Streamflow Statistics for the Paradise and Pocono Creek Watersheds and Selected Streamflow-Gaging Stations in Monroe County, Pennsylvania

by Ronald E. Thompson and Gregory J. Cavallo

In cooperation with the
Delaware River Basin Commission and the
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Contents

Abstract ... 1
Introduction ... 1
- Purpose and Scope ... 1
- Study Area ... 1
- Hydrogeologic Setting ... 1
- Previous Investigations ... 3
- Continuous- and Partial-Record Stations ... 3
- Methods For Determining Streamflow Statistics at Continuous- and Partial-Record Stations ... 4

Streamflow Statistics for Monroe County, Pennsylvania ... 6
- Subbasin Yields in the Paradise and Pocono Creek Watersheds ... 6
- Observed Streamflow Statistics for Continuous-Record Stations ... 6
- Predicted Streamflow Statistics for Partial-Record Stations ... 6

Comparison of Predicted and Observed Streamflow Statistics for Continuous-Record Stations ... 13
- Regression Analyses of Continuous-Record Station Data ... 13
- Differences in Predicted and Observed Streamflow Statistics for Continuous-Record Stations ... 13

Limitations of the Investigation and Statistics ... 19
Summary and Conclusions ... 19
Acknowledgments ... 19
Selected References ... 19

Figures

1. Map showing bedrock geology, Paradise and Pocono Creek watershed boundaries, and selected streamflow-gaging stations in Monroe County, Pennsylvania ... 2
2. Graph showing concurrent daily mean flows at Brodhead Creek near Analomink, Pa., and intermittent measurements at Pocono Creek near Stroudsburg, Pa. ... 5
3. Graph showing log 10-transformed concurrent daily mean flows at Brodhead Creek near Analomink, Pa., and intermittent measurements at Pocono Creek near Stroudsburg, Pa. ... 5
4. Map showing bedrock geology and base-flow measurement locations in the Paradise and Pocono Creek watersheds, Monroe County, Pennsylvania ... 7
5. Graph showing observed and predicted streamflow statistics for Lehigh River at Stoddartsville, Pa. ... 13

Tables

1. Selected continuous- and partial-record stations in Monroe County, Pennsylvania. 4
2. Locations in downstream order, base flows measured, and subbasin yields for the Paradise and Pocono Creek watersheds, Monroe County, Pennsylvania: October 25-27, 2000; May 2-3, 2001; and July 8-9, 2003. 8
3. Observed streamflow statistics for continuous-record stations in Monroe County, Pennsylvania. 11
4. Regression coefficients and equations for predicting 7-day, low-flow recurrence-interval statistics at partial-record stations in Monroe County, Pennsylvania. 12
5. Predicted streamflow statistics for partial-record stations in Monroe County, Pennsylvania. 14
6. Regression coefficients and equations for predicting 7-day, low-flow recurrence-interval statistics at continuous-record stations (treated as partial-record stations) in Monroe County, Pennsylvania. 16
7. Predicted streamflow statistics and percent differences from observed statistics for continuous-record stations in Monroe County, Pennsylvania. 17

Conversion Factors and Datum

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.6463	million gallons per day per square mile [$(Mgal/d)/mi^2$]

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8$$

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Abstract

A suite of 36 observed streamflow statistics, ranging from high to low flows, were computed for 7 continuous-record and predicted for 12 partial-record streamflow-gaging stations in Monroe County, Pa. The predicted statistics for the partial-record stations were determined from regression analyses of intermittent streamflow measurements made at the partial-record stations and concurrent daily mean flows at index continuous-record stations. The prediction methodology has been previously used only for estimating low-flow statistics. Results from this study indicate the methodology may have applicability for predicting high- and intermediate-flow statistics as well. Three sets of base-flow measurements were made at 40 sites in the Paradise and Pocono Creek watersheds to determine subbasin yields and stream reaches gaining or losing flow. Subbasin yields, the base-flow measurements normalized to respective drainage areas, were consistent for each measurement period.

Introduction

The Delaware River Basin Commission (DRBC) has established a "Goal-Based Planning Approach" targeted for use by watershed groups in the basin. These groups are starting or have started an inventory of water resources and will use the inventory as part of a comprehensive process for planning development. The U.S. Geological Survey (USGS), the DRBC, and the Brodhead Watershed Association cooperated in a study to determine streamflow statistics in the Paradise and Pocono Creek watersheds and surrounding parts of Monroe County, Pa. The technical information developed for this study will help form a basis for evaluating the effects of competing water uses on water quantity in the Pocono and Paradise Creek watersheds and other parts of Monroe County. The Pocono Creek watershed planning effort served as a pilot project for the DRBC approach, and the Paradise Creek watershed planning effort is following the same process. Streamflow statistics are needed in Monroe County to quantify surface-water resources and to serve as input for ground-water models. Subbasin yields for the Paradise and Pocono Creek watersheds also are needed at management area outlets (pour points) and to determine stream reaches that are gaining or losing flow.

Purpose and Scope

This report presents observed and predicted streamflow statistics for selected streamflow-gaging stations (stations) in Monroe County, Pa., and subbasin yields for the Paradise and Pocono Creek watersheds. The report also discusses the methods used to determine the streamflow statistics, an analysis of the prediction methodology, and limitations of the methods and the statistics. Thirty-six streamflow statistics were computed for 7 continuous-record stations and predicted for 12 partial-record stations. The statistics computed at the continuous-record stations are referred to as "observed" in this report. Subbasin yields were determined at 29 sites in the Pocono Creek watershed during 2000 and 2001 and at 11 sites in the Paradise Creek watershed during 2003.

Study Area

Monroe County is in the Pocono Mountains area of northeastern Pennsylvania and, for the period 1931-2000, had an average annual temperature of 47°F and average annual precipitation of 44 in. (National Climatic Data Center, 2002). Average annual potential evaporation ranges from 25 to 27 in. (Flippo, 1982a).

The Lehigh River flows along the northwestern boundary of the county, and the Delaware River is part of the southeastern boundary. The Borough of Stroudsburg, on the south-central boundary, is the county seat. Paradise and Pocono Creeks, which flow in an easterly direction and share a common watershed divide, are tributaries to Brodhead Creek, which flows in a southerly direction (fig. 1).

Hydrogeologic Setting

The surficial geology in Monroe County includes glacial deposits, sandstones, conglomerates, siltstones, shales, and small amounts of carbonate rock that have been deformed by

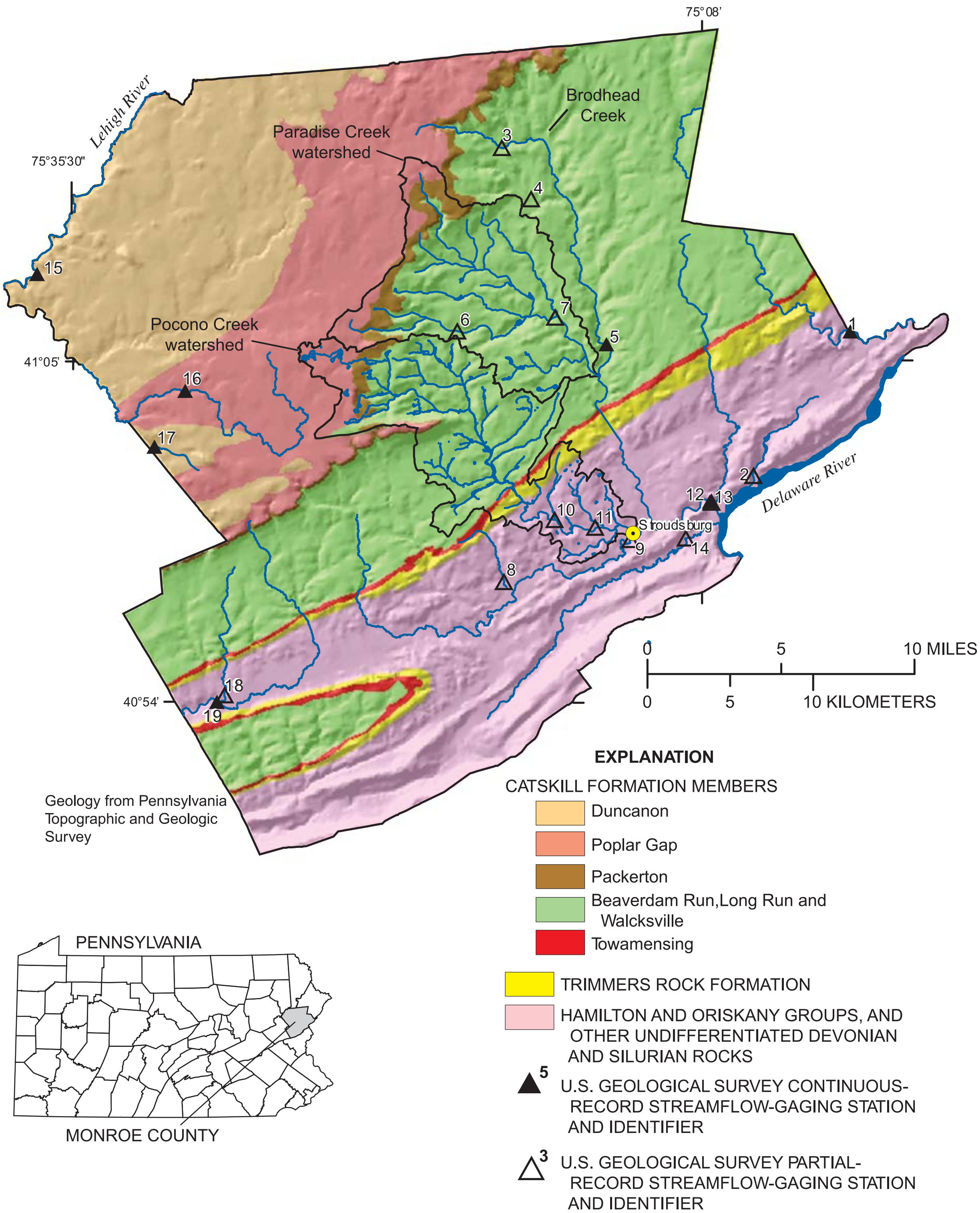

Figure 1. Bedrock geology, Paradise and Pocono Creek watershed boundaries, and selected streamflow-gaging stations in Monroe County, Pennsylvania

intense folding in the southeastern third of the county and gentle folding throughout the remainder of the county. Parts of the Upper, Middle, and Lower Series of the Devonian System are all exposed in the landscape. Carswell and Lloyd (1979) identified the Duncannon, Poplar Gap, Packerton, Long Run, Beaverdam Run, Walcksville, and Towamensing Members of the Catskill Formation, which makes up approximately two-thirds of the exposed bedrock. The remaining third includes the Trimmers Rock Formation and parts of the Hamilton and Oriskany Groups, as well as other undifferentiated Devonian and Silurian rocks (fig. 1). These bedrock units generally have low primary porosity and permeability; however, post-depositional deformation and fracturing have increased secondary permeability. Deformation also has produced synclines and anticlines that provide preferential pathways for ground-water flow.

During the Pleistocene Epoch, as many as four separate periods of glaciation covered most of the county (Epstein and others, 1974) and left unconsolidated deposits of clay, silt, sand, gravel, cobbles, and boulders up to approximately 100-ft thick in the stream valleys of Monroe County (R.A. Sloto, U.S. Geological Survey, oral commun., 2004). Areas where porous glacial deposits are connected to the water table typically yield higher stream base flows per unit of drainage area during dry periods than nonglaciated parts of Pennsylvania.

Previous Investigations

White and Sloto (1990) computed 2-, 5-, 10-, 25-, 50-, and 100-year recurrence-interval base flows for 309 stations in Pennsylvania and on the Delaware River in New York and New Jersey. Schreffler (1998) used the Maintenance of Variance Extension, Type 1 (MOVE1) technique (Hirsch, 1982) to predict low-flow and harmonic mean statistics at 34 partial-record stations in Chester County, Pa. Ehlke and Reed (1999) compared methods for predicting streamflow statistics for Pennsylvania streams. They found the 7-day, 10-year low flow computed using a log-Pearson, Type III distribution (Riggs, 1968b) and the regression of basin characteristics method presented in Flippo (1982b) differed significantly only for about 7 percent of Pennsylvania, although the same methods produced 50- and 100-year flood predictions that differed significantly for 24 percent of the State. Senior and Koerkle (2003) simulated flows in the Christina River Basin, Pennsylvania, Maryland, and Delaware, using Hydrologic Simulation Program-Fortran (HSPF) software (Donigian and others, 1984) and found annual differences between observed and simulated values ranging from -6.9 to 6.5 percent and an overall error for a 4-year period of -1.1 percent.

Other approaches have been used to predict low-flow statistics at locations without daily mean flow data. One approach has been to determine drainage area of the location, divide it by the drainage area of a nearby, hydrologically similar, continuous-record station with statistics computed from daily mean flow data, and multiply the area-ratio result by the needed statistic(s) from the continuous-record station (U.S. Geological Survey, 2002).

A second approach used graphical correlation analysis of intermittent measurements at partial-record stations and concurrent daily mean flows at nearby continuous-record stations to predict low-flow statistics at partial-record stations. For Pennsylvania streams, that method was exemplified in Busch and Shaw (1966), who used procedures discussed by Searcy (1960). Page and Shaw (1977) updated the Busch and Shaw results using procedures discussed by Riggs (1972). Hardison and Moss (1972) reviewed statistics predicted by correlation of base-flow measurements and concurrent daily mean flows and discussed the accuracy of the predicted low-flow statistics.

A third approach has been regression-based modeling. Riggs (1973) discussed multiple regression using low-flow statistics as predicted values and basin characteristics (for example, drainage area) as explanatory variables. Hardison (1971) presented an analysis of regression error for predicted statistics at ungaged sites. Tasker (U.S. Geological Survey, written commun., 1978) expanded on Hardison (1971) by describing the relation of standard errors in logarithmic units and standard errors in percent. Stedinger and Thomas (1985) proposed an alternative approach using linear regression of intermittent measurements at partial-record stations and concurrent daily mean flows at continuous-record stations to generate an unbiased estimator with minimum mean square error for predicting low-flow recurrence-interval statistics at the partial-record stations. Wilson (2000) evaluated the Stedinger and Thomas (1985) approach using combinations of continuous-record stations in Indiana. Wilson found the most accurate and least variable results were produced when two index stations on the same stream or tributaries of the partial-record station were used. Regression-based modeling that follows the Stedinger and Thomas (1985) methodology is the approach used in this study to predict streamflow statistics.

Continuous- and Partial-Record Stations

Continuous-record stations record gage height of the stream water surface (stage) continuously or at small time intervals, such as 15 minutes. Stations are connected to the streams through intake pipes or other stage-sensing devices, such as pressure transducers. Stage-flow relations are established by making flow measurements at different stages, and daily mean flows are computed using the stage records and stage-flow relations.

Little or no stage data are collected at partial-record stations. The primary data collected at these stations are intermittent measurements of flow made over multiple years. Some partial-record stations are operated specifically to obtain low-flow data; others are used to obtain measurements over a wide range of flows.

Information about the continuous- and partial-record stations used for analyses is shown in table 1, and their locations are mapped on figure 1. Drainage areas for the stations range in size from 259 to 2.39 mi^2. Continuous-record stations with short periods of daily mean flows were analyzed as partial-record stations for this study and are identified in table 1.

Methods for Determining Streamflow Statistics at Continuous- and Partial-Record Stations

Observed streamflow statistics for the continuous-record stations were computed from daily mean flows retrieved from USGS databases. The observed statistics include mean monthly flows, mean annual flow, 7-day low flows for 4 recurrence intervals, 13 flow durations, mean annual base flow, and base flows for 5 recurrence intervals. The mean monthly and the mean annual flow statistics were obtained from Durlin and Schaffstall (1997, 2004). To determine the 7-day low-flow recurrence-interval and flow-duration statistics, daily mean flow data were obtained from NWISWeb data for Pennsylvania (U.S. Geological Survey, 2004) and processed using Surface-Water Statistics (SWSTAT) software (Flynn and others, 1995). To determine the annual base-flow recurrence-interval statistics, the daily mean flow data obtained from NWISWeb were first processed using the local-minimum option in the Hydrograph Separation Program (HYSEP) software developed by Sloto (1988), and the resulting daily mean base-flow data were then processed using SWSTAT.

The procedure for obtaining predicted statistics for the partial-record stations started with a plotting and correlation process developed in the USGS Pennsylvania Water Science Center (E.H. Koerkle, U.S. Geological Survey, written commun., 2004). The process plotted intermittent measurements made at the 12 partial-record stations on 4-day daily mean flow hydrographs preceding the measurements for the 7 continuous-record stations being tested as index stations. The plotting aspect allowed acceptance or elimination of each measurement based on whether the continuous-record stations being tested appeared to be in a base-flow regime. After all measurements and associated hydrographs were reviewed, the process produced a correlation coefficient (*r*) for each continuous- and partial-record station relation. Only those relations with *r* values

Table 1. Selected continuous- and partial-record stations in Monroe County, Pennsylvania.

[Horizontal datum is North American Datum of 1927; mi^2, square miles; Station type: C, continuous-record station; P, partial-record station with intermittent streamflow measurements; C-P, short continuous record used as a partial record for this report; Period of station record is the time span operated as a continuous-record and/or partial-record station—no ending date indicates station in operation through 2003]

U.S. Geological Survey station identification number	Station description	Location number in figure 1	Latitude (decimal degrees)	Longitude (decimal degrees)	Drainage area (mi^2)	Station type	Period of station record
01439500	Bush Kill at Shoemakers, Pa.	1	41.088056	75.038056	117	C	1908–
01440250	Shawnee Creek at Shawnee, Pa.	2	41.011667	75.111111	4.58	P	1970–1973
01440272	Buck Hill Creek at Buck Hill Falls, Pa.	3	41.191944	75.286944	5.76	P	1977–1980
01440300	Mill Creek at Mountainhome, Pa.	4	41.163889	75.266667	5.84	P	1960–1999
01440400	Brodhead Creek near Analomink, Pa.	5	41.084722	75.215000	65.9	C	1957–
01440485	Swiftwater Creek at Swiftwater, Pa.	6	41.093889	75.322500	6.59	C-P	2001–
01440500	Paradise Creek at Henryville, Pa.	7	41.100000	75.251389	30.2	P	1965–1991
01440800	Kettle Creek at Snydersville, Pa.	8	40.958333	75.293611	5.28	P	1944–1957
01441000	McMichael Creek near Stroudsburg, Pa.	9	40.979167	75.201389	65.3	P	1970–1991
01441495	Pocono Creek above Wigwam Run near Stroudsburg, Pa.	10	40.990833	75.255556	38.9	C-P	2002–
01441500	Pocono Creek near Stroudsburg, Pa.	11	40.986111	75.226389	41.0	C-P	1932–2001
01442500	Brodhead Creek at Minisink Hills, Pa.	12	40.998611	75.143056	259	C	1950–
01442600	Marshall Creek at Minisink Hills, Pa.	13	40.998056	75.142078	27.1	P	1958–1991
01442700	Cherry Creek at Delaware Water Gap, Pa.	14	40.979167	75.161111	19.3	P	1958–1968
01447500	Lehigh River at Stoddartsville, Pa.	15	41.130278	75.625833	91.7	C	1943–
01447680	Tunkhannock Creek near Long Pond, Pa.	16	41.065278	75.520556	20.0	C	1965–
01448500	Dilldown Creek near Long Pond, Pa.	17	41.035556	75.543611	2.39	C	1948–1996
01449355	Middle Creek at Kresgeville, Pa.	18	40.900833	75.497222	18.6	P	1970–1991
01449360	Pohopoco Creek at Kresgeville, Pa.	19	40.897500	75.502778	49.9	C	1966–

equal to or greater than 0.70 were retained for further analyses (Stedinger and Thomas, 1985). Although 2 of the 12 partial-record stations used in this study had only 6 suitable measurements, instead of a minimum of 10 as recommended by Stedinger and Thomas (1985), those two stations had good relations with the respective index gage and were included to increase geographic coverage. The other 10 partial-record stations had 10 or more such measurements.

All the retained relations of partial-record station measurements and continuous-record station concurrent daily mean flows were plotted for visual examination. Concurrent daily mean flow data for Brodhead Creek near Analomink (an index station) and intermittent measurements made at Pocono Creek near Stroudsburg (a partial-record station) are shown as an example (fig. 2). The data appear linear, but non-constant variance from a line of best fit is evident in the funnel-shaped plot as the concurrent daily means and intermittent measurements increase in magnitude. Non-constant variance, which also occurred in the other relation plots, violates the assumption of constant variance inherent in parametric regression (Helsel and Hirsch, 1992).

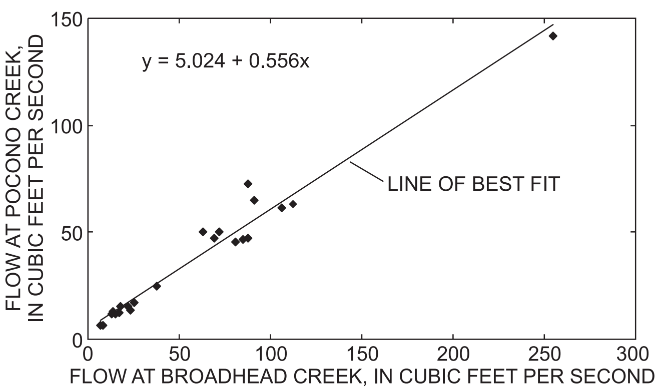

Figure 2. Concurrent daily mean flows at Brodhead Creek near Analomink, Pa., and intermittent measurements at Pocono Creek near Stroudsburg, Pa.

The data were log 10-transformed and re-plotted to see if the non-constant variance could be removed for further analyses. An example plot is shown in figure 3, which contains transformed data from figure 2 and a line of best fit. Transforming the data eliminated non-constant variance from the relation between Brodhead Creek near Analomink and Pocono Creek near Stroudsburg, as well as measured flows at the partial-record stations and concurrent daily mean flows at the respective index stations in the other correlations.

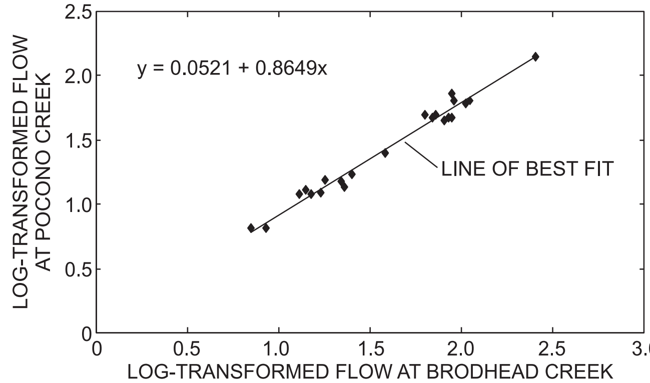

Figure 3. Log 10-transformed concurrent daily mean flows at Brodhead Creek near Analomink, Pa., and intermittent measurements at Pocono Creek near Stroudsburg, Pa.

Regression analyses were then conducted on transformed data using Generalized Least Squares-Network Analysis (GLS-NET) software (Tasker and Stedlinger, 1989). The analyses of the daily mean flows for the seven continuous-record stations being tested as indexes and the measurements at each partial-record station took the form

$$LogQ_P = A + bLogQ_{C1} + cLogQ_{C2} + dLogQ_{C3} + eLogQ_{C4} + fLogQ_{C5} + gLogQ_{C6} + hLogQ_{C7}, \quad (1)$$

where

Log is the base 10 logarithm,

Q_P is an intermittent flow measurement at a partial-record station,

A is the intercept,

Q_{C1} is the concurrent daily mean for Bush Kill at Shoemakers,

Q_{C2} is the concurrent daily mean for Brodhead Creek near Analomink,

Q_{C3} is the concurrent daily mean for Brodhead Creek at Minisink Hills,

Q_{C4} is the concurrent daily mean for Lehigh River at Stoddartsville,

Q_{C5} is the concurrent daily mean for Tunkhannock Creek near Long Pond,

Q_{C6} is the concurrent daily mean for Dilldown Creek near Long Pond,

Q_{C7} is the concurrent daily mean for Pohopoco Creek at Kresgeville, and

b, c, d, e, f, g, and h are regression coefficients specific to each partial-record station.

Determining relative subbasin yields for the Paradise and Pocono Creek watersheds was accomplished by making 3 sets of base-flow measurements at 40 locations. The measured flows were then divided by the respective drainage areas of the locations to arrive at the subbasin yields during the time periods when the measurements were made.

Streamflow Statistics for Monroe County, Pennsylvania

Stream reaches with possible gains or losses in flow were determined by analyzing the subbasin yields in downstream order. Observed statistics for continuous-record stations and predicted statistics for partial-record stations in Monroe County, when combined with the subbasin yields, provided an encapsulation of the surface-water resources in the county.

Subbasin Yields in the Paradise and Pocono Creek Watersheds

Base flows in the Paradise and Pocono Creek watersheds were measured during low- and intermediate-flow regimes based on indexed flow in Brodhead Creek. The flow in Brodhead Creek near Analomink, an index station, during the October 25-27, 2000, measurements in the Pocono Creek watershed was at a rate equaled or exceeded about 85 percent of the time, a low-flow regime. During the May 2-3, 2001, measurements in the Pocono Creek watershed and the July 8-9, 2003, measurements in the Paradise Creek watershed, the Analomink station was at a rate equaled or exceeded about 50 percent of the time, an intermediate-flow regime. Some of the measurements were made at locations identified by the planning groups as management area pour points. Other locations were selected to evaluate reaches for possible gains and losses in flow and to cover a range of geographic areas and drainage-area sizes. The locations of the base-flow measurement sites are mapped in figure 4.

Subbasin yields in the Paradise and Pocono Creek watersheds are shown in table 2. During Oct. 25-27, 2000, a reach of the Pocono Creek between Sullivan Trail and above State Route 715 at Tannersville showed a loss in yield from 0.54 to 0.38 $ft^3/s/mi^2$ (table 2). A similar loss was measured during May 2-3, 2001, when the yields dropped from 1.33 to 1.03 $ft^3/s/mi^2$ in the same reach. These losses may indicate a low yield from the Scot Run subbasin, which is a tributary in that reach; a natural geohydrologic effect such as some part of the flow going underground over the reach; an anthropogenic effect, such as large ground-water withdrawals pulling flow from Pocono Creek; or other factors not observed during the measurements.

The subbasin yields within the watersheds during each set of measurements were relatively consistent. The consistency during each measurement period was reflected in standard deviations that were no more than one-third the magnitude of the means and in the close agreement between the means and medians. Two exceptions are the maximum and minimum yields in the Pocono Creek watershed during the October 25-27, 2000, period. The 0.64 $ft^3/s/mi^2$ yield for Pocono Creek above the confluence with Coolmoor Run probably reflects an increased ground-water discharge effect from holding ponds upstream from that location. The 0.11 $ft^3/s/mi^2$ yield for Wigwam Run above the confluence with Pocono Creek probably indicates flow interception by subsurface drains associated with the Interstate 80 corridor upstream from the measurement site.

Other exceptions are the maximum yield and the low yields from three subbasins in the Paradise Creek watershed during the July 7-8, 2003, period. The 2.73-$ft^3/s/mi^2$ yield for Swiftwater Creek at Swiftwater probably reflects surface-water discharges from treatment facilities upstream. However, the effect on yields in the main stem of Paradise Creek diminished downstream. The low yields of 1.06 $ft^3/s/mi^2$ for Cranberry Creek and 0.71 $ft^3/s/mi^2$ for Butz Run likely reflect the relatively flat gradient of those two subbasins and a bog-like effect that would be manifested as relatively low yields during intermediate base flows, as occurred during the measurements, and high base flows and relatively high yields during low base flows.

Observed Streamflow Statistics for Continuous-Record Stations

The observed statistics for the seven continuous-record stations in Monroe County are shown in table 3. The range between the maximum and minimum statistics for each station, as exemplified by 1,270 ft^3/s (1 percent chance of being equaled or exceeded, D1) and 5.8 ft^3/s (lowest average flow expected for 7 consecutive days every 20 years, Q7,20) for Bush Kill at Shoemakers, reflects the large absolute differences in the observed statistics for each station. The range in flows equaled or exceeded 1 percent of the time for all seven stations (from 3,410 to 32 ft^3/s) reflects the two orders of magnitude range in drainage areas (from 259 to 2.39 mi^2).

Predicted Streamflow Statistics for Partial-Record Stations

The 7-day, low-flow regression coefficients and resulting equations for the seven continuous-record stations tested as index stations are shown in table 4. Although all continuous-record stations tested as index stations appeared in at least one partial-record station relation with a correlation coefficient (r) equal to or greater than 0.70 during the tests, the best relations (lowest standard errors and highest coefficients of determination, R^2) contained only four of the seven tested stations. An evaluation of the basin characteristics for the tested stations revealed no basis as to why three of the seven in table 4 were not included in the best relations. Two of the partial-record stations had 2 index stations in the best relations. The remaining 10 partial-record stations had only 1 index station in the best relations. Ten of the relations had standard errors less than 31 percent and coefficients of determination (R^2) greater than or equal to 0.90.

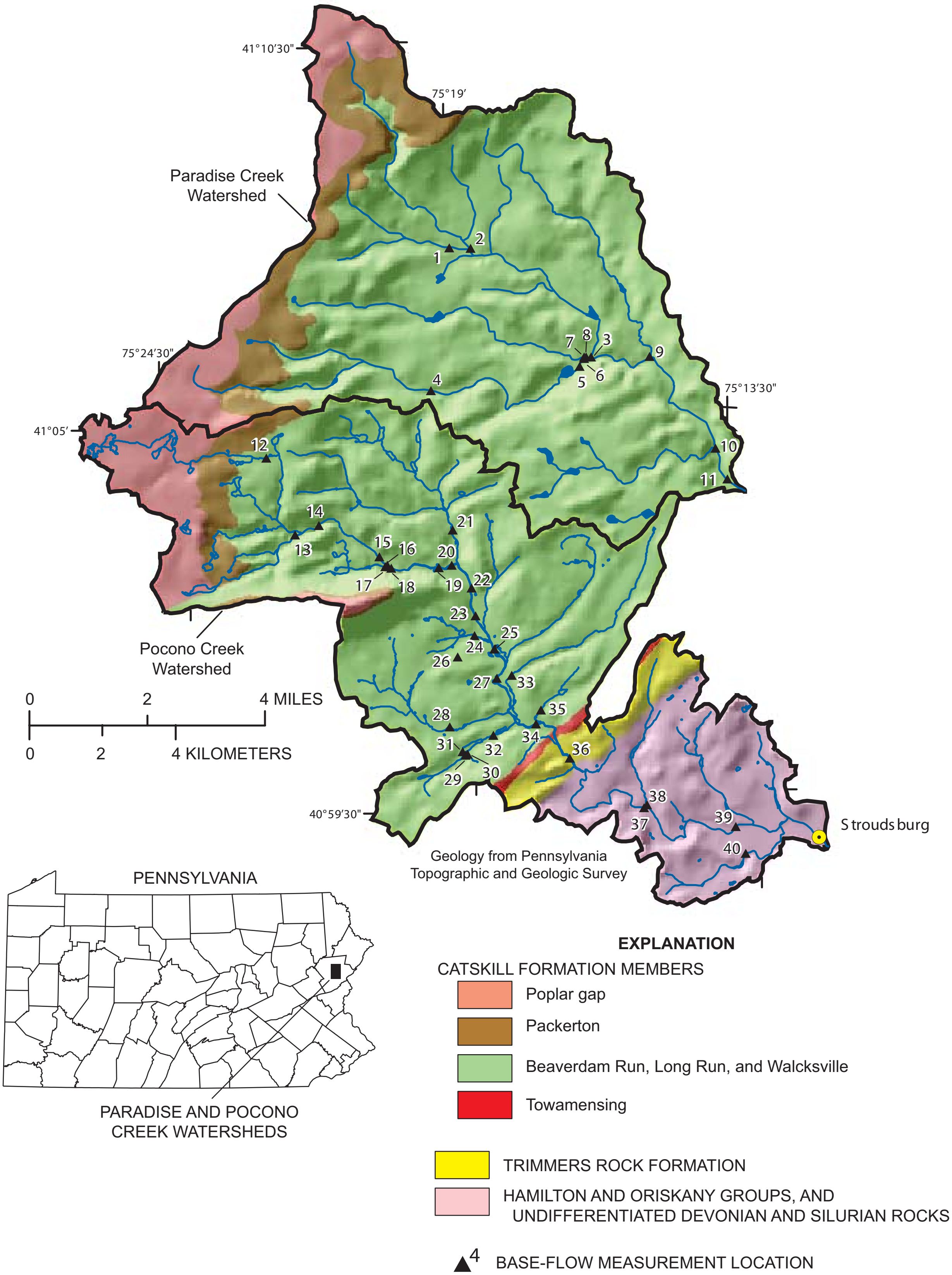

Figure 4. Bedrock geology and base-flow measurement locations in the Paradise and Pocono Creek watersheds, Monroe County, Pennsylvania.

Table 2. Locations in downstream order, base flows measured, and subbasin yields for the Paradise and Pocono Creek watersheds, Monroe County, Pennsylvania: October 25-27, 2000; May 2-3, 2001; and July 8-9, 2003.

[Horizontal datum is North American Datum of 1927; mi^2, square miles; ft^3/s, cubic feet per second; $ft^3/s/mi^2$, cubic feet per second per square mile; NA, not appropriate or indeterminable; --, no data]

Latitude/ longitude (decimal degrees)	Location description	Base-flow measure-ment location (fig. 1)	Drainage area (mi^2)	Pocono Creek locations October 25-27, 2000			Pocono Creek locations May 2-3, 2001			Paradise Creek locations July 8-9, 2003		
				Date of measure-ment	Base flow measured (ft^3/s)	Sub-basin yield ($ft^3/s/mi^2$)	Date of measure-ment	Base flow measured (ft^3/s)	Sub-basin yield ($ft^3/s/mi^2$)	Date of measure-ment	Base flow measured (ft^3/s)	Sub-basin yield ($ft^3/s/mi^2$)
41.128611/ 75.315278	Paradise Creek at Devils Hole Road	1	3.18	--	--	--	--	--	--	7/9	6.87	2.16
41.128333/ 75.308333	Devils Hole Creek above confluence with Paradise Creek	2	6.15	--	--	--	--	--	--	7/9	11.8	1.92
41.101111/ 75.269722	Paradise Creek upstream from Swiftwater Creek confluence	3	13.9	--	--	--	--	--	--	7/9	23.2	1.67
41.093889/ 75.322500	Swiftwater Creek at Swiftwater	4	6.59	--	--	--	--	--	--	7/8	18.0	2.73
41.098889/ 75.273611	Swiftwater Creek at Hulbert Hill Road bridge	5	9.81	--	--	--	--	--	--	7/8	21.6	2.20
41.100833/ 75.271944	Swiftwater Creek above confluence with Forest Hills Run	6	10.2	--	--	--	--	--	--	7/8	19.8	1.94
41.101111/ 75.271944	Forest Hills Run above confluence with Swiftwater Creek	7	4.77	--	--	--	--	--	--	7/8	7.90	1.66
41.101111/ 75.271389	Swiftwater Creek below confluence with Forest Hills Run	8	15.0	--	--	--	--	--	--	7/8	27.7	1.85
41.100833/ 75.250556	Cranberry Creek above confluence with Paradise Creek	9	7.38	--	--	--	--	--	--	7/9	7.79	1.06
41.078056/ 75.229722	Butz Run above confluence with Paradise Creek	10	3.68	--	--	--	--	--	--	7/9	2.61	.71
41.070556/ 75.226111	Paradise Creek above confluence with Brodhead Creek	11	43.8	--	--	--	--	--	--	7/9	63.8	1.46
41.078528/ 75.377000	Dry Sawmill Run at Skyview Drive	12	3.21	10/25	0.77	0.24	--	--	--	--	--	--
41.059583/ 75.368083	Wolf Swamp Run at Confluence near Tannersville	13	2.25	10/25	.54	.24	--	--	--	--	--	--
41.061700/ 75.360200	Pocono Creek at Wilke Road	14	8.65	--	--	--	5/2	11.6	1.34	--	--	--
41.053700/ 75.340800	Pocono Creek at Camelback Road	15	9.32	--	--	--	5/2	12.0	1.29	--	--	--

Table 2. Locations in downstream order, base flows measured, and subbasin yields for the Paradise and Pocono Creek watersheds, Monroe County, Pennsylvania: October 25-27, 2000; May 2-3, 2001; and July 8-9, 2003.—Continued

[Horizontal datum is North American Datum of 1927; mi^2, square miles; ft^3/s, cubic feet per second; $ft^3/s/mi^2$, cubic feet per second per square mile; NA, not appropriate or indeterminable; --, no data]

Latitude/ longitude (decimal degrees)	Location description	Base-flow measure-ment location (fig. 1)	Drainage area (mi^2)	Pocono Creek locations October 25-27, 2000			Pocono Creek locations May 2-3, 2001			Paradise Creek locations July 8-9, 2003		
				Date of measure-ment	Base flow measured (ft^3/s)	Sub-basin yield ($ft^3/s/mi^2$)	Date of measure-ment	Base flow measured (ft^3/s)	Sub-basin yield ($ft^3/s/mi^2$)	Date of measure-ment	Base flow measured (ft^3/s)	Sub-basin yield ($ft^3/s/mi^2$)
41.051583/ 75.338278	Pocono Creek above confluence with Coolmoor Run	16	9.37	10/25	6.01	0.64	--	--	--	--	--	--
41.051333/ 75.338889	Coolmoor Run above confluence with Pocono Creek	17	1.52	10/25	.37	.24	--	--	--	--	--	--
41.050889/ 75.336917	Pocono Creek below Confluence with Coolmoor Run	18	10.9	10/25	6.47	.59	5/2	15.6	1.43	--	--	--
				10/27	5.90	.54	--	--	--	--	--	--
41.050750/ 75.321361	Pocono Creek at Sullivan Trail	19	11.5	10/27	6.17	.54	5/2	15.3	1.33	--	--	--
41.051200/ 75.317100	Pocono Creek above Scot Run near Tannersville	20	11.6				5/2	15.0	1.29	--	--	--
41.059861/ 75.316417	Scot Run above Scotrun Avenue at SR611	21	6.09	10/25	1.22	.20	--	--	--	--	--	--
41.045583/ 75.310778	Pocono Creek above SR715 at Tannersville	22	18.8	10/27	7.11	.38	5/2	19.4	1.03	--	--	--
41.038806/ 75.309806	Pocono Creek at Tannersville	23	19.0	10/25	5.97	.31	5/2	19.5	1.03	--	--	--
				10/26	5.65	.30	--	--	--	--	--	--
41.033944/ 75.310194	Mill Run above Old Mill Road	24	1.27	10/25	.37	.29	--	--	--	--	--	--
41.030528/ 75.303889	Pocono Creek below Warner Road at Tannersville	25	22.2	10/27	7.54	.34	5/2	24.3	1.09	--	--	--
41.028778/ 75.315972	Bulgers Run above Learn Road	26	2.34	10/25	.69	.29	--	--	--	--	--	--
41.023389/ 75.303306	Pocono Creek below Stadden Road near Tannersville	27	25.2	10/26	10.3	.41	5/2	31.0	1.23	--	--	--
41.011889/ 75.319167	Reeders Run above Reeders Run Road	28	2.90	10/26	1.13	.39	--	--	--	--	--	--
41.004833/ 75.314222	Rocky Run above Hunter Lake at Golden Slipper Road	29	NA	10/26	.48	--	--	--	--	--	--	--

Table 2. Locations in downstream order, base flows measured, and subbasin yields for the Paradise and Pocono Creek watersheds, Monroe County, Pennsylvania: October 25-27, 2000; May 2-3, 2001; and July 8-9, 2003.—Continued

[Horizontal datum is North American Datum of 1927; mi^2, square miles; ft^3/s, cubic feet per second; $ft^3/s/mi^2$, cubic feet per second per square mile; NA, not appropriate or indeterminable; --, no data]

Latitude/ longitude (decimal degrees)	Location description	Base-flow measurement location (fig. 1)	Drainage area (mi^2)	Pocono Creek locations October 25-27, 2000			Pocono Creek locations May 2-3, 2001			Paradise Creek locations July 8-9, 2003		
				Date of measurement	Base flow measured (ft^3/s)	Sub-basin yield ($ft^3/s/mi^2$)	Date of measurement	Base flow measured (ft^3/s)	Sub-basin yield ($ft^3/s/mi^2$)	Date of measurement	Base flow measured (ft^3/s)	Sub-basin yield ($ft^3/s/mi^2$)
41.005028/ 75.313444	Rocky Run spring tributary above Golden Slipper Road	30	NA	10/26	0.05	--	--	--	--	--	--	--
41.005750/ 75.315111	Rocky Run spring tributary below Reeders Run Road	31	NA	10/26	.05	--	--	--	--	--	--	--
41.009528/ 75.304972	Rocky Run below Hunter Lake	32	2.14	10/26	.80	0.37	--	--	--	--	--	--
41.024028/ 75.298361	Cranberry Creek above SR611 at Learn Road	33	4.06	10/26	1.44	.35	--	--	--	--	--	--
41.012000/ 75.290861	Pocono Creek below SR611 near Barton Glen	34	36.2	10/26	13.7	.38	--	--	--	--	--	--
41.015333/ 75.289194	Laurel Lake Run above Beehler Road	35	.81	10/26	.32	.40	--	--	--	--	--	--
41.003500/ 75.280100	Pocono Creek at Rimrock Drive	36	38.0	--	--	--	5/3	40.5	1.07	--	--	--
40.990861/ 75.256222	Pocono Creek above Wigwam Run near Stroudsburg	37	40.7	10/26	16.0	.39	5/3	41.3	1.01	--	--	--
40.991556/ 75.255194	Wigwam Run above confluence with Pocono Creek	38	1.82	10/26	.20	.11	--	--	--	--	--	--
40.985722/ 75.226417	Pocono Creek near Stroudsburg	39	44.0	10/27	15.2	.35	5/3	45.3	1.03	--	--	--
40.979111/ 75.223306	Little Pocono Creek below Tan-ite Road	40	1.17	10/27	.33	.28	--	--	--	--	--	--
				Mean		.36			1.09			1.76
				Standard deviation		.12			.15			.55
				Median		.35			1.16			1.85
				Maximum		.64			1.43			2.73
				Minimum		.11			1.01			.71

Table 3. Observed streamflow statistics for continuous-record stations in Monroe County, Pennsylvania.

[USGS, U.S. Geological Survey; Q7,x, 7-day low-flow statistic for selected recurrence interval; Dx, flow-duration statistic equaled or exceeded selected percent of time; x-year BFLO, base flow for selected recurrence interval]

Statistic	Streamflow at USGS streamflow-gaging station, in cubic feet per second							
	01439500	01440400	01442500	01447500	01447680	01448500	01449360	
Mean monthly flow								
Oct.	124	74	318	118	33	2.9	64	
Nov.	209	124	537	178	42	4.6	91	
Dec.	263	169	722	213	51	5.9	125	
Jan.	258	152	620	195	44	5.2	113	
Feb.	271	158	657	197	43	5.0	114	
Mar.	433	250	985	306	65	7.6	159	
Apr.	429	249	978	353	75	9.2	157	
May	303	179	697	252	55	6.6	125	
June	200	115	451	167	45	4.3	101	
July	128	58	254	107	28	2.8	65	
Aug.	98	43	240	90	22	2.3	52	
Sept.	94	56	250	90	27	2.2	57	
Mean annual flow	234	135	558	189	45	4.9	102	
Q7,2	18	13	79	24	7.4	.8	24	
Q7,5	10	8.9	57	16	4.7	.5	18	
Q7,10	7.4	7.3	48	13	3.7	.4	15	
Q7,20	5.8	6.2	42	11	3.1	.4	13	
D99	8.8	7.7	49	14	4.2	.1	15	
D95	17	13	72	23	7.4	.4	22	
D90	27	17	94	33	10	.8	28	
D80	52	30	144	54	16	1.4	38	
D70	83	47	204	77	21	2.0	49	
D60	121	65	269	102	26	2.6	61	
D50	161	85	349	130	32	3.2	75	
D40	209	109	449	162	39	4.0	92	
D30	269	142	583	203	48	5.2	114	
D20	362	193	796	267	63	6.8	145	
D10	531	301	1,230	399	91	9.8	202	
D5	719	432	1,760	559	130	15	275	
D1	1,270	887	3,410	1,090	244	32	510	
Mean annual base flow	153	83	321	121	30	3.3	71	
2-year BFLO	157	84	325	122	30	3.4	73	
5-year BFLO	125	68	262	101	24	2.7	59	
10-year BFLO	110	61	232	91	20	2.4	52	
25-year BFLO	95	54	203	80	17	2.1	45	
50-year BFLO	85	49	186	74	16	1.9	41	
								All stations
Maximum	1,270	887	3,410	1,090	244	32	510	3,410
Minimum	5.8	6.2	42	11	3.1	.1	13	.1

Table 4. Regression coefficients and equations for predicting 7-day, low-flow recurrence-interval statistics at partial-record stations in Monroe County, Pennsylvania.

[8-digit numbers beginning with 014 are station numbers shown in table 1; --, not significant at the p<0.05 level; station number$_s$ indicates statistic predicted or observed as appropriate to equation; ft^3/s, cubic feet per second]

Log of statistic at partial-record station	Regression coefficients for continuous-record stations tested as index stations								Residual standard error		Adjusted coefficient of determination (R^2)
	Intercept (A)	$Log_{01439500}$ (b)	$Log_{01440400}$ (c)	$Log_{01442500}$ (d)	$Log_{01447500}$ (e)	$Log_{01447680}$ (f)	$Log_{01448500}$ (g)	$Log_{01449360}$ (h)	Log units	Percent	
$Log_{01440250}$	-2.9365	--	--	1.4896	--	--	--	--	0.11	25.7	0.96
$Log_{01440272}$	.68574	-1.0838	2.0971	--	--	--	--	--	.10	23.3	.96
$Log_{01440300}$	-.94344	.87306	--	--	--	--	--	--	.20	48.6	.85
$Log_{01440485}$	.16532	-.36102	.9206	--	--	--	--	--	.05	11.6	.96
$Log_{01440500}$	.20316	--	.75311	--	--	--	--	--	.03	6.9	.98
$Log_{01440800}$	-1.4081	1.1343	--	--	--	--	--	--	.17	40.7	.78
$Log_{01441000}$	.63422	.59265	--	--	--	--	--	--	.10	23.3	.90
$Log_{01441495}$	-.89884	--	--	1.0254	--	--	--	--	.04	9.2	.99
$Log_{01441500}$	.10733	--	.82561	--	--	--	--	--	.05	11.6	.98
$Log_{01442600}$	-.36495	.85071	--	--	--	--	--	--	.13	30.6	.92
$Log_{01442700}$	.22781	--	.64020	--	--	--	--	--	.11	25.7	.91
$Log_{01449355}$	-.39796	--	--	--	--	--	--	0.98443	.04	9.2	.97

Equations for predicting 7-day, low-flow statistics at partial-record stations using statistics from continuous-record index stations

Predicted partial-record station statistic$_s$ (ft^3/s)		Continuous-record index station(s) (ft^3/s)
01440250_s	=	$0.00116(01442500_s^{1.4896})$
01440272_s	=	$0.206(01439500_s^{-1.0838})(01440400_s^{2.0971})$
01440300_s	=	$0.114(01439500_s^{0.87306})$
01440485_s	=	$1.46(01439500_s^{-0.36102})(01440400_s^{0.9206})$
01440500_s	=	$1.60(01440400_s^{0.75311})$
01440800_s	=	$0.0391(01439500s^{1.1343})$
01441000_s	=	$4.31(01439500s^{0.59265})$
01441495_s	=	$0.126(01442500_s^{1.0254})$
01441500_s	=	$1.28(01440400_s^{0.82561})$
01442600_s	=	$0.432(01439500_s^{0.85071})$
01442700_s	=	$1.69(01440400_s^{0.64020})$
01449355_s	=	$0.400(01449360_s^{0.98443})$

Although the Stedinger and Thomas (1985) methodology was developed for predicting low-flow recurrence-interval statistics, the equations resulting from this method (table 4) were used to predict all the statistics shown in table 3 for the partial-record stations. The predicted statistics for the partial-record stations are shown in table 5. The same descriptions and acronyms discussed above for table 3 apply to the statistics in table 5.

The range between the maximum and minimum statistics for each station in table 5, as exemplified by 212 and 0.3 ft^3/s for Shawnee Creek at Shawnee, reflect smaller absolute differences than in table 3, but approximately the same range in order of magnitude. The smaller range in D1 values (flows equaled or exceeded 1 percent of the time), from 439 to 57 ft^3/s, for all stations reflects a smaller range of drainage areas (from 65.3 to 4.58 mi^2) for the partial-record stations than for the continuous-record stations.

Comparison of Predicted and Observed Streamflow Statistics for Continuous-Record Stations

The seven continuous-record stations used in the analyses for this study also were treated as if each was a partial-record station similar to Wilson (2000). The test was used to determine how well the Stedinger and Thomas (1985) methodology predicted statistics compared to those observed for the continuous-record stations and to provide quantitative results on how well the methodology predicted high- and intermediate-flow statistics that were based on low-flow coefficients and equations.

Regression Analyses of Continuous-Record Station Data

Regression coefficients and equations for continuous-record stations tested as indexes for predicting 7-day low-flow statistics at the other continuous-record stations are shown in table 6. The only continuous-record station not included in a best relation as an index was Dilldown Creek near Long Pond, the station with the smallest drainage area (2.39 mi^2). This result was similar to the Wilson (2000) finding that stations with larger drainage areas tended to have better predictive capabilities than stations with smaller drainage areas.

All seven relations shown in table 6 had standard errors of less than 30 percent and coefficients of determination (R^2) greater than or equal to 0.89. These results indicate the relations are good fits for predicting 7-day, low-flow recurrence-interval statistics at the respective continuous-record stations. Although only 2 of the 12 partial-record stations had 2 significant index stations, 4 of the 7 continuous-record stations treated in the same manner had multiple indexes. The Dilldown Creek near Long Pond station was the only station to have three index stations in its best relation.

Differences in Predicted and Observed Streamflow Statistics for Continuous-Record Stations

Although the Stedinger and Thomas (1985) methodology was developed specifically for predicting low-flow recurrence-interval statistics at partial-record stations, the equations in table 6 were used to predict the previously discussed 36 statistics for the 7 continuous-record stations. An example of the relation between observed and predicted statistics for Lehigh River at Stoddartsville is shown in figure 5. Good agreement between the predicted and observed statistics is visually evident.

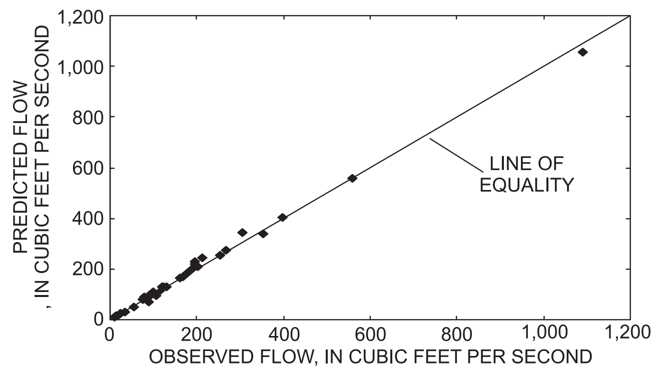

Figure 5. Observed and predicted streamflow statistics for Lehigh River at Stoddartsville, Pa.

Predicted statistics for the seven continuous-record stations using the equations in table 6 are shown in table 7, along with the absolute percent differences from the observed statistics. The predicted statistics range from a maximum of about 2,660 ft^3/s (flow equaled or exceeded 1 percent of the time, D1) to a minimum of 0.3 ft^3/s (lowest average flow expected for 7 consecutive days every 20 years, Q7,20).

The mean difference of 9 percent and the median difference of 7 percent of all predicted statistics from all observed statistics for the continuous-record stations do not show a large disparity. The small differences may be a function of the previously mentioned plotting and correlation procedure and the best relations discussed above. The mean differences indicate by their small magnitudes that there may be a consistent relation between low-flow statistics and higher-flow statistics at a station and that the Stedinger and Thomas (1985) methodology may be appropriate for predicting high- and intermediate-flow statistics for partial-record stations. The maximum difference (123 percent) and the second highest difference (52 percent) in observed and predicted statistics both occurred for the Dilldown Creek near Long Pond station and were not for high-flow but for low-flow statistics. Those high values are mathematical by-products caused when the differences in observed and predicted statistics are much greater than their averages, artifacts from the very low flows that occur at small drainage-area stations like Dilldown Creek. The actual absolute difference between the observed and predicted statistics for those two highest percent differences was only 0.3 ft^3/s.

Table 5. Predicted streamflow statistics for partial-record stations in Monroe County, Pennsylvania.

[USGS, U.S. Geological Survey; Q7,x, 7-day low-flow statistic for selected recurrence interval; Dx, flow-duration statistic equaled or exceeded selected percent of time; x-year BFLO, base flow for selected recurrence interval]

Statistic	Streamflow at USGS partial-record gaging station, in cubic feet per second											
	01440250	01440272	01440300	01440485	01440500	01440800	01441000	01441495	01441500	01442600	01442700	01449355
Mean monthly flow												
Oct.	6.2	9.2	7.7	14	41	9.3	75	41	45	26	27	24
Nov.	13	15	12	18	60	17	102	69	68	41	37	34
Dec.	21	23	15	22	76	22	117	93	88	49	45	46
Jan.	17	19	15	20	70	21	116	80	81	49	42	42
Feb.	18	19	15	20	72	22	119	84	84	51	43	42
Mar.	33	31	23	26	102	38	157	127	122	75	58	59
Apr.	33	31	23	26	102	38	156	126	122	75	58	58
May	20	22	17	22	79	26	127	89	93	56	47	46
June	10	14	12	17	57	16	100	58	64	39	35	38
July	4.4	5.4	7.9	11	34	9.6	76	33	37	27	23	24
Aug.	4.1	3.8	6.2	9	27	7.1	65	31	29	21	19	20
Sept.	4.3	6.9	6.0	12	33	6.8	64	32	36	21	22	21
Mean annual flow	14	16	13	19	64	19	109	72	73	45	39	38
Q7,2	.8	2.1	1.4	5.6	11	1.0	24	11	11	5.1	8.7	9.0
Q7,5	.5	1.4	.8	4.6	8.2	.5	16	7.9	7.6	2.9	6.3	6.7
Q7,10	.4	1.2	.5	4.1	7.1	.3	13	6.6	6.4	2.2	5.4	5.7
Q7,20	.3	1.0	.4	3.8	6.2	.2	11	5.7	5.6	1.7	4.7	4.9
D99	.4	1.4	.8	4.4	7.4	.5	16	6.2	6.9	2.7	6.2	5.8
D95	.7	2.1	1.4	5.6	11	1.0	23	9.2	11	4.8	8.7	8.4
D90	1.0	2.2	2.0	6.0	13	1.6	30	12	13	7.1	10	11
D80	1.9	3.6	3.6	8.0	21	3.5	45	18	21	12	15	14
D70	3.2	5.5	5.4	10	29	5.9	59	26	31	19	20	18
D60	4.8	7.2	7.5	12	37	9.0	74	34	40	26	24	23
D50	7.1	9.3	10	14	45	12	88	45	50	33	29	28
D40	10	12	12	16	55	17	102	58	62	41	34	34
D30	15	16	15	19	67	22	119	75	77	50	40	42
D20	24	22	20	22	84	31	141	102	99	65	49	54
D10	46	36	27	29	117	48	178	158	142	90	65	74
D5	79	56	36	36	154	68	212	226	192	116	82	101

Table 5. Predicted streamflow statistics for partial-record stations in Monroe County, Pennsylvania.—Continued

[USGS, U.S. Geological Survey; Q7,x, 7-day low-flow statistic for selected recurrence interval; Dx, flow-duration statistic equaled or exceeded selected percent of time; x-year BFLO, base flow for selected recurrence interval]

Statistic	Streamflow at USGS partial-record gaging station, in cubic feet per second												
	01440250	01440272	01440300	01440485	01440500	01440800	01441000	01441495	01441500	01442600	01442700	01449355	
D1	212	136	58	57	265	130	298	439	348	189	130	185	
Mean annual base flow	6.3	9.4	9.2	14	45	12	85	41	49	31	29	27	
2-year BFLO	6.4	9.3	9.4	14	45	12	86	42	50	32	29	27	
5-year BFLO	4.6	7.7	7.7	12	38	9.3	75	34	42	26	25	22	
10-year BFLO	3.9	7.0	6.9	12	35	8.1	70	30	38	24	23	20	
25-year BFLO	3.2	6.4	6.1	11	32	6.8	64	26	34	21	22	17	
50-year BFLO	2.8	5.9	5.5	11	30	6.0	60	24	32	19	20	15	
													All stations
Maximum	212	136	58	57	265	130	298	439	348	189	130	185	439
Minimum	.3	1.0	.4	3.8	6.2	.2	11	5.7	5.6	1.7	4.7	4.9	.2

Table 6. Regression coefficients and equations for predicting 7-day, low-flow recurrence-interval statistics at continuous-record stations (treated as partial-record stations) in Monroe County, Pennsylvania.

[8-digit numbers beginning with 014 are station numbers shown in table 1; --, not significant at the $p<0.05$ level; station number$_s$ indicates statistic predicted or observed as appropriate to equation; ft^3/s, cubic feet per second]

Log of statistic at partial-record station	Regression coefficients for continuous-record stations tested as index stations								Residual standard error		Adjusted coefficient of determination (R^2)
	Intercept (A)	$Log_{01439500}$ (b)	$Log_{01440400}$ (c)	$Log_{01442500}$ (d)	$Log_{01447500}$ (e)	$Log_{01447680}$ (f)	$Log_{01448500}$ (g)	$Log_{01449360}$ (h)	Log units	Percent	
$Log_{01439500}$	0.09679	--	1.0778	--	--	--	--	--	0.10	23.3	0.96
$Log_{01440400}$	-.44118	0.55203	--	0.45264	--	--	--	--	.06	13.9	.98
$Log_{01442500}$	.92013	--	.84948	--	--	--	--	--	.06	13.9	.97
$Log_{01447500}$	.40183	--	.88924	--	--	--	--	--	.10	23.3	.92
$Log_{01447680}$	-.54615	--	--	--	0.25001	--	--	0.81666	.12	28.2	.89
$Log_{01448500}$	-1.3515	--	.18917	--	--	0.37486	--	.48439	.08	18.6	.96
$Log_{01449360}$	.56051	--	.31613	--	--	.47369	--	--	.09	20.9	.92

Equations for predicting 7-day, low-flow recurrence-interval statistics at continuous-record stations (treated as partial-record stations) using statistics from continuous-record index stations		
Predicted partial-record station statistic$_s$ (ft^3/s)		Continuous-record index station(s) (ft^3/s)
01439500_s	=	$1.25(01440400_s^{1.0778})$
01440400_s	=	$0.362(01439500_s^{0.55203})(01442500_s^{0.45264})$
01442500_s	=	$8.32(01440400_s^{0.84948})$
01447500_s	=	$2.52(01440400_s^{0.88924})$
01447680_s	=	$0.284(01447500_s^{0.25001})(01449360_s^{0.81666})$
01448500_s	=	$0.0445(01440400_s^{0.18917})(01447680_s^{0.37486})(01449360_s^{0.48439})$
01449360_s	=	$3.64(01440400_s^{0.31613})(01447680_s^{0.47369})$

Table 7. Predicted streamflow statistics and percent differences from observed statistics for continuous-record stations in Monroe County, Pennsylvania.

[USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; %, percent difference from observed; Q7,x, 7-day low-flow statistics for selected recurrence interval; Dx, flow-duration statistics equaled or exceeded selected percent of time; x-year BFLO, base flow for selected recurrence interval]

Statistic	Predicted streamflow and percent differences for continuous-record streamflow-gaging stations														
	01439500		01440400		01442500		01447500		01447680		01448500		01449360		
	ft^3/s	%	ft^3/s	%	ft^3/s	%	ft^3/s	%	ft^3/s	%	ft^3/s	%	ft^3/s	%	
Mean monthly flow															
Oct.	129	4	70	5	322	1	116	2	28	16	2.8	4	74	15	
Nov.	225	8	119	4	499	7	183	3	41	2	4.0	14	98	7	
Dec.	315	18	154	9	650	11	242	13	56	9	5.3	10	118	5	
Jan.	281	8	143	6	594	4	220	12	50	14	4.7	10	107	6	
Feb.	293	8	150	5	614	7	227	14	51	17	4.7	6	107	6	
Mar.	480	10	234	7	906	8	342	11	75	14	7.0	8	150	6	
Apr.	478	11	232	7	903	8	341	3	77	2	7.4	22	161	2	
May	335	10	164	9	682	2	254	1	58	6	5.5	18	125	0	
June	208	4	107	7	468	4	172	3	44	2	4.3	1	99	2	
July	99	25	65	11	262	3	93	14	28	1	2.5	10	64	2	
Aug.	72	31	54	23	203	17	72	23	22	0	2.0	16	52	1	
Sept.	96	2	54	3	254	2	90	0	24	13	2.3	5	62	8	
Mean annual flow	247	5	129	5	537	4	198	5	46	2	4.4	11	104	2	
Q7,2	20	11	13	0	73	8	25	4	8.5	14	.7	13	21	13	
Q7,5	13	26	8.3	7	52	9	17	6	5.7	19	.5	0	15	18	
Q7,10	10	30	6.5	12	43	11	14	7	4.7	24	.4	0	12	22	
Q7,20	8.3	35	5.3	16	38	10	12	9	3.9	23	.3	29	11	17	
D99	11	25	7.0	9	47	4	15	10	5	18	.4	123	14	9	
D95	20	15	12	8	74	2	25	7	8	5	.7	52	21	4	
D90	26	2	17	3	92	2	31	5	10	4	.9	12	26	6	
D80	49	6	30	1	150	4	52	4	15	6	1.4	0	40	4	
D70	79	5	46	2	219	7	77	1	20	4	1.9	5	52	6	
D60	112	7	64	1	289	7	103	1	26	0	2.4	7	64	4	
D50	150	7	85	0	362	4	131	1	33	2	3.1	4	76	2	
D40	196	6	110	1	448	0	164	1	41	4	3.8	5	91	1	
D30	261	3	142	0	560	4	207	2	51	7	4.8	8	109	5	
D20	363	0	192	0	727	9	272	2	67	6	6.3	7	137	6	
D10	586	10	290	4	1,061	15	404	1	97	6	9.3	5	187	8	

Table 7. Predicted streamflow statistics and percent differences from observed statistics for continuous-record stations in Monroe County, Pennsylvania.—Continued

[USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; %, percent difference from observed; Q7,x, 7-day low-flow statistics for selected recurrence interval; Dx, flow-duration statistics equaled or exceeded selected percent of time; x-year BFLO, base flow for selected recurrence interval]

Statistic	Predicted streamflow and percent differences for continuous-record streamflow-gaging stations														
	01439500		01440400		01442500		01447500		01447680		01448500		01449360		
	ft^3/s	%	ft^3/s	%	ft^3/s	%	ft^3/s	%	ft^3/s	%	ft^3/s	%	ft^3/s	%	
D5	866	19	403	7	1,442	20	556	0	136	4	13.2	13	248	10	
D1	1,880	39	743	18	2,657	25	1,055	3	266	9	25.9	21	420	19	
Mean annual base flow	146	4	79	5	355	10	128	6	31	2	2.9	13	74	4	
2-year BFLO6	148	6	80	5	359	10	130	6	31	5	2.9	14	74	1	
5-year BFLO	118	6	63	7	300	14	107	6	25	5	2.3	13	62	5	
10-year BFLO	105	5	55	10	273	16	98	7	22	10	2.0	17	55	6	
25-year BFLO	92	3	50	9	246	19	88	9	19	11	1.7	19	49	9	
50-year BFLO	83	3	45	9	227	20	80	8	17	8	1.6	18	46	12	
															All stations
															%
Mean		12		7		9		6		8		15		7	9
Median		7		7		8		5		6		10		6	7
Maximum		39		23		25		23		24		123		22	123
Minimum		0		0		0		0		0		0		0	0

Limitations of the Investigation and Statistics

The study and the resulting statistics are limited to streams in Monroe County, Pa. The subbasin yields calculated from the three sets of miscellaneous measurements are relative to those periods and flow regimes and may not reflect the full range of hydrologic conditions in the Paradise and Pocono Creek watersheds. The methodology proposed by Stedinger and Thomas (1985) for predicting low-flow recurrence-interval statistics was the only one used for predicting statistics at partial-record stations; other methods briefly mentioned in the previous studies section of this report may have resulted in more accurate statistics. The Stedinger and Thomas (1985) methodology for predicting statistics does not apply to stream locations having intermittent flow. The standard errors in percent and the coefficients of determination (R^2) in tables 4 and 6 are diagnostics reflecting the expected errors in the predicted statistics using the selected methodology. The predicted statistics for the partial-record stations that had only six usable measurements for the analyses may have more error than indicated in table 4. All the observed, predicted, and basin-yield statistics are estimates affected by time and measurement errors.

Summary and Conclusions

Streamflow statistics are needed in the Paradise and Pocono Creek watersheds and in surrounding parts of Monroe County, Pa., to quantify surface-water resources and as input to ground-water models. Subbasin yields for the Paradise and Pocono Creek watersheds also are needed for various purposes. In order to fulfill these objectives, the U.S. Geological Survey, the Delaware River Basin Commission, and the Brodhead Watershed Association cooperated in a study to determine the needed streamflow statistics.

Monroe County is in the Pocono Mountains of northeastern Pennsylvania. Surficial geology includes glacial deposits, sandstones, conglomerates, siltstones, shales, and small amounts of carbonate rock. Areas where porous glacial deposits are connected to the water table typically yield higher stream base flows per unit of drainage area during dry periods than nonglaciated parts of Pennsylvania.

Different approaches have been used previously by researchers to predict low-flow statistics at locations in Pennsylvania and other states without daily mean flow data. For this study, observed streamflow statistics for continuous-record stations were computed from daily mean flows retrieved from U.S. Geological Survey databases. Predicted statistics for the partial-record stations were obtained by correlating intermittent measurements made at partial-record stations with concurrent daily mean flows from seven continuous-record stations operated in Monroe County.

Relative subbasin yields for the Paradise and Pocono Creek watersheds were consistent during each measurement period with few exceptions. One exception was a losing reach along the Pocono Creek main stem. Another exception was the high subbasin yield for Swiftwater Creek in the Paradise Creek watershed that probably reflects surface-water discharges from treatment facilities upstream.

A suite of 36 streamflow statistics were computed for 7 continuous-record stations and predicted for 12 partial-record stations in Monroe County, Pa. The statistics for each station ranged in magnitude from a high-flow duration equaled or exceeded only 1 percent of the time (D1) to the 7-day, 20-year recurrence-interval low flow (Q7,20) or the low-flow duration equaled or exceeded 99 percent of the time (D99). Low standard errors and high coefficients of determination (R^2) indicate good agreement in using intermittent measurements at partial-record stations and concurrent daily mean flows at continuous-record stations to predict low-flow recurrence-interval statistics for the partial-record stations.

The study and the resulting statistics are limited to streams in Monroe County. All the observed, predicted, and subbasin-yield statistics are estimates affected by time and measurement errors. The comparison of predicted and observed statistics for the continuous-record stations indicates the prediction methodology used in the study may have application potential for predicting high- and intermediate-flow statistics, not just for low-flow statistics as done in previous investigations. Although all the statistics contain error, as discussed herein, these statistics do constitute the results needed by Delaware River Basin watershed groups for planning purposes and input for ground-water modeling.

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