation of BOD in non-storm conditions may be attributable to inaccurate simulation of routing and chemical processes in the channel, including rates of decay and settling. Undersimulation of BOD may result in undersimulation of BOD decay and consequent oxygen depletion. The amount of oxygen in the stream reach can affect the extent of nitrification and denitrification reactions.

Overall, the simulation provides a reasonable estimate of dissolved-oxygen concentrations that are needed for the instream simulation of nutrients. Errors in the simulation of instream dissolved-oxygen concentrations will affect the simulation of instream chemical and biochemical reactions involving nutrients.

Nitrogen

The two inorganic species of nitrogen, nitrate and ammonia, were simulated. Nitrogen loads from point and nonpoint sources were included in the simulation. Loads from point-source discharges were estimated from reported monthly average data for input to the model on an hourly time step. For most point-source discharges, nitrate was estimated from reported ammonia loads using the ratios specified in USEPA, Region 3 (2000b), and nitrite was assumed to be negligible. The ratio of nitrate to ammonia in point-source effluent used for model data sets was 0.84 for municipal and small wastewater treatment plants (WWTP's) and 0.21 for industrial discharges. For nonpoint sources, concentrations of nitrate and ammonia in sediment (soil), interflow, and ground water were estimated as fixed concentrations that differed by land use. Nitrate was assumed to be transported solely in the dissolved form. Ammonia was assumed to be transported in both dissolved and adsorbed forms.

Water-quality data from two nonpoint-source monitoring stations, Trout Run at Avondale and White Clay Creek near Newark, were used in the calibration of concentrations of dissolved nitrate and dissolved and particulate ammonia nitrogen in stormflow and base flow. Simulated and observed concentrations of dissolved nitrate

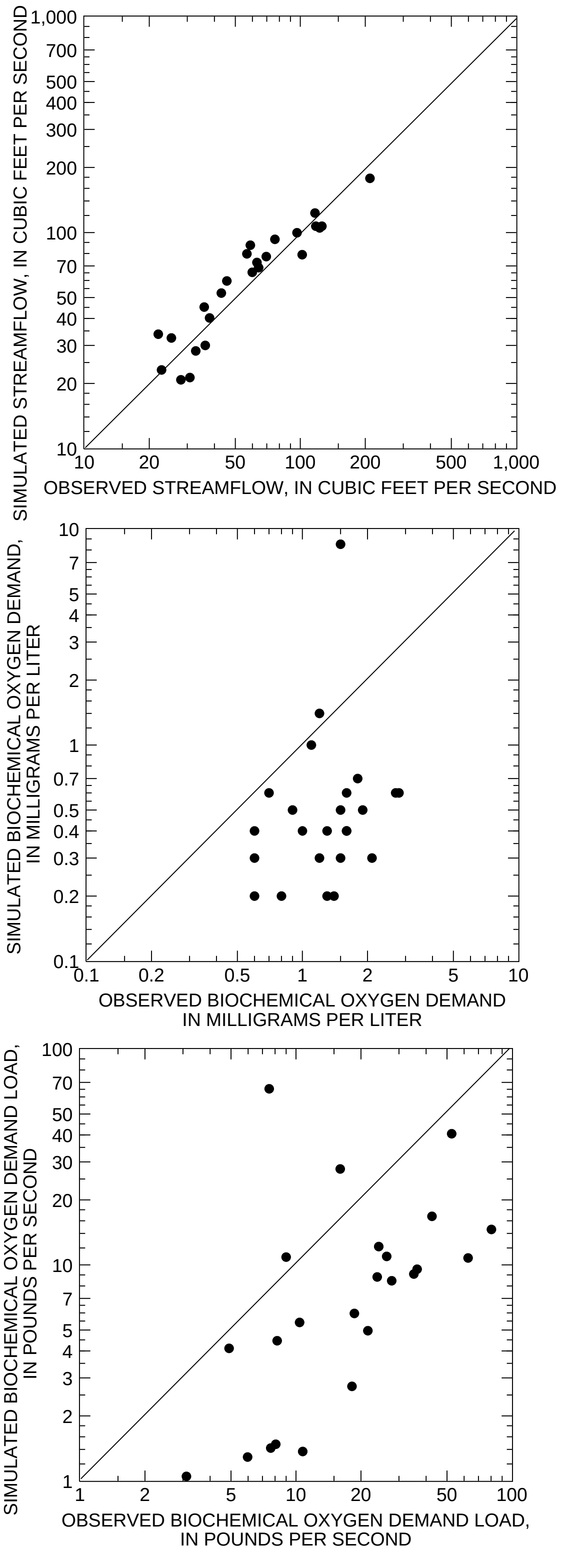


Figure 31. Simulated and observed streamflow and biochemical oxygen demand (BOD) concentrations and loads at streamflow-measurement station 01478245, White Clay Creek near Strickersville, Pa., 1995-98. (Observed BOD data from PADEP.)

are shown in figure 32 for the storm with the best-simulated streamflow at each of the two nonpoint-source monitoring sites. Simulated and observed streamflow and concentrations of nitrate for all sampled storms at the two nonpoint-source monitoring sites in the White Clay Creek Basin are shown in Appendix 2. Observed and simulated nitrate concentrations generally decrease as streamflow increases during storms.

Data from composite stormflow samples collected in 1998 were used in the calculation of loads of dissolved nitrate and dissolved and particulate ammonia nitrogen. Calculated loads served as the observed values in overall evaluation of nitrogen transport during storms. Simulated and observed streamflow and load data for dissolved nitrate for sampled storms are presented in table 20. Simulated and observed loads were calculated for nitrate in a manner similar to those loads calculated for other water-quality constituents, described in the section on suspended sediment. Both flow and the nitrate load tend to be under-simulated at the two monitoring sites. Overall differences between simulated and observed nitrate loads are similar to differences between simulated and observed streamflow at the two sites. Overall errors in nitrate load simulation is -39 percent at Trout Run and -19 percent at White Clay Creek, indicating that the nitrate simulation can be considered “fair” to “good” using criteria established by Donigian and others (1984) for monthly or annual loads. As discussed in the section on sediment, some error in load simulation is due to error in streamflow simulation and the difference between the load error and the streamflow-volume error may be useful in evaluating the water-quality component of the overall load error. At the Trout Run and White Clay Creek near Newark sites, the cumulative error in simulated dissolved nitrate load adjusted for the cumulative error in simulated streamflow is -7 and -9 percent, respectively, for storms in 1998. Using monthly or yearly annual load criteria (Donigian and others, 1984) to evaluate errors due to the water-quality component of the nitrate simulation, the nitrate calibration is ‘very good’ for cumulative storm loads at the two sites.

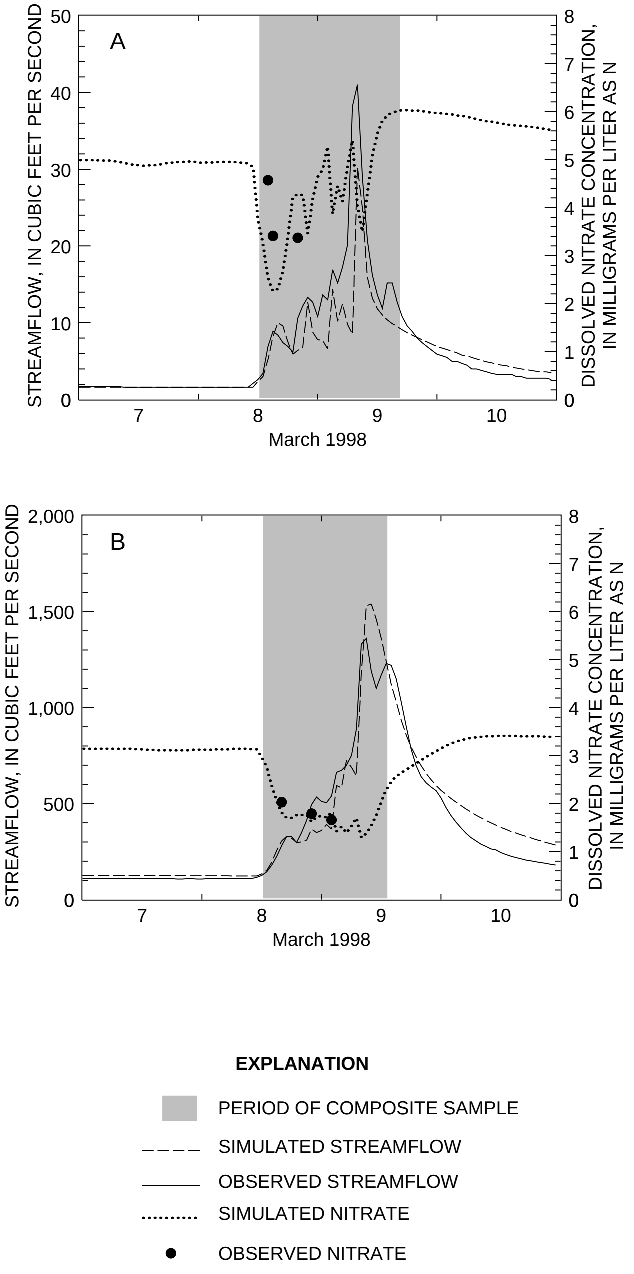


Figure 32. Simulated and observed streamflow and concentrations of dissolved nitrate for the storm with the best-simulated streamflow component sampled in 1998 at the nonpoint-source monitoring sites in the White Clay Creek Basin, (A) 01478137, Trout Run at Avondale, Pa., (B) 01479000 White Clay Creek near Newark, Del.

Table 20. *Simulated and observed streamflow and nitrate, dissolved ammonia, and particulate ammonia loads for storms sampled in 1998 at two nonpoint-source monitoring sites in the White Clay Creek Basin, 01478137 Trout Run at Avondale, Pa., and 01479000 White Clay Creek near Newark, Del.*

[ft^3/s, cubic feet per second; Sim., simulated; Obs., observed; diff., difference; --, not calculable]

Dates of storm sampling	Observed peak discharge[1] (ft^3/s)	Streamflow (millions of cubic feet)			Nitrate load (pounds as nitrogen)			Dissolved ammonia load (pounds as nitrogen)			Particulate ammonia load (pounds as nitrogen)		
		Sim.	Obs.	Percent diff.[2]	Sim.	Obs.	Percent diff.[2]	Sim.	Obs.	Percent diff.[2]	Sim.	Obs.	Percent diff.[2]
Trout Run at Avondale, Pa													
February 4-5	4.04	0.17	0.22	-24	34.8	91.5	-62	0.79	13.08	-94	0.04	1.10	-97
March 8-9	41.	1.04	1.46	-29	279.0	324.1	-14	14.87	105.89	-86	6.82	2.76	147
June 11-13	39.40	.60	.87	-31	93.3	165.3	-44	3.73	33.88	-89	.29	1.71	-83
July 8-9	29.6	.33	.49	-33	51.8	69.5	-25	1.26	15.50	-92	.07	[3] 0	--
October 8-10	21.2	.40	.78	-49	30.4	147.1	-79	1.19	33.45	-96	.03	[3] 0	--
Total - all storms		2.53	3.82	-34	489.2	797.5	-39	21.85	201.81	-89	7.25	5.57	30
White Clay Creek near Newark, Del.													
March 8-9	1,360	48.16	50.10	-4	4,493	5,256	-6	185.9	174.1	7	29.50	[3]0	--
May 1-2	131	12.83	12.07	6	2,158	1,907	13	30.2	[4] 1.5	1, 881	1.33	[5] --	--
June 11-13	690	22.94	24.94	-8	1,806	2,758	-35	76.4	42.6	80	5.25	[3] 0	--
July 8-9	355	7.18	19.48	-63	1,269	2,032	-38	14.0	12.3	13	.10	18.47	-99
October 8-9	193	11.95	9.31	28	665	1,489	-55	37.0	[6] 1.5	2,413	1.21	23.54	-95
Total - all storms		103.06	115.91	-11	10,830	13,441	-19	343.5	232.0	48	37.39	42.01	-11

[1] Peak mean hourly discharge during period of composite sampling.

[2] 100 × (simulated-observed)/observed.

[3] In the composite sample, dissolved ammonia concentration was greater than total ammonia concentration, so particulate ammonia concentration was assumed to be 0 mg/L as N.

[4] Composite sample concentration of dissolved ammonia was reported as less than 0.004 mg/L; observed load was estimated by assuming concentration was 0.002 mg/L (0.5 times the reporting level).

[5] Composite sample concentration of total ammonia was reported as less than 0.004 mg/L; observed particulate load was estimated to be zero because dissolved ammonia concentration was also less than 0.004 mg/L as N.

[6] Composite sample concentration of dissolved ammonia was reported as less than 0.005 mg/L; observed load was estimated by assuming concentration was 0.0025 mg/L (0.5 times the reporting level).

Simulated concentrations of dissolved nitrate in base flow were within 0.5 mg/L of observed concentrations for most samples at the two monitoring stations (fig. 33). Streamflow was well simulated for all base-flow samples, as shown in figure 26. Nitrate concentrations for the April base-flow samples were undersimulated by 0.9 mg/L at both sites. The average difference between observed and simulated concentrations of nitrate was 3 percent or 0.22 mg/L as N. In base flow, nitrate tended to be slightly undersimulated at Trout Run and slightly oversimulated at White Clay Creek near Newark. Numerous sewage treatment plants discharge into the stream above the streamflow-measurement station 01479000 White Clay Creek near Newark and, therefore, affect nitrate concentrations in the stream at that site. Observed hourly concentrations of nitrate for NPDES discharges were not available but were interpolated from reported monthly average concentrations of ammonia assuming a constant ratio of nitrate to ammonia. However, the ratio of nitrate to ammonia in effluent probably fluctuates through time.

Nitrate concentrations in grab samples collected by PADEP at White Clay Creek near Strickersville, Pa., 1995-98 and by DNREC at White Clay Creek near Newark, Del., 1994-98 are similar to simulated concentrations at the two sites (fig. 34). At the White Clay Creek near Strickersville site, simulated nitrate concentrations tend to be lower than observed concentrations by an average of 0.36 mg/L as N. The average observed concentration of nitrate at the near Strickersville site was 3.87 mg/L as N. At the White Clay Creek near Newark site, simulated concentrations of nitrate tend to be higher than observed concentrations by an average of 0.22 mg/L as N. The average

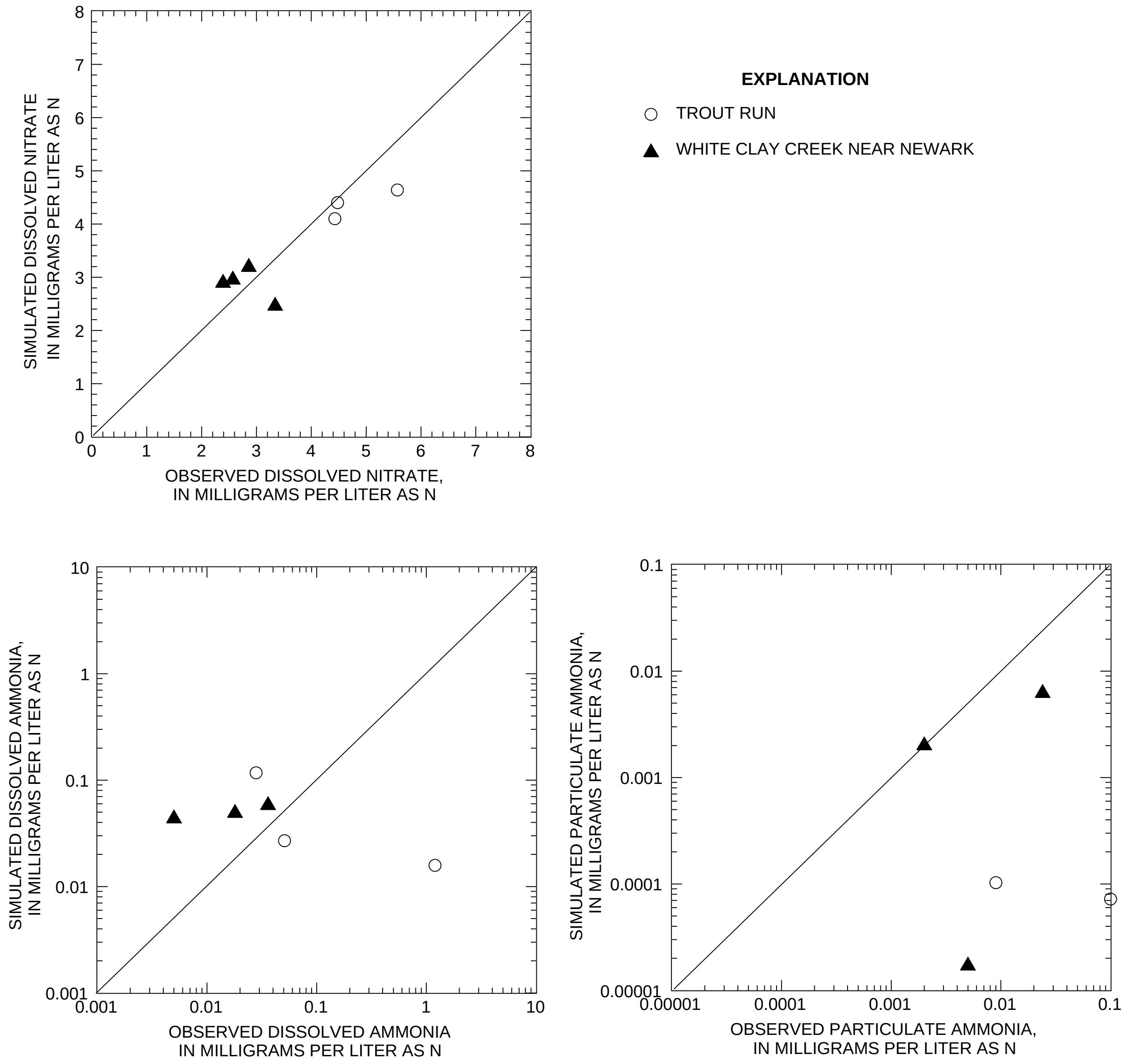


Figure 33. Simulated and observed concentrations of nitrate and dissolved and particulate ammonia during base-flow conditions in 1998 at two monitoring sites in the White Clay Creek Basin, 01478137 Trout Run at Avondale, Pa., and 01479000 White Clay Creek near Newark, Del.

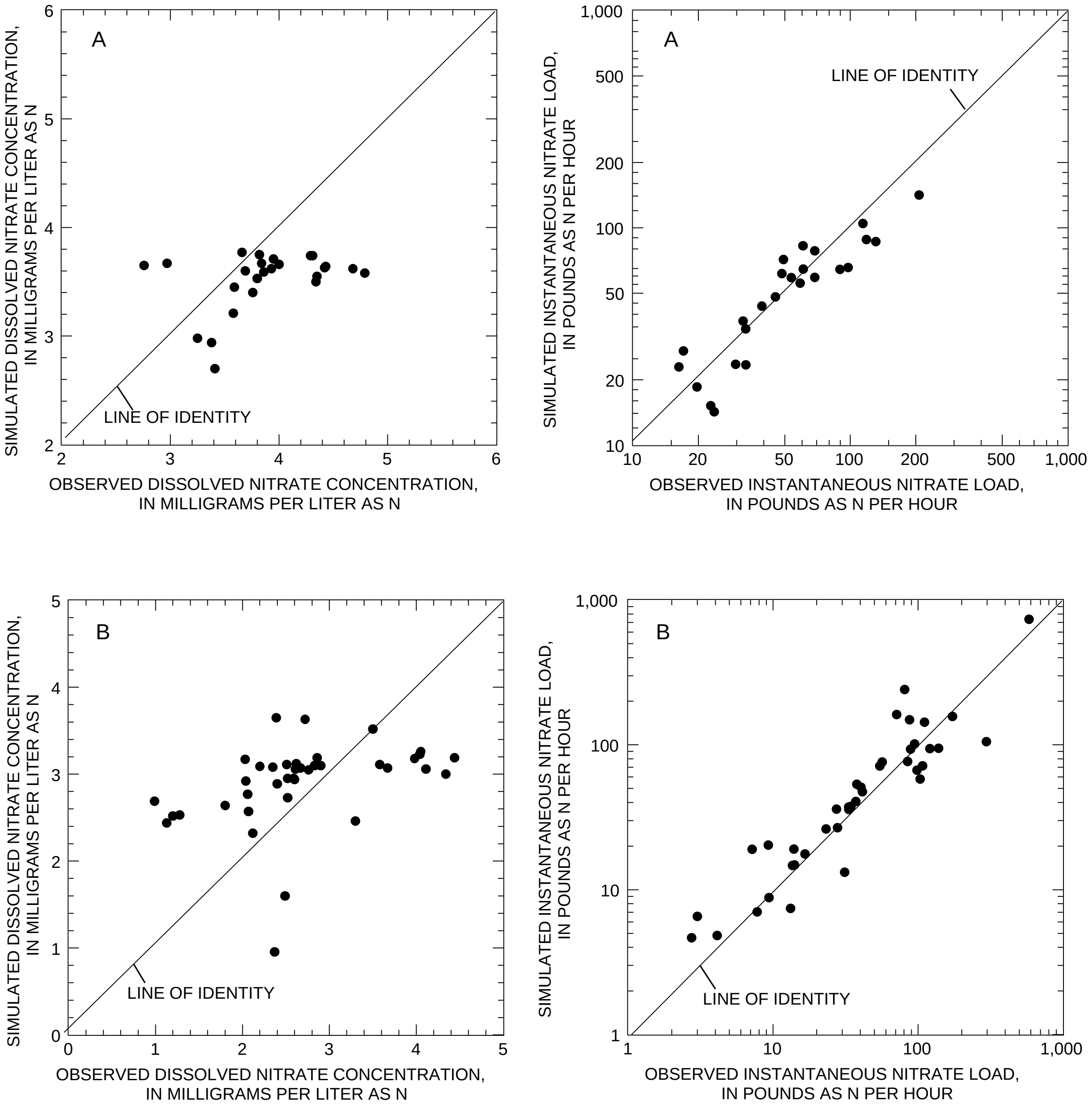


Figure 34. Simulated and observed concentrations and loads of nitrate at streamflow-measurement stations (A) 01478265 White Clay Creek near Strickersville, Pa., and (B) 01479000 White Clay Creek near Newark, Del. (Nitrate concentrations from Pennsylvania Department of Environmental Protection and Delaware Department of Natural Resources and Environmental Control grab samples, 1994-98.)

observed concentration of nitrate at the near Newark site was 2.68 mg/L as N. Instantaneous loads were calculated by multiplying the hourly mean streamflow by the concentration of the grab sample or simulated hourly mean nitrate concentration. The overall difference between simulated and observed instantaneous loads was -10 percent (indicating undersimulation) at the near Strickersville site and 8 percent (indicating oversimulation) at the near Newark site. Comparison of simulated and observed data at these two sites indicates that the calibration of nitrate can be considered “good” to “very good” using criteria for monthly or annual loads (Donigian and others, 1984).

Simulated concentrations of dissolved and particulate ammonia were compared to observed concentrations of dissolved and particulate ammonia in stormflow and base-flow samples where observed concentrations of particulate ammonia were calculated by subtracting dissolved ammonia concentrations from total ammonia concentrations. For 1998 data at the two nonpoint-source monitoring sites in White Clay Creek, the ratio of dissolved to total ammonia ranges from 1.4 to 0.28; the average is 0.90. About 30 percent of the samples had dissolved to total ammonia ratios greater than 1.0 (concentrations of dissolved ammonia greater than concentrations of total ammonia), indicating errors in the measurement of either dissolved or total ammonia. For those samples that had dissolved to total ammonia ratios greater than 1.0, it was assumed that the concentration of particulate ammonia was 0 mg/L as N.

Simulated and observed concentrations of dissolved and particulate ammonia are shown in figures 35 and 36, respectively, for the storm with the best-simulated streamflow at each of the two nonpoint-source monitoring sites. Simulated and observed streamflow and concentrations of dissolved and particulate ammonia for all sampled storms at the two nonpoint-source monitoring sites in the White Clay Creek Basin are shown in Appendix 2. Observed and simulated concentrations of dissolved and particulate ammonia generally tend to increase as streamflow increases during storms.

Simulated and observed streamflow and loads of dissolved and particulate ammonia nitrogen for storms in 1998 are presented in table 20. Simulated and observed loads were calculated for dissolved and particulate ammonia in a manner similar to those loads calculated for other water-

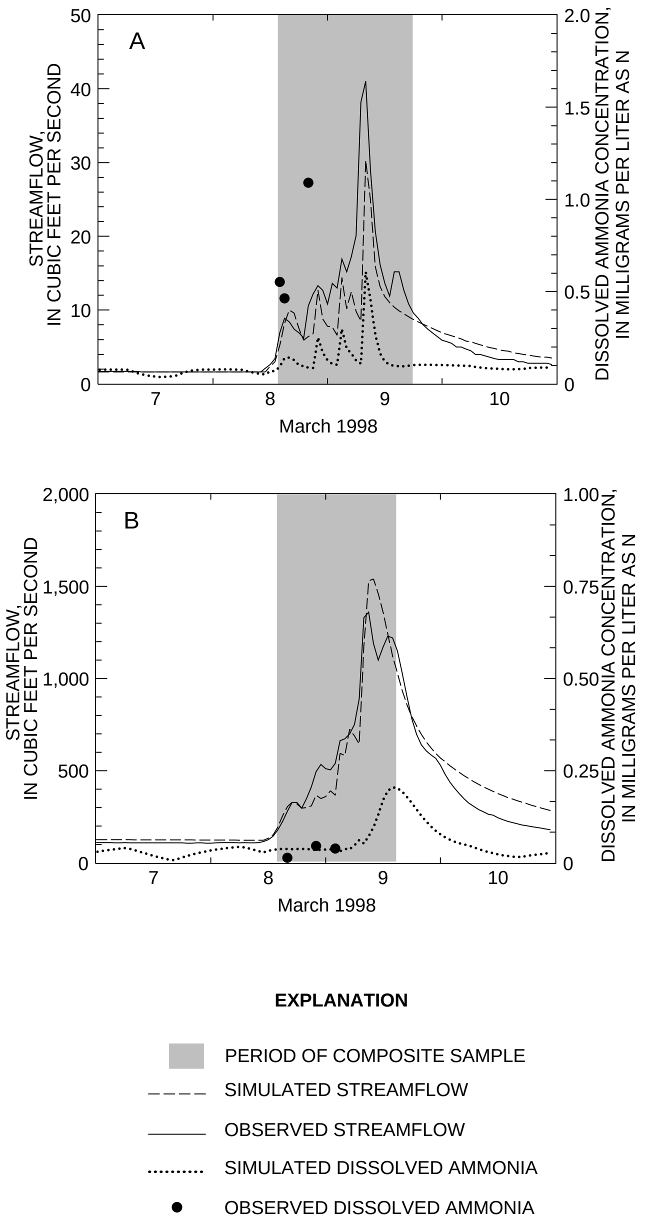


Figure 35. Simulated and observed streamflow and concentrations of dissolved ammonia for the storm sampled in 1998 with the best-simulated streamflow component at the nonpoint-source monitoring sites in the White Clay Creek Basin, (A) 01478137, Trout Run at Avondale, Pa., (B) 01479000 White Clay Creek near Newark, Del.

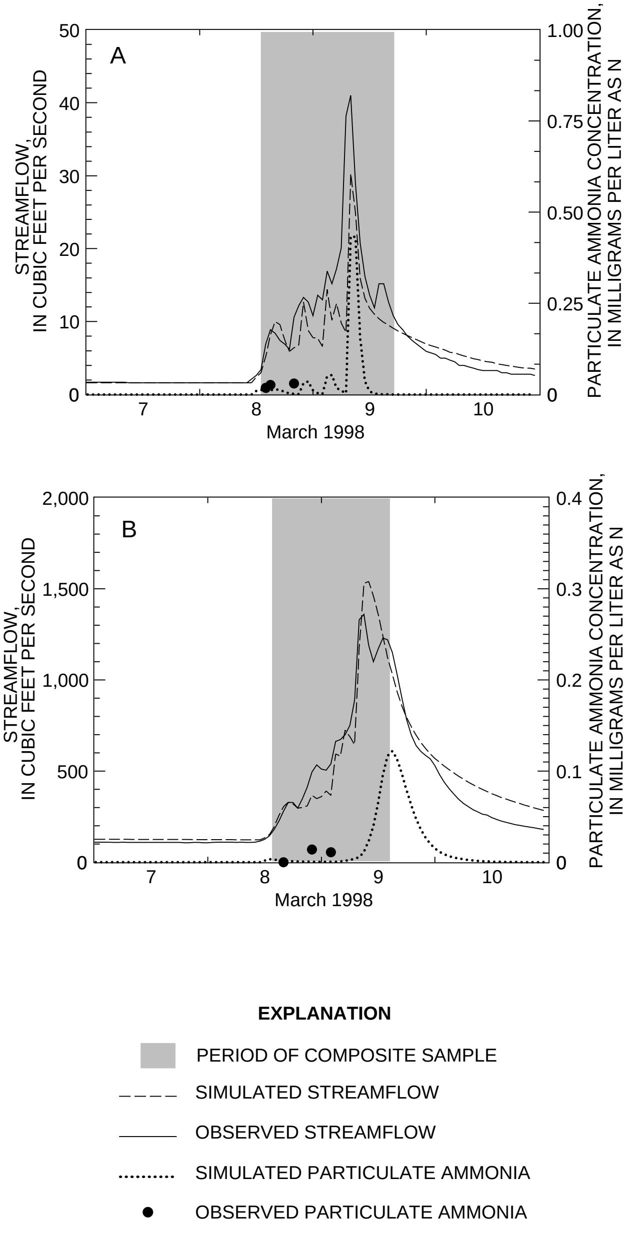


Figure 36. Simulated and observed streamflow and concentrations of particulate ammonia for the storm sampled in 1998 with the best-simulated streamflow component at the nonpoint-source monitoring sites in the White Clay Creek Basin, (A) 01478137, Trout Run at Avondale, Pa., (B) 01479000 White Clay Creek near Newark, Del.

quality constituents, described in the section on suspended sediment. Flow and dissolved ammonia were undersimulated and particulate ammonia oversimulated at the mushroom agricultural-basin (Trout Run) and the whole-basin (White Clay Creek near Newark) sites. Flow and particulate ammonia were undersimulated but dissolved ammonia was oversimulated at the whole-basin site (White Clay Creek near Newark). Differences in the ratio between dissolved and total ammonia at the two sites partly may account for the differences in simulation errors at the sites. A review of 1998 monitoring data indicates that, on average, dissolved ammonia represents about 98 percent of total ammonia concentrations at the Trout Run site and 81 percent of total ammonia concentrations at the White Clay Creek near Newark site.

The differences between observed and simulated loads of ammonia may be due in part to errors in sampling or sampling analysis. Also, because of the small number of storms sampled for the study, one poor storm simulation may have a large effect on the apparent overall differences between observed and simulated loads. Such is the case for the large apparent error in load of dissolved ammonia (2,413 percent high for the October storm at White Clay Creek near Newark) (table 20), although some of the load error may be related to a questionably low laboratory analysis for dissolved ammonia in the October 1998 composite storm sample. As discussed in the sections on sediment and nitrate, some error in load simulation is because of error in streamflow simulation and the difference between the load error and the streamflow-volume error may be useful in evaluating the water-quality component of the overall load error. At the Trout Run and White Clay Creek near Newark sites, the cumulative error in simulated dissolved ammonia load adjusted for the cumulative error in simulated streamflow is -84 and 66 percent, respectively, for storms in 1998. The cumulative error in simulated particulate ammonia load adjusted for the error in simulated streamflow is 97 and 0.1 percent, respectively, for the Trout Run and White Clay Creek near Newark sites for storms in 1998. Using monthly or yearly annual load criteria (Donigian and others, 1984) to evaluate errors due to the water-quality component of the ammonia simulation, the dissolved and particulate ammonia calibration ranges from ‘very good’ to worse than ‘fair’ for cumulative storm loads at the two sites.

Simulated concentrations of dissolved ammonia under base-flow conditions were both higher and lower than observed concentrations at Trout Run, the mushroom-agricultural monitoring site. Simulated base-flow concentrations of dissolved ammonia were greater than observed concentrations by up to 0.04 mg/L as N at the whole-basin monitoring site White Clay Creek near Newark (fig. 33). As noted previously, streamflow was well simulated for all base-flow samples (fig. 26). The oversimulation of dissolved ammonia at the White Clay Creek site probably is related to the lack of temporal resolution in estimated ammonia concentrations in discharges from sewage treatment plants upstream and also to errors in the plankton simulation. Hourly mean ammonia loads for point-source discharges were estimated from reported monthly average ammonia values; however, hourly values probably vary within each month. Simulated concentrations of particulate ammonia were less than 0.006 mg/L as N at the two nonpoint-source monitoring sites and are less than the observed concentrations of particulate ammonia, which ranged from 0.002 to 0.100 mg/L as N. Most observed concentrations of particulate ammonia were less than 0.025 mg/L as N in base-flow samples and may partly represent laboratory error or uncertainty in the calculated particulate concentrations.

Overall, the nitrate and dissolved and particulate ammonia simulation under base-flow and stormflow conditions generally appears to represent the observed patterns of ammonia concentrations in response to flow conditions and defined land uses. Dissolved ammonia storm loads and base-flow concentrations tend to be oversimulated at the whole-basin site (White Clay Creek near Newark) that is downstream from several point-source discharges and this oversimulation partly may be related to inaccurate characterization of ammonia uptake upstream of the sampling site and (or) inadequate characterization of ammonia in discharges. Commonly, errors expressed in percent are greater for particulate ammonia simulation than for dissolved ammonia simulation and are greater for the ammonia simulation than the nitrate simulation. Of the nitrogen species simulated, nitrate represents the greatest amount and particulate ammonia represents the least amount of the inorganic nitrogen load. In storms, nitrate loads are an order of magnitude greater than dissolved ammonia loads and two orders of magnitude greater than particulate ammonia loads (table 20).

Simulated annual yields of nitrogen varied by land use. Annual yields of nitrate and ammonia are presented per land-use category within each segment in tables 21 and 23 for 1995-97, and average annual yields of nitrate and ammonia for the simulation period are presented per land-use category within each segment in tables 22 and 24. Nitrate yields from agricultural areas are larger than from other land uses simulated and are similar in magnitude to those measured in predominantly agricultural basins in the Chesapeake Bay watershed (Langland and others, 1995). Simulated annual nitrate yields for forested and urban land uses also are similar to those measured in predominantly forested and urban basins, respectively, in the Chesapeake Bay watershed (Langland and others, 1995). Simulated nitrate and ammonia yields are greatest from the mushroom-growing type of land use. Large amounts of nitrate and ammonia have been reported to leach out during the weathering of mushroom compost piles (Guo and others, 2001a; 2001b). Simulated annual nitrate and ammonia yields from impervious areas are less than 20 percent of reported annual atmospheric deposition loads for these constituents (Lynch and others, 1992).

Table 21. *Annual precipitation and simulated annual nitrate yields by land use for three segments of the Hydrological Simulation Program–Fortran (HSPF) model for White Clay Creek Basin, 1995-97*

	Segment	Year			
		1995	1996	1997	1995-97 average
Observed precipitation (inches)[1]	7	40.11	63.75	33.37	45.74
Simulated annual nitrate yield (pounds as nitrogen per acre per year), by land-use category[2]					
Residential - unsewered	7	8.28	21.8	10.9	13.66
Residential - sewered	7	4.46	11.7	5.64	7.27
Urban	7	4.65	11.5	5.57	7.24
Agricultural - animal/crop	7	17.4	43.3	18.8	26.5
Agricultural - row crop	7	15.0	37.5	15.8	22.8
Agricultural - mushroom	7	21.6	52.9	21.8	32.1
Forested	7	.83	2.24	1.25	1.44
Open	7	3.05	7.92	3.8	4.92
Wetlands/water	7	.877	2.67	1.43	1.66
Undesignated	7	3.06	7.89	3.73	4.89
Impervious - residential	7	1.99	2.05	2.03	2.02
Impervious - urban	7	1.99	2.05	2.03	2.02
Observed precipitation (inches)	5	40.62	60.48	36.91	46.00
Simulated annual nitrate yield (pounds as nitrogen per acre per year), by land-use category[2]					
Residential - unsewered	5	8.38	20.1	12.7	13.73
Residential - sewered	5	4.59	10.6	6.57	7.25
Urban	5	4.75	10.8	6.54	7.36
Agricultural - animal/crop	5	18.2	38.5	21.7	26.1
Agricultural - row crop	5	18.2	38.9	21.9	26.3
Agricultural - mushroom	5	21.1	45.3	24.5	30.3
Forested	5	.88	2.05	1.39	1.44
Open	5	3.11	7.14	4.35	4.87
Wetlands/water	5	.85	2.44	1.56	1.62
Undesignated	5	3.13	7.21	4.39	4.91
Impervious - residential	5	2.03	2.08	2.02	2.04
Impervious - urban	5	2.03	2.08	2.02	2.04
Observed precipitation (inches)	8	40.62	60.48	36.91	46.00
Simulated annual nitrate yield (pounds as nitrogen per acre per year), by land-use category[2]					
Residential - unsewered	8	10.1	22.8	13.5	15.47
Residential - sewered	8	5.52	11.9	6.97	8.13
Urban	8	5.68	12.1	6.96	8.25
Agricultural - animal/crop	8	21.5	41.8	23.5	28.9
Agricultural - row crop	8	18.4	35.2	19.7	24.4
Agricultural - mushroom	8	26.7	55.2	29.0	37.0
Forested	8	.96	2.18	1.46	1.53
Open	8	3.74	8.00	4.64	5.46
Wetlands/water	8	1.19	3.08	1.94	2.07
Undesignated	8	3.74	8.01	4.65	5.47
Impervious - residential	8	2.03	2.08	2.03	2.05
Impervious - urban	8	2.03	2.08	2.03	2.05

[1] Precipitation input to segment 7 = 0.85 x precipitation recorded at Coatesville.

[2] In pervious areas, unless where noted.

Table 22. *Observed average annual precipitation and simulated average annual nitrate yield for pervious and impervious land areas by land use in three segments of the Hydrological Simulation Program–Fortran (HSPF) model for White Clay Creek Basin, 1995-97*

	1995-97 Average			
	Segment 7	**Segment 5**	**Segment 8**	**Average of all segments**
Observed precipitation (inches)	[1]45.74	46.00	46.00	45.91
Simulated average annual nitrate yield (tons as nitrogen per acre per year), by land-use category[2]				
Residential - unsewered	13.66	13.73	15.47	14.28
Residential - sewered	7.27	7.25	8.13	7.55
Urban	7.24	7.36	8.25	7.62
Agricultural - animals/crops	26.5	26.1	28.9	27.2
Agricultural - row crop	22.8	26.3	24.4	24.5
Agricultural - mushroom	32.1	30.3	37.0	33.1
Forested	1.44	1.44	1.53	1.47
Open	4.92	4.87	5.46	5.08
Wetlands/water	1.66	1.62	2.07	1.78
Undesignated	4.89	4.91	5.47	5.09
Impervious - residential	2.02	2.04	2.05	2.04
Impervious - urban	2.02	2.04	2.05	2.04

[1] Precipitation for segment 7 = 0.85 x precipitation at Coatesville 2 W.

[2] In pervious areas, unless where noted.

Table 23. *Annual precipitation and simulated annual total ammonia yields by land use for three segments of the Hydrological Simulation Program–Fortran (HSPF) model for White Clay Creek Basin, 1995-97*

	Segment	Year			
		1995	1996	1997	1995-97 average
Observed precipitation (inches)[1]	7	40.11	63.75	33.37	45.74
Simulated annual total ammonia yield (pounds as nitrogen per acre per year), by land-use category[2]					
Residential - unsewered	7	.108	.311	.089	.169
Residential - sewered	7	.060	.164	.049	.091
Urban	7	.080	.164	.050	.098
Agricultural - animal / crop	7	.805	1.860	.146	.937
Agricultural - row crop	7	.595	1.41	.129	.711
Agricultural - mushroom	7	4.26	8.24	.858	4.45
Forested	7	.022	.060	.034	.039
Open	7	.089	.235	.087	.137
Wetlands / water	7	.014	.047	.023	.028
Undesignated	7	.093	.236	.086	.138
Impervious - residential	7	.365	.370	.371	.369
Impervious - urban	7	.423	.427	.428	.426
Observed precipitation (inches)	5	40.62	60.48	36.91	46.00
Simulated annual total ammonia yield (pounds as nitrogen per acre per year), by land-use category[2]					
Residential - unsewered	5	.112	.206	.103	.140
Residential - sewered	5	.066	.118	.057	.080
Urban	5	.085	.139	.059	.094
Agricultural - animal / crop	5	1.08	1.31	.232	.874
Agricultural - row crop	5	.914	1.15	.207	.757
Agricultural - mushroom	5	4.63	5.98	.951	3.85
Forested	5	.022	.057	.038	.039
Open	5	.098	.188	.100	.129
Wetlands / water	5	.014	.043	.025	.027
Undesignated	5	.096	.189	.101	.129
Impervious - residential	5	.374	.377	.371	.374
Impervious - urban	5	.437	.436	.430	.434
Observed precipitation (inches)	8	40.62	60.48	36.91	46.00
Simulated annual total ammonia yield (pounds as nitrogen per acre per year), by land-use category[2]					
Residential - unsewered	8	.127	.204	.107	.146
Residential - sewered	8	.077	.117	.060	.085
Urban	8	.091	.129	.060	.093
Agricultural - animal / crop	8	.702	.536	.147	.462
Agricultural - row crop	8	.374	.348	.126	.283
Agricultural - mushroom	8	2.51	2.78	.415	1.90
Forested	8	.025	.062	.040	.042
Open	8	.110	.194	.106	.137
Wetlands / water	8	.020	.055	.033	.036
Undesignated	8	.109	.194	.106	.136
Impervious - residential	8	.374	.377	.371	.374
Impervious - urban	8	.436	.436	.431	.434

[1] Precipitation input to segment 7 = 0.85 x precipitation recorded at Coatesville 2 W.

[2] In pervious areas, unless where noted.

Table 24. *Observed average annual precipitation and simulated average annual total ammonia yield for pervious and impervious land areas by land use in three segments of the Hydrological Simulation Program–Fortran (HSPF) model for White Clay Creek Basin, 1995-97*

	1995-97 Average			
	Segment 7	**Segment 5**	**Segment 8**	**Average of all segments**
Observed precipitation (inches)	[1]45.74	46.00	46.00	45.91
Simulated average annual total ammonia yield (tons as nitrogen per acre per year), by land-use category[2]				
Residential - unsewered	.169	.140	.146	.152
Residential - sewered	.091	.080	.085	.085
Urban	.098	.094	.093	.095
Agricultural - animals/crops	.937	.874	.462	.758
Agricultural - row crop	.711	.757	.283	.584
Agricultural - mushroom	4.45	3.85	1.90	3.40
Forested	.039	.039	.042	.040
Open	.137	.129	.137	.134
Wetlands/water	.028	.027	.036	.030
Undesignated	.138	.129	.136	.134
Impervious - residential	.369	.374	.374	.372
Impervious - urban	.426	.434	.434	.432

[1] Precipitation for segment 7 = 0.85 x precipitation at Coatesville 2 W.

[2] In pervious areas, unless where noted.

Phosphorus

The model was used to simulate inorganic phosphorus in the dissolved and particulate states. The model simulates dissolved inorganic phosphorus as dissolved orthophosphate and particulate inorganic phosphorus as adsorbed orthophosphate. Phosphorus loads from point and nonpoint sources are included in the simulation. Loads from point-source discharges were estimated from reported average monthly values for input on an hourly time step to the model. For nonpoint sources, dissolved and particulate phosphorus differed by land use and were estimated on the basis of fixed concentrations in sediment (soil), interflow, and ground water. Orthophosphate was assumed to be transported in both dissolved and particulate (adsorbed) forms from the land surface and in the stream channel. A review of 1995-98 PADEP monitoring data collected commonly under moderate (non-storm) flow conditions, indicates that, on average, dissolved orthophosphate represents about 79 percent of total phosphorus concentrations. For data collected in 1998 under a range of flow conditions at two monitoring stations in the basin, dissolved orthophosphate represented about 62 percent of total phosphorus.

Water-quality data from three monitoring stations in the White Clay Creek Basin were used in the calibration of dissolved and particulate orthophosphate. Observed concentrations of particulate orthophosphate were calculated by subtracting concentrations of dissolved phosphorus from concentrations of total phosphorus and assuming the difference was particulate (adsorbed) orthophosphate. For data collected by PADEP at White Clay Creek near Strickersville and by DNREC at White Clay Creek near Newark, particulate orthophosphate was estimated by subtracting orthophosphate from total phosphorus to make use of the longer period of record covered by PADEP and DNREC samples that included orthophosphate but not dissolved phosphate analysis. This approach may overestimate particulate orthophosphate because of the inclusion of organic and other inorganic forms of phosphorus. The accuracy of these estimated values also depends on the accuracy of laboratory methodology, which at low concentrations near detection levels, may have substantial uncertainty (Childress and others, 1999).

Simulated and observed concentrations of dissolved and particulate orthophosphate are shown in figures 37 and 38 for the storm with the best-simulated streamflow at each of the two nonpoint-source monitoring sites, 01478137 Trout Run

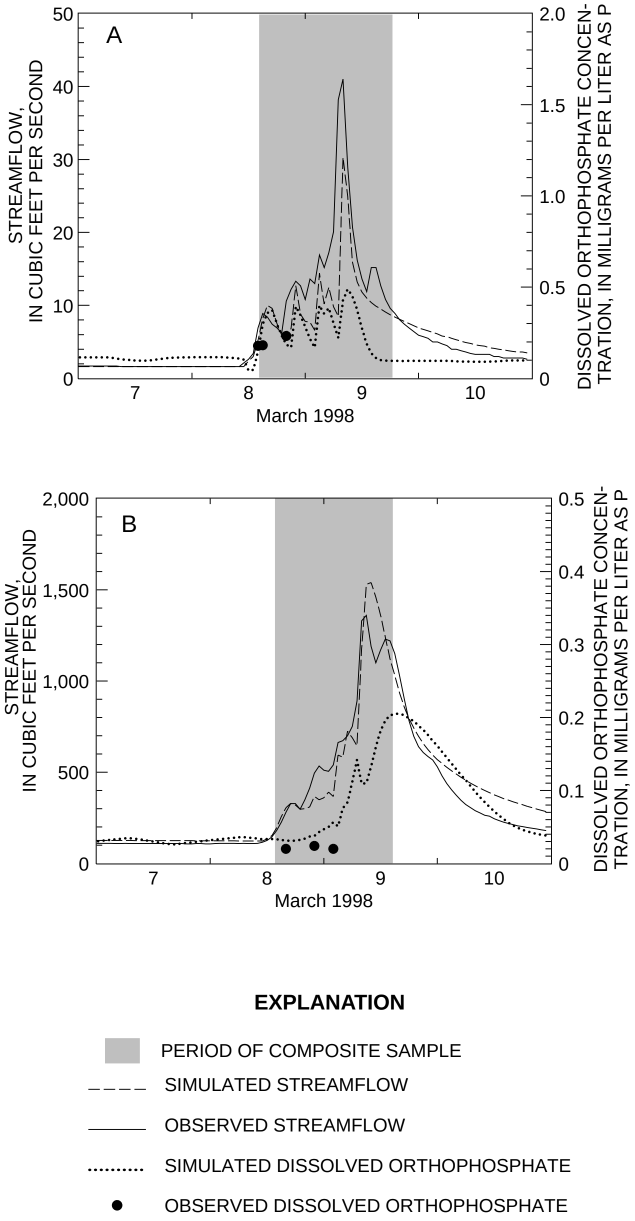


Figure 37. Simulated and observed streamflow and concentrations of dissolved orthophosphate for the storm sampled in 1998 with the best-simulated streamflow component at the nonpoint-source monitoring sites in the White Clay Creek Basin, (A) 01478137, Trout Run at Avondale, Pa., (B) 01479000 White Clay Creek near Newark, Del.

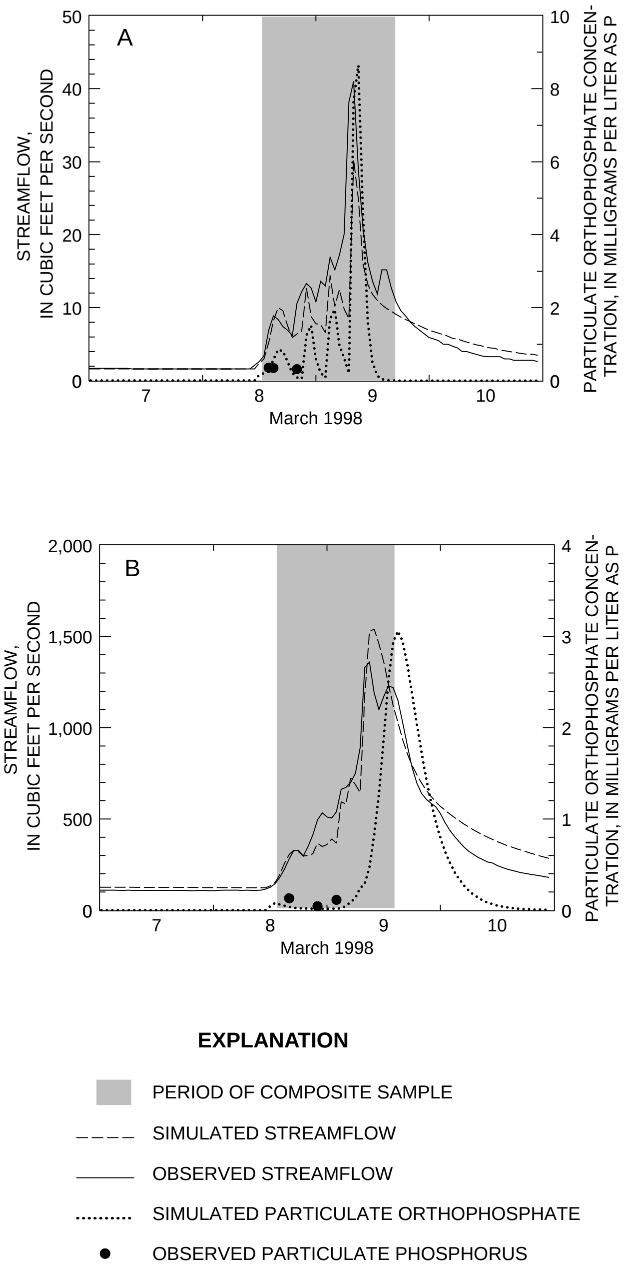


Figure 38. Simulated and observed streamflow and concentrations of particulate orthophosphate for the storm sampled in 1998 with the best-simulated streamflow component at the nonpoint-source monitoring sites in the White Clay Creek Basin, (A) 01478137, Trout Run at Avondale, Pa., (B) 01479000 White Clay Creek near Newark, Del.

at Avondale and 01479000 White Clay Creek near Newark. Simulated and observed streamflow and concentrations of dissolved and particulate orthophosphate for all sampled storms at the two nonpoint-source monitoring sites in the White Clay Creek Basin are shown in Appendix 2. Observed and simulated concentrations of dissolved and particulate orthophosphate generally tend to increase as streamflow increases during storms.

Data from composite stormflow samples collected in 1998 were used in the calculation of loads of dissolved and particulate phosphate. Simulated and observed loads were calculated for dissolved and particulate phosphorus in a manner similar to those loads calculated for other water-quality constituents, described in the section on suspended sediment. Calculated loads served as the observed values in the evaluation of overall orthophosphate transport during storms. Simulated and observed streamflow and loads of dissolved orthophosphate and particulate orthophosphate are presented in table 25. Dissolved and particulate orthophosphate loads tend to be undersimulated when flow is undersimulated and oversimulated when flow is oversimulated. Flow and dissolved and particulate orthophosphate are undersimulated for most storm events at the mushroom agricultural subbasin site (Trout Run) and the whole-basin site (White Clay Creek near Newark) (table 25). Apparent oversimulation of particulate orthophosphate at the Trout Run site for the March 1998 storm probably is due to problems in composite sample analyses. In the March 1998 composite storm sample from the Trout Run site, the reported dissolved orthophosphate concentrations were greater than the reported total phosphorus concentrations and almost 15 times greater than the particulate orthophosphate concentrations (estimated from total phosphorus concentrations minus dissolved phosphorus concentrations); these results indicate that the reported total phosphorus concentration probably is too low in the March composite sample from Trout Run. If the questionable March sample is excluded from the summary of results, the total difference in loads of particulate phosphorus is -89 percent at the Trout Run site.

As discussed in the sections on sediment and nitrogen, some error in load simulation is due to error in streamflow simulation and the difference between the load error and the streamflow-volume error may be useful in evaluating the water-quality component of the overall load error. At the Trout Run and White Clay Creek near Newark sites, the

Table 25. *Simulated and observed streamflow, and loads of dissolved and particulate orthophosphate for storms sampled in 1998 at two nonpoint-source monitoring sites in the White Clay Creek Basin, 01478137 Trout Run at Avondale, Pa., and 01479000 White Clay Creek near Newark, Del.*

[ft^3/s, cubic feet per second; Sim., simulated; Obs., observed; diff., difference; na, not applicable; --, no data]

Dates of storm sampling	Observed peak flow[1] (ft^3/s)	Streamflow (millions of cubic feet)			Dissolved orthophosphate load (pounds as phosphorus)			Particulate orthophosphate load (pounds as phosphorus)		
		Sim.	Obs.	Percent diff.[2]	Sim.	Obs.	Percent diff.[2]	Sim.	Obs.	Percent diff.[2]
Trout Run at Avondale, Pa										
February 4-5	4.04	0.17	0.22	-24	0.94	2.05	-54	0.64	3.64	-82
March 8-9	41.0	1.04	1.46	-29	21.3	40.9	-48	154.3	[3]2.76	5,485
June 11-13	39.4	.60	.87	-31	7.45	17.1	-56	14.6	74.6	-80
July 8-9	29.6	.33	.49	-33	1.77	11.5	-85	.94	74.7	-99
October 8-10	21.2	.40	.78	-49	1.93	18.4	-90	na	--	--
Total - all storms		2.53	3.82	-34	33.4	89.9	-63	170.4	155.7	9
White Clay Creek near Newark, Del.										
March 8-9	1,360	48.16	50.10	-4	275.1	76.0	262	1,069	795	-34
May 1-2	131	12.83	12.07	6	24.3	33.6	-28	27	294	-91
June 11-13	690	22.94	24.94	-8	45.2	53.6	-16	60	508	-88
July 8-9	355	7.18	19.48	-63	12.5	89.9	-86	2	515	-100
October 8-9	193	11.95	9.31	28	21.6	11.2	93	na	--	--
Total - all storms		103.06	115.91	-11	378.7	264.2	43	1,158	2,111	-45

[1] Peak mean hourly discharge during period of composite sampling.

[2] 100 x (simulated - observed)/observed.

[3] Observed concentration in composite sample probably too low; unreliable value.

cumulative error in simulated dissolved orthophosphate load adjusted for the cumulative error in simulated streamflow is -44 and 61 percent, respectively, for storms in 1998. The cumulative error in simulated particulate orthophosphate load adjusted for the error in simulated streamflow is 56 and -36 percent, respectively, for the Trout Run and White Clay Creek near for storms in 1998. Using monthly or yearly annual load criteria (Donigian and others, 1984) to evaluate errors due to the water-quality component of the orthophosphate simulation, the dissolved and particulate orthophosphate calibration ranges from ‘good’ to somewhat worse than ‘fair’ for individual and cumulative storm loads at the two sites.

Simulated concentrations of dissolved orthophosphate under base-flow conditions generally were within 0.3 mg/L as phosphorus (P) of observed concentrations at the two monitoring stations, with the exception of one value (fig. 39). The mean difference between observed and simulated concentrations of dissolved orthophosphate for base-flow conditions was 0.28 mg/L as P, and the average percent difference was 51 percent (low). As noted previously, streamflow was well simulated for all base-flow samples (fig. 32). A few simulated concentrations of particulate orthophosphate were <0.005 or 0 mg/L as P at the two sites and generally are less than the calculated observed concentrations of particulate orthophosphate, which ranged from 0.011 to 0.337 mg/L as P (fig. 39). The mean difference between observed and simulated concentrations of particulate orthophosphate for base-flow conditions was 0.08 mg/L as P, and the average percent difference was 42 percent. Differences between observed and simulated concentrations of particulate orthophosphate at low concentrations may be due in part to laboratory error or uncertainty in the calculated particulate concentrations.

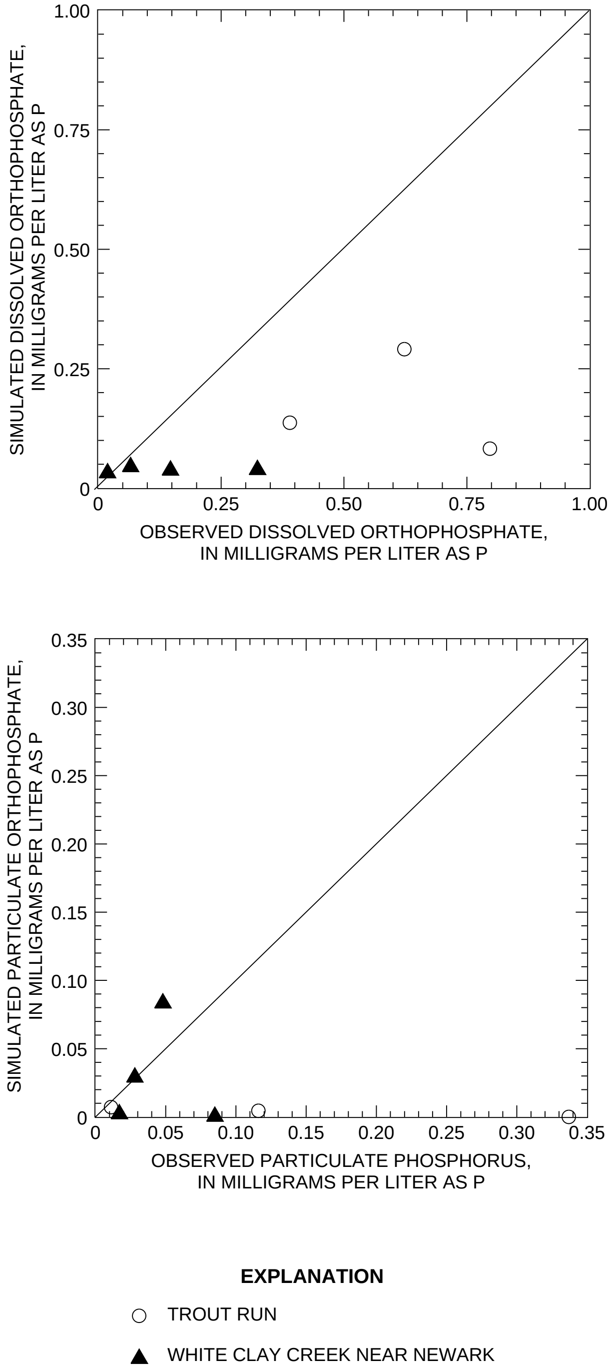


Figure 39. Simulated and observed concentrations of dissolved and particulate orthophosphate during base-flow conditions in 1998 at two monitoring sites in the White Clay Creek Basin, 01478137 Trout Run at Avondale, Pa., and 01479000 White Clay Creek near Newark, Del.

Concentrations and loads of dissolved orthophosphate and particulate phosphorus tended to be undersimulated at main stem monitoring sites, 01478265 White Clay Creek near Strickersville and 01479000 White Clay Creek near Newark, as indicated by comparison of simulated and observed data collected by PADEP and DNREC, respectively (figs. 40 and 41). Data collected by PADEP and DNREC at these sites generally were collected under non-storm conditions. In non-storm conditions, undersimulation at sites downstream of discharges may be caused partly by inadequate characterization of discharges or errors in the algal plankton simulation that results in nutrient uptake.

Overall, the dissolved and particulate orthophosphate simulation under base-flow and stormflow conditions generally appears to represent the observed patterns of phosphorus concentrations in response to flow conditions and defined land uses. At the two nonpoint monitoring sites, Trout Run at Avondale and White Clay Creek near Newark, errors expressed in percent are somewhat greater for particulate orthophosphate simulation than for dissolved orthophosphate simulation during storms. In storms at these sites, particulate orthophosphate loads commonly are from 2 to 10 times greater than dissolved orthophosphate loads (table 25).

Simulated annual yields of phosphorus varied by land use. Yields of total orthophosphate are presented per land-use category per segment per year in table 26 for 1995-97, and mean annual yields of total orthophosphate for the simulation period are presented per land-use category per segment in table 27. Phosphorus yields from mushroom agricultural land use are higher than for any other land use. The main source of phosphorus in mushroom agricultural areas is spent mushroom substrate or compost, which is commonly stored outside, exposed to weathering or leaching. The phosphorus content of mushroom compost is about 8,400 parts per million (ppm) (Beyer, 1999). A simulated annual phosphorus yield of 35 pounds per acre is equivalent to the complete phosphorus loss of about 4,200 lb (about 3 ft^3) of manure per acre.

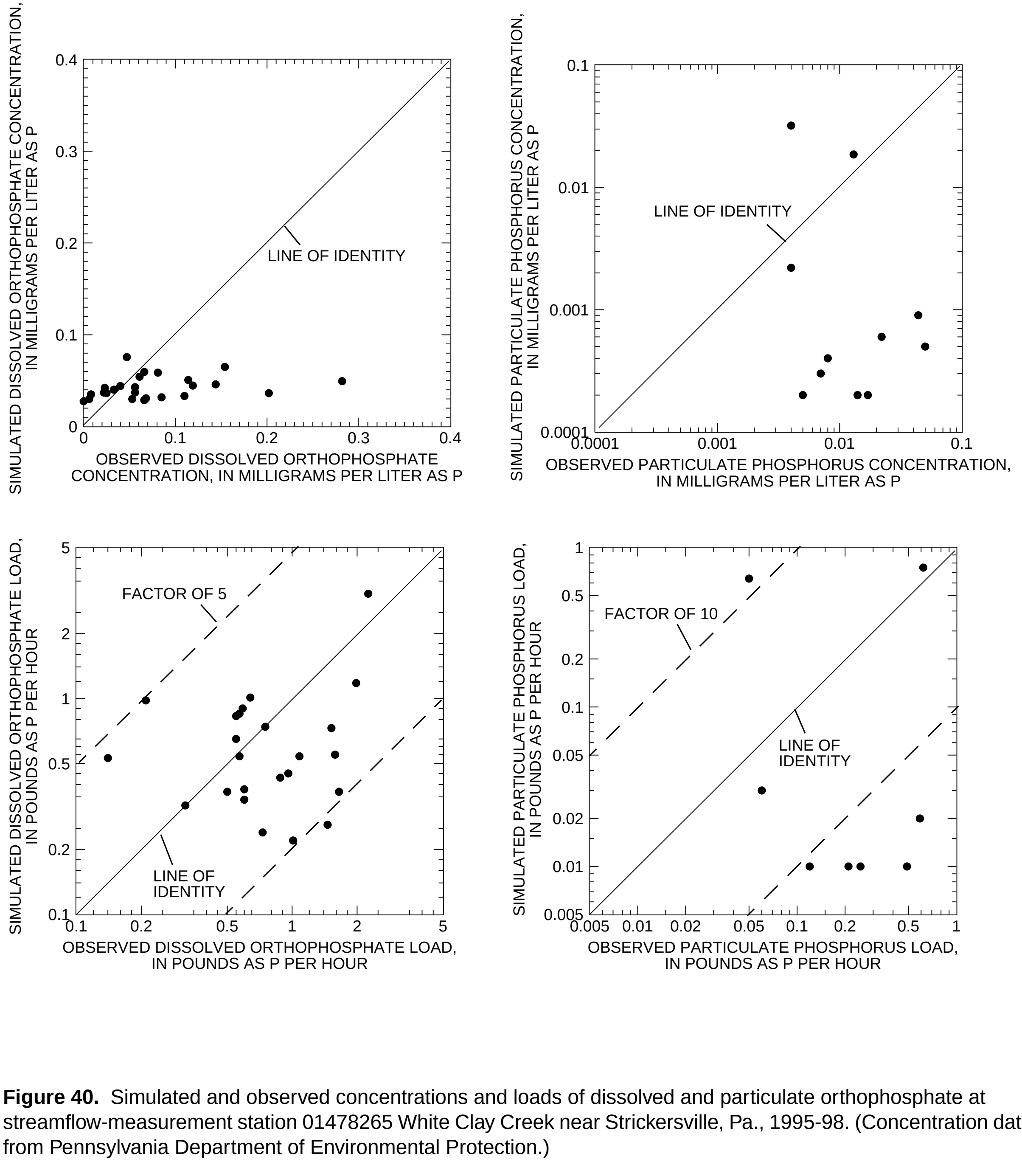


Figure 40. Simulated and observed concentrations and loads of dissolved and particulate orthophosphate at streamflow-measurement station 01478265 White Clay Creek near Strickersville, Pa., 1995-98. (Concentration data from Pennsylvania Department of Environmental Protection.)

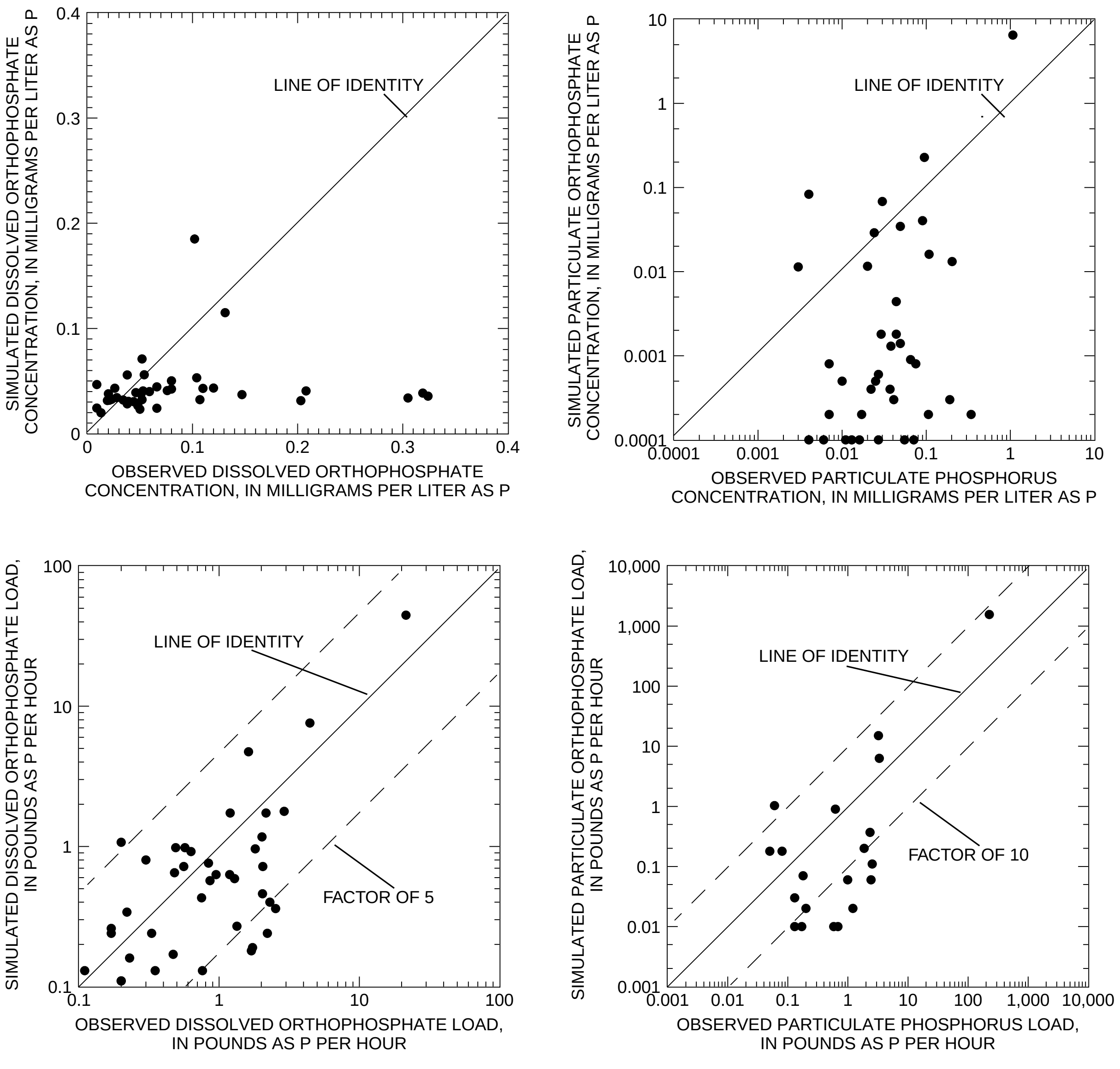


Figure 41. Simulated and observed concentrations and loads of dissolved orthophosphate and particulate phosphorus at streamflow-measurement station 01479000 White Clay Creek near Newark, Del., 1994-98. (Concentration data from Delaware Department of Natural Resources and Environmental Control.)

Table 26. *Annual precipitation and simulated annual yields of total orthophosphate by land use for three segments of Hydrological Simulation Program–Fortran model for White Clay Creek Basin, 1995-97*

	Segment	Year			
		1995	1996	1997	1995-97 average
Observed precipitation (inches)[1]	7	40.11	63.75	33.37	45.74
Simulated annual total orthophosphate yield (pounds as phosphorus per acre per year), by land-use category[2]					
Residential - unsewered	7	.174	.526	.090	.263
Residential -sewered	7	.211	.597	.094	.301
Urban	7	.331	.602	.102	.345
Agricultural - animal/crop	7	7.48	17.2	.723	8.47
Agricultural - row crop	7	7.15	16.8	.681	8.21
Agricultural - mushroom	7	38.3	72.4	6.22	39.0
Forested	7	.011	.032	.017	.020
Open	7	.238	.651	.050	.313
Wetlands/water	7	.007	.024	.011	.014
Undesignated	7	.269	.667	.054	.330
Impervious - residential	7	.390	.399	.387	.392
Impervious - urban	7	.889	.879	.880	.883
Observed precipitation (inches)	5	40.62	60.48	36.91	46.00
Simulated annual total orthophosphate yield (pounds as phosphorus per acre per year), by land-use category[2]					
Residential - unsewered	5	.182	.274	.102	.186
Residential -sewered	5	.245	.341	.108	.231
Urban	5	.360	.468	.120	.316
Agricultural - animal/crop	5	10.3	11.7	1.47	7.82
Agricultural - row crop	5	9.80	11.6	1.37	7.59
Agricultural - mushroom	5	42.1	53.0	7.22	34.1
Forested	5	.012	.029	.019	.020
Open	5	.306	.343	.061	.237
Wetlands/water	5	.007	.022	.013	.014
Undesignated	5	.288	.332	.059	.226
Impervious - residential	5	.414	.411	.394	.406
Impervious - urban	5	.963	.915	.907	.928
Observed precipitation (inches)	8	40.62	60.48	36.91	46.00
Simulated annual total orthophosphate yield (pounds as phosphorus per acre per year), by land-use category[2]					
Residential - unsewered	8	.199	.236	.103	.179
Residential -sewered	8	.278	.283	.107	.223
Urban	8	.360	.349	.112	.274
Agricultural - animal/crop	8	8.38	4.95	.670	4.67
Agricultural - row crop	8	7.85	4.56	.605	4.34
Agricultural - mushroom	8	34.7	35.7	3.33	24.6
Forested	8	.013	.031	.020	.021
Open	8	.294	.213	.051	.186
Wetlands/water	8	.010	.028	.017	.018
Undesignated	8	.284	.206	.050	.180
Impervious - residential	8	.411	.412	.395	.406
Impervious - urban	8	.953	.918	.907	.926

[1] Precipitation input to segment 7 = 0.85 x precipitation recorded at Coatesville 2 W.

[2] In pervious areas, unless where noted.

Table 27. *Observed 1995-97 average annual precipitation and simulated 1995-97 average annual total orthophosphate yield for pervious and impervious land areas by land use in three segments of the Hydrological Simulation Program–Fortran model for White Clay Creek Basin*

	1995-97 Average			
	Segment 7	Segment 5	Segment 8	Average of all segments
Observed precipitation (inches)	[1]45.74	46.00	46.00	45.91
Simulated average annual total orthophosphate yield (tons as phosphorus per acre per year), by land-use category[2]				
Residential - unsewered	.263	.186	.179	.210
Residential -sewered	.301	.231	.223	.252
Urban	.345	.316	.274	.312
Agricultural - animals/crops	8.47	7.82	4.67	6.99
Agricultural - row crop	8.21	7.59	4.34	6.71
Agricultural - mushroom	39.0	34.1	24.6	32.6
Forested	.020	.020	.021	.020
Open	.313	.237	.186	.245
Wetlands/water	.014	.014	.018	.015
Undesignated	.330	.226	.180	.245
Impervious - residential	.392	.406	.406	.401
Impervious - urban	.883	.928	.926	.912

[1] Precipitation for segment 7 = 0.85 x precipitation at Coatesville 2 W.
[2] In pervious areas, unless where noted.

Model Sensitivity Analysis

Calibration of water temperature is specified by 13 parameters—5 are for pervious land surfaces, 2 are for impervious land surfaces, and 6 are for stream reaches. For water-temperature simulation, the model is more sensitive to parameters in the reach modules than to parameters in pervious and impervious modules. Water temperature in a reach is modeled as a function of the variables, upstream flow and land surface inflow temperatures, air temperature, and various radiation, conduction, and convection gains or losses. Of these variables, radiation, conduction, and convection gains and losses have calibration parameters. Although no formal sensitivity analysis was done for parameters affecting water temperature, through the calibration process it was found that simulated water temperatures are sensitive most to the parameters CFSAEX, the solar radiation correction factor, and KCOND, the conduction-convection coefficient. Daily high temperatures are affected by CFSAEX and nighttime low temperatures by KCOND. In combination, CFSAEX and KCOND also influence daily mean water temperature.

The simulated sediment yield from pervious and impervious land areas is dependent on parameters affecting soil detachment, soil scour, and soil or sediment washoff and is sensitive to parameters affecting soil detachment (KRER, JRER), soil washoff (KSER, JSER), and soil scour processes (KGER, JGER) for pervious land surfaces, and solids build up (ACCSDP, REMDSP) and washoff processes for impervious land surfaces (KEIM, JEIM). Sediment washoff or transport capacity is dependent on surface runoff (SURO) and, therefore, the hydrologic component of the simulation. In addition, calibration of suspended sediment in the stream channel is sensitive to parameters controlling shear stress regimes (TAUD, TAUS) that determine deposition on and scour of the channel bottom. The sensitivity of sediment yield to changes in parameters affecting pervious land-surface processes was investigated by varying parameter values by selected multiplication factors. Results reported for White Clay Creek near Newark, Del., include the total effects in the three segments above the station (table 28).

The simulated yields of nitrate, ammonia, and orthophosphate from pervious land areas are dependent on parameters affecting sediment yield except those controlling sediment scour processes. Nitrate yields are less affected than ammonia and

Table 28. *Sensitivity of model output for yields of total sediment, nitrate, ammonia, and orthophosphate at White Clay Creek near Newark, Del., to changes in selected parameters that affect sediment contributions from pervious land areas, October 1994 to October 1998*

[KRER, coefficient in soil detachment equation; JRER, exponent in soil detachment equation; KSER, coefficient in detached-sediment washoff equation; JSER, exponent in detached-sediment washoff equation; KGER, coefficient in soil-matrix scour equation; JGER, exponent in soil-matrix scour equation]

Parameter	Multiplication factor	Sediment yield		Nitrate yield		Ammonia yield		Orthophosphate yield	
		Tons per acre	Percent difference[1]	Pounds per acre	Percent difference[1]	Pounds per acre	Percent difference[1]	Pounds per acre	Percent difference[1]
Preliminary calibration value[2]	1	3.183	0	53.04	0	1.9311	0	17.081	0
Detachment processes									
KRER	.5	2.00	-37.29	50.91	-4.02	1.27	-34.08	10.16	-40.52
	2	4.00	25.55	54.48	2.71	2.49	29.01	22.78	33.34
JRER	.5	4.01	25.96	54.50	2.75	2.51	30.00	22.96	34.39
	1.5	2.63	-17.48	52.03	-1.91	1.57	-18.72	13.38	-21.66
Washoff processes									
KSER	.5	2.06	-35.39	51.08	-3.70	1.42	-26.33	11.64	-31.87
	2	3.79	19.11	54.07	1.94	2.16	11.79	19.49	14.12
JSER	.75	3.91	22.87	54.28	2.33	2.23	15.37	20.27	18.66
	1.5	2.14	-32.62	51.20	-3.47	1.43	-25.99	11.80	-30.93
Soil scour processes									
KGER	.5	3.13	-1.67	53.04	0.0	1.93	0.0	17.08	0.0
	2	3.29	3.32	53.04	0.0	1.93	0.0	17.08	0.0
JGER	.5	3.37	5.99	53.04	0.0	1.93	0.0	17.08	0.0
	1.5	3.14	-1.37	53.04	0.0	1.93	0.0	17.08	0.0

[1] Percent difference from calibrated value = 100 × (changed result - calibrated result)/calibrated result.

[2] All parameters.

phosphorus by changes in sediment yield because the model, as set up, simulates surface-runoff and ground-water transport of these constituents from land areas to streams in different relative amounts. The largest amounts of nitrate from land areas enter the streams through ground-water discharge (AGWO). The largest amounts of ammonia and orthophosphate from most land areas enter streams with sediment in surface runoff (SURO). The difference in transport mechanisms is supported by studies that indicate nitrate commonly leaches from soils to ground water more readily than ammonia and phosphorus (Guo and others, 2001a) and that the majority of nitrate and phosphorus yields in nearby basins are in base flow and stormflow, respectively (Lietman, 1997).

The simulated yields of nitrate, ammonia, and phosphate from pervious and impervious land areas also are dependent on parameters affecting concentrations of the constituent on detached soil or sediment (POTFW) and in interflow (IFLW-CONC) and ground water (GRND-CONC). The sensitivity of simulated total yields to changes in values of these parameters was investigated by varying the parameter values by selected multiplication factors (table 29). The parameters affecting interflow and ground-water concentrations affect nitrate yields more than yields of ammonia and orthophosphate because of differences in the main mechanisms that deliver these nutrients to the streams. Consequently, changes to parameters affecting concentrations of nutrients on detached soil (POTFW) affect yields of ammonia and orthophosphate more than nitrate.

Table 29. *Sensitivity of model output for total nutrient yields at White Clay Creek near Newark, Del., to changes in selected parameters that affect nutrient contributions from pervious land areas, October 1994 - October 1998*

[N, nitrogen; P, phosphorus; POTFW, potency factor of sediment in washoff; IFLW-CONC, concentration in interflow; GRND-CONC, concentration in ground water]

Parameter	Multiplication factor	Nitrate as N		Ammonia as N		Phosphate as P	
		Pounds per acre	Percent difference[1]	Pounds per acre	Percent difference[1]	Pounds per acre	Percent difference[1]
Preliminary calibration value[2]	1	53.04	0	1.9311	0	17.081	0
POTFW	.5	50.34	-5.10	1.11	-42.66	8.73	-48.87
	2	58.47	10.23	3.52	82.09	33.77	97.71
IFLW-CONC	.5	48.11	-9.30	1.89	-2.13	17.04	-0.27
	2	63.23	19.21	2.01	4.14	17.17	0.50
GRND-CONC	.5	34.25	-35.44	1.80	-6.88	16.92	-0.94
	2	90.50	70.62	2.19	13.62	17.35	1.56

[1] Percent difference from calibrated value = 100 x (changed result - calibrated result)/calibrated result.
[2] All parameters.

Model Limitations

The ability of the model to simulate water-quality constituents depends on the adequacy of the hydrologic and physical process simulation and therefore will be limited by the accuracy of hydrologic model. In this case, the hydrologic model simulation is quite good if considered over long time periods, but not so good for individual storms. Simulation for water-quality variables may have a high degree of uncertainty for short-term simulations. In addition, the water-quality calibration was based on relatively few observed water-quality data, and as a result, greater uncertainty is associated with the simulation of water quality and assessment of the model performance is more difficult than would be for a calibration with many water-quality data.

The oversimulation of summer-season water temperature in headwater streams such as Trout Run at Avondale, Pa., may affect other instream processes in the model. The effect may be minimal, however, because water temperatures are no longer oversimulated by the time streamflow reaches the main stem sites. Of more concern are the much larger swings in simulated water temperature that occurred at Trout Run when streamflow was unusually low and which may occur at the main stem sites under similar low-flow conditions.

Simulation of concentrations of suspended sediment, nitrate, ammonia, and phosphorus for individual storms or short periods of time may not be well simulated by the model because of hydrologic limitations related to accuracy of rainfall data. The timing and intensity of rainfall affect detachment processes for soil and soil-related constituents as well as transport of the solids from land to streams. The simulation of sediment was calibrated using measured concentrations of suspended solids in samples collected at one point in the stream. However, the suspended-solids samples may not accurately represent suspended-sediment concentrations in the stream because of differences in analytical methods for suspended solids and suspended sediment and because depth-integrated, flow-weighted samples are needed to characterize sediment in streams that may not be well mixed. Simulation of water quality may be less accurate for small-basin areas than for large-basin areas because of spatial resolution of the model. The hydrologic component of the model for two segments (5 and 8) was calibrated at sites on the main branches and main stem of the White Clay Creek rather than at small-basin sites. In addition, water-quality calibration parameters for most land uses were taken from a calibrated model for the adjacent Brandywine Creek Basin (Senior and Koerkle, 2003) rather than being specifically adjusted for White Clay Creek.

The model probably does not fully describe the effects of in-stream biological processes on the concentrations of nutrients. The simulation of nitrogen and phosphorus included the biological processes of algal plankton and benthic algal nutrient uptake and release but not the role of zooplankton. The magnitude of diurnal fluctuations in concentrations of dissolved oxygen due to processes of in-stream photosynthesis and respiration apparently was not characterized fully by the simulation. The simulation of in-stream nutrient concentrations is further affected by the quality and quantity of information about nutrients in discharge from point sources. For example, although the model is run on an hourly time step, data on point-source discharges generally are available as monthly mean values for ammonia and phosphorus contributions. Further, nitrate contributions from point-source discharges were extrapolated using a fixed ratio from reported monthly average ammonia values because no other data were available. However, the ratio of nitrate to ammonia probably fluctuates through time. The model, as configured, is better used to estimate loads of nonpoint-source nutrients from land areas than to predict concentrations at downstream sites after considerable in-stream transport and residence time.

The simulation of particulate orthophosphate was calibrated to an estimated value, calculated as observed total phosphorus minus observed dissolved phosphorus. This difference, however, may include forms of phosphorus other than orthophosphate. Because the model, as configured, only simulates inorganic phosphorus as orthophosphate, particulate phosphorus that includes forms of phosphorus other than adsorbed orthophosphate may be undersimulated.

MODEL APPLICATIONS

The HSPF model for the White Clay Creek Basin was developed to assist in the assessment of suspended sediment and nutrient loads from nonpoint sources to streams. The model load estimates may be used as part of an ongoing total maximum daily load (TMDL) assessment for the Christina River Basin to indicate the possible location and magnitude of load reductions that might be needed to maintain or improve water quality where impaired. These load estimates are based on the land-use conditions during the period of calibration and do not reflect the effects of best management practices put in place after 1998.

The model can be used to estimate loads from individual basins for the purposes of evaluating relative contributions of suspended sediment, nitrogen, and orthophosphate. This information may be helpful in assessing areas that appear to generate elevated nonpoint-source loads of these constituents. For example, simulated total loads and loads per acre (yields) in 1995 for selected headwater areas are listed in table 30. Precipitation in 1995 was similar to the long-term average, and yields in that year might be assumed to be similar to average. Effluent from sewage treatment plants is discharged in relatively small amounts to many headwater basins of White Clay Creek, and these contributions are included in the loads reported in table 30. Results of model simulation indicate that, for this time period, nitrate, ammonia, and orthophosphate yields (loads per acre) are least in the predominantly residential subbasins (Pike Creek, Mill Creek, and Middle Run) and greatest in the predominantly agricultural subbasins (Trout Run, and the upper West East and Middle Branches of White Clay Creek). Relative basin size does not necessarily determine the relative magnitude of the basin load. In some cases, the total load increases with basin size. For example, the simulated total nitrate loads are greatest in the second largest basin, the predominantly agricultural West Branch White Clay Creek near Chesterville, and least in the smallest subbasin, the agricultural Trout Run. In other cases, the magnitude of total load is not proportional to basin size. For example, the simulated total orthophosphate yields are greatest in Trout Run, a stream draining an area of a large number of mushroom growing operations, and least in Pike Creek, a mid-sized subbasin that drains a predominantly residential area served by sewers.

The HSPF model for the White Clay Creek Basin can be used to compare simulated loads in the White Clay Creek and other modeled areas to loads calculated from observed data in similar basins. Simulated loads for the White Clay Creek and adjacent Brandywine Creek Basins, where monitoring data are limited, are within the range of loads calculated in nearby basins to the west that drain to the Chesapeake Bay, where monitoring data are extensive (Langland and others, 1995). Evaluation of monitoring data from these nearby basins indicates a positive correlation between the percentage of land in agricultural use and calculated yields of nitrate, ammonia, phosphorus, and suspended sediment. Similar relations are indicated by results of the HSPF models for selected headwater subbasins in both White Clay Creek and Brandywine Creek Basins. Comparison of simulated and calculated yields suggests that the simulation provides reasonable results (figs. 42 and 43).

Table 30. *Simulated yields (loads per acre) and total loads of nitrate, ammonia, orthophosphate, and suspended sediment in 1995 for reaches draining selected headwater subbasins in the Hydrological Simulation Program–Fortran (HSPF) model of the White Clay Creek Basin (See figure 15 for location of model reaches.)*

[lb, pounds]

Model reach number	Subbasin stream name	Drainage area (acres)	Yield ‘				Total load (mass)			
			Nitrate (lb/acre)	Ammonia (lb/acre)	Ortho-phosphate (lb/acre)	Suspended sediment (tons/ acre)	Nitrate (lb)	Ammonia (lb)	Ortho-phosphate (lb)	Suspended sediment (tons)
1	West Br. near Chesterville[1]	6,538	11.23	0.77	7.10	1.46	73,400	5,058	46,400	9,559
2	Middle Br. at Wickerton[2]	6,090	11.23	.61	4.90	1.17	68,370	3,721	29,840	7,113
4	East Br. near West Grove[3]	3,971	10.36	.66	6.07	1.12	41,120	2,604	24,100	4,437
5	Upper East Br. near London Grove	1,706	12.30	.81	7.74	1.35	20,980	1,383	13,200	2,308
6	East Br. above Avondale[4]	5,369	11.65	0.78	7.23	1.30	62,540	4,206	38,830	6,962
7	Trout Run	878	14.07	2.44	21.82	1.58	12,350	2,144	19,160	1,383
15	Middle Run	2,490	6.63	.37	3.18	.92	16,510	920	7,923	2,284
16	Pike Creek	4,250	4.44	.27	1.20	.54	18,860	1,158	5,117	2,306
17	Mill Creek	8,285	4.85	.34	1.82	.61	40,160	2,851	15,040	5,045

[1] Receives effluent from Avongrove School District sewage treatment plant for a total of 3.6 pounds nitrate nitrogen, 4.3 pounds of ammonia nitrogen, and 11.2 pounds phosphorus in 1995.

[2] Receives effluent from West Grove Borough municipal sewage treatment plant for a total of 795 pounds nitrate nitrogen, 946 pounds ammonia nitrogen, and 1,160 pounds phosphorus in 1995.

[3] Receives effluent from Avongrove Trailer Park sewage treatment plant for a total of 14.4 pounds nitrate nitrogen, 17.5 pounds ammonia nitrogen, and 34.9 pounds phosphorus in 1995.

[4] Excludes loads from reach 5. Reach 6 receives effluent from Chatham Acres sewage treatment plant for a total of 28.3 pounds nitrate nitrogen, 33.6 pounds ammonia nitrogen, and 40.9 pounds phosphorus in 1995.

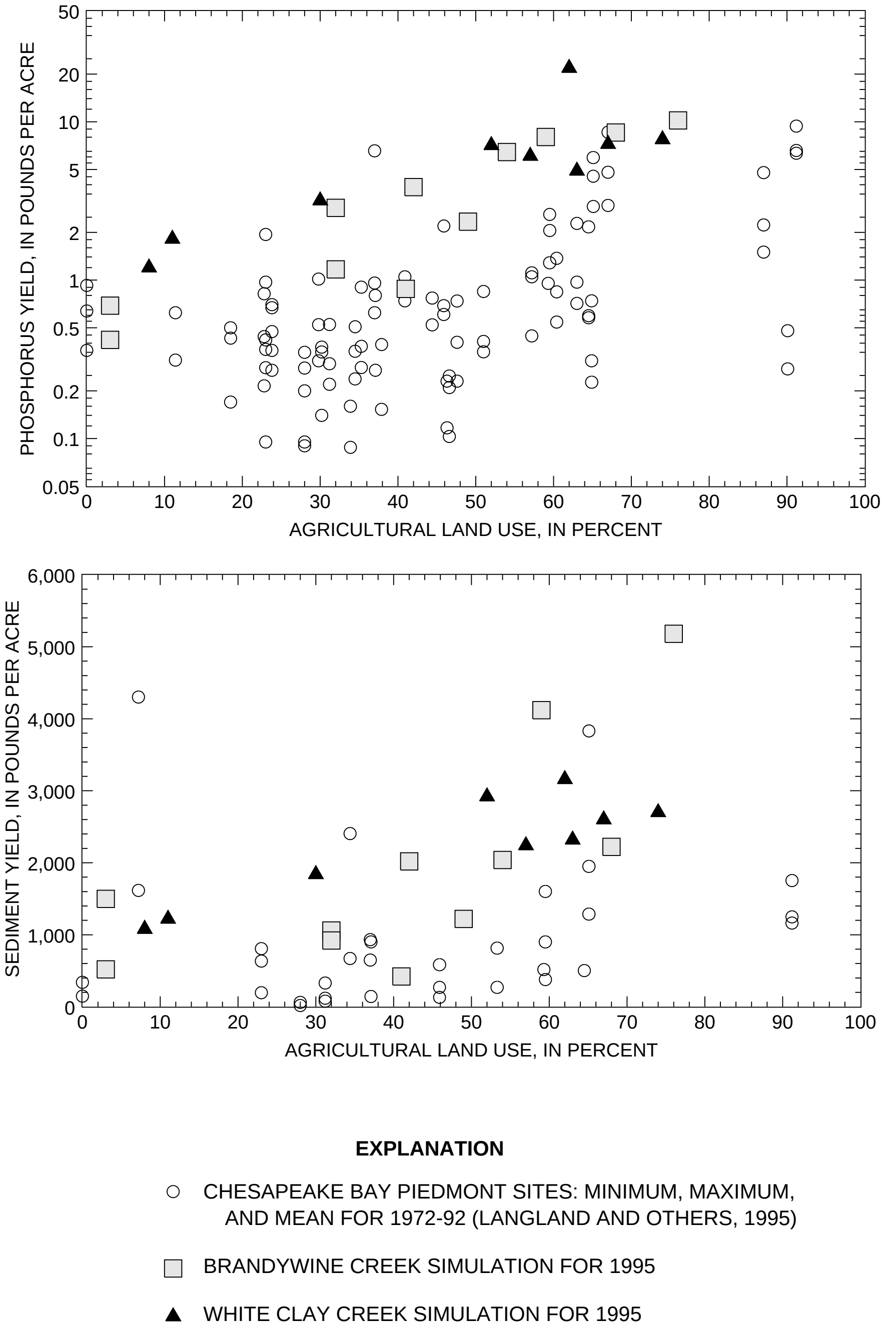


Figure 42. Phosphorus and sediment yields in relation to percentage agricultural land use as calculated from observed data for subbasins in the Chesapeake Bay Watershed and as simulated by Hydrologic Simulation Program–Fortran (HSPF) model tor selected subbasins in the Brandywine Creek and White Clay Creek Basins.

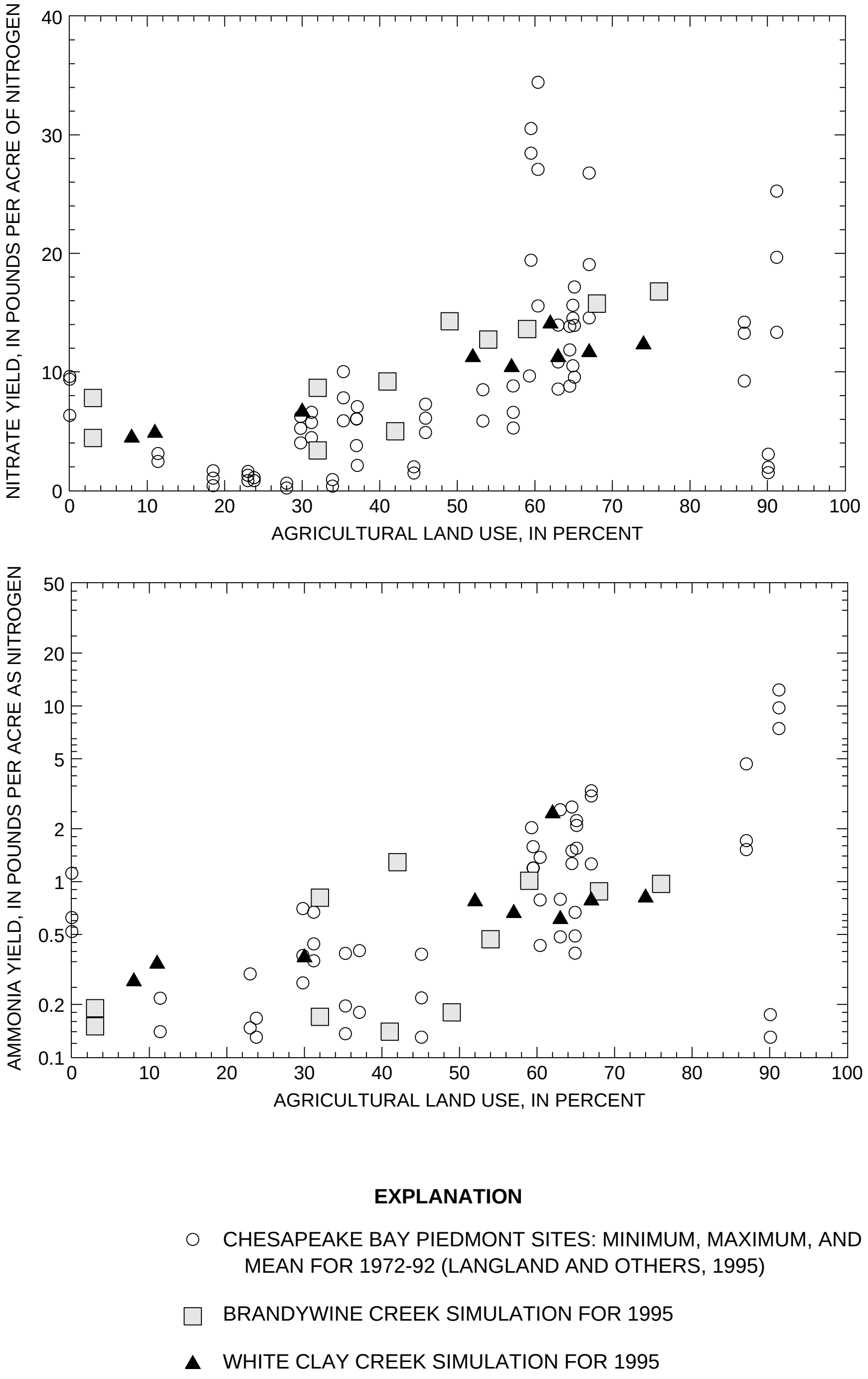


Figure 43. Nitrate and ammonia yields in relation to percentage agricultural land use as calculated from observed data for subbasins in the Chesapeake Bay watershed and as simulated by Hydrologic Simulation Program–Fortran (HSPF) model tor selected subbasins in the Brandywine Creek and White Clay Creek Basins.

The role of precipitation in generating sediment loads from land areas may be examined by plotting daily sediment yields and daily precipitation (fig. 44) for the model period. The plot of daily sediment yields for the drainage area above White Clay Creek near Newark and the daily average precipitation measured at the Coatesville 2 W and University Farm at Newark meteorological stations shows that daily loads generally increase with daily precipitation above about 0.5 in. Only 2 percent of the total sediment load generated from land areas during the model period is associated with daily precipitation of 0.5 in. or less. About 75 percent of the total sediment loads from land areas were generated by daily precipitation ranging from 0.5 to 2.0 in. Of the 75 percent of the sediment loads, daily precipitation ranging from 0.5 to 1.0 in. generated 24 percent, from 1.0 to 1.5 in. generated 28 percent, and from 1.5 to 2 in. generated 23 percent.

Concentrations, streamflow, and loads for ungaged areas may be estimated using the HSPF model. For example, water-quality samples were collected by DNREC near the mouth of Pike Creek but no streamflow data are available at that site. Comparison of observed and simulated values indicates that the model provides fairly good estimates of nitrate and dissolved orthophosphate values for the stream in this ungaged basin. At Pike Creek from 1994-98, observed concentrations of nitrate ranged from 0.73 to 2.95 mg/L as N; the average concentration was 2.07 mg/L as N. The difference between observed and simulated nitrate concentrations ranged from -1.40 to 1.12 mg/L as N; the average difference was 0.32 mg/L as N.

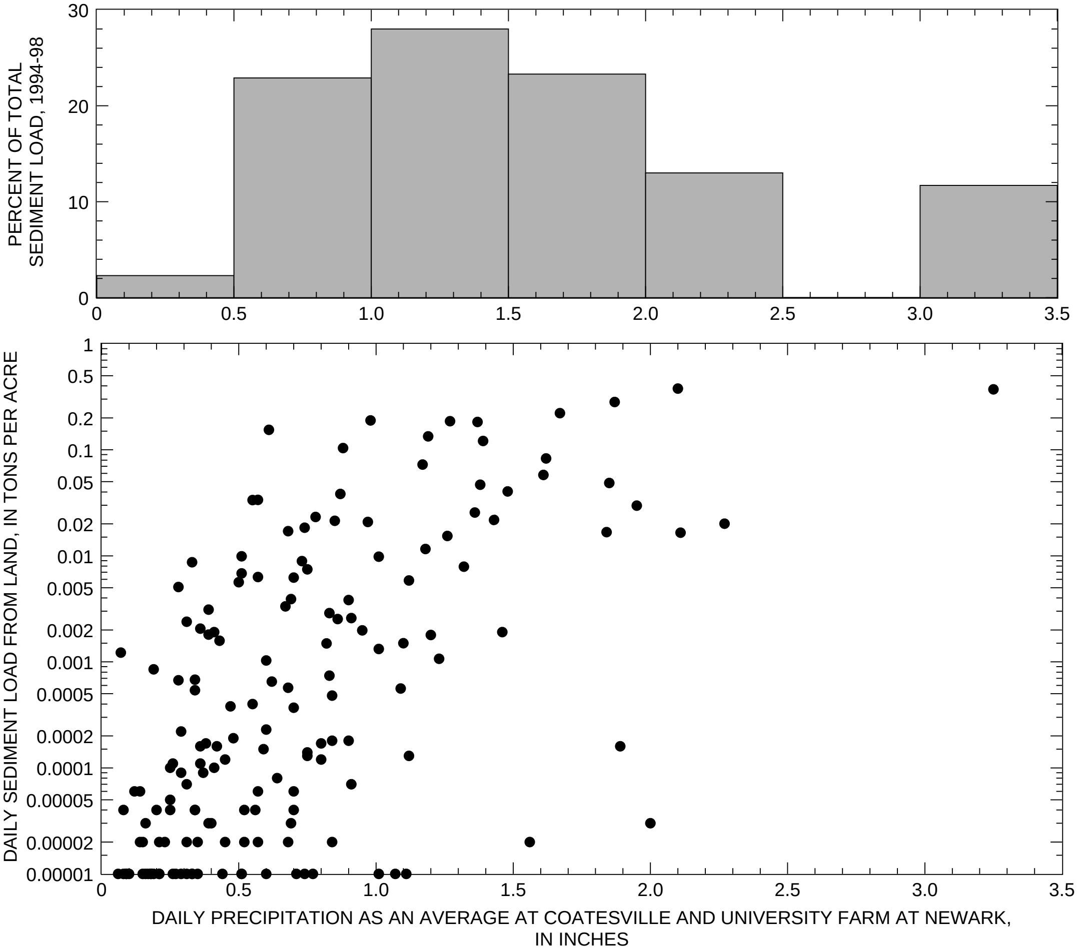


Figure 44. Simulated daily sediment yield and percentage of total simulated sediment yield for the drainage area above White Clay Creek near Newark, Del., in relation to observed daily average precipitation at the Coatesville 2 W and University Farm at Newark NOAA meteorological stations, October 1994 to October 1998.

Observed concentrations of dissolved orthophosphate ranged from 0.004 to 0.134 mg/L as P; the average concentration was 0.021 mg/L as P. The difference between observed and simulated dissolved orthophosphate concentrations ranged from 0.055 to -0.013 mg/L as P; the average difference was 0.003 mg/L as P.

The HSPF model for the White Clay Creek Basin also can be used to compare simulated loads from nonpoint sources generated from land areas to reported loads from point-source discharges to streams in the basin. For example, simulated loads of total nitrate, ammonia, and orthophosphate from pervious and impervious land areas as estimated by the HSPF model for the drainage area above White Clay Creek near Newark, Del., are listed with estimated and reported loads from point-source discharges to the White Clay Creek in table 31. Simulated loads for nitrate from nonpoint sources are about 400 times the estimated loads for these constituents from point sources. Simulated loads for ammonia from nonpoint sources are about 10 times the estimated loads for these constituents from point sources. Simulated total orthophosphate loads from nonpoint sources are about 100 times the estimated total phosphorus loads from point sources.

Table 31. *Total simulated nonpoint-source and estimated point-source loads of nitrate, ammonia, and phosphorus in the White Clay Creek Basin for the 4-year period October 1994 through September 1998*

	Total load, in tons		
	Nitrate	**Ammonia**	**Phosphorus**
Nonpoint source[1]	1,414	54	455
Point source[2]	[3] 3.5	4	4.7

[1] Calculated for drainage area above the gage 01479000 White Clay Creek near Newark, Del.

[2] Includes all discharges above White Clay Creek near Newark, Del.

[3] Estimated from reported ammonia loads.

The simulated loads shown in table 31 are for the whole basin for the 4-year period (October 1994 -September 1998) and include a range of hydrologic conditions. Using the model, simulated loads from selected subbasins and the whole White Clay Creek Basin could be estimated under baseflow and stormflow conditions. The HSPF model for the White Clay Creek Basin may be used as a predictive tool to estimate loads under statistically identified flow conditions based on some period of record.

An important part of using the White Clay Creek model as a predictive tool is determining that hydrologic conditions outside of the calibration period are represented adequately by calibration data. For this determination, the streamflow duration curve at station 01479000 White Clay Creek near Newark, Del., for the simulation period was compared to the duration curve for the 42-year period of record (October 1, 1959, to September 30, 2001) (fig. 45). In general, the observed streamflow duration curve for the simulation period compares reasonably well with the longer 42-year duration curve except for the highest 0.1 percent and lowest 0.1 percent of flows. The highest 0.1 percent of flows were greater in simulation-period data and represent conditions that occur no more than 0.1 percent of the time in the 42-year period of record. The lowest 0.1 percent flows of the 42-year record not observed during the 4-year simulation-period data likely will have minimal effect on estimation of nonpoint-source loads. Therefore, the model appears to be calibrated to hydrologic conditions representative of long-term conditions.

SUMMARY AND CONCLUSIONS

The Christina River Basin drains 565 mi^2 in Pennsylvania, Maryland, and Delaware and is used for recreation, drinking water supply, and support of aquatic life. The Christina River Basin includes the major subbasins of Brandywine Creek, Red Clay Creek, and White Clay Creek. The White Clay Creek is the second largest of the subbasins and drains an area of 108 mi^2. Monitoring data indicate that water quality in some parts of the Christina River Basin is impaired and does not support designated uses of the stream. A water-quality management strategy developed by a group of local, county, state, and federal agencies to address water-quality problems included a modeling component to evaluate the effects of point and nonpoint-source contributions of nutrients and suspended sediment on stream-water quality. The model selected for the nonpoint-source evaluation was HSPF. The HSPF model for the Christina River Basin was constructed and calibrated by the USGS in cooperation with the Delaware River Basin Commission, DNREC, and PADEP and consists of four independent models, one for each of the four main subbasins. This report covers the White Clay Creek subbasin only.

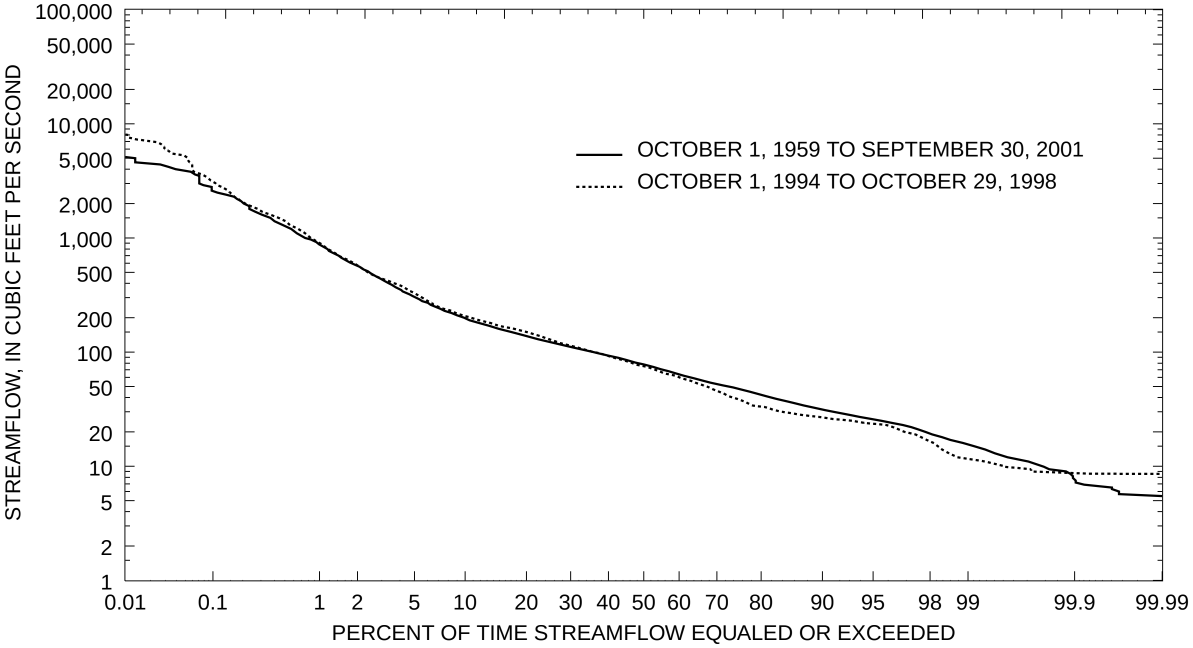


Figure 45. Duration curves of observed daily mean streamflow at 01479000 White Clay Creek near Newark, Del., for the period of record October 1, 1959, to September 30, 2001, and the period of model simulation, October 1, 1994, to October 29, 1998.

The USGS also developed and executed a nonpoint-source monitoring plan to collect water-quality data in the each of the three major subbasins and in the Christina River Basin and in small areas predominantly covered by one land use for model calibration. Under this plan, stormflow and base-flow samples were collected during 1998 at two sites in the White Clay Creek subbasin and at nine sites elsewhere in the Christina River Basin. One of the monitored stream sites, Trout Run at Avondale, Pa., in the White Clay Creek subbasin, drains a 1.37-mi^2 area predominantly covered by one land use, mushroom-growing agriculture. The other site, White Clay Creek near Newark, which is near the outlet of the White Clay Creek, drains about 90 mi^2 of mixed land uses. Water samples were analyzed for dissolved and total nutrients and suspended solids. Because suspended sediment analyses were not available, suspended-solids data were used as a surrogate for suspended-sediment data. Concentrations of suspended solids and total phosphorus were higher in stormflow than in base-flow samples, whereas dissolved nitrate concentrations tended to be higher in base-flow than stormflow samples. Water quality differed between the two nonpoint-source monitoring sites in the White Clay Creek subbasin. Suspended solids and nutrient concentrations were higher in the stream draining the predominantly agricultural area than in main stem downstream that drained areas of mixed land uses.

The HSPF model for the White Clay Creek Basin was used to simulate streamflow, suspended sediment, and the nutrients of nitrogen and phosphorus. For the model, the basin was subdivided into 17 reaches draining areas that ranged from 1.37 to 13 mi^2. Ten different pervious land uses and two impervious land uses were selected for simulation. Land-use areas were determined from 1995 land-use data. The predominant land uses in the basin are agricultural, forested, residential, and urban. Mushroom growing is an important type of agriculture in parts of the basin.

The hydrologic component of the model was run at an hourly time step and calibrated using streamflow data at four USGS streamflow-measurement stations for the 4-year simulation period of October 1, 1994, through October 29, 1998. Two of the four streamflow-measurement stations had a period of record shorter than 4 years. Daily precipitation data from two NOAA meteorological stations and hourly precipitation and other meteorological data from one NOAA station were used for model input. The difference between observed and simulated streamflow volume ranged from -0.9 to 1.8 percent for the 4-year period at the two calibration sites with sufficient record. Annual differences between observed and simulated streamflow generally were greater than the overall error for the 4-year simulation period. For example, at the White Clay Creek near Newark site near the outlet of the basin (drainage area of about 90 mi^2), annual differences between observed and simulated streamflow ranged from -5.8 to 14.4 percent and the overall error for the 4-year period was -0.9 percent. At the two streamflow-measurement stations with 4 years of record, calibration errors for total flow volume, low-flow-recession rate, 50-percent lowest flows, 10-percent highest flows, storm peaks and other seasonal measures generally were within recommended criteria for a satisfactory calibration. Much of the error in simulating storm events on an hourly time step can be attributed to uncertainty in the hourly rainfall data.

The water-quality component of the model used parameters from a calibrated model for the adjacent Brandywine Creek Basin and was calibrated with monitoring data collected at two nonpoint-source monitoring sites at USGS streamflow-measurement stations during six storms and four base-flow periods in 1998. Additional data collected by PADEP and DNREC from 1994 to 1998 at two USGS streamflow-measurement stations also were used to evaluate model calibration. Measured concentrations of suspended solids in stream samples were used as estimates for suspended sediment concentrations. Fewer data were available for water-quality calibration than for streamflow calibration. On the basis of limited water-quality data, the model simulates loads of suspended sediment, nitrate, dissolved and particulate ammonia, and dissolved and particulate orthophosphorus for storms that are within an order of magnitude of observed loads for most of the monitoring sites. Using recommended criteria for monthly or annual loads, simulation errors for loads of suspended sediment, nitrate, ammonia, and orthophosphate in individual storms ranged from ‘very good’ (errors less than 15 percent for sediment and less than 20 percent for other constituents) to worse than ‘fair’ (errors greater than 35 percent for sediment and greater than 40 percent for other constituents). The error in simulated water-quality loads typically is larger than the error in stormflow simulation and includes the error in stormflow simulation. Error in simulation of dissolved constituents generally was less than the error in simulation of particulate constituents.

Simulated yields (loads per acre) for suspended sediment, nitrate, ammonia, and orthophosphate were greatest from agricultural land uses compared to other simulated land uses. Simulated yields of suspended sediment, nitrate, and ammonia for subbasins in the White Clay Creek Basin were similar to yields calculated from monitoring data for subbasins in the nearby Chesapeake Bay drainage and to those simulated using a HSPF model for the adjacent Brandywine Creek Basin. Yields (expressed in pounds per acre) of these constituents tend to increase as the percentage of agricultural land increases. Simulated loads of nitrogen and phosphorus from nonpoint sources are greater than estimated loads of nitrogen and phosphorus from point sources in the White Clay Creek Basin.

Users of the White Clay Creek HSPF model should be aware of model limitations and consider the following when predictive scenarios are desired: duration curves indicate the model simulates streamflow reasonably well when evaluated over a broad range of conditions and time, although streamflow and the corresponding water-quality for individual storm events may not be well simulated; streamflow duration curves for the simulation period compare well with duration curves for the 42-year period ending in 2001 at White Clay Creek near Newark, Del., and include all but the extreme high-flow events; the magnitude of simulation errors tend to be inversely correlated to drainage area, with relative errors in flow and water-quality simulations for small drainage areas typically greater than relative errors for larger drainage areas; and calibration for water-quality was based on sparse data, with the result of increasing uncertainty in the water-quality simulation.

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APPENDIX 1

STORMFLOW AND BASE-FLOW WATER-QUALITY DATA

Table 1. *Results of laboratory analysis of stormflow samples collected at two sites in the White Clay Creek Basin, 1998*

DATE	TIME	ENDING DATE	ENDING TIME	AGENCY ANALYZING SAMPLE (CODE NUMBER) (00028)	AGENCY COLLECTING SAMPLE (CODE NUMBER) (00027)	ELEV. OF LAND SURFACE DATUM (FT. ABOVE NGVD) (72000)	DISCHARGE, IN CUBIC FEET PER SECOND (00060)	DISCHARGE, INST. CUBIC FEET PER SECOND (00061)	DRAINAGE AREA (SQ. MI.) (81024)	SPECIFIC CONDUCTANCE LAB (US/CM) (90095)	CHLORIDE, DISSOLVED (MG/L AS CL) (00940)	RESIDUE TOTAL AT 105 DEG. C, SUSPENDED (MG/L) (00530)	NITROGEN, AMMONIA DISSOLVED (MG/L AS N) (00608)
01478137 TROUT RUN AT AVONDALE, PA (LAT 39 49 18N LONG 075 46 46W)													
FEB 1998													
04...	1720	19980205	1225	10003	1028	270	<13	--	1.34	895	61.0	124	.932
04...	1850	--	--	10003	1028	270	--	4.3	1.34	735	57.0	194	.829
05...	0225	--	--	10003	1028	270	--	3.2	1.34	929	64.0	98	1.04
05...	0230	--	--	10003	1028	270	--	3.2	1.34	927	64.0	45	1.04
05...	1730	--	--	10003	1028	270	--	2.6	1.34	951	--	15	1.19
MAR													
08...	1400	19980309	1620	10003	1028	270	18	--	1.34	587	41.4	293	1.15
08...	1500	--	--	10003	1028	270	--	6.9	1.34	593	43.2	86	.552
08...	1630	--	--	10003	1028	270	--	9.1	1.34	503	34.4	94	.464
08...	2145	--	--	10003	1028	270	--	11	1.34	558	37.8	74	1.09
JUN													
11...	2119	19980613	1101	10003	1028	270	8.0	--	1.34	522	39.2	543	.613
11...	2219	--	--	10003	1028	270	--	1.4	1.34	912	63.1	11	.099
11...	2319	--	--	10003	1028	270	--	2.7	1.34	819	57.0	43	.237
12...	0019	--	--	10003	1028	270	--	5.2	1.34	607	49.2	61	.432
JUL													
08...	0718	--	--	10003	1028	270	--	6.2	1.34	543	34.3	180	.831
08...	0718	19980708	1654	10003	1028	270	12	--	1.34	377	26.4	965	.502
08...	0818	--	--	10003	1028	270	--	14	1.34	417	35.5	80	.527
08...	0918	--	--	10003	1028	270	--	23	1.34	318	22.4	627	.591
08...	1018	--	--	10003	1028	270	--	25	1.34	271	16.6	633	.338
08...	1218	--	--	10003	1028	270	--	7.4	1.34	511	34.5	179	1.07
OCT													
08...	1112	--	--	10003	1028	270	--	3.2	1.34	461	30.0	341	.035
08...	1112	19981009	2319	10003	1028	270	4.0	--	1.34	469	42.0	360	.680
08...	1212	--	--	10003	1028	270	--	14	1.34	386	31.0	540	.577
08...	1312	--	--	10003	1028	270	--	12	1.34	412	32.0	244	.600
08...	1512	--	--	10003	1028	270	--	9.1	1.34	533	54.0	289	1.50
08...	1612	--	--	10003	1028	270	--	6.6	1.34	587	57.0	144	1.06
01479000 WHITE CLAY CREEK NEAR NEWARK, DE (LAT 39 41 57N LONG 075 40 30W)													
MAR 1998													
08...	1330	19980309	1230	10003	1028	11.60	597	--	89.10	172	14.0	215	.055
08...	1745	--	--	10003	1028	11.60	--	320	89.10	191	17.1	59	.014
08...	2345	--	--	10003	1028	11.60	--	534	89.10	185	14.6	93	.046
09...	0345	--	--	10003	1028	11.60	--	647	89.10	164	13.5	104	.039
MAY													
01...	1835	19980502	2159	10003	1028	11.60	108	--	89.10	258	21.4	131	<.004
JUN													
12...	0157	--	--	10003	1028	11.60	--	109	89.10	175	22.0	94	.012
12...	0157	19980612	1851	10003	1028	11.60	422	--	89.10	218	13.4	226	.027
12...	0357	--	--	10003	1028	11.60	--	186	89.10	209	17.5	107	.005
12...	0557	--	--	10003	1028	11.60	--	224	89.10	179	15.4	90	.014
12...	0957	--	--	10003	1028	11.60	--	674	89.10	170	8.4	314	.059
12...	1157	--	--	10003	1028	11.60	--	595	89.10	137	11.6	224	.090
JUL													
08...	0840	--	--	10003	1028	11.60	--	134	89.10	182	15.2	171	.631
08...	0840	19980709	0407	10003	1028	11.60	244	--	89.10	194	13.6	224	.010
08...	1040	--	--	10003	1028	11.60	--	487	89.10	154	10.9	226	.060
08...	1240	--	--	10003	1028	11.60	--	186	89.10	137	8.8	119	.049
08...	1640	--	--	10003	1028	11.60	--	311	89.10	189	13.7	83	.041
08...	1840	--	--	10003	1028	11.60	--	347	89.10	237	17.1	84	.043
OCT													
08...	1320	19981009	1143	10003	1028	11.60	120	--	89.10	237	20.0	275	<.005
08...	1320	--	--	10003	1028	11.60	--	82	89.10	228	20.0	204	<.005
08...	1520	--	--	10003	1028	11.60	--	105	89.10	218	22.0	114	<.005
08...	1720	--	--	10003	1028	11.60	--	104	89.10	200	15.0	123	.012
08...	1920	--	--	10003	1028	11.60	--	84	89.10	193	16.0	47	.011

Table 1. *Results of laboratory analysis of stormflow samples collected at two sites in the White Clay Creek Basin, 1998—Continued*

01478137 Trout Run at Avondale, PA (LAT 39 49 18N LONG 075 46 46W)

DATE	NITROGEN, AMMONIA + ORGANIC DIS. (MG/L AS N) (00623)	NITROGEN, AMMONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITROGEN, AMMONIA TOTAL (MG/L AS N) (00610)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N) (00631)	PHOSPHORUS DISSOLVED (MG/L AS P) (00666)	PHOSPHORUS ORTHO, DISSOLVED (MG/L AS P) (00671)	PHOSPHORUS TOTAL (MG/L AS P) (00665)	CARBON, ORGANIC DISSOLVED (MG/L AS C) (00681)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)	OXYGEN DEMAND, BIOCHEM CARBON. 20 (MG/L) (80087)	OXYGEN DEMAND, CHEMICAL (HIGH LEVEL) (MG/L) (00340)
FEB 1998											
04...	1.9	2.9	1.01	6.52	.361	.146	.620	26.0	--	>12	--
04...	2.1	2.1	.971	5.08	.813	.620	1.64	17.0	--	>12	--
05...	2.2	2.9	1.10	6.55	.328	.099	.708	25.0	--	>12	--
05...	2.1	3.5	1.08	6.93	.286	.140	.514	24.0	--	>12	--
05...	2.5	4.6	1.23	6.72	.380	.319	.528	30.0	--	--	--
MAR											
08...	1.9	2.4	1.18	3.52	.411	.444	.441	28.0	--	13	--
08...	3.0	3.9	.571	4.57	.178	.150	.534	13.0	--	7.7	--
08...	2.6	4.3	.492	3.41	.181	.173	.530	13.0	--	7.7	--
08...	2.9	3.1	1.12	3.37	.233	.212	.549	22.0	--	7.7	--
JUN											
11...	4.3	7.3	.644	2.99	.290	.309	1.64	28.0	--	5.5	--
11...	3.9	4.1	.112	5.14	.352	.527	.416	27.0	--	5.9	--
11...	4.1	4.0	.258	5.16	.338	.379	.481	25.0	--	5.3	--
12...	2.6	3.5	.471	3.84	.325	.332	.536	23.0	--	6.5	--
JUL											
08...	2.5	3.9	.801	3.54	.403	.401	.930	15.0	--	14	--
08...	2.0	7.0	.449	2.25	.362	.371	2.78	19.0	--	13	--
08...	1.9	5.4	.508	2.37	.595	.612	1.71	15.0	--	18	--
08...	2.1	6.3	.564	1.92	.429	.438	2.14	18.0	--	18	--
08...	1.2	5.7	.253	1.97	.284	.308	1.92	14.0	--	>21	--
08...	4.4	5.2	.986	3.36	.588	.599	1.11	30.0	--	10	--
OCT											
08...	--	--	.046	.511	--	.038	--	10.0	--	11	--
08...	--	--	.611	2.99	--	.374	--	19.0	--	16	--
08...	--	--	.503	2.61	--	.695	--	13.0	--	20	--
08...	--	--	.778	2.14	--	.455	--	13.0	--	17	--
08...	--	--	1.35	3.21	--	.475	--	23.0	--	16	--
08...	--	--	.864	3.60	--	.449	--	22.0	--	10	--

01479000 WHITE CLAY CREEK NEAR NEWARK, DE (LAT 39 41 57N LONG 075 40 30W)

DATE	NITROGEN, AMMONIA + ORGANIC DIS. (MG/L AS N) (00623)	NITROGEN, AMMONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITROGEN, AMMONIA TOTAL (MG/L AS N) (00610)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N) (00631)	PHOSPHORUS DISSOLVED (MG/L AS P) (00666)	PHOSPHORUS ORTHO, DISSOLVED (MG/L AS P) (00671)	PHOSPHORUS TOTAL (MG/L AS P) (00665)	CARBON, ORGANIC DISSOLVED (MG/L AS C) (00681)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)	OXYGEN DEMAND, BIOCHEM CARBON. 20 (MG/L) (80087)	OXYGEN DEMAND, CHEMICAL (HIGH LEVEL) (MG/L) (00340)
MAR 1998											
08...	.63	2.3	.05	1.66	.093	.024	.344	10	9.0	25	52
08...	.41	1.1	.01	2.03	.090	.020	.221	8.0	6.0	7.3	16
08...	.48	1.4	.06	1.79	.118	.024	.162	6.0	4.0	5.4	14
09...	.63	1.5	.05	1.66	.097	.020	.210	5.0	5.0	4.3	46
MAY											
01...	.41	.76	<.004	2.50	.038	.044	.423	17	18	38	16
JUN											
12...	.69	1.9	.01	2.40	.062	.032	.204	16	25	16	<1
12...	.40	2.5	.02	1.75	.088	.034	.410	13	22	11	<1
12...	.55	2.0	.01	2.53	.108	.075	.266	11	13	9.2	<1
12...	.76	1.7	.03	1.85	.130	.060	.208	7.0	5.0	7.0	<1
12...	.78	3.0	.06	1.40	.077	.044	.717	8.0	11	4.8	1
12...	.77	2.5	.07	1.59	.089	.064	.450	9.0	9.0	5.5	<1
JUL											
08...	1.2	3.7	.68	1.78	.069	.096	.598	38	22	>22	120
08...	.26	2.3	.03	1.65	.031	.073	.449	10	7.0	16	55
08...	.64	2.0	.06	1.24	.053	.083	.432	6.0	6.0	8.2	50
08...	.73	1.4	.04	1.16	.233	.082	.308	7.0	6.0	7.3	42
08...	.29	1.00	.06	1.56	.041	.900	.231	6.0	5.0	6.9	2
08...	.17	1.3	.05	2.18	.116	.129	.404	6.0	4.0	6.0	39
OCT											
08...	--	--	.04	2.53	--	.190	--	8.0	9.0	16	4
08...	--	--	.03	1.89	--	<.005	--	33	38	18	85
08...	--	--	<.01	1.99	--	.123	--	7.0	8.0	7.5	14
08...	--	--	.02	1.62	--	.099	--	8.0	8.0	6.0	18
08...	--	--	.04	1.60	--	.127	--	8.0	9.0	5.8	10

Remark codes used in this report:
< -- Less than
> -- Greater than

Table 2. *Results of laboratory analysis of base-flow samples collected at two sites in the White Clay Creek Basin, 1998*

DATE	TIME	AGENCY ANA-LYZING SAMPLE (CODE NUMBER) (00028)	AGENCY COL-LECTING SAMPLE (CODE NUMBER) (00027)	ELEV. OF LAND SURFACE DATUM (FT. ABOVE NGVD) (72000)	DIS-CHARGE, INST. CUBIC FEET PER SECOND (00061)	DRAIN-AGE AREA (SQ. MI.) (81024)	OXYGEN, DIS-SOLVED (MG/L) (00300)	PH WATER WHOLE FIELD (STAND-ARD UNITS) (00400)	SPE-CIFIC CON-DUCT-ANCE (US/CM) (00095)	TEMPER-ATURE WATER (DEG C) (00010)	ANC WATER UNFLTRD FET FIELD MG/L AS CACO3 (00410)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL) (00940)	RESIDUE TOTAL AT 105 DEG. C, SUS-PENDED (MG/L) (00530)
01478137 TROUT RUN AT AVONDALE, PA (LAT 39 49 18N LONG 075 46 46W)													
APR 1998													
27...	1240	10003		270	1.5	1.34	11.0	8.1	680	13.2	188	63.4	9
JUL													
23...	1215	10003		270	1.2	1.34	7.1	7.1	700	25.1	223	50.0	6
SEP													
15...	1240	10003		270	.30	1.34	7.9	7.5	750	20.4	251	50.0	<1
01479000 WHITE CLAY CREEK NEAR NEWARK, DE (LAT 39 41 57N LONG 075 40 30W)													
JAN 1998													
12...	0946	10003	1028	11.60	57	89.10	10.4	6.3	211	4.2	69	26.0	3
APR													
27...	0858	10003	1028	11.60	110	89.10	10.6	6.4	271	1.3	43	23.6	5
JUL													
23...	1055	10003	1028	11.60	61	89.10	8.0	7.6	248	24.8	63	20.0	8
SEP													
15...	1022	10003	1028	11.60	24	89.10	8.5	6.9	322	22.1	84	26.0	1

DATE	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS N) (00608)	NITRO-GEN,AM-MONIA + ORGANIC DIS. (MG/L AS N) (00623)	NITRO-GEN,AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO-GEN, AMMONIA TOTAL (MG/L AS N) (00610)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N) (00631)	PHOS-PHORUS DIS-SOLVED (MG/L AS P) (00666)	PHOS-PHORUS ORTHO, DIS-SOLVED (MG/L AS P) (00671)	PHOS-PHORUS TOTAL (MG/L AS P) (00665)	CARBON, ORGANIC DIS-SOLVED (MG/L AS C) (00681)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)	OXYGEN DEMAND, BIOCHEM CARBON. 20 (MG/L) (80087)	OXYGEN DEMAND, CHEM-ICAL (HIGH LEVEL) (MG/L) (00340)	PHEO-PHYTIN PHYTO-PLANK-TON, ACID M. (UG/L) (32218)
01478137 TROUT RUN AT AVONDALE, PA (LAT 39 49 18N LONG 075 46 46W)													
APR 1998													
27...	1.20	4.2	4.6	1.30	5.57	.797	.718	.913	25	8.2	<2.00	--	<2.00
JUL													
23...	.051	.56	1.1	.06	4.48	.390	.385	.401	8.0	2.5	8.00	--	8.00
SEP													
15...	.15	.59	1.3	.03	4.43	.623	.653	.960	7.0	<2.4	<2.00	--	<2.00
01479000 WHITE CLAY CREEK NEAR NEWARK, DE (LAT 39 41 57N LONG 075 40 30W)													
JAN 1998													
12...	--	--	.27	.03	2.86	--	.066	.083	4.0	5.0	<2.40	--	5.00
APR													
27...	.018	.64	.88	.02	3.34	.015	.019	.043	4.0	5.0	2.5	26	<2.00
JUL													
23...	.036	.77	1.2	.06	2.39	.095	.147	.143	4.0	4.0	<2.4	8	<2.00
SEP													
15...	<.005	.59	.65	.01	2.57	.280	.324	.365	4.0	3.0	<2.4	5	<2.00

DATE	CHLORO-HPYLL A PHYTO-PLANK-TON ACID M. (UG/L) (32211)
01478137 TROUT RUN AT AVONDALE, PA (LAT 39 49 18N LONG 075 46 46W)	
APR 1998	
27...	53.00
JUL	
23...	5.00
SEP	
15...	3.00
01479000 WHITE CLAY CREEK NEAR NEWARK, DE (LAT 39 41 57N LONG 075 40 30W)	
JAN 1998	
12...	3.00
APR	
27...	8.00
JUL	
23...	8.00
SEP	
15...	3.00

Remark codes used in this report:

< -- Less than

APPENDIX 2

SIMULATED STORMFLOW AND WATER QUALITY FOR SAMPLED STORMS IN 1998

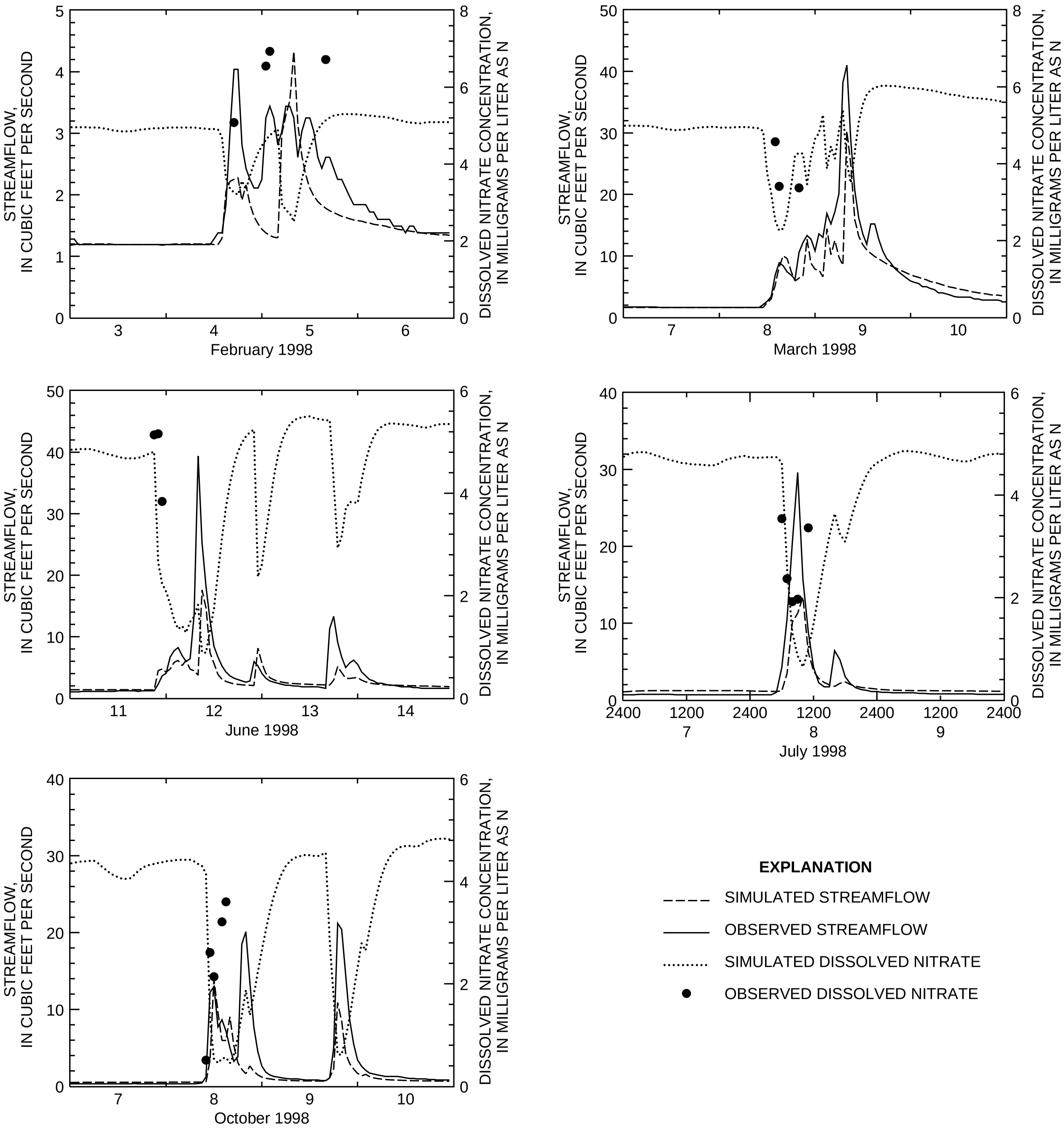

Figure 1. Simulated and observed streamflow and concentrations of dissolved nitrate during five storms in 1998 at streamflow-measurement station 01478137, Trout Run at Rt. 41 at Avondale, Pa.

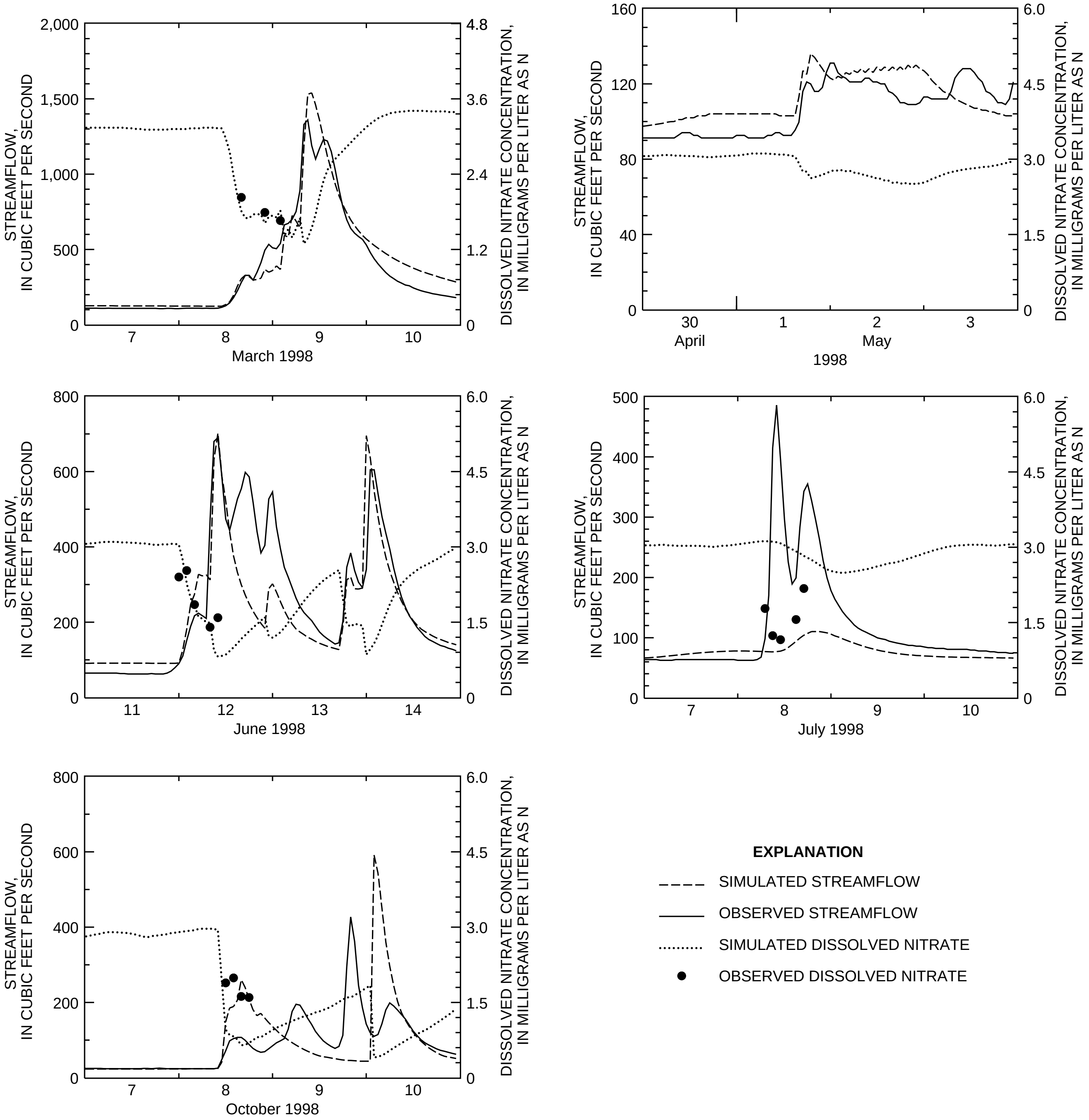

Figure 2. Simulated and observed streamflow and concentrations of dissolved nitrate during five storms in 1998 at streamflow-measurement station 0147900, White Clay Creek near Newark, Del. (Instantaneous samples were not collected during the May 1998 storm at this station.)

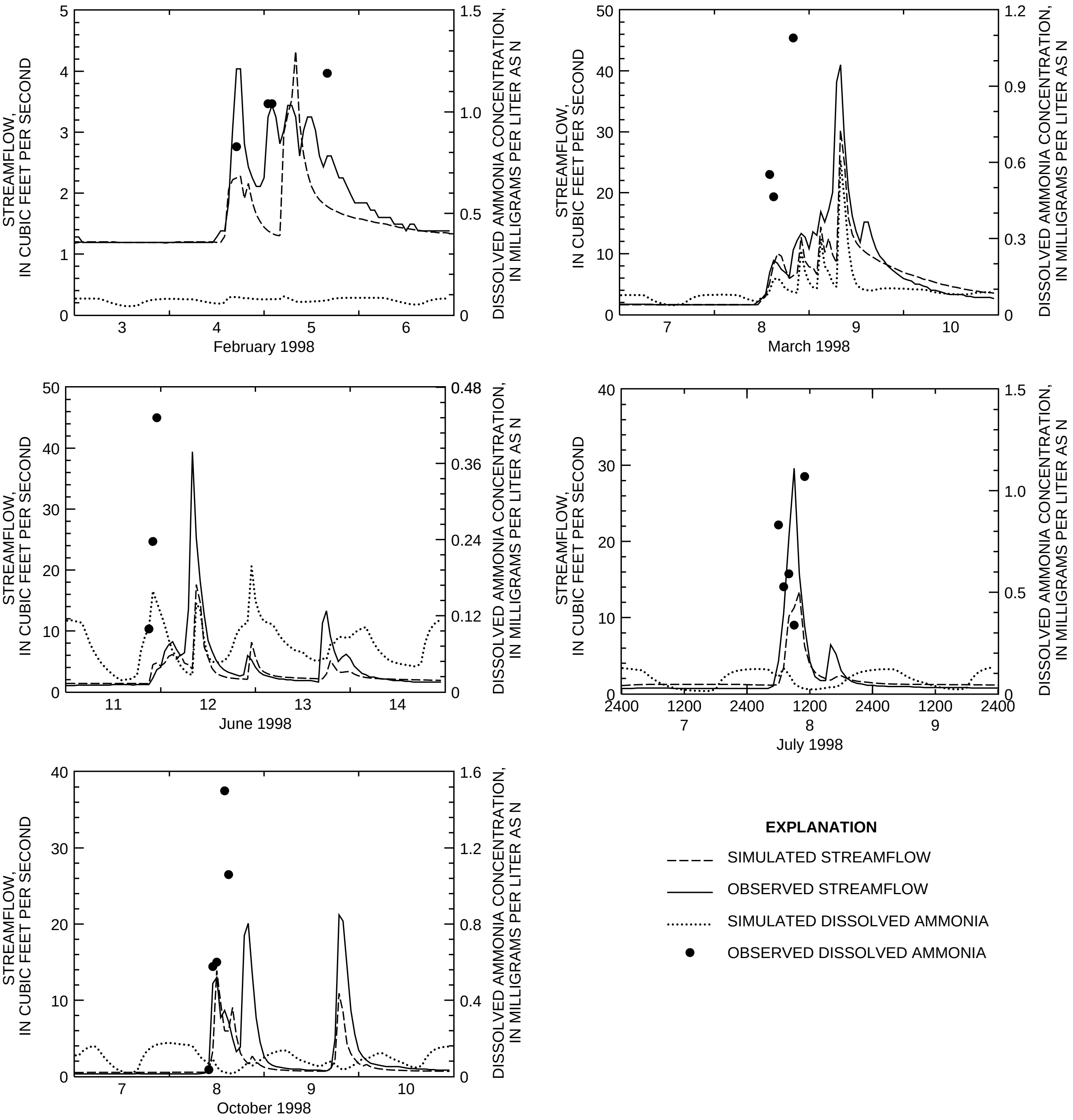

Figure 3. Simulated and observed streamflow and concentrations of dissolved ammonia during five storms in 1998 at streamflow-measurement station 01478137, Trout Run at Rt. 41 at Avondale, Pa.

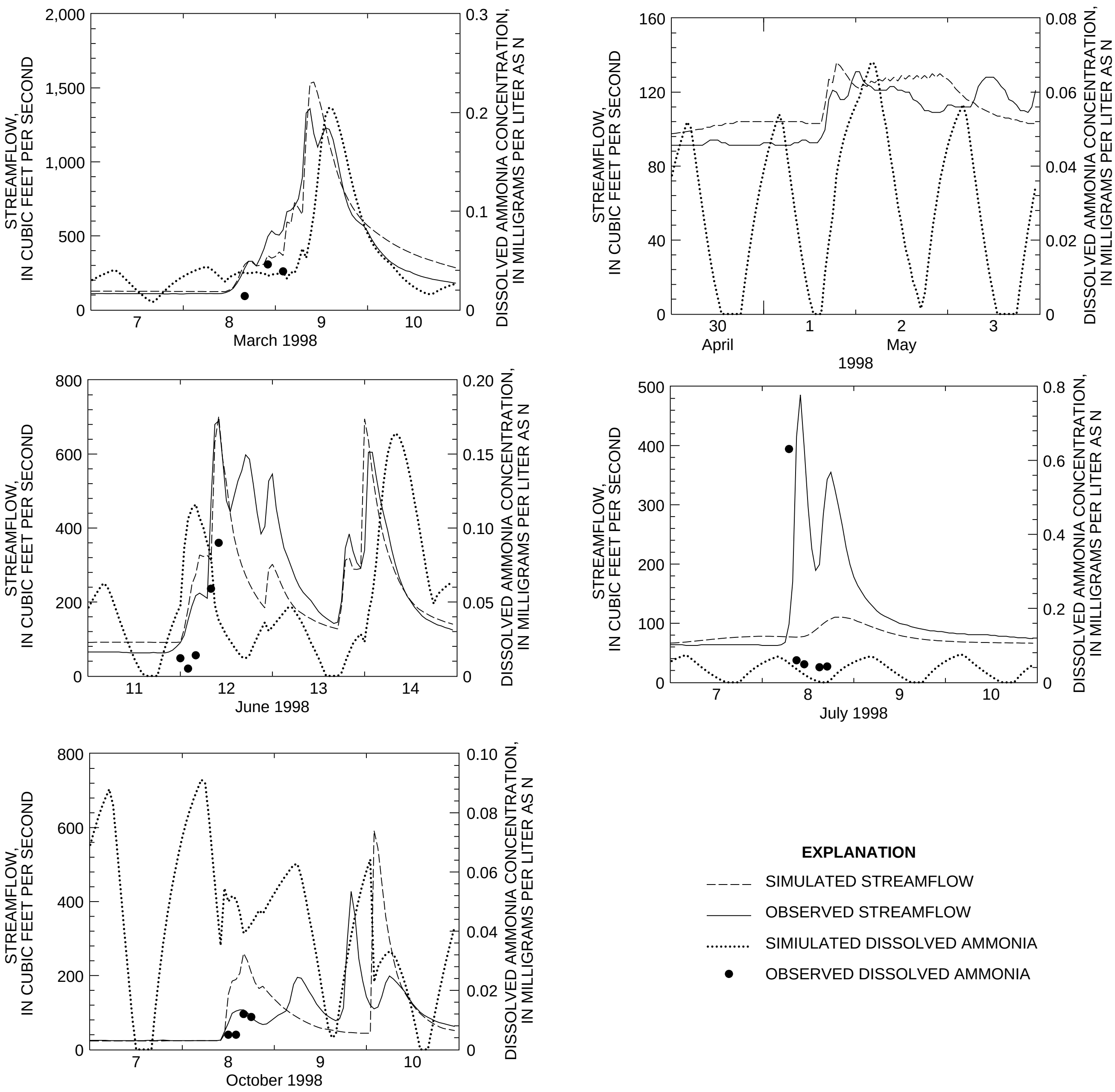

Figure 4. Simulated and observed streamflow and concentrations of dissolved ammonia during five storms in 1998 at streamflow-measurement station 0147900, White Clay Creek near Newark, Del. (Instantaneous samples were not collected during the May 1998 storm at this station.)

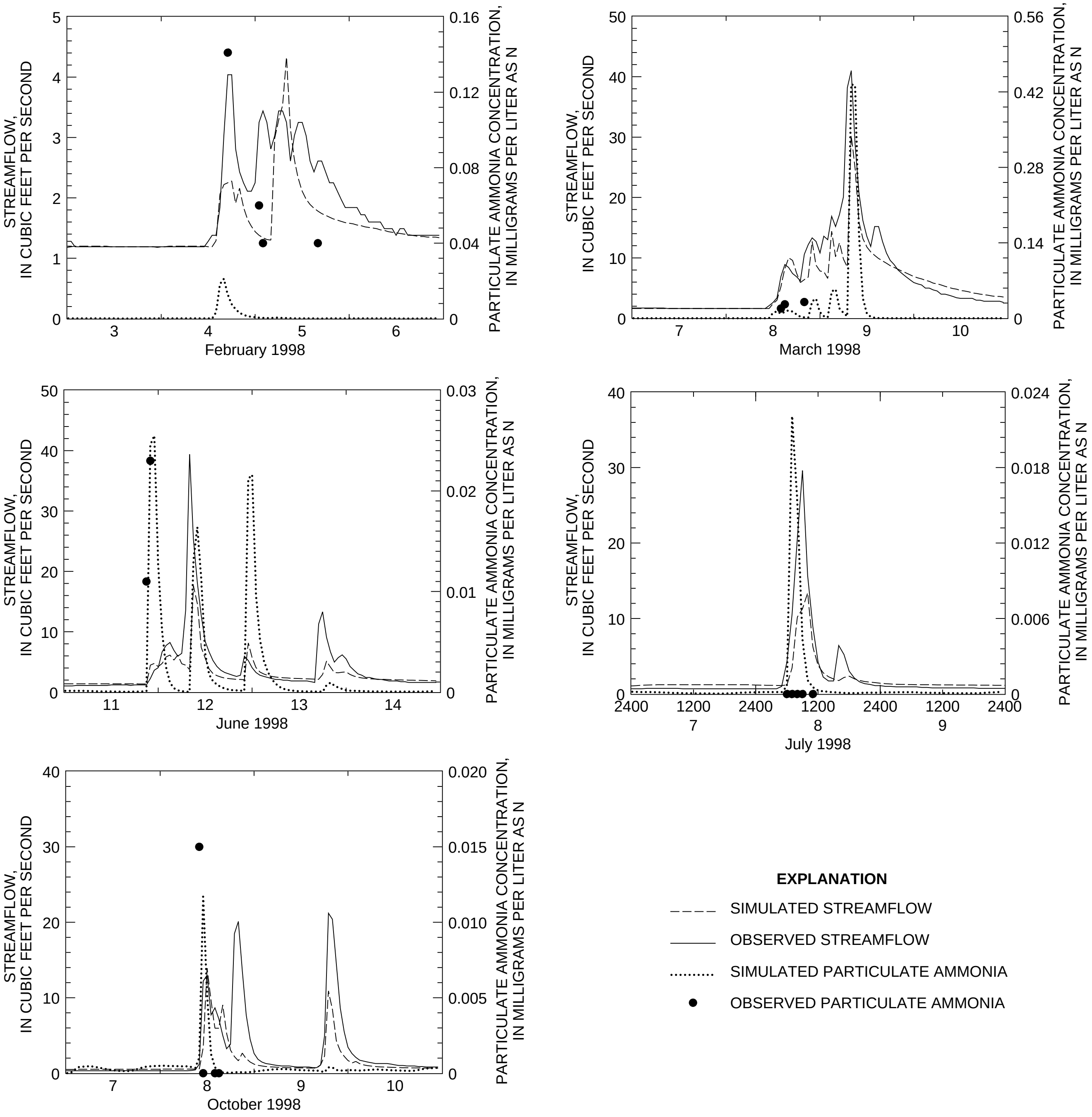

Figure 5. Simulated and observed streamflow and concentrations of particulate ammonia during five storms in 1998 at streamflow-measurement station 01478137, Trout Run at Rt. 41 at Avondale, Pa.

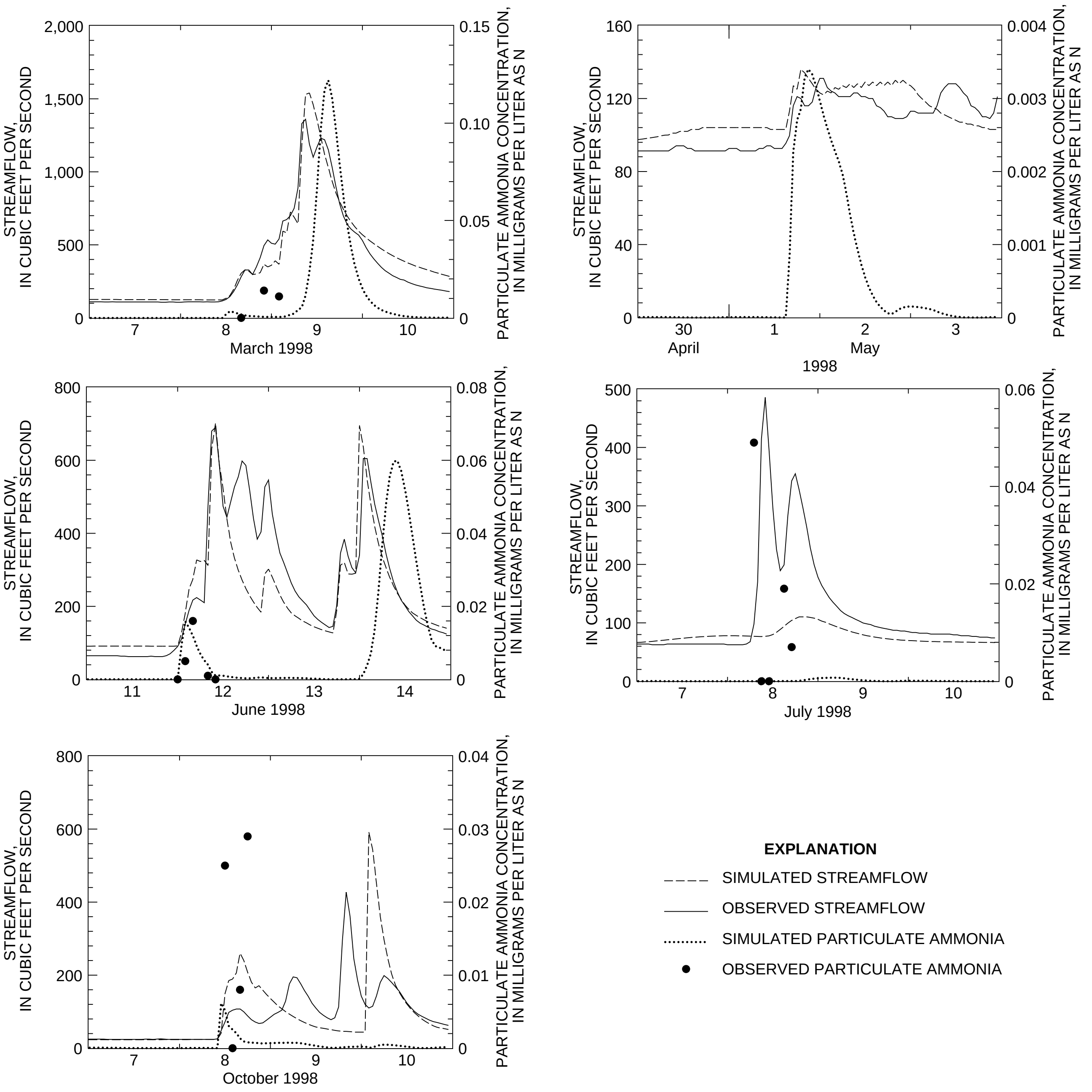

Figure 6. Simulated and observed streamflow and concentrations of particulate ammonia during five storms in 1998 at streamflow-measurement station 0147900, White Clay Creek near Newark, Del. (Instantaneous samples were not collected during the May 1998 storm at this station.)

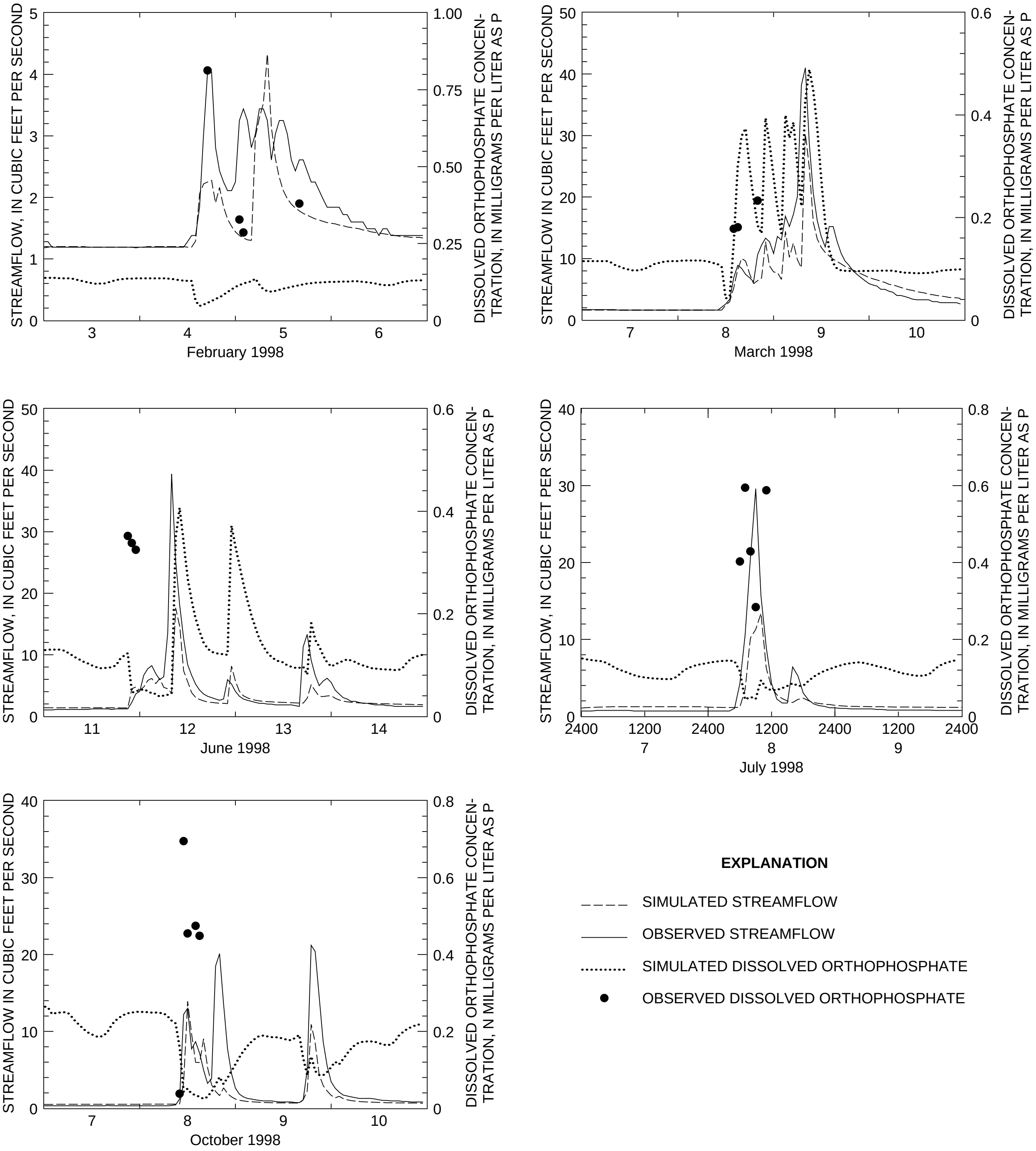

Figure 7. Simulated and observed streamflow and concentrations of dissolved orthophosphate during five storms in 1998 at streamflow-measurement station 01478137, Trout Run at Rt. 41 at Avondale, Pa.

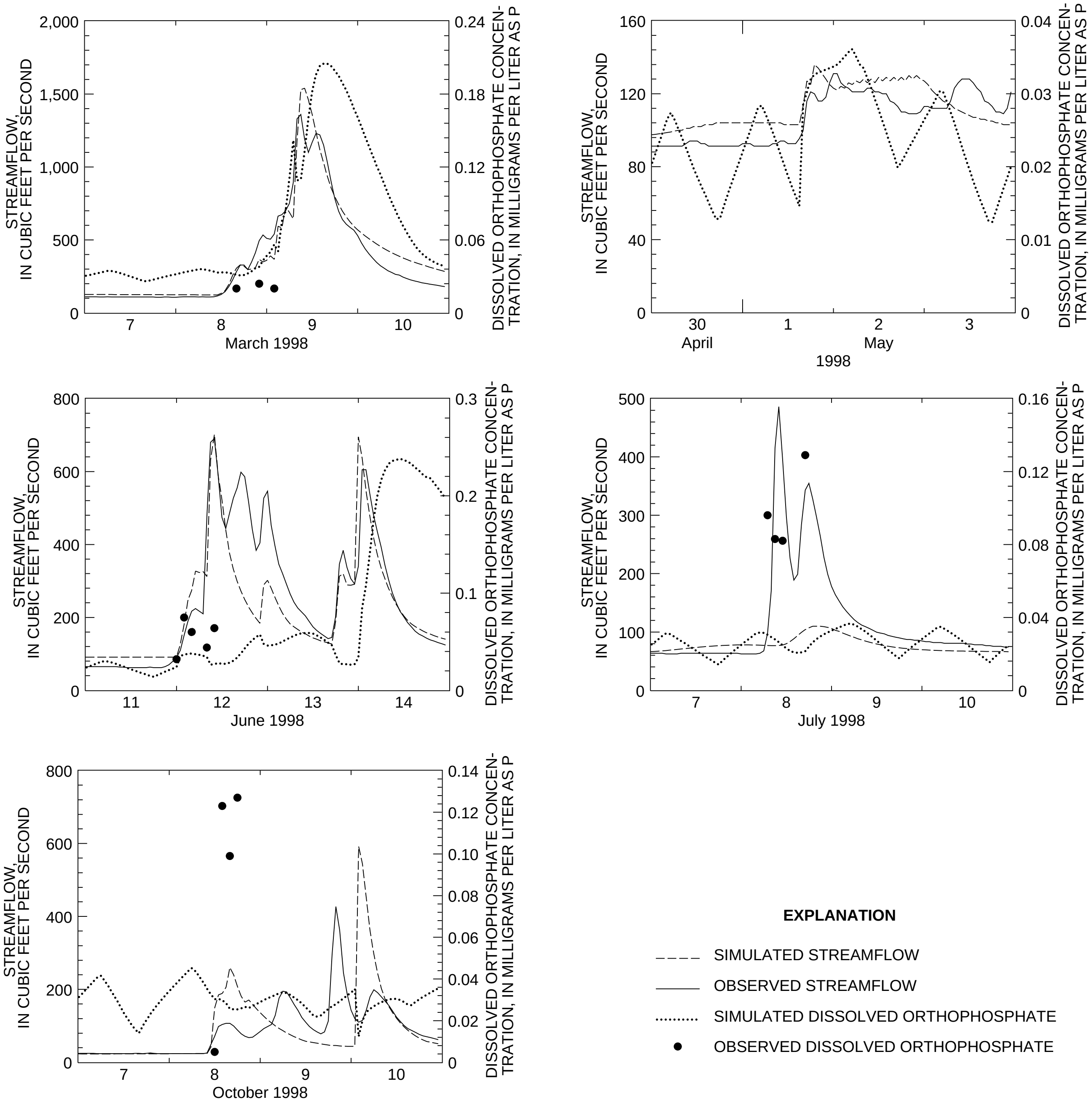

Figure 8. Simulated and observed streamflow and concentrations of dissolved orthophosphate during five storms in 1998 at streamflow-measurement station 0147900, White Clay Creek near Newark, Del. (Instantaneous samples were not collected during the May 1998 storm at this station.)

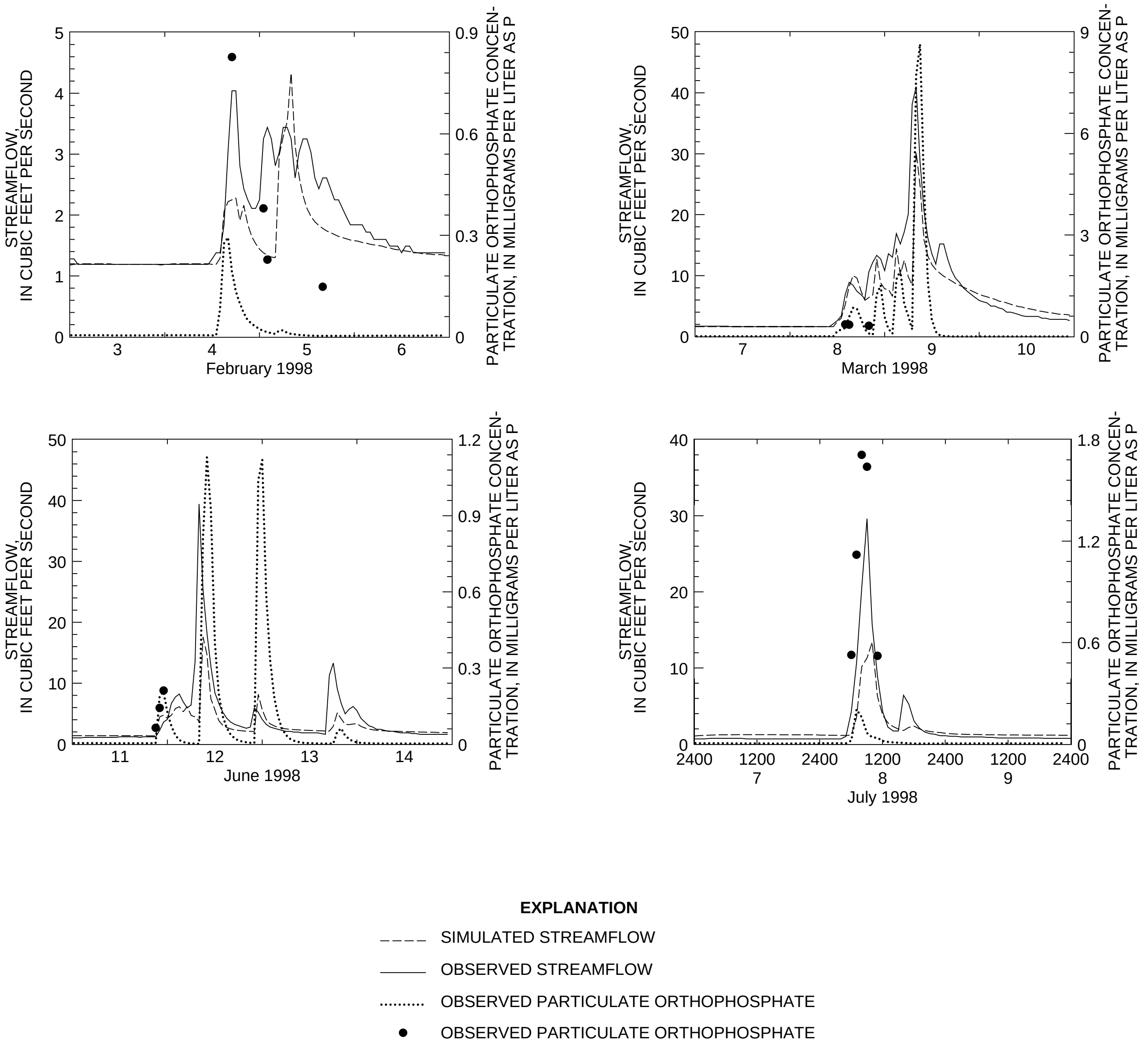

Figure 9. Simulated and observed streamflow and concentrations of particulate orthophosphate during five storms in 1998 at streamflow-measurement station 01478137, Trout Run at Rt. 41 at Avondale, Pa.

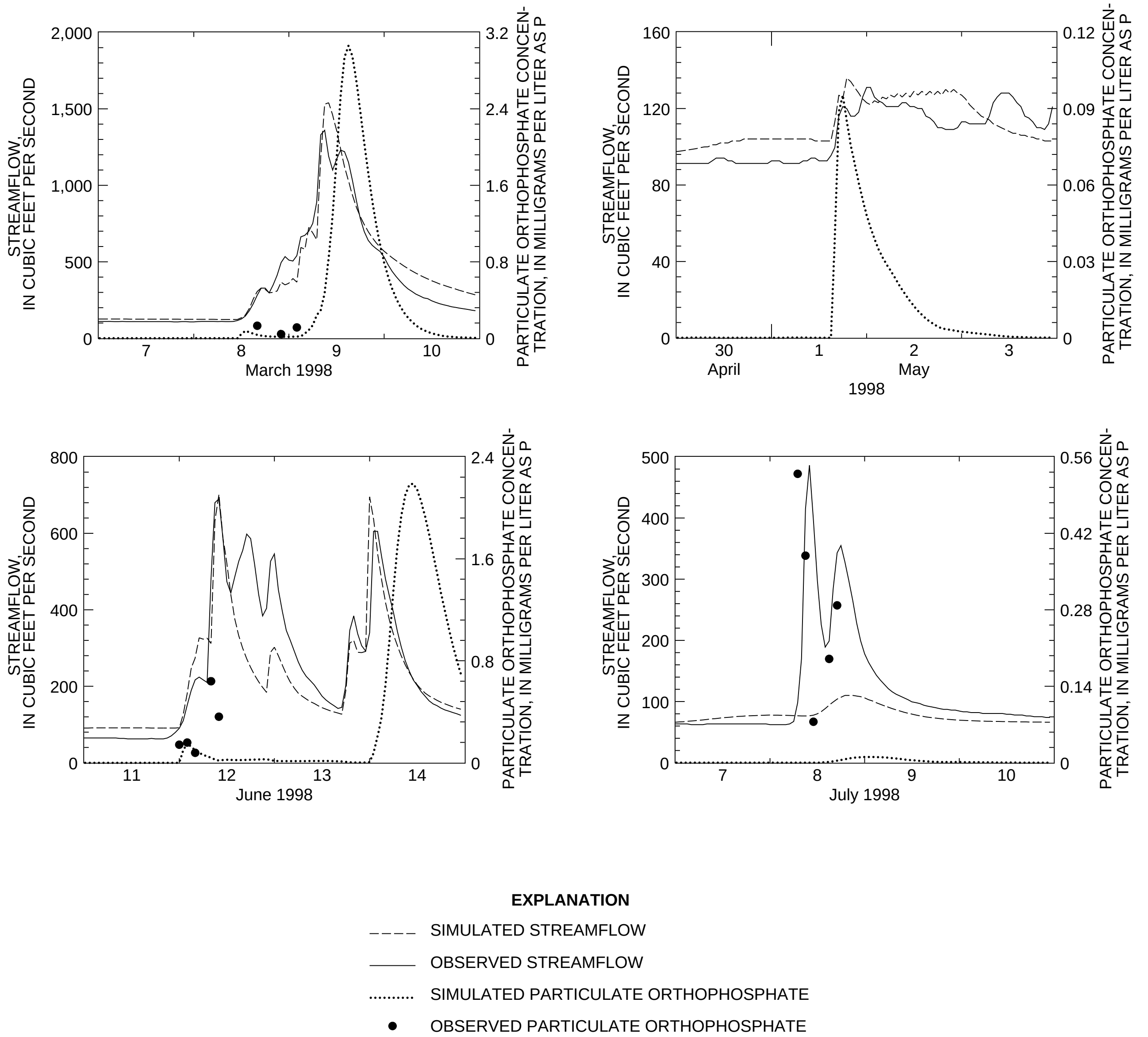

Figure 10. Simulated and observed streamflow and concentrations of particulate orthophosphate during five storms in 1998 at streamflow-measurement station 0147900, White Clay Creek near Newark, Del. (Instantaneous samples were not collected during the May 1998 storm at this station.)

APPENDIX 3

USER CONTROL INPUT (UCI) FILE
FOR HSPF MODEL OF WHITE CLAY CREEK BASIN

```
RUN
GLOBAL
WHITE CLAY CREEK HYDROLOGY - BASE SCENARIO - ALL SEGMENTS
  START       1994 10  1  0  0  END    1998 10 29 24  0
  RUN INTERP OUTPUT LEVEL    3    2
  RESUME     0 RUN     1                   UNIT SYSTEM     1
END GLOBAL

FILES
<type>  <UN#>***<------------fname---------------------------------------------->
WDM        26   whtclay.wdm
MESSU      25   whtclay.ech
           90   whtclay.out
END FILES

OPN SEQUENCE
    INGRP              INDELT  1:00
      PERLND     702
      PERLND     703
      PERLND     704
      PERLND     705
      PERLND     706
      PERLND     707
      PERLND     708
      PERLND     709
      PERLND     710
      PERLND     711
      IMPLND     701
      IMPLND     702
      RCHRES       2
      COPY       100
      RCHRES       4
      RCHRES       5
      GENER        1
      GENER        2
      COPY        10
      COPY       300
      RCHRES       6
      RCHRES       7
      GENER        3
      GENER        4
      COPY        11
      COPY       400
      PERLND     502
      PERLND     503
      PERLND     504
      PERLND     505
      PERLND     506
      PERLND     507
      PERLND     508
      PERLND     509
      PERLND     510
      PERLND     511
      IMPLND     501
      IMPLND     502
      RCHRES       1
      COPY       200
      RCHRES       3
      RCHRES       8
      RCHRES       9
      GENER        5
      GENER        6
      COPY        12
      COPY       500
      RCHRES      10
      GENER        7
      GENER        8
      COPY        13
      COPY       530
      RCHRES      11
      COPY       540
      RCHRES      15
      COPY       550
      RCHRES      16
      COPY       560
      PERLND     802
      PERLND     803
      PERLND     804
      PERLND     805
      PERLND     806
      PERLND     807
      PERLND     808
      PERLND     809
      PERLND     810
      PERLND     811
      IMPLND     801
      IMPLND     802
      RCHRES      12
      GENER        9
      GENER       10
      COPY        14
      COPY       600
```

```
      RCHRES      13
      RCHRES      17
      GENER       11
      GENER       12
     COPY       15
      COPY       610
      RCHRES      14

    END INGRP

END OPN SEQUENCE

PERLND
  ACTIVITY
    #    # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC   ***
  502  811    1    1    1    1    1    1    1    0    0    0    0    0
  END ACTIVITY

  PRINT-INFO
    #    # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC *********
  502  811    6    6    5    5    6    6    5    0    0    0    0    0    0   12
  END PRINT-INFO

  GEN-INFO
    #    #      NAME          NBLKS  UCI   IN  OUT ENGL METR  ***
  702     RESIDENTIAL-SEPTIC      1    1    1    1   90    0
  703     RESIDENTIAL-SEWER       1    1    1    1   90    0
  704     COMMERCIAL/INDUSTRY     1    1    1    1   90    0
  705     AGRICULTURAL-COWS       1    1    1    1   90    0
  706     AGRICULTURAL-CROPS      1    1    1    1   90    0
  707     AGRICULTURAL-MUSHROOM   1    1    1    1   90    0
  708     FOREST                  1    1    1    1   90    0
  709     OPEN LAND               1    1    1    1   90    0
  710     WETLANDS, WATER         1    1    1    1   90    0
  711     undesignated use        1    1    1    1   90    0
  502     RESIDENTIAL-SEPTIC      1    1    1    1   90    0
  503     RESIDENTIAL-SEWER       1    1    1    1   90    0
  504     COMMERCIAL/INDUSTRY     1    1    1    1   90    0
  505     AGRICULTURAL-COWS       1    1    1    1   90    0
  506     AGRICULTURAL-CROPS      1    1    1    1   90    0
  507     AGRICULTURAL-MUSHROOM   1    1    1    1   90    0
  508     FOREST                  1    1    1    1   90    0
  509     OPEN LAND               1    1    1    1   90    0
  510     WETLANDS, WATER         1    1    1    1   90    0
  511     undesignated use        1    1    1    1   90    0
  802     RESIDENTIAL-SEPTIC      1    1    1    1   90    0
  803     RESIDENTIAL-SEWER       1    1    1    1   90    0
  804     COMMERCIAL/INDUSTRY     1    1    1    1   90    0
  805     AGRICULTURAL-COWS       1    1    1    1   90    0
  806     AGRICULTURAL-CROPS      1    1    1    1   90    0
  807     AGRICULTURAL-MUSHROOM   1    1    1    1   90    0
  808     FOREST                  1    1    1    1   90    0
  809     OPEN LAND               1    1    1    1   90    0
  810     WETLANDS, WATER         1    1    1    1   90    0
  811     undesignated use        1    1    1    1   90    0
  END GEN-INFO

**** AIR TEMPERATURE ****

  ATEMP-DAT
               ELDAT    AIRTMP ***
    #    #      (ft)   (deg F) ***
  702  711    -200.0      48.3
  502  511     175.0      53.6
  802  811       0.0      53.6
  END ATEMP-DAT

**** SNOW ****

  ICE-FLAG
*** <PLS > ICEFG
*** #    #
  502  811    1
  END ICE-FLAG

  SNOW-PARM1
*** <PLS >       LAT     MELEV     SHADE    SNOWCF    COVIND
*** #    #     (deg)      (ft)                          (in)
  702  711     39.86      450.      0.20       1.0      0.60
  502  511     39.77      250.      0.20       1.0      0.60
  802  811     39.70       75.      0.20       1.0      0.60
  END SNOW-PARM1

  SNOW-PARM2
*** <PLS >     RDSCN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT
*** #    #              (degF)                                (in/day)
  702  711      0.15      30.0      0.05      0.60      0.03     0.010
  502  511      0.15      30.0      0.05      0.60      0.03     0.021
  802  811      0.15      30.0      0.05      0.60      0.03     0.021
  END SNOW-PARM2

**** HYDROLOGY ****
```

```
  PWAT-PARM1
*** <PLS >                   Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE IFFC
  702         1    0    0    1    0    0    0    1    1    1
  703         1    0    0    1    0    0    0    1    1    1
  704         1    0    0    1    0    0    0    1    1    1
  705         1    0    0    1    0    0    0    1    1    1
  706         1    0    0    1    0    0    0    1    1    1
  707         1    0    0    1    0    0    0    1    1    1
  708         1    0    0    1    0    0    0    1    1    1
  709         1    0    0    1    0    0    0    1    1    1
  710         1    0    0    0    0    0    0    1    0    1
  711         1    0    0    1    0    0    0    1    1    1
  502         1    0    0    1    0    0    0    1    1    1
  503         1    0    0    1    0    0    0    1    1    1
  504         1    0    0    1    0    0    0    1    1    1
  505         1    0    0    1    0    0    0    1    1    1
  506         1    0    0    1    0    0    0    1    1    1
  507         1    0    0    1    0    0    0    1    1    1
  508         1    0    0    1    0    0    0    1    1    1
  509         1    0    0    1    0    0    0    1    1    1
  510         1    0    0    0    0    0    0    1    0    1
  511         1    0    0    1    0    0    0    1    1    1
  802         1    0    0    1    0    0    0    1    1    1
  803         1    0    0    1    0    0    0    1    1    1
  804         1    0    0    1    0    0    0    1    1    1
  805         1    0    0    1    0    0    0    1    1    1
  806         1    0    0    1    0    0    0    1    1    1
  807         1    0    0    1    0    0    0    1    1    1
  808         1    0    0    1    0    0    0    1    1    1
  809         1    0    0    1    0    0    0    1    1    1
  810         1    0    0    0    0    0    0    1    0    1
  811         1    0    0    1    0    0    0    1    1    1
  END PWAT-PARM1

  PWAT-PARM2
***  <PLS>    FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
***  x - x                (in)   (in/hr)      (ft)              (1/in)   (1/day)
  702            0.0     8.500     0.120     275.0    0.1962     0.000     0.987
  703            0.0     8.500     0.120     275.0    0.1908     0.000     0.987
  704            0.0     8.500     0.120     275.0    0.1944     0.000     0.987
  705            0.0     8.500     0.130     275.0    0.1727     0.000     0.987
  706            0.0     8.500     0.130     275.0    0.1727     0.000     0.987
  707            0.0     8.500     0.070     275.0    0.1727     0.000     0.987
  708            0.0     8.500     0.170     275.0    0.1980     0.000     0.987
  709            0.0     8.500     0.130     275.0    0.1962     0.000     0.987
  710            0.0     8.500     0.100     275.0    0.1835     0.000     0.987
  711            0.0     8.500     0.120     275.0    0.1763     0.000     0.987
  502            0.0     8.000     0.140     500.0    0.2623     0.000     0.985
  503            0.0     8.000     0.140     500.0    0.1998     0.000     0.985
  504            0.0     8.000     0.140     500.0    0.1423     0.000     0.985
  505            0.0     8.000     0.140     500.0    0.2290     0.000     0.985
  506            0.0     8.000     0.140     500.0    0.2290     0.000     0.985
  507            0.0     8.000     0.070     500.0    0.2290     0.000     0.985
  508            0.0     8.000     0.180     500.0    0.3076     0.000     0.985
  509            0.0     8.000     0.140     500.0    0.2089     0.000     0.985
  510            0.0     8.000     0.100     500.0    0.2107     0.000     0.985
  511            0.0     8.000     0.140     500.0    0.1016     0.000     0.985
  802            0.0     7.500     0.120     200.0    0.1423     0.000     0.986
  803            0.0     7.500     0.120     200.0    0.1423     0.000     0.986
  804            0.0     7.500     0.120     200.0    0.0928     0.000     0.986
  805            0.0     7.500     0.130     200.0    0.1175     0.000     0.986
  806            0.0     7.500     0.130     200.0    0.1175     0.000     0.986
  807            0.0     7.500     0.080     200.0    0.1175     0.000     0.986
  808            0.0     7.500     0.170     200.0    0.1246     0.000     0.986
  809            0.0     7.500     0.120     200.0    0.0840     0.000     0.986
  810            0.0     7.500     0.100     200.0    0.0367     0.000     0.986
  811            0.0     7.500     0.120     200.0    0.0594     0.000     0.986
  END PWAT-PARM2

  PWAT-PARM3
***  <PLS>    PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
***  x - x   (deg F)   (deg F)
  702  709      40.0      36.0       2.0       2.0     0.030     0.045     0.000
  710           40.0      36.0       2.0       2.0     0.030     0.045     0.400
  711           40.0      36.0       2.0       2.0     0.030     0.045     0.000
  502  509      40.0      36.0       2.0       2.0     0.010     0.040     0.000
  510           40.0      36.0       2.0       2.0     0.010     0.040     0.300
  511           40.0      36.0       2.0       2.0     0.010     0.040     0.000
  802  809      40.0      36.0       2.0       2.0     0.000     0.010     0.000
  810           40.0      36.0       2.0       2.0     0.000     0.010     0.050
  811           40.0      36.0       2.0       2.0     0.000     0.010     0.000
  END PWAT-PARM3

  PWAT-PARM4
*** <PLS >     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x      (in)      (in)                         (1/day)
  702          0.050     0.700      0.35       1.5     0.300     0.600
  703          0.050     0.700      0.30       1.5     0.300     0.600
  704          0.050     0.600      0.25       1.5     0.300     0.600
  705          0.050     0.400      0.20       1.5     0.300     0.700
```

```
  706          0.050     0.400      0.30       1.5     0.300     0.700
  707          0.050     0.600      0.30       1.5     0.300     0.600
  708          0.100     1.000      0.35       1.5     0.300     0.800
  709          0.050     0.600      0.30       1.5     0.300     0.600
  710          0.050     1.000      0.05       1.5     0.300     0.900
  711          0.050     0.600      0.30       1.5     0.300     0.600
  502          0.050     0.700      0.35       0.9     0.300     0.600
  503          0.050     0.700      0.30       0.9     0.300     0.600
  504          0.050     0.600      0.25       0.9     0.300     0.600
  505          0.050     0.400      0.20       0.9     0.300     0.700
  506          0.050     0.400      0.30       0.9     0.300     0.700
  507          0.050     0.600      0.30       0.9     0.300     0.600
  508          0.100     1.000      0.35       0.9     0.300     0.800
  509          0.050     0.600      0.30       0.9     0.300     0.600
  510          0.050     1.000      0.05       0.9     0.300     0.900
  511          0.050     0.600      0.30       0.9     0.300     0.600
  802          0.050     0.800      0.35       3.0     0.300     0.600
  803          0.050     0.800      0.30       3.0     0.300     0.600
  804          0.050     0.700      0.25       3.0     0.300     0.600
  805          0.050     0.400      0.20       3.0     0.300     0.700
  806          0.050     0.400      0.30       3.0     0.300     0.700
  807          0.050     0.600      0.30       3.0     0.300     0.600
  808          0.100     1.200      0.35       3.0     0.300     0.800
  809          0.050     0.700      0.30       3.0     0.300     0.600
  810          0.050     1.000      0.05       3.0     0.300     0.900
  811          0.050     0.700      0.30       3.0     0.300     0.600
  END PWAT-PARM4

  MON-INTERCEP
*** <PLS >  Interception storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  702  704 .040 .040 .060 .080 .100 .100 .100 .100 .080 .060 .040 .040
  705  707 .030 .030 .030 .030 .060 .090 .110 .110 .110 .080 .070 .030
  708      .040 .040 .070 .110 .140 .160 .160 .150 .120 .090 .050 .040
  709  711 .040 .040 .060 .080 .100 .100 .100 .100 .080 .060 .040 .040
  502  504 .040 .040 .060 .080 .100 .100 .100 .100 .080 .060 .040 .040
  505  507 .030 .030 .030 .030 .060 .090 .110 .110 .110 .080 .070 .030
  508      .040 .040 .070 .110 .140 .160 .160 .150 .120 .090 .050 .040
  509  511 .040 .040 .060 .080 .100 .100 .100 .100 .080 .060 .050 .040
  802  804 .040 .040 .060 .080 .100 .100 .100 .100 .080 .060 .040 .040
  805  807 .030 .030 .030 .030 .060 .090 .110 .110 .110 .080 .070 .030
  808      .040 .040 .070 .110 .140 .160 .160 .150 .120 .090 .050 .040
  809  811 .040 .040 .060 .080 .100 .100 .100 .100 .080 .060 .050 .040
  END MON-INTERCEP

  MON-UZSN
*** <PLS >  Upper zone storage at start of each month  (inches)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  705  706 .350 .350 .400 .430 .450 .450 .400 .400 .400 .400 .350 .350
  505  506 .400 .400 .400 .430 .450 .450 .400 .400 .400 .400 .400 .400
  805  806 .400 .400 .400 .430 .450 .450 .400 .400 .400 .400 .400 .400
  END MON-UZSN

  MON-IRC
***
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  502  811  0.3  0.3  0.3  0.3  0.4  0.5  0.5  0.5  0.4  0.4  0.4  0.3
  END MON-IRC

  MON-LZETPARM
*** <PLS >  Lower zone evapotranspir parm at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  702  707  0.7  0.7  0.7  0.7  0.7  0.7  0.7  0.7  0.0  0.3  0.7  0.7
  708       0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.0  0.4  0.8  0.8
  709  711  0.7  0.7  0.7  0.7  0.7  0.7  0.7  0.7  0.0  0.3  0.7  0.7
  502  507  0.7  0.7  0.7  0.7  0.7  0.7  0.7  0.7  0.0  0.3  0.7  0.7
  508       0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.0  0.4  0.8  0.8
  509  511  0.7  0.7  0.7  0.7  0.7  0.7  0.7  0.7  0.0  0.3  0.7  0.7
  802  807  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.0  0.3  0.6  0.6
  808       0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.0  0.4  0.8  0.8
  809  811  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.0  0.3  0.6  0.6
  END MON-LZETPARM

  PWAT-STATE1
***  <PLS>  PWATER state variables (in)
***  x - x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  702            0.0       0.0       .70       0.0       8.5       1.0       0.0
  703            0.0       0.0       .70       0.0       8.5       1.0       0.0
  704            0.0       0.0       .60       0.0       8.5       1.0       0.0
  705            0.0       0.0       .40       0.0       8.5       1.0       0.0
  706            0.0       0.0       .40       0.0       8.5       1.0       0.0
  707            0.0       0.0       .60       0.0       8.5       1.0       0.0
  708            0.0       0.0      1.00       0.0       8.5       1.0       0.0
  709            0.0       0.0       .60       0.0       8.5       1.0       0.0
  710            0.0       0.0       .90       0.0       8.5       1.0       0.0
  711            0.0       0.0       .60       0.0       8.5       1.0       0.0
  502            0.0       0.0       .70       0.0       8.5       1.6       0.0
  503            0.0       0.0       .70       0.0       8.5       1.6       0.0
  504            0.0       0.0       .60       0.0       8.5       1.6       0.0
  505            0.0       0.0       .40       0.0       8.5       1.6       0.0
  506            0.0       0.0       .40       0.0       8.5       1.6       0.0
  507            0.0       0.0       .60       0.0       8.5       1.6       0.0
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  508            0.0       0.0      1.00       0.0       8.5       1.6       0.0
  509            0.0       0.0       .60       0.0       8.5       1.6       0.0
  510            0.0       0.0       .90       0.0       8.5       1.6       0.0
  511            0.0       0.0       .60       0.0       8.5       1.6       0.0
  802            0.0       0.0       .80       0.0       7.5       1.5       0.0
  803            0.0       0.0       .80       0.0       7.5       1.5       0.0
  804            0.0       0.0       .70       0.0       7.5       1.5       0.0
  805            0.0       0.0       .40       0.0       7.5       1.5       0.0
  806            0.0       0.0       .40       0.0       7.5       1.5       0.0
  807            0.0       0.0       .70       0.0       7.5       1.5       0.0
  808            0.0       0.0      1.20       0.0       7.5       1.5       0.0
  809            0.0       0.0       .70       0.0       7.5       1.5       0.0
  810            0.0       0.0       .90       0.0       7.5       1.5       0.0
  811            0.0       0.0       .70       0.0       7.5       1.5       0.0
  END PWAT-STATE1

  SED-PARM1
*** <PLS >  Sediment parameters 1
*** x -  x  CRV VSIV SDOP
  502  811    1    0    1
  END SED-PARM1

  SED-PARM2
*** <PLS >      SMPF      KRER      JRER     AFFIX     COVER      NVSI
*** x -  x                                  (/day)           lb/ac-day
  702  703     1.000     0.500     2.000     0.010     0.000     1.000
  704          1.000     0.500     2.000     0.010     0.000     1.000
  705  706     1.000     0.500     2.000     0.010     0.000     1.000
  707          1.000     0.500     2.000     0.010     0.000     1.000
  708          1.000     0.450     2.000     0.002     0.000     2.000
  709          1.000     0.500     2.000     0.010     0.000     2.000
  710          1.000     0.400     2.000     0.002     0.000     2.000
  711          1.000     0.500     2.000     0.010     0.000     2.000
  502  503     1.000     0.500     2.000     0.010     0.000     1.000
  504          1.000     0.500     2.000     0.010     0.000     1.000
  505  506     1.000     0.520     2.000     0.010     0.000     1.000
  507          1.000     0.520     2.000     0.010     0.000     1.000
  508          1.000     0.450     2.000     0.002     0.000     2.000
  509          1.000     0.500     2.000     0.010     0.000     2.000
  510          1.000     0.400     2.000     0.002     0.000     2.000
  511          1.000     0.500     2.000     0.010     0.000     2.000
  802  803     1.000     0.500     2.000     0.010     0.000     1.000
  804          1.000     0.500     2.000     0.010     0.000     1.000
  805  806     1.000     0.520     2.000     0.010     0.000     1.000
  807          1.000     0.520     2.000     0.010     0.000     1.000
  808          1.000     0.450     2.000     0.002     0.000     2.000
  809          1.000     0.500     2.000     0.010     0.000     2.000
  810          1.000     0.400     2.000     0.002     0.000     2.000
  811          1.000     0.450     2.000     0.010     0.000     2.000
  END SED-PARM2

  SED-PARM3
*** <PLS >  Sediment parameter 3
*** x -  x      KSER      JSER      KGER      JGER
  702          0.350     1.750     0.020     2.000
  703          0.450     1.750     0.040     2.000
  704          0.650     1.750     0.090     2.000
  705  706     2.250     1.750     0.080     2.000
  707          2.450     1.750     0.080     2.000
  708          0.185     1.750     0.000     2.000
  709          0.450     1.750     0.005     2.000
  710          0.008     1.750     0.000     2.000
  711          0.450     1.750     0.005     2.000
  502          0.150     1.800     0.010     2.000
  503          0.225     1.800     0.020     2.000
  504          0.375     1.800     0.055     2.000
  505  506     1.650     1.800     0.045     2.000
  507          1.800     1.800     0.045     2.000
  508          0.100     1.800     0.000     2.000
  509          0.225     1.800     0.004     2.000
  510          0.005     1.800     0.000     2.000
  511          0.225     1.800     0.004     2.000
  802          0.350     1.700     0.025     2.000
  803          0.550     1.700     0.045     2.000
  804          0.800     1.700     0.100     2.000
  805  806     2.600     1.700     0.085     2.000
  807          2.800     1.700     0.090     2.000
  808          0.250     1.700     0.000     2.000
  809          0.500     1.700     0.007     2.000
  810          0.008     1.700     0.000     2.000
  811          0.500     1.700     0.007     2.000
  END SED-PARM3

  MON-COVER
*** <PLS >  Monthly values for erosion related cover
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  702  704 0.90 0.90 0.90 0.91 0.93 0.93 0.93 0.93 0.93 0.91 0.90 0.90
***  705  706 0.50 0.45 0.00 0.00 0.10 0.50 0.75 0.93 0.93 0.85 0.70 0.55
  705  706 0.50 0.45 0.20 0.10 0.15 0.45 0.65 0.65 0.65 0.60 0.60 0.55
  707      0.50 0.45 0.10 0.10 0.10 0.50 0.50 0.50 0.50 0.50 0.50 0.50
  708      0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97
  709      0.90 0.90 0.90 0.90 0.92 0.93 0.93 0.93 0.93 0.91 0.90 0.90
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  710      0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97
  711      0.90 0.90 0.90 0.90 0.92 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  502  504 0.90 0.90 0.90 0.91 0.93 0.93 0.93 0.93 0.93 0.91 0.90 0.90
*** 505  507 0.50 0.45 0.00 0.00 0.10 0.50 0.75 0.93 0.93 0.85 0.70 0.55
  505  506 0.50 0.45 0.20 0.10 0.15 0.45 0.65 0.65 0.65 0.60 0.60 0.55
  507      0.50 0.45 0.10 0.10 0.10 0.50 0.50 0.50 0.50 0.50 0.50 0.50
  508      0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97
  509      0.90 0.90 0.90 0.90 0.92 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  510      0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97
  511      0.90 0.90 0.90 0.90 0.92 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  802  804 0.90 0.90 0.90 0.91 0.93 0.93 0.93 0.93 0.93 0.91 0.90 0.90
***  805  807 0.50 0.45 0.00 0.00 0.10 0.50 0.75 0.93 0.93 0.85 0.70 0.55
  805  806 0.50 0.45 0.20 0.10 0.15 0.45 0.65 0.65 0.65 0.60 0.60 0.55
  807      0.50 0.45 0.10 0.10 0.10 0.50 0.50 0.50 0.50 0.50 0.50 0.50
  808      0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97
  809      0.90 0.90 0.90 0.90 0.92 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  810      0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97
  811      0.90 0.90 0.90 0.90 0.92 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  END MON-COVER

  SED-STOR
*** <PLS >  Detached sediment storage (tons/acre)
*** x -  x      DETS
  502  811    0.4000
  END SED-STOR

  PSTEMP-PARM1
*** <PLS >  Flags for section PSTEMP
*** x -  x SLTV ULTV LGTV TSOP
  502  811    1    1    0    1
  END PSTEMP-PARM1

  PSTEMP-PARM2
PERLND ***      ASLT      BSLT     ULTP1     ULTP2     LGTP1     LGTP2
  502  811      32.0      0.50      32.0      0.90      54.0       0.0
  END PSTEMP-PARM2

  MON-ASLT
PERLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  502  811 32.9 35.3 37.9 42.7 46.9 52.6 55.0 54.3 51.4 46.3 40.5 36.6
  END MON-ASLT

  MON-BSLT
PERLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  502  811 0.13 0.13 0.13 0.13 0.13 0.13 0.13 0.13 0.13 0.13 0.13 0.13
  END MON-BSLT

  MON-ULTP1
PERLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  502  811 40.0 41.0 43.0 46.0 48.6 52.8 56.8 57.8 53.5 48.8 45.0 42.0
  END MON-ULTP1

  MON-ULTP2
PERLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  502  811 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10
  END MON-ULTP2

  PSTEMP-TEMPS
PERLND ***     AIRTC     SLTMP     ULTMP     LGTMP
 502  811      50.0      60.0      57.0      53.0
  END PSTEMP-TEMPS

  PWT-PARM2
PERLND ***      ELEV     IDOXP     ICO2P     ADOXP     ACO2P
  502  811      300.      9.80         0      9.80         0
  END PWT-PARM2

  MON-IFWDOX
PERLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  502  811 11.0 10.0 10.0 10.0 9.00 8.50 7.00 7.00 8.00 9.00 10.0 11.0
  END MON-IFWDOX

  MON-GRNDDOX
PERLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  502  811 11.0 10.0 10.0 10.0 9.00 9.00 9.00 9.00 9.00 9.00 10.0 11.0
  END MON-GRNDDOX

  PWT-TEMPS
PERLND ***     SOTMP     IOTMP     AOTMP
  502  811       60.       57.       53.
  END PWT-TEMPS

  PWT-GASES
PERLND ***     SODOX     SOCO2     IODOX     IOCO2     AODOX     AOCO2
  502  811       9.8         0       9.8         0       9.8         0
  END PWT-GASES

*** Water Quality Constituents N and P ***
  NQUALS
    #    # NQAL  ***
  502  811    5
  END NQUALS
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QUAL-PROPS
  #    #<--QUALID-->    QTID  QSD VPFW VPFS  QSO  VQO QIFW VIQC QAGW VAQC  ***
502  811         NO3     LBS    1    2    0    0    0    1    4    1    4
END QUAL-PROPS

QUAL-INPUT
  #    #     SQO   POTFW   POTFS   ACQOP  SQOLIM   WSQOP    IOQC    AOQC  ***
502        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
503        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
504        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
505        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
506        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
507        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
508        0.100      1.      1.  0.0137  0.2500   0.500      1.      1. ***
509        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
510        0.100      1.      1.  0.0137  0.2500   0.500      1.      1. ***
511        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
702        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
703        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
704        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
705        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
706        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
707        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
708        0.100      1.      1.  0.0137  0.2500   0.500      1.      1. ***
709        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
710        0.100      1.      1.  0.0137  0.2500   0.500      1.      1. ***
711        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
802        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
803        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
804        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
805        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
806        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
807        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
808        0.100      1.      1.  0.0137  0.2500   0.500      1.      1. ***
809        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
810        0.100      1.      1.  0.0137  0.2500   0.500      1.      1. ***
811        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
END QUAL-INPUT

MON-POTFW
          Potency factors for NO3 (lb NO3-N/ton sediment)             ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
502       1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5
702       1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5
802       1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5
503       1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4
703       1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4
803       1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4
504       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
704       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
804       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
505       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
705       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
805       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
506       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
706       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
806       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
507       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
707       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
807       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
508        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
708        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
808        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
509        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
709        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
809        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
510        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
710        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
810        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
511        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
711        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
811        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
END MON-POTFW

MON-IFLW-CONC
          Interflow concentration of NO3-N (mg/l)                     ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
502       3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5
702       3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5
802       3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5
503       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
703       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
803       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
504       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
704       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
804       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
505       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
705       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
805       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
506       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
706       5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0
```

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806       5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0
507       8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0
707       8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0
807       8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0
508      .400 .400 .400 .350 .350 .300 .300 .250 .300 .300 .350 .400
708      .400 .400 .400 .350 .350 .300 .300 .250 .300 .300 .350 .400
808      .400 .400 .400 .350 .350 .300 .300 .250 .300 .300 .350 .400
509       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
709       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
809       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
510      .700 .680 .600 .570 .530 .470 .430 .360 .430 .500 .570 .640
710      .700 .680 .600 .570 .530 .470 .430 .360 .430 .500 .570 .640
810      .700 .680 .600 .570 .530 .470 .430 .360 .430 .500 .570 .640
511       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
711       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
811       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
END MON-IFLW-CONC

MON-GRND-CONC
          Active groundwater concentration of NO3-N (mg/l)            ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
502       3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5
702       3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5
802       3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5
503       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
703       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
803       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
504       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
704       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
804       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
505       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
705       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
805       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
506       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
706       5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0
806       5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0
507       8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0
707       8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0
807       8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0
508      .400 .400 .400 .350 .350 .300 .300 .250 .300 .300 .350 .400
708      .400 .400 .400 .350 .350 .300 .300 .250 .300 .300 .350 .400
808      .400 .400 .400 .350 .350 .300 .300 .250 .300 .300 .350 .400
509       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
709       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
809       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
510      .700 .680 .600 .570 .530 .470 .430 .360 .430 .500 .570 .640
710      .700 .680 .600 .570 .530 .470 .430 .360 .430 .500 .570 .640
810      .700 .680 .600 .570 .530 .470 .430 .360 .430 .500 .570 .640
511       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
711       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
811       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
END MON-GRND-CONC

QUAL-PROPS
  #    #<--QUALID-->    QTID  QSD VPFW VPFS  QSO  VQO QIFW VIQC QAGW VAQC  ***
502  811         NH4     LBS    1    2    0    0    0    1    4    1    4
END QUAL-PROPS

MON-POTFW
          Potency factors for NH4 (lb NH4-N/ton sediment)             ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
502       .24  .24  .24  .24  .24  .24  .24  .24  .24  .24  .24  .24
702       .24  .24  .24  .24  .24  .24  .24  .24  .24  .24  .24  .24
802       .24  .24  .24  .24  .24  .24  .24  .24  .24  .24  .24  .24
503       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
703       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
803       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
504       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
704       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
804       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
505       .40  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40
705       .40  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40
805       .30  .30  .30  .30  .30  .30  .30  .30  .30  .30  .30  .30
506       .35  .35  .35  .35  .35  .35  .35  .35  .35  .35  .35  .35
706       .30  .30  .30  .30  .30  .30  .30  .30  .30  .30  .30  .30
806       .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15
507       1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5
707       1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5
807       .95  .95  .95  .95  .95  .95  .95  .95  .95  .95  .95  .95
508      .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002
708      .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002
808      .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002
509       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
709       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
809       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
510      .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002
710      .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002
810      .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002
511       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
711       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
811       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
END MON-POTFW
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MON-IFLW-CONC
          Interflow concentration of NH4-N (mg/l)                     ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
502      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
702      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
802      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
503      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
703      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
803      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
504      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
704      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
804      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
505      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
705      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
805      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
506      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
706      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
806      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
507      .100 .100 .100 .100 .100 .100 .100 .100 .100 .100 .100 .100
707      .150 .150 .150 .150 .150 .150 .150 .150 .150 .150 .150 .150
807      .080 .080 .080 .080 .080 .080 .080 .080 .080 .080 .080 .080
508      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
708      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
808      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
509      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
709      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
809      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
510      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
710      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
810      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
511      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
711      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
811      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
END MON-IFLW-CONC

MON-GRND-CONC
          Active groundwater concentration of NH4-N (mg/l)            ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
502      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
702      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
802      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
503      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
703      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
803      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
504      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
704      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
804      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
505      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
705      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
805      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
506      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
706      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
806      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
507      .060 .060 .060 .060 .060 .060 .060 .060 .060 .060 .060 .060
707      .060 .060 .060 .060 .060 .060 .060 .060 .060 .060 .060 .060
807      .050 .050 .050 .050 .050 .050 .050 .050 .050 .050 .050 .050
508      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
708      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
808      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
509      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
709      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
809      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
510      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
710      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
810      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
511      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
711      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
811      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
END MON-GRND-CONC

QUAL-PROPS
  #    #<--QUALID-->    QTID  QSD VPFW VPFS  QSO  VQO QIFW VIQC QAGW VAQC  ***
502  811         PO4     LBS    1    2    0    0    0    1    4    1    4
END QUAL-PROPS

MON-POTFW
          Potency factors for PO4 (lb PO4-P/ton sediment)             ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
502       0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
702       0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
802       0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
503       0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
703       0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
803       0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
504       0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
704       0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
804       0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
505       4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
705       4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
805       4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
506       4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
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706       4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
806       4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
507       14.  14.  14.  14.  14.  14.  14.  14.  14.  14.  14.  14.
707       14.  14.  14.  14.  14.  14.  14.  14.  14.  14.  14.  14.
807       14.  14.  14.  14.  14.  14.  14.  14.  14.  14.  14.  14.
508      .010 .010 .010 .010 .010 .025 .035 .035 .025 .010 .010 .010
708      .010 .010 .010 .010 .010 .025 .035 .035 .025 .010 .010 .010
808      .010 .010 .010 .010 .010 .025 .035 .035 .025 .010 .010 .010
509       0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8
709       0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8
809       0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8
510      .020 .020 .020 .020 .020 .025 .035 .035 .035 .020 .020 .020
710      .020 .020 .020 .020 .020 .025 .035 .035 .025 .020 .020 .020
810      .020 .020 .020 .020 .020 .025 .035 .035 .025 .020 .020 .020
511       0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8
711       0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8
811       0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8
END MON-POTFW

MON-IFLW-CONC
          Interflow concentration of PO4-P (mg/l)                    ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
502      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
702      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
802      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
503      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
703      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
803      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
504      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
704      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
804      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
505      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
705      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
805      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
506      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
706      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
806      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
507      .120 .120 .120 .120 .120 .120 .120 .120 .120 .120 .120 .120
707      .120 .120 .120 .120 .120 .120 .120 .120 .120 .120 .120 .120
807      .120 .120 .120 .120 .120 .120 .120 .120 .120 .120 .120 .120
508      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
708      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
808      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
509      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
709      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
809      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
510      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
710      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
810      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
511      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
711      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
811      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
END MON-IFLW-CONC

MON-GRND-CONC
          Active groundwater concentration of PO4-P (mg/l)            ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
502      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
702      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
802      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
503      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
703      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
803      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
504      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
704      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
804      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
505      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
705      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
805      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
506      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
706      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
806      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
507      .060 .060 .060 .060 .060 .060 .060 .060 .060 .060 .060 .060
707      .070 .070 .070 .070 .070 .070 .070 .070 .070 .070 .070 .070
807      .060 .060 .060 .060 .060 .060 .060 .060 .060 .060 .060 .060
508      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
708      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
808      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
509      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
709      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
809      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
510      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
710      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
810      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
511      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
711      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
811      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
END MON-GRND-CONC

QUAL-PROPS
  #    #<--QUALID-->    QTID  QSD VPFW VPFS  QSO  VQO QIFW VIQC QAGW VAQC  ***
502  811         BOD     LBS    1    2    0    0    0    1    4    1    4
```

```
END QUAL-PROPS

MON-POTFW
          Potency factors for BOD (lb BOD/ton sediment)               ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
502       25.  25.  25.  25.  25.  25.  25.  25.  25.  25.  25.  25.
702       25.  25.  25.  25.  25.  25.  25.  25.  25.  25.  25.  25.
402       25.  25.  25.  25.  25.  25.  25.  25.  25.  25.  25.  25.
503       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
703       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
803       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
504       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
704       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
804       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
505       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
705       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
805       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
506       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
706       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
806       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
507       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
707       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
807       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
508       8.5  8.5  8.5  8.5  8.5  5.5  5.5  5.5  5.5  8.5  8.5  8.5
708       8.5  8.5  8.5  8.5  8.5  5.5  5.5  5.5  5.5  8.5  8.5  8.5
808       8.5  8.5  8.5  8.5  8.5  5.5  5.5  5.5  5.5  8.5  8.5  8.5
509       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
709       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
809       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
510       8.5  8.5  8.5  8.5  8.5  5.5  5.5  5.5  5.5  8.5  8.5  8.5
710       8.5  8.5  8.5  8.5  8.5  5.5  5.5  5.5  5.5  8.5  8.5  8.5
810       8.5  8.5  8.5  8.5  8.5  5.5  5.5  5.5  5.5  8.5  8.5  8.5
511       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
711       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
811       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
END MON-POTFW

MON-IFLW-CONC
          Interflow concentration of BOD (mg/l)                         ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
502       .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65
702       .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65
802       .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65
503        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
703        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
803        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
504        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
704        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
804        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
505        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
705        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
805        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
506        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
706        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
806        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
507        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
707        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
807        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
508        .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
708        .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
808        .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
509        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
709        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
809        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
510        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
710        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
810        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
511        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
711        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
811        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
END MON-IFLW-CONC

MON-GRND-CONC
          Active groundwater concentration of BOD (mg/l)                ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
502       .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65
702       .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65
802       .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65
503        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
703        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
803        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
504        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
704        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
804        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
505        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
705        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
805        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
506        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
706        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
806        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
507        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
707        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
```

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807        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
508        .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
708        .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
808        .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
509        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
709        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
809        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
510        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
710        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
810        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
511        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
711        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
811        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
END MON-GRND-CONC

QUAL-PROPS
  #    #<--QUALID-->    QTID  QSD VPFW VPFS  QSO  VQO QIFW VIQC QAGW VAQC  ***
502  811        ORGN     LBS    1    1    0    0    0    1    4    1    4
END QUAL-PROPS

MON-POTFW
          Potency factors for ORGN (lb ORGN/ton sediment)             ***
502       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
702       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
802       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
503       1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3
703       1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3
803        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
504        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
704        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
804        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
505       4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
705       4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
805       4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
506       3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0
306       3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0
806       3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0
507       5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0
707       5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0
807       5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0
508       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
708       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
808       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
509       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
709       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
809       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
510       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
710       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
810       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
511       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
711       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
811       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
END MON-POTFW

MON-IFLW-CONC
          Interflow concentration of ORGN (mg/l)                      ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
502       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
702       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
802       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
503        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
703        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
803        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
504        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
704        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
804        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
505        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
705        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
805        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
506        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
706        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
806        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
507        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
707        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
807        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
508        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
708        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
808        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
509       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
709       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
809       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
510        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
710        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
810        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
511       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
711       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
811       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
END MON-IFLW-CONC

MON-GRND-CONC
          Active groundwater concentration of ORGN (mg/l)             ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
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  502  811  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15
  END MON-GRND-CONC

END PERLND

IMPLND
  ACTIVITY
    #    # ATMP SNOW IWAT  SLD  IWG IQAL  ***
  501  802    1    1    1    1    1    1
  END ACTIVITY

  PRINT-INFO
    #    # ATMP SNOW IWAT  SLD  IWG IQAL PIVL  PYR  ***
  501  802    6    6    5    5    5    5    0   12
  END PRINT-INFO

  GEN-INFO
    #    #      NAME            UCI   IN  OUT ENGL METR  ***
  701     ROADS,BUILDING-resid    1    1    1   90    0
  702     ROADS,BUILDING-urban    1    1    1   90    0
  501     ROADS,BUILDING-resid    1    1    1   90    0
  502     ROADS,BUILDING-urban    1    1    1   90    0
  801     ROADS,BUILDING-resid    1    1    1   90    0
  802     ROADS,BUILDING-urban    1    1    1   90    0
  END GEN-INFO

**** AIR TEMPERATURE ****

  ATEMP-DAT
              ELDAT    AIRTMP ***
    #    #      (ft)   (deg F) ***
  701  702    -200.0      48.3
  501  502     175.0      53.6
  801  802       0.0      53.6
  END ATEMP-DAT

**** SNOW ****

  ICE-FLAG
*** <ILS > ICEFG
*** #    #
  501  802    1
  END ICE-FLAG

  SNOW-PARM1
*** <ILS >       LAT     MELEV     SHADE    SNOWCF    COVIND
*** #    #     (deg)      (ft)                         (in)
  701  702     39.86      450.      0.20       1.0      0.60
  501  502     39.77      250.      0.20       1.0      0.60
  801  802     39.70       75.      0.20       1.0      0.60
  END SNOW-PARM1

  SNOW-PARM2
*** <ILS >     RDSCN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT
*** #    #              (degF)                                (in/day)
  701  702      0.15      30.0      0.08      0.60      0.03      0.05
  501  502      0.15      30.0      0.08      0.60      0.03      0.05
  801  802      0.15      30.0      0.08      0.60      0.03      0.05
  END SNOW-PARM2

**** HYDROLOGY ****

  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
  501  802    1    1    1    0    0
  END IWAT-PARM1

  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                          (in)
  701          150.0     0.036      0.07       0.0
  702          150.0     0.031      0.05       0.0
  501          150.0     0.036      0.07       0.0
  502          150.0     0.031      0.05       0.0
  801          150.0     0.036      0.07       0.0
  802          150.0     0.031      0.05       0.0
  END IWAT-PARM2

  IWAT-PARM3
*** <ILS >    PETMAX    PETMIN
*** x -  x   (deg F)   (deg F)
  501  802      40.0      35.0
  END IWAT-PARM3

  MON-RETN
*** <ILS >  Retention storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  501  802  .03  .03  .04  .04  .04  .06  .06  .06  .04  .04  .04  .03
  END MON-RETN

  IWAT-STATE1
```

```
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
  501  802       0.0       0.0
  END IWAT-STATE1

  SLD-PARM1
*** <ILS >     Flags
*** x -  x VASD VRSD SDOP
  501  802    0    0    1
  END SLD-PARM1

  SLD-PARM2
IMPLND ***      KEIM      JEIM    ACCSDP    REMSDP
  701            1.0       1.2    0.0010      0.08
  702            1.0       1.2    0.0040      0.08
  501            1.0       1.2    0.0010      0.08
  502            1.0       1.2    0.0040      0.08
  801            1.0       1.2    0.0010      0.08
  802            1.0       1.2    0.0040      0.08
  END SLD-PARM2

  SLD-STOR
IMPLND ***      SLDS
  501  802      0.05
  END SLD-STOR

  IWT-PARM1
*** <ILS >  Flags for section IWTGAS
*** x -  x WTFV CSNO
  501  802    1    1
  END IWT-PARM1

  IWT-PARM2
IMPLND ***      ELEV      AWTF      BWTF
  701  702      450.      34.0      0.3
  501  502      250.      34.0      0.3
  801  802       75.      34.0      0.3
  END IWT-PARM2

  MON-AWTF
IMPLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  501  802 32.9 36.0 39.1 45.1 50.3 57.4 60.4 59.6 55.9 49.5 42.4 37.4
  END MON-AWTF

  MON-BWTF
IMPLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  501  802 0.38 0.38 0.38 0.38 0.38 0.38 0.38 0.38 0.38 0.38 0.38 0.38
  END MON-BWTF

  IWT-INIT
*** <ILS > SOTMP       SODOX      SOCO2
*** x -  x(deg F)     (mg/l)     (mg C/l)
  501  802  55.
  END IWT-INIT
*** WATER QUALITY CONSTITUENTS ***

  NQUALS
    #    # NQAL  ***
  501  502    4
  701  702    4
  801  802    4
  END NQUALS

  QUAL-PROPS
    #    #<--QUALID-->    QTID  QSD VPFW  QSO  VQO  ***
  501  502         NO3     LBS    0    0    1    0
  701  702         NO3     LBS    0    0    1    0
  801  802         NO3     LBS    0    0    1    0
  END QUAL-PROPS

  QUAL-INPUT
    #    #     SQO   POTFW   ACQOP  SQOLIM   WSQOP  ***
  501  502   0.050          0.0060  0.4000   0.500
  701  702   0.050          0.0060  0.4000   0.500
  801  802   0.050          0.0060  0.4000   0.500
  END QUAL-INPUT

  QUAL-PROPS
    #    #<--QUALID-->    QTID  QSD VPFW  QSO  VQO  ***
  501  502         NH4     LBS    1    0    1    0
  701  702         NH4     LBS    1    0    1    0
  801  802         NH4     LBS    1    0    1    0
  END QUAL-PROPS

  QUAL-INPUT
    #    #     SQO   POTFW   ACQOP  SQOLIM   WSQOP  ***
  501  502   0.020     0.1  0.0010  0.1200   0.500
  701  702   0.020     0.1  0.0010  0.1200   0.500
  801  802   0.020     0.1  0.0010  0.1200   0.500
  END QUAL-INPUT

  QUAL-PROPS
```

```
    #    #<--QUALID-->    QTID  QSD VPFW  QSO  VQO  ***
  501  502         PO4     LBS    1    0    1    0
  701  702         PO4     LBS    1    0    1    0
  801  802         PO4     LBS    1    0    1    0
  END QUAL-PROPS

  QUAL-INPUT
    #    #     SQO   POTFW   ACQOP  SQOLIM   WSQOP  ***
  501        0.010     1.2  0.0006  0.0090   0.500
  502        0.010     1.0  0.0004  0.0090   0.500
  701        0.010     1.2  0.0006  0.0090   0.500
  702        0.010     1.0  0.0004  0.0090   0.500
  801        0.010     1.2  0.0006  0.0090   0.500
  802        0.010     1.0  0.0004  0.0090   0.500
  END QUAL-INPUT

  QUAL-PROPS
    #    #<--QUALID-->    QTID  QSD VPFW  QSO  VQO  ***
  501  502         BOD     LBS    0    0    1    0
  701  702         BOD     LBS    0    0    1    0
  801  802         BOD     LBS    0    0    1    0
  END QUAL-PROPS

  QUAL-INPUT
    #    #     SQO   POTFW   ACQOP  SQOLIM   WSQOP  ***
  501  502   1.900          0.3600  9.0000   0.500
  701  702   1.900          0.3600  9.0000   0.500
  801  802   1.900          0.3600  9.0000   0.500
  END QUAL-INPUT
END IMPLND

RCHRES
  ACTIVITY
    RCHRES  Active Sections (1=Active; 0=Inactive)           ***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG ***
    1   17    1    1    0    1    1    0    1    1    1    0
  END ACTIVITY

  PRINT-INFO
    RCHRES  Print-flags                                         ***
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR ***
    1   17    5    6         6    5    5    5    5    5             12
  END PRINT-INFO

  GEN-INFO
    RCHRES<-------Name------->Nexit   Unit Systems   Printer      ***
    # -  #                          User t-series  Engl Metr LKFG ***
                                           in  out                ***
    1     WBR-MIDDLE BR           1    1    1    1   90    0    0
    2     MBR-WICKERTON           1    1    1    1   90    0    0
    3     MBR-STRICKLRSVL GAGE    1    1    1    1   90    0    0
    4     EBR-CHATHAM             1    1    1    1   90    0    0
    5     EBR-SPENCER RD.         1    1    1    1   90    0    0
    6     EBR-AVONDALE            2    1    1    1   90    0    0
    7     TROUT RUN               1    1    1    1   90    0    0
    8     EBR-LANDENBURG          2    1    1    1   90    0    0
    9     EBR-STRICKLRSVL GAGE    1    1    1    1   90    0    0
   10     MS-CHAMBERS ROCK RD.    1    1    1    1   90    0    0
   11     MS-NEWARK GAGE          5    1    1    1   90    0    0
   12     MS-DELAWARE PK GAGE     1    1    1    1   90    0    0
   13     MS-MILL CREEK           1    1    1    1   90    0    0
   14     MS-CHRISTINA            2    1    1    1   90    0    0
   15     MIDDLE RUN              1    1    1    1   90    0    0
   16     PIKE CREEK              2    1    1    1   90    0    0
   17     MILL CREEK              2    1    1    1   90    0    0
  END GEN-INFO

**** HYDRAULICS

  HYDR-PARM1
    RCHRES  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
    # -  #  FG FG FG FG  possible   exit *** possible   exit     possible   exit
    1    5   0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
    6        0  1  1  1    4  0  0  0  0       0  2  0  0  0       2  2  1  1  1
    7        0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
    8        0  1  1  1    4  0  0  0  0       0  2  0  0  0       2  2  1  1  1
    9   10   0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
   11        0  1  1  1    4  0  0  0  0       0  2  3  4  5       2  2  2  2  2
   12   13   0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
   14        0  1  1  1    4  0  0  0  0       0  2  0  0  0       2  2  1  1  1
   15        0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
   16   17   0  1  1  1    4  0  0  0  0       0  2  0  0  0       2  2  1  1  1
  END HYDR-PARM1

  HYDR-PARM2
    RCHRES    FTABNO       LEN     DELTH     STCOR        KS      DB50  ***
    # -  #             (miles)      (ft)      (ft)               (in)  ***
    1             1      7.33     230.0       0.0       0.5      0.01
    2             2      6.57     155.0       0.0       0.5      0.01
    3             3      7.18     180.0       0.0       0.5      0.01
    4             4      4.46     135.0       0.0       0.5      0.01
    5             5      2.49      45.0       0.0       0.5      0.01
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    6              6      5.92     100.0       0.0       0.5      0.01
    7              7      1.75      25.0       0.0       0.5      0.01
    8              8      4.09      35.0       0.0       0.5      0.01
    9              9      4.46     110.0       0.0       0.5      0.01
   10             10      1.67      20.0       0.0       0.5      0.01
   11             11      4.02      40.0       0.0       0.5      0.01
   12             12      5.28      48.0       0.0       0.5      0.01
   13             13      2.21       7.0       0.0       0.5      0.01
   14             14      2.97       4.0       0.0       0.5      0.01
   15             15      4.08     194.0       0.0       0.5      0.01
   16             16      5.85     232.0       0.0       0.5      0.01
   17             17      9.76     245.0       0.0       0.5      0.01
  END HYDR-PARM2

  HYDR-INIT
    RCHRES       VOL ***   Initial value of COLIND      Initial value  of OUTDGT
    # -  #     ac-ft ***   for each exit                for each exit (ft3)
    1           2.60       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    2           2.72       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    3           6.31       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    4           1.30       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    5           0.38       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    6           3.20       4.0  0.0  0.0  0.0  0.0       0.0  0.1  0.0  0.0  0.0
    7           0.16       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    8           5.51       4.0  0.0  0.0  0.0  0.0       0.0  .04  0.0  0.0  0.0
    9          10.33       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
   10           4.42       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
   11          10.96       4.0  0.0  0.0  0.0  0.0       0.0  3.1  0.2  .01  .03
   12          16.47       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
   13          12.28       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
   14          22.59       4.0  0.0  0.0  0.0  0.0       0.0 30.0  0.0  0.0  0.0
   15           0.78       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
   16           1.89       4.0  0.0  0.0  0.0  0.0       0.0  0.1  0.0  0.0  0.0
   17           6.28       4.0  0.0  0.0  0.0  0.0       0.0  0.1  0.0  0.0  0.0
  END HYDR-INIT

  HT-BED-FLAGS
RCHRES *** BDFG TGFG TSTP
    1   17    1    3
  END HT-BED-FLAGS

  HEAT-PARM
RCHRES ***      ELEV     ELDAT    CFSAEX    KATRAD     KCOND     KEVAP
    1    9      350.     -290.       .40       9.4      10.0       2.2
   10   17      200.      125.       .60       9.4      10.0       2.2
  END HEAT-PARM

  HT-BED-PARM
RCHRES ***    MUDDEP     TGRND      KMUD     KGRND
    1    9      0.01       61.        70       0.0
   10   17      0.01       61.        75       0.0
  END HT-BED-PARM

  MON-HT-TGRND
RCHRES ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
    1   17 39.0 40.0 44.0 50.0 57.0 64.0 69.0 70.0 66.0 60.0 51.0 44.0
  END MON-HT-TGRND

  HEAT-INIT
RCHRES ***        TW    AIRTMP
    1   17       59.       50.
  END HEAT-INIT

  SANDFG
*** RCHRES

*** x -  x SNDFG
    1   17    3
  END SANDFG

  SED-GENPARM
RCHRES ***    BEDWID    BEDWRN       POR
    1   17       25.        7.       0.7
  END SED-GENPARM

  SAND-PM
RCHRES ***         D         W       RHO     KSAND    EXPSND
    1   17      .005       0.1       2.6      0.10      3.92
  END SAND-PM

  SILT-CLAY-PM
RCHRES ***         D         W       RHO     TAUCD     TAUCS         M
    1    2   0.00040    0.0003       2.2      0.13      0.40      0.90
    3        0.00040    0.0003       2.2      0.15      0.60      0.90
    4        0.00040    0.0003       2.2      0.13      0.50      0.90
    5        0.00040    0.0003       2.2      0.10      0.21      0.90
    6        0.00040    0.0003       2.2      0.13      0.30      0.90
    7        0.00040    0.0003       2.2      0.06      0.20      0.90
    8        0.00040    0.0003       2.2      0.10      0.25      0.90
    9        0.00040    0.0003       2.2      0.35      1.05      0.90
   10        0.00040    0.0003       2.2      0.10      0.35      0.90
   11   12   0.00040    0.0003       2.2      0.18      0.50      0.90
```

```
   13   14   0.00040    0.0003       2.2      0.10      0.22      0.90
   15        0.00040    0.0003       2.2      0.13      0.45      0.90
   16        0.00040    0.0003       2.2      0.18      0.60      0.90
   17        0.00040    0.0003       2.2      0.13      0.45      0.90
  END SILT-CLAY-PM

  SILT-CLAY-PM
RCHRES ***         D         W       RHO     TAUCD     TAUCS         M
    1    2   0.00010   0.00001       2.1      0.15      0.45      0.90
    3        0.00010   0.00001       2.1      0.18      0.65      0.90
    4        0.00010   0.00001       2.1      0.15      0.55      0.90
    5        0.00010   0.00001       2.1      0.10      0.23      0.90
    6        0.00010   0.00001       2.1      0.15      0.35      0.90
    7        0.00010   0.00001       2.1      0.08      0.22      0.90
    8        0.00010   0.00001       2.1      0.12      0.30      0.90
    9        0.00010   0.00001       2.1      0.40      1.05      0.90
   10        0.00010   0.00001       2.1      0.12      0.40      0.90
   11   12   0.00010   0.00001       2.1      0.20      0.55      0.90
   13   14   0.00010   0.00001       2.1      0.10      0.25      0.90
   15        0.00010   0.00001       2.1      0.15      0.50      0.90
   16        0.00010   0.00001       2.1      0.20      0.65      0.90
   17        0.00010   0.00001       2.1      0.15      0.50      0.90
  END SILT-CLAY-PM

  SSED-INIT
RCHRES ***     SSED1     SSED2     SSED3
    1   17        1.       25.       25.
  END SSED-INIT

  BED-INIT
RCHRES ***    BEDDEP    SANDFR    SILTFR    CLAYFR
    1   17        4.       .70       .20       .10
  END BED-INIT

  BENTH-FLAG
*** RCHRES  Benthic release flag
*** x -  x BENF
    1   17    1
  END BENTH-FLAG

  SCOUR-PARMS
RCHRES ***    SCRVEL    SCRMUL
    1   17        3.         2
  END SCOUR-PARMS

  OX-FLAGS
*** RCHRES Oxygen flags
*** x -  x REAM
    1   17    3
  END OX-FLAGS

  OX-GENPARM
RCHRES ***    KBOD20     TCBOD    KODSET    SUPSAT
    1    7      .025     1.050      .200      1.25
    8   14      .015     1.050      .200      1.25
   15   17      .025     1.050      .200      1.25
  END OX-GENPARM

  OX-BENPARM
RCHRES ***     BENOD     TCBEN     EXPOD    BRBOD1    BRBOD2    EXPREL
    1   17       10.       1.1       1.2       10.       15.       2.5
  END OX-BENPARM

  OX-REAPARM
RCHRES ***    TCGINV      REAK    EXPRED    EXPREV
    1   17     1.024      .726    -1.673      .970
  END OX-REAPARM

  OX-INIT
RCHRES ***       DOX       BOD     SATDO
    1   17      11.3      2.92      12.0
  END OX-INIT

**** NUTRIENTS ****

  NUT-FLAGS
    RCHRES  TAM  NO2  PO4  AMV  DEN ADNH ADPO PHFG ***
    # -  #                                     ***
    1   17    1    0    1    0    1    1    1    2
  END NUT-FLAGS

  NUT-NITDENIT
    RCHRES    KTAM20    KNO220     TCNIT    KNO320     TCDEN    DENOXT ***
    # -  #       /hr       /hr                 /hr                mg/l ***
    1   17       .05      .050     1.045      .005      1.04        1.
  END NUT-NITDENIT

  NUT-BEDCONC
    RCHRES       Bed concentrations of NH4 & PO4 (mg/kg)               ***
    # -  #  NH4-sand  NH4-silt  NH4-clay  PO4-sand  PO4-silt  PO4-clay ***
    1   17        1.       30.       50.       90.      700.      900.
  END NUT-BEDCONC
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  NUT-ADSPARM
    RCHRES       Partition coefficients for NH4 AND PO4  (ml/g)        ***
    # -  #  NH4-sand  NH4-silt  NH4-clay  PO4-sand  PO4-silt  PO4-clay ***
    1   17       10.      500.      800.      600.    15000.    18000.
  END NUT-ADSPARM

  NUT-DINIT
    RCHRES       NO3       TAM       NO2       PO4        PH ***
    # -  #      mg/l      mg/l      mg/l      mg/l           ***
    1   17       2.0      .055                .033        7.
  END NUT-DINIT

  NUT-ADSINIT
    RCHRES        Initial suspended NH4 and PO4 concentrations (mg/kg) ***
    # -  #  NH4-sand  NH4-silt  NH4-clay  PO4-sand  PO4-silt  PO4-clay ***
    1   17       0.1       0.3       0.5       0.1       0.5       0.8
  END NUT-ADSINIT
**** PLANKTON ****

  PLNK-FLAGS
    RCHRES PHYF ZOOF BALF SDLT AMRF DECF NSFG ZFOO ***
    # -  #                                         ***
    1   17    1    0    1    0    0    1    1    2
  END PLNK-FLAGS

  PLNK-PARM1
    RCHRES    RATCLP    NONREF    LITSED     ALNPR      EXTB     MALGR ***
    # -  #                                              /ft       /hr ***
    1   10       .60        .5        0.       0.8       .20      .200
   11   14       .60        .5        0.       0.6       .20      .200
   15   17       .60        .5        0.       0.8       .20      .200
  END PLNK-PARM1

  PLNK-PARM2
    RCHRES *** CMMLT      CMMN     CMMNP      CMMP    TALGRH    TALGRL    TALGRM
    # -  # ***ly/min      mg/l      mg/l      mg/l     deg F     deg F     deg F
    1   17       .03      .045      .029      .015       95.       32.       55.
  END PLNK-PARM2

  PLNK-PARM3
    RCHRES     ALR20      ALDH      ALDL     OXALD     NALDH     PALDH ***
    # -  #       /hr       /hr       /hr       /hr      mg/l      mg/l ***
    1   17      .045      .010      .001       .03      .015      .001
  END PLNK-PARM3

  PHYTO-PARM
    RCHRES      SEED    MXSTAY      OREF    CLALDH    PHYSET    REFSET ***
    # -  #      mg/l      mg/l                ug/l                     ***
    1   17        .4        .8       20.       50.      .012      .010
  END PHYTO-PARM

  PLNK-INIT
    RCHRES     PHYTO       ZOO     BENAL       ORN       ORP       ORC ***
    # -  #      mg/l     org/l     mg/m2      mg/l      mg/l      mg/l ***
    1   17      .700       .03    1.0E-8        1.        .2        8.
  END PLNK-INIT
END RCHRES

FTABLES
  FTABLE      1
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.46      13.0       5.6       8.2      496.
      0.92      14.4      11.9      26.5      325.
      1.38      15.8      18.8      53.1      257.
      1.83      17.2      26.3      87.6      218.
      2.29      18.6      34.5     129.9      193.
      2.75      20.0      43.4     180.2      175.
      3.67      22.8      63.0     305.3      150.
      4.58      25.6      85.2     464.7      133.
      5.50      28.4     109.9     660.6      121.
      7.33     109.9     236.7     1298.      132.
      9.17     191.3     512.8     2239.      166.
     11.00     272.8     938.2     3569.      191.
     12.83     354.2    1513.0     5358.      205.
     14.67     435.7    2237.0     7670.      212.
  END FTABLE  1

  FTABLE      2
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.42       8.4       3.4       4.5      546.
      0.85       9.6       7.2      14.4      361.
      1.27      10.7      11.5      29.1      286.
      1.70      11.8      16.2      48.3      244.
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     2.13      12.9      21.5      72.1      216.
     2.55      14.0      27.2     100.6      196.
     3.40      16.2      40.1     172.5      169.
     4.25      18.5      54.8     265.5      150.
     5.10      20.7      71.5     381.2      136.
     6.80      74.9     152.7     763.7      145.
     8.50     129.0     326.0     1326.      178.
    10.20     183.2     591.3     2116.      203.
    11.90     237.3     948.8     3172.      217.
    13.60     291.5    1398.2     4531.      224.
 END FTABLE  2

 FTABLE      3
ROWS COLS ***
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.56      22.6      12.1      18.8      469.
     1.12      24.4      25.3      60.2      305.
     1.67      26.1      39.4     119.8      239.
     2.23      27.8      54.4     196.0      202.
     2.79      29.6      70.5     288.4      177.
     3.35      31.3      87.5     396.6      160.
     4.47      34.8     124.4     660.9      137.
     5.58      38.3     165.2     990.4      121.
     6.70      41.8     209.9     1387.      110.
     8.93     106.6     375.6     2598.      105.
    11.17     171.4     685.9     4238.      117.
    13.40     236.1    1140.9     6384.      130.
    15.63     300.9    1740.7     9098.      139.
    17.87     365.7    2485.1    12441.      145.
 END FTABLE  3

 FTABLE      4
ROWS COLS ***
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.46       8.0       3.5       6.2      413.
     0.92       8.8       7.4      19.6      272.
     1.38       9.5      11.5      38.9      216.
     1.83      10.2      16.1      63.4      184.
     2.29      10.9      20.9      93.0      163.
     2.75      11.7      26.1     127.8      148.
     3.67      13.1      37.5     212.8      128.
     4.58      14.6      50.2     319.2      114.
     5.50      16.1      64.2     448.0      104.
     7.33      69.6     142.7     869.1      119.
     9.17     123.1     319.3     1508.      154.
    11.00     176.6     594.0     2434.      177.
    12.83     230.1     966.8     3705.      189.
    14.67     283.6    1437.7     5372.      194.
 END FTABLE  4

 FTABLE      5
ROWS COLS ***
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.29       1.0       0.3       0.6      328.
     0.58       1.2       0.6       2.0      223.
     0.88       1.3       1.0       3.8      181.
     1.17       1.4       1.3       6.3      157.
     1.46       1.5       1.8       9.2      141.
     1.75       1.7       2.2      12.6      129.
     2.33       1.9       3.3      21.1      113.
     2.92       2.2       4.5      32.0      102.
     3.50       2.4       5.8      45.2       93.
     4.67      16.5      16.8      94.1      130.
     5.83      30.6      44.3     182.1      177.
     7.00      44.7      88.2     326.1      196.
     8.17      58.8     148.5     540.0      200.
     9.33      72.8     225.3     836.2      196.
 END FTABLE  5

 FTABLE      6
ROWS COLS ***
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.40       8.3       3.1       4.1      551.
     0.79       9.2       6.6      13.2      362.
     1.19      10.1      10.4      26.4      286.
     1.58      11.0      14.6      43.5      243.
     1.98      11.8      19.1      64.3      216.
     2.38      12.7      23.9      89.0      195.
     3.17      14.4      34.7     150.1      168.
     3.96      16.2      46.8     227.6      149.
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     4.75      17.9      60.3     322.6      136.
     6.33      77.0     135.5     634.1      155.
     7.92     136.1     304.2     1105.      200.
     9.50     195.3     566.6     1785.      230.
    11.08     254.4     922.5     2714.      247.
    12.67     313.5    1372.1     3929.      254.
 END FTABLE  6

 FTABLE      7
ROWS COLS ***
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.29       1.2       0.3       1.1      220.
     0.58       1.3       0.7       3.4      146.
     0.88       1.4       1.1       6.8      116.
     1.17       1.6       1.5      11.1      100.
     1.46       1.7       2.0      16.3       89.
     1.75       1.8       2.5      22.5       81.
     2.33       2.1       3.6      37.7       70.
     2.92       2.3       4.9      56.8       63.
     3.50       2.5       6.3      80.1       57.
     4.67      12.4      15.1     158.8       69.
     5.83      22.3      35.3     283.0       91.
     7.00      32.2      67.2     468.4      104.
     8.17      42.1     110.6     728.0      110.
     9.33      52.0     165.5     1074.      112.
 END FTABLE  7

 FTABLE      8
ROWS COLS ***
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.58      11.6       6.4      11.5      404.
     1.17      12.8      13.5      37.3      264.
     1.75      14.0      21.4      74.7      208.
     2.33      15.2      29.9     123.3      176.
     2.92      16.4      39.1     182.8      155.
     3.50      17.6      49.0     253.4      140.
     4.67      20.0      70.9     429.0      120.
     5.83      22.4      95.7     652.2      106.
     7.00      24.8     123.2     926.1       97.
     9.33      71.1     235.0     1788.       95.
    11.67     117.3     454.8     2976.      111.
    14.00     163.6     782.6     4550.      125.
    16.33     209.9    1218.3     6561.      135.
    18.67     256.1    1761.9     9056.      141.
 END FTABLE  8

 FTABLE      9
ROWS COLS ***
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.58      17.1       9.7      24.0      295.
     1.17      18.0      20.0      76.4      190.
     1.75      18.9      30.7     150.8      148.
     2.33      19.8      42.0     245.0      125.
     2.92      20.7      53.9     357.7      109.
     3.50      21.6      66.2     488.3       98.
     4.67      23.4      92.5     801.6       84.
     5.83      25.2     120.9     1184.       74.
     7.00      27.0     151.4     1635.       67.
     9.33      77.5     273.3     2968.       67.
    11.67     127.9     513.0     4781.       78.
    14.00     178.4     870.4     7171.       88.
    16.33     228.9    1345.5    10223.       96.
    18.67     279.3    1938.4    14012.      100.
 END FTABLE  9

 FTABLE     10
ROWS COLS ***
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.67       6.3       4.1      20.3      146.
     1.33       6.8       8.5      64.9       95.
     2.00       7.3      13.2     129.0       74.
     2.67       7.8      18.2     211.0       63.
     3.33       8.2      23.5     310.1       55.
     4.00       8.7      29.1     426.1       50.
     5.33       9.6      41.4     709.0       42.
     6.67      10.6      54.9     1061.       38.
     8.00      11.5      69.6     1484.       34.
    10.67      33.1     129.2     2780.       34.
    13.33      54.7     246.3     4575.       39.
    16.00      76.3     421.0     6975.       44.
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    18.67      97.9     653.3    10070.       47.
    21.33     119.5     943.2    13941.       49.
 END FTABLE 10

 FTABLE     11
ROWS COLS ***
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.75      18.2      13.2      31.3      307.
     1.50      19.3      27.3      99.8      198.
     2.25      20.5      42.2     197.7      155.
     3.00      21.6      58.0     322.0      131.
     3.75      22.7      74.6     471.5      115.
     4.50      23.9      92.1     645.4      104.
     6.00      26.2     129.6     1066.       88.
     7.50      28.4     170.5     1583.       78.
     9.00      30.7     214.9     2200.       71.
    12.00     128.2     453.2     4088.       80.
    15.00     225.6     983.8     6819.      105.
    18.00     323.1    1806.8    10631.      123.
    21.00     420.5    2922.2    15723.      135.
    24.00     518.0    4329.9    22276.      141.
 END FTABLE 11

 FTABLE     12
ROWS COLS ***
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.83      34.8      28.6      57.3      363.
     1.67      35.7      58.0     181.2      233.
     2.50      36.6      88.2     355.0      180.
     3.33      37.5     119.1     571.8      151.
     4.17      38.5     150.8     827.7      132.
     5.00      39.4     183.2     1120.      119.
     6.67      41.2     250.3     1805.      101.
     8.33      43.0     320.4     2618.       89.
    10.00      44.8     393.6     3551.       80.
    13.33     202.8     806.3     6213.       94.
    16.67     360.8    1745.8    10010.      127.
    20.00     518.9    3212.0    15284.      153.
    23.33     676.9    5204.9    22320.      169.
    26.67     834.9    7724.6    31376.      179.
 END FTABLE 12

 FTABLE     13
ROWS COLS ***
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.83      16.2      13.4      37.1      263.
     1.67      16.3      27.0     116.5      168.
     2.50      16.5      40.7     226.5      130.
     3.33      16.6      54.5     362.0      109.
     4.17      16.7      68.4     519.8       95.
     5.00      16.9      82.4     697.4       86.
     6.67      17.1     110.7     1106.       73.
     8.33      17.4     139.5     1577.       64.
    10.00      17.7     168.8     2102.       58.
    13.33     155.1     456.7     3639.       91.
    16.67     292.4    1202.5     6198.      141.
    20.00     429.8    2406.2    10228.      171.
    23.33     567.2    4067.8    16103.      183.
    26.67     704.5    6187.3    24154.      186.
 END FTABLE 13

 FTABLE     14
ROWS COLS ***
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.79      20.1      15.8      20.9      548.
     1.58      20.4      31.8      65.9      351.
     2.38      20.7      48.1     128.6      272.
     3.17      21.0      64.6     206.2      227.
     3.96      21.3      81.3     297.1      199.
     4.75      21.6      98.3     400.1      178.
     6.33      22.2     133.0     639.1      151.
     7.92      22.8     168.6     917.9      133.
     9.50      23.4     205.2     1233.      121.
    12.67    1163.4    2084.3     2710.      558.
    15.83    2303.4    7573.4     7170.      767.
    19.00    3443.4   16672.5    16335.      741.
    22.17    4583.4   29381.6    31627.      674.
    25.33    5723.4   45700.7    54311.      611.
 END FTABLE 14
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```
  FTABLE     15
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.20       6.4       1.2       2.3      382.
      0.40       6.8       2.6       7.5      247.
      0.60       7.3       4.0      15.0      193.
      0.80       7.7       5.5      24.5      162.
      1.00       8.2       7.1      36.0      143.
      1.20       8.7       8.8      49.5      128.
      1.60       9.6      12.4      82.4      109.
      2.00      10.5      16.4     123.3       97.
      2.40      11.4      20.8     172.5       87.
      3.20      27.2      36.2     320.0       82.
      4.00      43.0      64.3     517.4       90.
      4.80      58.9     105.0     772.2       99.
      5.60      74.7     158.5     1091.      105.
      6.40      90.5     224.5     1480.      110.
  END FTABLE 15

  FTABLE     16
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.23      11.6       2.5       3.3      556.
      0.45      12.5       5.2      10.5      360.
      0.68      13.5       8.1      21.0      281.
      0.90      14.4      11.3      34.5      237.
      1.13      15.4      14.6      51.0      208.
      1.35      16.3      18.2      70.3      188.
      1.80      18.2      26.0     118.0      160.
      2.25      20.1      34.6     177.7      141.
      2.70      22.0      44.0     250.2      128.
      3.60      64.5      83.0     472.6      127.
      4.50     107.1     160.2     780.4      149.
      5.40     149.6     275.7     1191.      168.
      6.30     192.2     429.5     1720.      181.
      7.20     234.7     621.6     2380.      190.
  END FTABLE 16

  FTABLE     17
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.23      22.0       4.7       2.9     1166.
      0.45      23.9       9.9       9.5      755.
      0.68      25.7      15.5      19.0      590.
      0.90      27.6      21.5      31.3      498.
      1.13      29.5      27.9      46.3      437.
      1.35      31.4      34.7      64.0      394.
      1.80      35.1      49.7     107.6      335.
      2.25      38.8      66.3     162.5      296.
      2.70      42.6      84.6     229.3      268.
      3.60     103.4     150.4     432.9      252.
      4.50     164.3     270.8     707.2      278.
      5.40     225.1     446.0     1063.      305.
      6.30     286.0     676.0     1509.      325.
      7.20     346.8     960.8     2056.      339.
  END FTABLE 17
END FTABLES

COPY
  TIMESERIES
    # -  #  NPT  NMN ***
   10  650        17
  END TIMESERIES
END COPY

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
*** Meteorological data
WDM1    78 PREC   0 ENGL          0.85     PERLND 702 711 EXTNL  PREC   1 1
WDM1    75 PREC   0 ENGL          1.00     PERLND 502 511 EXTNL  PREC   1 1
WDM1    75 PREC   0 ENGL          1.00     PERLND 802 811 EXTNL  PREC   1 1
WDM1   160 NO3X   0 METR           1.0     PERLND 502 811 EXTNL  NIADCN 1 1
WDM1   161 NH3X   0 METR           1.0     PERLND 502 811 EXTNL  NIADCN 2 1
WDM1    78 PREC   0 ENGL        877.92     COPY   400   0 INPUT  MEAN   4 1
WDM1    75 PREC   0 ENGL        37893.     COPY   500   0 INPUT  MEAN   4 1
WDM1    75 PREC   0 ENGL        44372.     COPY   540   0 INPUT  MEAN   4 1
WDM1    75 PREC   0 ENGL        56722.     COPY   600   0 INPUT  MEAN   4 1
WDM1    50 ATMP   0 ENGL           1.0     PERLND 702 711 EXTNL  GATMP  1 1
WDM1    50 ATMP   0 ENGL           1.0     PERLND 502 511 EXTNL  GATMP  1 1
WDM1    50 ATMP   0 ENGL           1.0     PERLND 802 811 EXTNL  GATMP  1 1
WDM1    45 DWPT   0 ENGL           1.0     PERLND 502 811 EXTNL  DTMPG  1 1
WDM1    30 WIND   0 ENGL           1.0     PERLND 502 811 EXTNL  WINMOV 1 1
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WDM1    20 PETX   0 ENGL           1.1     PERLND 502 811 EXTNL  PETINP 1 1
WDM1    10 SOLR   0 ENGL           1.0     PERLND 502 811 EXTNL  SOLRAD 1 1
WDM1    78 PREC   0 ENGL          0.85     IMPLND 701 702 EXTNL  PREC   1 1
WDM1    75 PREC   0 ENGL          1.00     IMPLND 501 502 EXTNL  PREC   1 1
WDM1    75 PREC   0 ENGL          1.00     IMPLND 801 802 EXTNL  PREC   1 1
WDM1   160 NO3X   0 METR           1.0     IMPLND 502 802 EXTNL  IQADCN 1 1
WDM1   161 NH3X   0 METR           1.0     IMPLND 502 802 EXTNL  IQADCN 2 1
WDM1    50 ATMP   0 ENGL           1.0     IMPLND 701 702 EXTNL  GATMP  1 1
WDM1    50 ATMP   0 ENGL           1.0     IMPLND 501 502 EXTNL  GATMP  1 1
WDM1    50 ATMP   0 ENGL           1.0     IMPLND 801 802 EXTNL  GATMP  1 1
WDM1    45 DWPT   0 ENGL           1.0     IMPLND 501 802 EXTNL  DTMPG  1 1
WDM1    30 WIND   0 ENGL           1.0     IMPLND 501 802 EXTNL  WINMOV 1 1
WDM1    20 PETX   0 ENGL           1.1     IMPLND 501 802 EXTNL  PETINP 1 1
WDM1    10 SOLR   0 ENGL           1.0     IMPLND 501 802 EXTNL  SOLRAD 1 1
WDM1    75 PREC   0 ENGL          1.00     RCHRES   1     EXTNL  PREC   1 1
WDM1    78 PREC   0 ENGL          0.85     RCHRES   2     EXTNL  PREC   1 1
WDM1    75 PREC   0 ENGL          1.00     RCHRES   3     EXTNL  PREC   1 1
WDM1    78 PREC   0 ENGL          0.85     RCHRES   4   7 EXTNL  PREC   1 1
WDM1    75 PREC   0 ENGL          1.00     RCHRES   8  11 EXTNL  PREC   1 1
WDM1    75 PREC   0 ENGL          1.00     RCHRES  12  14 EXTNL  PREC   1 1
WDM1    75 PREC   0 ENGL          1.00     RCHRES  15  17 EXTNL  PREC   1 1
WDM1   160 NO3X   0 METR           1.0     RCHRES   1  17 EXTNL  NUADCN 1 1
WDM1   161 NH3X   0 METR           1.0     RCHRES   1  17 EXTNL  NUADCN 2 1
WDM1    50 ATMP   0 ENGL           1.0     RCHRES   1   7 EXTNL  GATMP  1 1
WDM1    50 ATMP   0 ENGL           1.0     RCHRES   8  17 EXTNL  GATMP  1 1
WDM1    45 DWPT   0 ENGL           1.0     RCHRES   1  17 EXTNL  DEWTMP 1 1
WDM1    40 COVR   0 ENGL           1.0     RCHRES   1  17 EXTNL  CLOUD  1 1
WDM1    30 WIND   0 ENGL           1.0     RCHRES   1  17 EXTNL  WIND   1 1
WDM1    20 PETX   0 ENGL           1.1     RCHRES   1  17 EXTNL  POTEV  1 1
WDM1    10 SOLR   0 ENGL           1.0     RCHRES   1  17 EXTNL  SOLRAD 1 1
*** Point source Discharges ***
*** FMC
WDM1   300 PTSQ   0 ENGL           1.0     RCHRES  12     EXTNL  IVOL   1 1
WDM1   301 TSSX   0 ENGL           1.0     RCHRES  12     INFLOW ISED   3 1
WDM1   302 BODX   0 ENGL           1.0     RCHRES  12     INFLOW OXIF   2 1
WDM1   303 NH3X   0 ENGL           1.0     RCHRES  12     INFLOW NUIF1  2 1
WDM1   304 NO3X   0 ENGL           1.0     RCHRES  12     INFLOW NUIF1  1 1
WDM1   305 NO2X   0 ENGL           1.0     RCHRES  12     INFLOW NUIF1  3 1
WDM1   308 NO3X   0 ENGL ***          0.6     RCHRES   5     INFLOW NUIF1  1 1
WDM1   306 PO4X   0 ENGL           1.0     RCHRES  12     INFLOW NUIF1  4 1
WDM1   308 HEAT   0 ENGL           1.0     RCHRES  12     INFLOW IHEAT  1 1
*** Avongrove School District
WDM1   310 PTSQ   0 ENGL           1.0     RCHRES   1     EXTNL  IVOL   1 1
WDM1   311 TSSX   0 ENGL           1.0     RCHRES   1     INFLOW ISED   3 1
WDM1   312 BODX   0 ENGL           1.0     RCHRES   1     INFLOW OXIF   2 1
WDM1   313 NH3X   0 ENGL           1.0     RCHRES   1     INFLOW NUIF1  2 1
WDM1   314 NO3X   0 ENGL           1.0     RCHRES   1     INFLOW NUIF1  1 1
WDM1   315 NO2X   0 ENGL           1.0     RCHRES   1     INFLOW NUIF1  3 1
WDM1   308 NO3X   0 ENGL ***          0.6     RCHRES   5     INFLOW NUIF1  1 1
WDM1   316 PO4X   0 ENGL           1.0     RCHRES   1     INFLOW NUIF1  4 1
WDM1   318 HEAT   0 ENGL           1.0     RCHRES   1     INFLOW IHEAT  1 1
*** West Grove Borough Sewer Authority
WDM1   320 PTSQ   0 ENGL           1.0     RCHRES   2     EXTNL  IVOL   1 1
WDM1   321 TSSX   0 ENGL           1.0     RCHRES   2     INFLOW ISED   3 1
WDM1   322 BODX   0 ENGL           1.0     RCHRES   2     INFLOW OXIF   2 1
WDM1   323 NH3X   0 ENGL           1.0     RCHRES   2     INFLOW NUIF1  2 1
WDM1   324 NO3X   0 ENGL           1.0     RCHRES   2     INFLOW NUIF1  1 1
WDM1   325 NO2X   0 ENGL           1.0     RCHRES   2     INFLOW NUIF1  3 1
WDM1   308 NO3X   0 ENGL ***          0.6     RCHRES   5     INFLOW NUIF1  1 1
WDM1   326 PO4X   0 ENGL           1.0     RCHRES   2     INFLOW NUIF1  4 1
WDM1   328 HEAT   0 ENGL           1.0     RCHRES   2     INFLOW IHEAT  1 1
*** FL Hamilton Oates FTP
WDM1   330 PTSQ   0 ENGL           1.0     RCHRES   9     EXTNL  IVOL   1 1
WDM1   331 TSSX   0 ENGL           1.0     RCHRES   9     INFLOW ISED   3 1
WDM1   332 BODX   0 ENGL           1.0     RCHRES   9     INFLOW OXIF   2 1
WDM1   333 NH3X   0 ENGL           1.0     RCHRES   9     INFLOW NUIF1  2 1
WDM1   334 NO3X   0 ENGL           1.0     RCHRES   9     INFLOW NUIF1  1 1
WDM1   335 NO2X   0 ENGL           1.0     RCHRES   9     INFLOW NUIF1  3 1
WDM1   308 NO3X   0 ENGL ***          0.6     RCHRES   5     INFLOW NUIF1  1 1
WDM1   336 PO4X   0 ENGL           1.0     RCHRES   9     INFLOW NUIF1  4 1
WDM1   338 HEAT   0 ENGL           1.0     RCHRES   9     INFLOW IHEAT  1 1
*** HP
WDM1   340 PTSQ   0 ENGL           1.0     RCHRES   8     EXTNL  IVOL   1 1
WDM1   341 TSSX   0 ENGL           1.0     RCHRES   8     INFLOW ISED   3 1
WDM1   342 BODX   0 ENGL           1.0     RCHRES   8     INFLOW OXIF   2 1
WDM1   343 NH3X   0 ENGL           1.0     RCHRES   8     INFLOW NUIF1  2 1
WDM1   344 NO3X   0 ENGL           1.0     RCHRES   8     INFLOW NUIF1  1 1
WDM1   345 NO2X   0 ENGL           1.0     RCHRES   8     INFLOW NUIF1  3 1
WDM1   308 NO3X   0 ENGL ***          0.6     RCHRES   5     INFLOW NUIF1  1 1
WDM1   346 PO4X   0 ENGL           1.0     RCHRES   8     INFLOW NUIF1  4 1
WDM1   348 HEAT   0 ENGL           1.0     RCHRES   8     INFLOW IHEAT  1 1
*** Avondale Borough Sewer Authority
WDM1   350 PTSQ   0 ENGL           1.0     RCHRES   8     EXTNL  IVOL   1 1
WDM1   351 TSSX   0 ENGL           1.0     RCHRES   8     INFLOW ISED   3 1
WDM1   352 BODX   0 ENGL           1.0     RCHRES   8     INFLOW OXIF   2 1
WDM1   353 NH3X   0 ENGL           1.0     RCHRES   8     INFLOW NUIF1  2 1
WDM1   354 NO3X   0 ENGL           1.0     RCHRES   8     INFLOW NUIF1  1 1
WDM1   355 NO2X   0 ENGL           1.0     RCHRES   8     INFLOW NUIF1  3 1
WDM1   308 NO3X   0 ENGL ***          0.6     RCHRES   5     INFLOW NUIF1  1 1
WDM1   356 PO4X   0 ENGL           1.0     RCHRES   8     INFLOW NUIF1  4 1
WDM1   358 HEAT   0 ENGL           1.0     RCHRES   8     INFLOW IHEAT  1 1
*** Avongrove Trailer Park
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WDM1   360 PTSQ   0 ENGL           1.0     RCHRES   4     EXTNL  IVOL   1 1
WDM1   361 TSSX   0 ENGL           1.0     RCHRES   4     INFLOW ISED   3 1
WDM1   362 BODX   0 ENGL           1.0     RCHRES   4     INFLOW OXIF   2 1
WDM1   363 NH3X   0 ENGL           1.0     RCHRES   4     INFLOW NUIF1  2 1
WDM1   364 NO3X   0 ENGL           1.0     RCHRES   4     INFLOW NUIF1  1 1
WDM1   365 NO2X   0 ENGL           1.0     RCHRES   4     INFLOW NUIF1  3 1
WDM1   308 NO3X   0 ENGL ***          0.6     RCHRES   5     INFLOW NUIF1  1 1
WDM1   366 PO4X   0 ENGL           1.0     RCHRES   4     INFLOW NUIF1  4 1
WDM1   368 HEAT   0 ENGL           1.0     RCHRES   4     INFLOW IHEAT  1 1
*** Tojo Mushroom
WDM1   370 PTSQ   0 ENGL           1.0     RCHRES   7     EXTNL  IVOL   1 1
WDM1   371 TSSX   0 ENGL           1.0     RCHRES   7     INFLOW ISED   3 1
WDM1   372 BODX   0 ENGL           1.0     RCHRES   7     INFLOW OXIF   2 1
WDM1   373 NH3X   0 ENGL           1.0     RCHRES   7     INFLOW NUIF1  2 1
WDM1   374 NO3X   0 ENGL           1.0     RCHRES   7     INFLOW NUIF1  1 1
WDM1   375 NO2X   0 ENGL           1.0     RCHRES   7     INFLOW NUIF1  3 1
WDM1   308 NO3X   0 ENGL ***          0.6     RCHRES   5     INFLOW NUIF1  1 1
WDM1   376 PO4X   0 ENGL           1.0     RCHRES   7     INFLOW NUIF1  4 1
WDM1   378 HEAT   0 ENGL           1.0     RCHRES   7     INFLOW IHEAT  1 1
*** Chatham Acres
WDM1   380 PTSQ   0 ENGL           1.0     RCHRES   6     EXTNL  IVOL   1 1
WDM1   381 TSSX   0 ENGL           1.0     RCHRES   6     INFLOW ISED   3 1
WDM1   382 BODX   0 ENGL           1.0     RCHRES   6     INFLOW OXIF   2 1
WDM1   383 NH3X   0 ENGL           1.0     RCHRES   6     INFLOW NUIF1  2 1
WDM1   384 NO3X   0 ENGL           1.0     RCHRES   6     INFLOW NUIF1  1 1
WDM1   385 NO2X   0 ENGL           1.0     RCHRES   6     INFLOW NUIF1  3 1
WDM1   308 NO3X   0 ENGL ***          0.6     RCHRES   5     INFLOW NUIF1  1 1
WDM1   386 PO4X   0 ENGL           1.0     RCHRES   6     INFLOW NUIF1  4 1
WDM1   388 HEAT   0 ENGL           1.0     RCHRES   6     INFLOW IHEAT  1 1
***  Chadds Ford Invest. Co./Red Fox
WDM1   390 PTSQ   0 ENGL           1.0     RCHRES   6     EXTNL  IVOL   1 1
WDM1   391 TSSX   0 ENGL           1.0     RCHRES   6     INFLOW ISED   3 1
WDM1   392 BODX   0 ENGL           1.0     RCHRES   6     INFLOW OXIF   2 1
WDM1   393 NH3X   0 ENGL           1.0     RCHRES   6     INFLOW NUIF1  2 1
WDM1   394 NO3X   0 ENGL           1.0     RCHRES   6     INFLOW NUIF1  1 1
WDM1   395 NO2X   0 ENGL           1.0     RCHRES   6     INFLOW NUIF1  3 1
WDM1   308 NO3X   0 ENGL ***          0.6     RCHRES   5     INFLOW NUIF1  1 1
WDM1   396 PO4X   0 ENGL           1.0     RCHRES   6     INFLOW NUIF1  4 1
WDM1   398 HEAT   0 ENGL           1.0     RCHRES   6     INFLOW IHEAT  1 1
*** Stonebar Restaurant and Apt. complex
WDM1   400 PTSQ   0 ENGL           1.0     RCHRES   5     EXTNL  IVOL   1 1
WDM1   401 TSSX   0 ENGL           1.0     RCHRES   5     INFLOW ISED   3 1
WDM1   402 BODX   0 ENGL           1.0     RCHRES   5     INFLOW OXIF   2 1
WDM1   403 NH3X   0 ENGL           1.0     RCHRES   5     INFLOW NUIF1  2 1
WDM1   404 NO3X   0 ENGL           1.0     RCHRES   5     INFLOW NUIF1  1 1
WDM1   405 NO2X   0 ENGL           1.0     RCHRES   5     INFLOW NUIF1  3 1
WDM1   308 NO3X   0 ENGL ***          0.6     RCHRES   5     INFLOW NUIF1  1 1
WDM1   406 PO4X   0 ENGL           1.0     RCHRES   5     INFLOW NUIF1  4 1
WDM1   408 HEAT   0 ENGL           1.0     RCHRES   5     INFLOW IHEAT  1 1
*** Withdrawals ***
*** Laurel Valley Farms
WDM1   200 WITH   0 ENGL           1.0SAME RCHRES   8     EXTNL  OUTDGT 2 1
*** Loch Nairn Golf C.
WDM1   210 WITH   0 ENGL           1.0SAME RCHRES   6     EXTNL  OUTDGT 2 1
*** Papermill Water Treatment Plant
WDM1   220 WITH   0 ENGL           1.0SAME RCHRES  11     EXTNL  OUTDGT 2 1
*** United Water-Stanton DE, Water Treatment Plant
WDM1   230 WITH   0 ENGL           1.0SAME RCHRES  14     EXTNL  OUTDGT 2 1
*** Curtis Paper
WDM1   240 WITH   0 ENGL           1.0SAME RCHRES  11     EXTNL  OUTDGT 3 1
*** MBNA Louviers
WDM1   260 WITH   0 ENGL           1.0SAME RCHRES  11     EXTNL  OUTDGT 4 1
*** MBNA Deerfield Golf C.
WDM1   270 WITH   0 ENGL           1.0SAME RCHRES  11     EXTNL  OUTDGT 5 1
*** Delcastle Golf C.
WDM1   280 WITH   0 ENGL           1.0SAME RCHRES  17     EXTNL  OUTDGT 2 1
*** 3 Little Bakers C.C.
WDM1   290 WITH   0 ENGL           1.0SAME RCHRES  16     EXTNL  OUTDGT 2 1

END EXT SOURCES

EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
*** mult factor for rovol is 12/area
*** mult factor for others 1/area
***
***(Gage: Trout Run)
RCHRES   7 ROFLOW ROVOL     .013668671     WDM   1130 FLOW     ENGL      REPL
RCHRES   7 HYDR   RO                       WDM   1139 FLOW     ENGL      REPL
COPY   400 OUTPUT MEAN   1  .001139056     WDM   1131 SURO     ENGL      REPL
COPY   400 OUTPUT MEAN   2  .001139056     WDM   1132 IFWO     ENGL      REPL
COPY   400 OUTPUT MEAN   3  .001139056     WDM   1133 AGWO     ENGL      REPL
COPY   400 OUTPUT MEAN   4  .001139056     WDM   1134 PREC     ENGL      REPL
COPY   400 OUTPUT MEAN   5  .001139056     WDM   1135 PETX     ENGL      REPL
COPY   400 OUTPUT MEAN   6  .001139056     WDM   1136 TAET     ENGL      REPL
COPY   400 OUTPUT MEAN   7  .001139056     WDM   1137 UZSX     ENGL      REPL
COPY   400 OUTPUT MEAN   8  .001139056     WDM   1138 LZSX     ENGL      REPL
***(Gage: Stricklersville)
RCHRES   9 ROFLOW ROVOL     .000316681     WDM   1120 FLOW     ENGL      REPL
RCHRES   9 HYDR   RO                       WDM   1129 FLOW     ENGL      REPL
COPY   500 OUTPUT MEAN   1  .000026390     WDM   1121 SURO     ENGL      REPL
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COPY   500 OUTPUT MEAN   2  .000026390     WDM   1122 IFWO     ENGL      REPL
COPY   500 OUTPUT MEAN   3  .000026390     WDM   1123 AGWO     ENGL      REPL
COPY   500 OUTPUT MEAN   4  .000026390     WDM   1124 PREC     ENGL      REPL
COPY   500 OUTPUT MEAN   5  .000026390     WDM   1125 PETX     ENGL      REPL
COPY   500 OUTPUT MEAN   6  .000026390     WDM   1126 TAET     ENGL      REPL
COPY   500 OUTPUT MEAN   7  .000026390     WDM   1127 UZSX     ENGL      REPL
COPY   500 OUTPUT MEAN   8  .000026390     WDM   1128 LZSX     ENGL      REPL
***(Gage: At Newark)
RCHRES  11 OFLOW  OVOL   1  .000270441     WDM   1110 FLOW     ENGL      REPL
RCHRES  11 HYDR   O      1                 WDM   1119 FLOW     ENGL      REPL
COPY   540 OUTPUT MEAN   1  .000022537     WDM   1111 SURO     ENGL      REPL
COPY   540 OUTPUT MEAN   2  .000022537     WDM   1112 IFWO     ENGL      REPL
COPY   540 OUTPUT MEAN   3  .000022537     WDM   1113 AGWO     ENGL      REPL
COPY   540 OUTPUT MEAN   4  .000022537     WDM   1114 PREC     ENGL      REPL
COPY   540 OUTPUT MEAN   5  .000022537     WDM   1115 PETX     ENGL      REPL
COPY   540 OUTPUT MEAN   6  .000022537     WDM   1116 TAET     ENGL      REPL
COPY   540 OUTPUT MEAN   7  .000022537     WDM   1117 UZSX     ENGL      REPL
COPY   540 OUTPUT MEAN   8  .000022537     WDM   1118 LZSX     ENGL      REPL
COPY   540 OUTPUT MEAN   9  .000022537     WDM   2000 AGWS     ENGL      REPL
***(Gage: Near Newwark[Delaware Park])
RCHRES  12 ROFLOW ROVOL     .000211558     WDM   1100 FLOW     ENGL      REPL
RCHRES  12 HYDR   RO                       WDM   1109 FLOW     ENGL      REPL
COPY   600 OUTPUT MEAN   1  .000017630     WDM   1101 SURO     ENGL      REPL
COPY   600 OUTPUT MEAN   2  .000017630     WDM   1102 IFWO     ENGL      REPL
COPY   600 OUTPUT MEAN   3  .000017630     WDM   1103 AGWO     ENGL      REPL
COPY   600 OUTPUT MEAN   4  .000017630     WDM   1104 PREC     ENGL      REPL
COPY   600 OUTPUT MEAN   5  .000017630     WDM   1105 PETX     ENGL      REPL
COPY   600 OUTPUT MEAN   6  .000017630     WDM   1106 TAET     ENGL      REPL
COPY   600 OUTPUT MEAN   7  .000017630     WDM   1107 UZSX     ENGL      REPL
COPY   600 OUTPUT MEAN   8  .000017630     WDM   1108 LZSX     ENGL      REPL
*** total loads from pervious and impervious land
COPY   600 OUTPUT MEAN  10  1.00000000     WDM   2100 SOSED    ENGL      REPL
COPY   600 OUTPUT MEAN  11  1.00000000     WDM   2125 PONO3    ENGL      REPL
COPY   600 OUTPUT MEAN  12  1.00000000     WDM   2126 PONH4    ENGL      REPL
COPY   600 OUTPUT MEAN  13  1.00000000     WDM   2127 POPHOS   ENGL      REPL
COPY   600 OUTPUT MEAN  14  1.00000000     WDM   2130 SOSLD    ENGL      REPL
COPY   600 OUTPUT MEAN  15  1.00000000     WDM   2135 IONO3    ENGL      REPL
COPY   600 OUTPUT MEAN  16  1.00000000     WDM   2136 IONH4    ENGL      REPL
COPY   600 OUTPUT MEAN  17  1.00000000     WDM   2137 IOPHOS   ENGL      REPL
***
RCHRES   7 HTRCH  TW                       WDM   1530 WTEM     METR      REPL
RCHRES   9 HTRCH  TW                       WDM   1520 WTEM     METR      REPL
RCHRES  11 HTRCH  TW                       WDM   1510 WTEM     METR      REPL
RCHRES  12 HTRCH  TW                       WDM   1500 WTEM     METR      REPL
***(Reach 2 EBr Output)
RCHRES   2 ROFLOW ROVOL     .001970625     WDM   3100 FLOW     ENGL      REPL
***(Reach 4 EBr Output)
RCHRES   4 ROFLOW ROVOL     .003021909     WDM   3200 FLOW     ENGL      REPL
***(Reach 6 EBr Output)
RCHRES   6 ROFLOW ROVOL     .001668909     WDM   3300 FLOW     ENGL      REPL
***(Reach 3 MBr Output)
RCHRES   3 ROFLOW ROVOL     .000718966     WDM   3500 FLOW     ENGL      REPL
***(Reach 1 WBr Output)
RCHRES   1 ROFLOW ROVOL     .001835471     WDM   3600 FLOW     ENGL      REPL
***(Reach 10 MS Output)
RCHRES  10 ROFLOW ROVOL     .000298533     WDM   3700 FLOW     ENGL      REPL
***(Reach 8 MS Output)
RCHRES   8 OFLOW  OVOL   1  .000713632     WDM   3800 FLOW     ENGL      REPL
RCHRES   1 SEDTRN SSED   4                 WDM   1600 SEDC     METR      REPL
RCHRES   2 SEDTRN SSED   4                 WDM   1620 SEDC     METR      REPL
RCHRES   3 SEDTRN SSED   4                 WDM   1640 SEDC     METR      REPL
RCHRES   5 SEDTRN SSED   4                 WDM   1660 SEDC     METR      REPL
RCHRES   6 SEDTRN SSED   4                 WDM   1680 SEDC     METR      REPL
RCHRES   7 SEDTRN SSED   4                 WDM   1700 SEDC     METR      REPL
RCHRES   9 SEDTRN SSED   4                 WDM   1720 SEDC     METR      REPL
RCHRES  10 SEDTRN SSED   4                 WDM   1740 SEDC     METR      REPL
RCHRES  11 SEDTRN SSED   4                 WDM   1760 SEDC     METR      REPL
RCHRES  12 SEDTRN SSED   4                 WDM   1780 SEDC     METR      REPL
RCHRES  15 SEDTRN SSED   4                 WDM   1800 SEDC     METR      REPL
RCHRES  16 SEDTRN SSED   4                 WDM   1820 SEDC     METR      REPL
RCHRES  17 SEDTRN SSED   4                 WDM   1840 SEDC     METR      REPL
RCHRES   1 OXRX   DOX                      WDM   1661 DOXX     METR      REPL
*** Dissolved NO3
RCHRES   5 NUTRX  DNUST  1                 WDM   1663 NO3X     METR      REPL
*** Dissolved NH3
RCHRES   5 NUTRX  DNUST  2                 WDM   1664 NH4X     METR      REPL
*** Dissolved PO4
RCHRES   5 NUTRX  DNUST  4                 WDM   1665 PO4X     METR      REPL
*** BOD
RCHRES   5 OXRX   BOD                      WDM   1666 BODX     METR      REPL
COPY    10 OUTPUT MEAN   1                 WDM   1667 NH4P     METR      REPL
COPY    10 OUTPUT MEAN   2                 WDM   1668 PO4P     METR      REPL
RCHRES   5 PLANK  PKST3  4                 WDM   1669 TORN     METR      REPL
RCHRES   5 PLANK  PHYCLA 1                 WDM   1670 PHCA     METR      REPL
RCHRES   7 OXRX   DOX                      WDM   1701 DOXX     METR      REPL
RCHRES   7 NUTRX  DNUST  1                 WDM   1703 NO3X     METR      REPL
RCHRES   7 NUTRX  DNUST  2                 WDM   1704 NH4X     METR      REPL
RCHRES   7 NUTRX  DNUST  4                 WDM   1705 PO4X     METR      REPL
RCHRES   7 OXRX   BOD                      WDM   1706 BODX     METR      REPL
COPY    11 OUTPUT MEAN   1                 WDM   1707 NH4P     METR      REPL
COPY    11 OUTPUT MEAN   2                 WDM   1708 PO4P     METR      REPL
RCHRES   7 PLANK  PKST3  4                 WDM   1709 TORN     METR      REPL
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RCHRES   7 PLANK  PHYCLA 1                 WDM   1710 PHCA     METR      REPL
RCHRES   9 OXRX   DOX                      WDM   1721 DOXX     METR      REPL
RCHRES   9 NUTRX  DNUST  1                 WDM   1723 NO3X     METR      REPL
RCHRES   9 NUTRX  DNUST  2                 WDM   1724 NH4X     METR      REPL
RCHRES   9 NUTRX  DNUST  4                 WDM   1725 PO4X     METR      REPL
RCHRES   9 OXRX   BOD                      WDM   1726 BODX     METR      REPL
COPY    12 OUTPUT MEAN   1                 WDM   1727 NH4P     METR      REPL
COPY    12 OUTPUT MEAN   2                 WDM   1728 PO4P     METR      REPL
RCHRES   9 PLANK  PKST3  4                 WDM   1729 TORN     METR      REPL
RCHRES   9 PLANK  PHYCLA 1                 WDM   1730 PHCA     METR      REPL
RCHRES  12 OXRX   DOX                      WDM   1781 DOXX     METR      REPL
RCHRES  12 NUTRX  DNUST  1                 WDM   1783 NO3X     METR      REPL
RCHRES  12 NUTRX  DNUST  2                 WDM   1784 NH4X     METR      REPL
RCHRES  12 NUTRX  DNUST  4                 WDM   1785 PO4X     METR      REPL
RCHRES  12 OXRX   BOD                      WDM   1786 BODX     METR      REPL
COPY    14 OUTPUT MEAN   1                 WDM   1787 NH4P     METR      REPL
COPY    14 OUTPUT MEAN   2                 WDM   1788 PO4P     METR      REPL
RCHRES  12 PLANK  PKST3  4                 WDM   1789 TORN     METR      REPL
RCHRES  12 PLANK  PHYCLA 1                 WDM   1790 PHCA     METR      REPL
RCHRES  16 OXRX   DOX                      WDM   1821 DOXX     METR      REPL
RCHRES  16 NUTRX  DNUST  1                 WDM   1823 NO3X     METR      REPL
RCHRES  16 NUTRX  DNUST  2                 WDM   1824 NH4X     METR      REPL
RCHRES  16 NUTRX  DNUST  4                 WDM   1825 PO4X     METR      REPL
RCHRES  16 OXRX   BOD                      WDM   1826 BODX     METR      REPL
COPY    14 OUTPUT MEAN   1   ***              WDM   1827 NH4P     METR      REPL
COPY    14 OUTPUT MEAN   2   ***              WDM   1828 PO4P     METR      REPL
RCHRES  16 PLANK  PKST3  4    ***             WDM   1829 TORN     METR      REPL
RCHRES  16 PLANK  PHYCLA 1                 WDM   1830 PHCA     METR      REPL
*** sediment calibration data sets
RCHRES   1 HYDR   TAU                      WDM   9001 TAU      ENGL      REPL
RCHRES   2 HYDR   TAU                      WDM   9002 TAU      ENGL      REPL
RCHRES   3 HYDR   TAU                      WDM   9003 TAU      ENGL      REPL
RCHRES   4 HYDR   TAU                      WDM   9004 TAU      ENGL      REPL
RCHRES   5 HYDR   TAU                      WDM   9005 TAU      ENGL      REPL
RCHRES   6 HYDR   TAU                      WDM   9006 TAU      ENGL      REPL
RCHRES   7 HYDR   TAU                      WDM   9007 TAU      ENGL      REPL
RCHRES   8 HYDR   TAU                      WDM   9008 TAU      ENGL      REPL
RCHRES   9 HYDR   TAU                      WDM   9009 TAU      ENGL      REPL
RCHRES  10 HYDR   TAU                      WDM   9010 TAU      ENGL      REPL
RCHRES  11 HYDR   TAU                      WDM   9011 TAU      ENGL      REPL
RCHRES  12 HYDR   TAU                      WDM   9012 TAU      ENGL      REPL
RCHRES  13 HYDR   TAU                      WDM   9013 TAU      ENGL      REPL
RCHRES  14 HYDR   TAU                      WDM   9014 TAU      ENGL      REPL
RCHRES  15 HYDR   TAU                      WDM   9015 TAU      ENGL      REPL
RCHRES  16 HYDR   TAU                      WDM   9016 TAU      ENGL      REPL
RCHRES  17 HYDR   TAU                      WDM   9017 TAU      ENGL      REPL
PERLND 702 SEDMNT DETS                     WDM   9020 DETS     ENGL      REPL
PERLND 703 SEDMNT DETS                     WDM   9021 DETS     ENGL      REPL
PERLND 704 SEDMNT DETS                     WDM   9022 DETS     ENGL      REPL
PERLND 705 SEDMNT DETS                     WDM   9023 DETS     ENGL      REPL
PERLND 707 SEDMNT DETS                     WDM   9024 DETS     ENGL      REPL
PERLND 708 SEDMNT DETS                     WDM   9025 DETS     ENGL      REPL
PERLND 709 SEDMNT DETS                     WDM   9026 DETS     ENGL      REPL
PERLND 710 SEDMNT DETS                     WDM   9027 DETS     ENGL      REPL
PERLND 502 SEDMNT DETS                     WDM   9030 DETS     ENGL      REPL
PERLND 503 SEDMNT DETS                     WDM   9031 DETS     ENGL      REPL
PERLND 504 SEDMNT DETS                     WDM   9032 DETS     ENGL      REPL
PERLND 505 SEDMNT DETS                     WDM   9033 DETS     ENGL      REPL
PERLND 507 SEDMNT DETS                     WDM   9034 DETS     ENGL      REPL
PERLND 508 SEDMNT DETS                     WDM   9035 DETS     ENGL      REPL
PERLND 509 SEDMNT DETS                     WDM   9036 DETS     ENGL      REPL
PERLND 510 SEDMNT DETS                     WDM   9037 DETS     ENGL      REPL
PERLND 802 SEDMNT DETS                     WDM   9040 DETS     ENGL      REPL
PERLND 803 SEDMNT DETS                     WDM   9041 DETS     ENGL      REPL
PERLND 804 SEDMNT DETS                     WDM   9042 DETS     ENGL      REPL
PERLND 805 SEDMNT DETS                     WDM   9043 DETS     ENGL      REPL
PERLND 807 SEDMNT DETS                     WDM   9044 DETS     ENGL      REPL
PERLND 808 SEDMNT DETS                     WDM   9045 DETS     ENGL      REPL
PERLND 809 SEDMNT DETS                     WDM   9046 DETS     ENGL      REPL
PERLND 810 SEDMNT DETS                     WDM   9047 DETS     ENGL      REPL

END EXT TARGETS

SCHEMATIC
<-Source->                   <--Area-->    <-Target->   <ML>  ***
<Name>   #                   <-factor->    <Name>   #      #  ***
*** Note: All PLS-RCH and ILS-RCH multiplication factors are acres.
***       Conversion factors, where applicable, are in Mass-Link.
***
*** Segment 2 (Upper Middle, East Branch White Clay)
*** Tributary to Reach 2 (Upper Middle Br.)
PERLND 702                    685.2100     RCHRES   2      1
PERLND 703                     109.100     RCHRES   2      1
PERLND 704                      49.550     RCHRES   2      1
PERLND 705                      964.98     RCHRES   2      1
PERLND 706                    2894.940     RCHRES   2      1
PERLND 707                           0     RCHRES   2      1
PERLND 708                    1076.840     RCHRES   2      1
PERLND 709                      66.710     RCHRES   2      1
PERLND 710                      11.570     RCHRES   2      1
PERLND 711                      56.020     RCHRES   2      1
IMPLND 701                     122.890     RCHRES   2      2
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IMPLND 702                      51.630     RCHRES   2      2
*** Tributary to Reach 4 (Chatham Trib. to East Br.)
PERLND 702                     270.880     RCHRES   4      1
PERLND 703                     105.920     RCHRES   4      1
PERLND 704                      53.610     RCHRES   4      1
PERLND 705                     456.146     RCHRES   4      1
PERLND 706                    1596.511     RCHRES   4      1
PERLND 707                     228.073     RCHRES   4      1
PERLND 708                     932.040     RCHRES   4      1
PERLND 709                      97.160     RCHRES   4      1
PERLND 710                      17.120     RCHRES   4      1
PERLND 711                      82.940     RCHRES   4      1
IMPLND 701                      75.490     RCHRES   4      2
IMPLND 702                      55.110     RCHRES   4      2
*** Tributary to Reach 5 (Upper East Br. to WQN179)
PERLND 702                      27.300     RCHRES   5      1
PERLND 703                           0     RCHRES   5      1
PERLND 704                           0     RCHRES   5      1
PERLND 705                     252.522     RCHRES   5      1
PERLND 706                     883.827     RCHRES   5      1
PERLND 707                     126.261     RCHRES   5      1
PERLND 708                     391.790     RCHRES   5      1
PERLND 709                      12.900     RCHRES   5      1
PERLND 710                       2.890     RCHRES   5      1
PERLND 711                       5.430     RCHRES   5      1
IMPLND 701                       3.030     RCHRES   5      2
IMPLND 702                           0     RCHRES   5      2
*** Tributary to Reach 6 (Woodville trib. to East Br.)
PERLND 702                      85.040     RCHRES   6      1
PERLND 703                      42.480     RCHRES   6      1
PERLND 704                      70.740     RCHRES   6      1
PERLND 705                     736.255     RCHRES   6      1
PERLND 706                    2594.839     RCHRES   6      1
PERLND 707                     370.121     RCHRES   6      1
PERLND 708                    1196.710     RCHRES   6      1
PERLND 709                     162.320     RCHRES   6      1
PERLND 710                      11.270     RCHRES   6      1
PERLND 711                     113.640     RCHRES   6      1
IMPLND 701                      27.650     RCHRES   6      2
IMPLND 702                      73.310     RCHRES   6      2
*** Tributary to Reach 7 (Trout Run)
PERLND 702                     51.2400     RCHRES   7      1
PERLND 703                      43.710     RCHRES   7      1
PERLND 704                      11.130     RCHRES   7      1
PERLND 705                           0     RCHRES   7      1
PERLND 706                      54.415     RCHRES   7      1
PERLND 707                     489.735     RCHRES   7      1
PERLND 708                     151.540     RCHRES   7      1
PERLND 709                           0     RCHRES   7      1
PERLND 710                      11.790     RCHRES   7      1
PERLND 711                      25.940     RCHRES   7      1
IMPLND 701                      24.430     RCHRES   7      2
IMPLND 702                      13.990     RCHRES   7      2

    Reach Connections ***
RCHRES   5                                 RCHRES   6      3

***
*** Segment 5 (Lower White Clay Creek)
*** Tributary to Reach 1 (W.Br.White Clay Crk)
PERLND 502                    1023.420     RCHRES   1      1
PERLND 503                           0     RCHRES   1      1
PERLND 504                      61.380     RCHRES   1      1
PERLND 505                     677.122     RCHRES   1      1
PERLND 506                    2369.927     RCHRES   1      1
PERLND 507                     338.561     RCHRES   1      1
PERLND 508                    1711.340     RCHRES   1      1
PERLND 509                     133.780     RCHRES   1      1
PERLND 510                       4.240     RCHRES   1      1
PERLND 511                      42.970     RCHRES   1      1
IMPLND 501                     113.710     RCHRES   1      2
IMPLND 502                      61.380     RCHRES   1      2
*** Tributary to Reach 3 (Lower Middle Br. to confl.)
PERLND 502                     666.000     RCHRES   3      1
PERLND 503                           0     RCHRES   3      1
PERLND 504                           0     RCHRES   3      1
PERLND 505                     363.866     RCHRES   3      1
PERLND 506                    1364.498     RCHRES   3      1
PERLND 507                      90.967     RCHRES   3      1
PERLND 508                    1459.400     RCHRES   3      1
PERLND 509                      23.330     RCHRES   3      1
PERLND 510                      19.000     RCHRES   3      1
PERLND 511                       0.180     RCHRES   3      1
IMPLND 501                      76.130     RCHRES   3      2
IMPLND 502                           0     RCHRES   3      2
*** Tributary to Reach 8 (E.Br. to Landenburg)
PERLND 502                     554.500     RCHRES   8      1
PERLND 503                      24.390     RCHRES   8      1
PERLND 504                       23.41     RCHRES   8      1
PERLND 505                           0     RCHRES   8      1
PERLND 506                     962.240     RCHRES   8      1
PERLND 507                    1443.360     RCHRES   8      1
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PERLND 508                    1548.650     RCHRES   8      1
PERLND 509                      57.130     RCHRES   8      1
PERLND 510                      22.900     RCHRES   8      1
PERLND 511                      41.850     RCHRES   8      1
IMPLND 501                      72.060     RCHRES   8      2
IMPLND 502                      25.660     RCHRES   8      2
*** Tributary to Reach 9 (E.Br. to Stricklersville gage)
PERLND 502                     765.050     RCHRES   9      1
PERLND 503                     314.390     RCHRES   9      1
PERLND 504                      31.000     RCHRES   9      1
PERLND 505                     286.458     RCHRES   9      1
PERLND 506                    1002.603     RCHRES   9      1
PERLND 507                     143.229     RCHRES   9      1
PERLND 508                    1389.430     RCHRES   9      1
PERLND 509                     104.460     RCHRES   9      1
PERLND 510                      70.610     RCHRES   9      1
PERLND 511                      28.960     RCHRES   9      1
IMPLND 501                     219.740     RCHRES   9      2
IMPLND 502                      31.000     RCHRES   9      2
*** Tributary to Reach 10 (White Clay to Chambers Rock Rd)
PERLND 502                     259.110     RCHRES  10      1
PERLND 503                     102.010     RCHRES  10      1
PERLND 504                       1.560     RCHRES  10      1
PERLND 505                     124.486     RCHRES  10      1
PERLND 506                     497.944     RCHRES  10      1
PERLND 507                           0     RCHRES  10      1
PERLND 508                    1216.070     RCHRES  10      1
PERLND 509                       6.880     RCHRES  10      1
PERLND 510                      14.620     RCHRES  10      1
PERLND 511                       6.820     RCHRES  10      1
IMPLND 501                      72.510     RCHRES  10      2
IMPLND 502                       1.600     RCHRES  10      2
*** Tributary to Reach 11 (White Clay to Newark gage)
PERLND 502                      53.480     RCHRES  11      1
PERLND 503                     339.100     RCHRES  11      1
PERLND 504                     176.330     RCHRES  11      1
PERLND 505                           0     RCHRES  11      1
PERLND 506                     647.330     RCHRES  11      1
PERLND 507                           0     RCHRES  11      1
PERLND 508                    2289.790     RCHRES  11      1
PERLND 509                     297.190     RCHRES  11      1
PERLND 510                      33.150     RCHRES  11      1
PERLND 511                      10.160     RCHRES  11      1
IMPLND 501                     151.270     RCHRES  11      2
IMPLND 502                     177.290     RCHRES  11      2
*** Tributary to Reach 12 (White Clay to Race Track gage)
PERLND 802                           0     RCHRES  12      1
PERLND 803                    1352.100     RCHRES  12      1
PERLND 804                     570.240     RCHRES  12      1
PERLND 805                           0     RCHRES  12      1
PERLND 806                     527.440     RCHRES  12      1
PERLND 807                           0     RCHRES  12      1
PERLND 808                     601.720     RCHRES  12      1
PERLND 809                     548.020     RCHRES  12      1
PERLND 810                      52.520     RCHRES  12      1
PERLND 811                     570.240     RCHRES  12      1
IMPLND 801                     579.470     RCHRES  12      2
IMPLND 802                     808.810     RCHRES  12      2
*** Tributary to Reach 13 (White Clay to Mill Creek)
PERLND 802                           0     RCHRES  13      1
PERLND 803                      92.060     RCHRES  13      1
PERLND 804                     192.530     RCHRES  13      1
PERLND 805                           0     RCHRES  13      1
PERLND 806                     149.150     RCHRES  13      1
PERLND 807                           0     RCHRES  13      1
PERLND 808                     152.540     RCHRES  13      1
PERLND 809                      95.560     RCHRES  13      1
PERLND 810                      20.960     RCHRES  13      1
PERLND 811                     363.660     RCHRES  13      1
IMPLND 801                      39.450     RCHRES  13      2
IMPLND 802                     232.940     RCHRES  13      2
*** Tributary to Reach 14 (White Clay to Christina conflu.)
PERLND 802                           0     RCHRES  14      1
PERLND 803                     232.260     RCHRES  14      1
PERLND 804                     252.770     RCHRES  14      1
PERLND 805                           0     RCHRES  14      1
PERLND 806                           0     RCHRES  14      1
PERLND 807                           0     RCHRES  14      1
PERLND 808                     304.830     RCHRES  14      1
PERLND 809                     473.830     RCHRES  14      1
PERLND 810                     314.160     RCHRES  14      1
PERLND 811                     229.210     RCHRES  14      1
IMPLND 801                      99.540     RCHRES  14      2
IMPLND 802                     278.240     RCHRES  14      2
*** Tributary to Reach 15 (Middle Run)
PERLND 502                           0     RCHRES  15      1
PERLND 503                     361.380     RCHRES  15      1
PERLND 554                      47.630     RCHRES  15      1
PERLND 505                           0     RCHRES  15      1
PERLND 506                     734.140     RCHRES  15      1
PERLND 507                           0     RCHRES  15      1
PERLND 508                    1050.460     RCHRES  15      1
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PERLND 509                      81.030     RCHRES  15      1
PERLND 510                           0     RCHRES  15      1
PERLND 511                      11.210     RCHRES  15      1
IMPLND 501                     154.880     RCHRES  15      2
IMPLND 502                      48.880     RCHRES  15      2
*** Tributary to Reach 16 (Pike Creek)
PERLND 502                           0     RCHRES  16      1
PERLND 503                    1656.070     RCHRES  16      1
PERLND 504                     262.270     RCHRES  16      1
PERLND 505                           0     RCHRES  16      1
PERLND 506                     357.500     RCHRES  16      1
PERLND 507                           0     RCHRES  16      1
PERLND 508                     547.530     RCHRES  16      1
PERLND 509                     387.820     RCHRES  16      1
PERLND 510                           0     RCHRES  16      1
PERLND 511                      59.910     RCHRES  16      1
IMPLND 501                      709.75     RCHRES  16      2
IMPLND 502                      268.93     RCHRES  16      2
*** Tributary to Reach 17 (Mill Creek)
PERLND 502                      41.920     RCHRES  17      1
PERLND 503                    2824.670     RCHRES  17      1
PERLND 504                     550.910     RCHRES  17      1
PERLND 505                      90.659     RCHRES  17      1
PERLND 506                     725.272     RCHRES  17      1
PERLND 507                      90.659     RCHRES  17      1
PERLND 508                     971.870     RCHRES  17      1
PERLND 509                     844.320     RCHRES  17      1
PERLND 510                       0.030     RCHRES  17      1
PERLND 511                     340.730     RCHRES  17      1
IMPLND 501                    1251.230     RCHRES  17      2
IMPLND 502                     588.500     RCHRES  17      2

    Reach Connections ***
RCHRES   1                                 RCHRES   3      3
RCHRES   2                                 RCHRES   3      3
RCHRES   4                                 RCHRES   8      3
RCHRES   6                                 RCHRES   8      4
RCHRES   7                                 RCHRES   8      3
RCHRES   3                                 RCHRES   9      3
RCHRES   8                                 RCHRES   9      4
RCHRES   9                                 RCHRES  10      3
RCHRES  10                                 RCHRES  11      3
RCHRES  11                                 RCHRES  12      4
RCHRES  15                                 RCHRES  12      3
RCHRES  16                                 RCHRES  12      4
RCHRES  12                                 RCHRES  13      3
RCHRES  13                                 RCHRES  14      3
RCHRES  17                                 RCHRES  14      4

*** HSPEXP ***
    W.Br.White Clay - Output from Reach 1 ***
PERLND 502                    1023.420     COPY   200     91
PERLND 503                           0     COPY   200     91
PERLND 504                      61.380     COPY   200     91
PERLND 505                     677.122     COPY   200     91
PERLND 506                    2369.927     COPY   200     91
PERLND 507                     338.561     COPY   200     91
PERLND 508                    1711.340     COPY   200     91
PERLND 509                     133.780     COPY   200     91
PERLND 510                       4.240     COPY   200     91
PERLND 511                      42.970     COPY   200     91
IMPLND 501                     113.710     COPY   200     92
IMPLND 502                      61.380     COPY   200     92
    Middle Br. White Clay - Output from Reach 2 ***
PERLND 702                    685.2100     COPY   100     91
PERLND 703                     109.100     COPY   100     91
PERLND 704                      49.550     COPY   100     91
PERLND 705                      964.98     COPY   100     91
PERLND 706                    2894.940     COPY   100     91
PERLND 707                           0     COPY   100     91
PERLND 708                    1076.840     COPY   100     91
PERLND 709                      66.710     COPY   100     91
PERLND 710                      11.570     COPY   100     91
PERLND 711                      56.020     COPY   100     91
IMPLND 701                     122.890     COPY   100     92
IMPLND 702                      51.630     COPY   100     92
*** Upper East Br. to WQN179 - Output from Reach 5
PERLND 702                      27.300     COPY   300     91
PERLND 703                           0     COPY   300     91
PERLND 704                           0     COPY   300     91
PERLND 705                     252.522     COPY   300     91
PERLND 706                     883.827     COPY   300     91
PERLND 707                     126.261     COPY   300     91
PERLND 708                     391.790     COPY   300     91
PERLND 709                      12.900     COPY   300     91
PERLND 710                       2.890     COPY   300     91
PERLND 711                       5.430     COPY   300     91
IMPLND 701                       3.030     COPY   300     92
IMPLND 702                           0     COPY   300     92
*** Trout Run - Output from Reach 7
PERLND 702                     51.2400     COPY   400     91
PERLND 703                      43.710     COPY   400     91
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PERLND 704                      11.130     COPY   400     91
PERLND 705                           0     COPY   400     91
PERLND 706                      54.415     COPY   400     91
PERLND 707                     489.735     COPY   400     91
PERLND 708                     151.540     COPY   400     91
PERLND 709                           0     COPY   400     91
PERLND 710                      11.790     COPY   400     91
PERLND 711                      25.940     COPY   400     91
IMPLND 701                      24.430     COPY   400     92
IMPLND 702                      13.990     COPY   400     92
*** Stricklersville gage - Output from Reach 9
PERLND 702                    1119.670     COPY   500     91
PERLND 703                     301.910     COPY   500     91
PERLND 704                     185.030     COPY   500     91
PERLND 705                    2409.903     COPY   500     91
PERLND 706                    8024.532     COPY   500     91
PERLND 707                    1214.190     COPY   500     91
PERLND 708                    3748.920     COPY   500     91
PERLND 709                     339.090     COPY   500     91
PERLND 710                      54.640     COPY   500     91
PERLND 711                     283.970     COPY   500     91
IMPLND 701                     253.970     COPY   500     92
IMPLND 702                     194.040     COPY   500     92
PERLND 502                    3008.970     COPY   500     91
PERLND 503                     338.780     COPY   500     91
PERLND 504                     115.790     COPY   500     91
PERLND 505                    1327.446     COPY   500     91
PERLND 506                    5699.268     COPY   500     91
PERLND 507                    2016.117     COPY   500     91
PERLND 508                    6108.820     COPY   500     91
PERLND 509                     318.700     COPY   500     91
PERLND 510                     116.750     COPY   500     91
PERLND 511                     113.960     COPY   500     91
IMPLND 501                     481.640     COPY   500     92
IMPLND 502                     118.040     COPY   500     92
     White Clay at Chambers Rock Rd - Output from Reach 10 ***
COPY   500                                 COPY   530     93
PERLND 502                      259.11     COPY   530     91
PERLND 503                      102.01     COPY   530     91
PERLND 504                        1.56     COPY   530     91
PERLND 505                     286.458     COPY   530     91
PERLND 506                    1002.603     COPY   530     91
PERLND 507                     143.229     COPY   530     91
PERLND 508                     1389.43     COPY   530     91
PERLND 509                      104.46     COPY   530     91
PERLND 510                       70.61     COPY   530     91
PERLND 511                       28.96     COPY   530     91
IMPLND 501                     219.749     COPY   530     92
IMPLND 502                        31.0     COPY   530     92
     White Clay at Newark gage - Output from Reach 11 ***
PERLND 702                    1119.670     COPY   540     91
PERLND 703                     301.910     COPY   540     91
PERLND 704                     185.030     COPY   540     91
PERLND 705                    2409.903     COPY   540     91
PERLND 706                    8024.532     COPY   540     91
PERLND 707                    1214.190     COPY   540     91
PERLND 708                    3748.920     COPY   540     91
PERLND 709                     339.090     COPY   540     91
PERLND 710                      54.640     COPY   540     91
PERLND 711                     283.970     COPY   540     91
IMPLND 701                     253.970     COPY   540     92
IMPLND 702                     194.040     COPY   540     92
PERLND 502                     3321.56     COPY   540     91
PERLND 503                      779.89     COPY   540     91
PERLND 504                      293.68     COPY   540     91
PERLND 505                    1451.932     COPY   540     91
PERLND 506                    6844.542     COPY   540     91
PERLND 507                    2016.117     COPY   540     91
PERLND 508                     9614.68     COPY   540     91
PERLND 509                      622.77     COPY   540     91
PERLND 510                      164.52     COPY   540     91
PERLND 511                      130.94     COPY   540     91
IMPLND 501                      705.42     COPY   540     92
IMPLND 502                      296.93     COPY   540     92
     Middle Run - Output from Reach 15 ***
PERLND 502                           0     COPY   550     91
PERLND 503                      361.38     COPY   550     91
PERLND 504                       47.63     COPY   550     91
PERLND 505                           0     COPY   550     91
PERLND 506                     734.140     COPY   550     91
PERLND 507                           0     COPY   550     91
PERLND 508                     1050.46     COPY   550     91
PERLND 509                       81.03     COPY   550     91
PERLND 510                           0     COPY   550     91
PERLND 511                       11.21     COPY   550     91
IMPLND 501                      154.88     COPY   550     92
IMPLND 502                       48.88     COPY   550     92
    Pike Creek - Output from Reach 16 ***
PERLND 502                           0     COPY   560     91
PERLND 503                     1656.07     COPY   560     91
PERLND 504                      262.27     COPY   560     91
PERLND 505                           0     COPY   560     91
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PERLND 506                     357.500     COPY   560     91
PERLND 507                           0     COPY   560     91
PERLND 508                      547.53     COPY   560     91
PERLND 509                      387.82     COPY   560     91
PERLND 510                           0     COPY   560     91
PERLND 511                       59.91     COPY   560     91
IMPLND 501                      709.75     COPY   560     92
IMPLND 502                      268.93     COPY   560     92
     White Clay at Race Track gage - Output from Reach 12 ***
PERLND 702                    1119.670     COPY   600     91
PERLND 703                     301.910     COPY   600     91
PERLND 704                     185.030     COPY   600     91
PERLND 705                    2409.903     COPY   600     91
PERLND 706                    8024.532     COPY   600     91
PERLND 707                    1214.190     COPY   600     91
PERLND 708                    3748.920     COPY   600     91
PERLND 709                     339.090     COPY   600     91
PERLND 710                      54.640     COPY   600     91
PERLND 711                     283.970     COPY   600     91
IMPLND 701                     253.970     COPY   600     92
IMPLND 702                     194.040     COPY   600     92
PERLND 502                     3321.56     COPY   600     91
PERLND 503                     2797.34     COPY   600     91
PERLND 504                      603.58     COPY   600     91
PERLND 505                    1451.932     COPY   600     91
PERLND 506                    7936.182     COPY   600     91
PERLND 507                    2016.117     COPY   600     91
PERLND 508                    11212.67     COPY   600     91
PERLND 509                     1091.62     COPY   600     91
PERLND 510                      164.52     COPY   600     91
PERLND 511                      202.06     COPY   600     91
IMPLND 501                     1570.05     COPY   600     92
IMPLND 502                      614.74     COPY   600     92
PERLND 802                           0     COPY   600     91
PERLND 803                      1352.1     COPY   600     91
PERLND 804                      570.24     COPY   600     91
PERLND 805                           0     COPY   600     91
PERLND 806                      527.44     COPY   600     91
PERLND 807                           0     COPY   600     91
PERLND 808                      601.72     COPY   600     91
PERLND 809                      548.02     COPY   600     91
PERLND 810                       52.52     COPY   600     91
PERLND 811                      570.24     COPY   600     91
IMPLND 801                      579.47     COPY   600     92
IMPLND 802                      808.81     COPY   600     92
    Mill - Output from Reach 17 ***
PERLND 502                       41.92     COPY   610     91
PERLND 503                     2824.67     COPY   610     91
PERLND 504                      550.91     COPY   610     91
PERLND 505                      90.659     COPY   610     91
PERLND 506                     752.272     COPY   610     91
PERLND 507                      90.659     COPY   610     91
PERLND 508                      971.87     COPY   610     91
PERLND 509                      844.32     COPY   610     91
PERLND 510                        0.03     COPY   610     91
PERLND 511                      340.73     COPY   610     91
IMPLND 501                     1251.23     COPY   610     92
IMPLND 502                      588.50     COPY   610     92
END SCHEMATIC

MASS-LINK
  MASS-LINK        1
<Srce>     <-Grp> <-Member-><--Mult-->     <Targ>         <-Grp> <-Member-> ***
<Name>     <Name> <Name> # #<-factor->     <Name>         <Name> <Name> # # ***
PERLND     PWATER PERO       0.0833333     RCHRES         INFLOW IVOL
PERLND     SEDMNT SOSED           0.10     RCHRES         INFLOW ISED   1
PERLND     SEDMNT SOSED           0.40     RCHRES         INFLOW ISED   2
PERLND     SEDMNT SOSED           0.50     RCHRES         INFLOW ISED   3
PERLND     PWTGAS POHT                     RCHRES         INFLOW IHEAT
PERLND     PWTGAS PODOXM                   RCHRES         INFLOW OXIF   1
PERLND     PQUAL  POQUAL 1                 RCHRES         INFLOW NUIF1  1
PERLND     PQUAL  POQUAL 2                 RCHRES         INFLOW NUIF1  2
PERLND     PQUAL  POQUAL 3                 RCHRES         INFLOW NUIF1  4
PERLND     PQUAL  POQUAL 4                 RCHRES         INFLOW OXIF   2
PERLND     PQUAL  POQUAL 5                 RCHRES         INFLOW PKIF   3
  END MASS-LINK    1

  MASS-LINK        2
<Srce>     <-Grp> <-Member-><--Mult-->     <Targ>         <-Grp> <-Member-> ***
<Name>     <Name> <Name> # #<-factor->     <Name>         <Name> <Name> # # ***
IMPLND     IWATER SURO       0.0833333     RCHRES         INFLOW IVOL
IMPLND     SOLIDS SOSLD           0.10     RCHRES         INFLOW ISED   1
IMPLND     SOLIDS SOSLD           0.40     RCHRES         INFLOW ISED   2
IMPLND     SOLIDS SOSLD           0.50     RCHRES         INFLOW ISED   3
IMPLND     IWTGAS SOHT                     RCHRES         INFLOW IHEAT
IMPLND     IWTGAS SODOXM                   RCHRES         INFLOW OXIF   1
IMPLND     IQUAL  SOQUAL 1                 RCHRES         INFLOW NUIF1  1
IMPLND     IQUAL  SOQUAL 2                 RCHRES         INFLOW NUIF1  2
IMPLND     IQUAL  SOQUAL 3                 RCHRES         INFLOW NUIF1  4
IMPLND     IQUAL  SOQUAL 4                 RCHRES         INFLOW OXIF   2
  END MASS-LINK    2
```

```
  MASS-LINK        3
<Srce>     <-Grp> <-Member-><--Mult-->     <Targ>         <-Grp> <-Member-> ***
<Name>     <Name> <Name> # #<-factor->     <Name>         <Name> <Name> # # ***
RCHRES     ROFLOW                          RCHRES         INFLOW
  END MASS-LINK    3

  MASS-LINK        4
<Srce>     <-Grp> <-Member-><--Mult-->     <Targ>         <-Grp> <-Member-> ***
<Name>     <Name> <Name> # #<-factor->     <Name>         <Name> <Name> # # ***
RCHRES     OFLOW         1                 RCHRES         INFLOW
  END MASS-LINK    4

  MASS-LINK       91
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER SURO                     COPY           INPUT  MEAN   1
PERLND     PWATER IFWO                     COPY           INPUT  MEAN   2
PERLND     PWATER AGWO                     COPY           INPUT  MEAN   3
PERLND     PWATER PET                      COPY           INPUT  MEAN   5
PERLND     PWATER TAET                     COPY           INPUT  MEAN   6
PERLND     PWATER UZS                      COPY           INPUT  MEAN   7
PERLND     PWATER LZS                      COPY           INPUT  MEAN   8
PERLND     PWATER AGWS                     COPY           INPUT  MEAN   9
PERLND     SEDMNT SOSED                    COPY           INPUT  MEAN  10
PERLND     PQUAL  POQUAL 1                 COPY           INPUT  MEAN  11
PERLND     PQUAL  POQUAL 2                 COPY           INPUT  MEAN  12
PERLND     PQUAL  POQUAL 3                 COPY           INPUT  MEAN  13
  END MASS-LINK   91

  MASS-LINK       92
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO                     COPY           INPUT  MEAN   1
IMPLND     IWATER PET                      COPY           INPUT  MEAN   5
IMPLND     IWATER IMPEV                    COPY           INPUT  MEAN   6
IMPLND     SOLIDS SOSLD                    COPY           INPUT  MEAN  14
IMPLND     IQUAL  SOQUAL 1                 COPY           INPUT  MEAN  15
IMPLND     IQUAL  SOQUAL 2                 COPY           INPUT  MEAN  16
IMPLND     IQUAL  SOQUAL 3                 COPY           INPUT  MEAN  17
  END MASS-LINK   92

  MASS-LINK       93
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
COPY       OUTPUT MEAN   1                 COPY           INPUT  MEAN   1
COPY       OUTPUT MEAN   2                 COPY           INPUT  MEAN   2
COPY       OUTPUT MEAN   3                 COPY           INPUT  MEAN   3
COPY       OUTPUT MEAN   4                 COPY           INPUT  MEAN   4
COPY       OUTPUT MEAN   5                 COPY           INPUT  MEAN   5
COPY       OUTPUT MEAN   6                 COPY           INPUT  MEAN   6
COPY       OUTPUT MEAN   7                 COPY           INPUT  MEAN   7
COPY       OUTPUT MEAN   8                 COPY           INPUT  MEAN   8
COPY       OUTPUT MEAN   9                 COPY           INPUT  MEAN   9
COPY       OUTPUT MEAN  10                 COPY           INPUT  MEAN  10
COPY       OUTPUT MEAN  11                 COPY           INPUT  MEAN  11
COPY       OUTPUT MEAN  12                 COPY           INPUT  MEAN  12
COPY       OUTPUT MEAN  13                 COPY           INPUT  MEAN  13
COPY       OUTPUT MEAN  14                 COPY           INPUT  MEAN  14
COPY       OUTPUT MEAN  15                 COPY           INPUT  MEAN  15
COPY       OUTPUT MEAN  16                 COPY           INPUT  MEAN  16
COPY       OUTPUT MEAN  17                 COPY           INPUT  MEAN  17
  END MASS-LINK   93

END MASS-LINK
NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
*** Results for calibration
     PARTICULATE N (ADSORBED NH3 + ORG N) ***
RCHRES   5 NUTRX  RSNH4  4                 GENER    1     INPUT  ONE
RCHRES   5 HYDR   VOL                      GENER    1     INPUT  TWO
GENER    1 OUTPUT TIMSER       0.368       COPY    10     INPUT  MEAN   1
RCHRES   7 NUTRX  RSNH4  4                 GENER    3     INPUT  ONE
RCHRES   7 HYDR   VOL                      GENER    3     INPUT  TWO
GENER    3 OUTPUT TIMSER       0.368       COPY    11     INPUT  MEAN   1
RCHRES   9 NUTRX  RSNH4  4                 GENER    5     INPUT  ONE
RCHRES   9 HYDR   VOL                      GENER    5     INPUT  TWO
GENER    5 OUTPUT TIMSER       0.368       COPY    12     INPUT  MEAN   1
RCHRES  10 NUTRX  RSNH4  4                 GENER    7     INPUT  ONE
RCHRES  10 HYDR   VOL                      GENER    7     INPUT  TWO
GENER    7 OUTPUT TIMSER       0.368       COPY    13     INPUT  MEAN   1
RCHRES  12 NUTRX  RSNH4  4                 GENER    9     INPUT  ONE
RCHRES  12 HYDR   VOL                      GENER    9     INPUT  TWO
GENER    9 OUTPUT TIMSER       0.368       COPY    14     INPUT  MEAN   1
RCHRES  17 NUTRX  RSNH4  4                 GENER   11     INPUT  ONE
RCHRES  17 HYDR   VOL                      GENER   11     INPUT  TWO
GENER   11 OUTPUT TIMSER       0.368       COPY    15     INPUT  MEAN   1
     PARTICULATE P (ADSORBED PO4 + ORG P) ***
RCHRES   5 NUTRX  RSPO4  4                 GENER    2     INPUT  ONE
RCHRES   5 HYDR   VOL                      GENER    2     INPUT  TWO
GENER    2 OUTPUT TIMSER       0.368       COPY    10     INPUT  MEAN   2
RCHRES   7 NUTRX  RSPO4  4                 GENER    4     INPUT  ONE
```

```
RCHRES   7 HYDR   VOL                     GENER    4     INPUT  TWO
GENER    4 OUTPUT TIMSER       0.368      COPY    11     INPUT  MEAN   2
RCHRES   9 NUTRX  RSPO4  4                GENER    6     INPUT  ONE
RCHRES   9 HYDR   VOL                     GENER    6     INPUT  TWO
GENER    6 OUTPUT TIMSER       0.368      COPY    12     INPUT  MEAN   2
RCHRES  10 NUTRX  RSPO4  4                GENER    8     INPUT  ONE
RCHRES  10 HYDR   VOL                     GENER    8     INPUT  TWO
GENER    8 OUTPUT TIMSER       0.368      COPY    13     INPUT  MEAN   2
RCHRES  12 NUTRX  RSPO4  4                GENER   10     INPUT  ONE
RCHRES  12 HYDR   VOL                     GENER   10     INPUT  TWO
GENER   10 OUTPUT TIMSER       0.368      COPY    14     INPUT  MEAN   2
RCHRES  17 NUTRX  RSPO4  4                GENER   12     INPUT  ONE
RCHRES  17 HYDR   VOL                     GENER   12     INPUT  TWO
GENER   12 OUTPUT TIMSER       0.368      COPY    15     INPUT  MEAN   2
END NETWORK

GENER
  OPCODE
    #thru# code ***
    1   12   19
  END OPCODE
END GENER

END RUN
```