

SURFACE WATER

This section describes the surface-water system in the Maurice River study area. Discharge, base-flow, and low-flow data for 4 streamflow-gaging stations and the results of low-flow correlations for 17 low-flow, partial-record sites in the study area are presented.

Discharge at Gaging Stations

The surface-water system in the study area includes the many tributaries, lakes, and wetland areas of the Maurice River and Cohansey River drainage systems, and the total areas and minor tributaries to the Delaware Bay. From their headwaters the Maurice and Cohansey Rivers flow about 20 and 25 mi, respectively, to the south and empty into the Delaware Bay. Overall, these streams are gaining and derive most of their flow from the unconfined ground-water system.

At various times, the USGS has maintained four continuous-record streamflow-gaging stations in the study area (fig. 3-1): Maurice River at Norma, N.J. (01411500), during 1922 to present (1924); Mercurio Creek near Millville, N.J. (01412000), during 1933-57 and 1977-85; West Branch Cohansey River at Seelye, N.J. (01412500), during 1951-67; and Cohansey River at Seelye, N.J. (01412800), during 1977-85. The minimum and maximum monthly mean discharge for these streamflow-gaging stations are shown in figures 3-2 through 3-5. The minimum and maximum daily discharge, the mean annual discharge, and the 30-day, 5-year and 7-day, 10-year low-flow discharges for these stations are listed in table 3-1.

A base-flow-equation technique described by Pettiberry and Herring (1979) and adopted by Stoltz (1988) makes use of a 3-day sliding-interval method to divide stream discharge into direct-runoff and base-flow components. Direct runoff consists of overland runoff and precipitation that falls directly on the stream. Base flow is the low-flow discharge of the stream and usually consists mostly of the constant flow of ground water from the aquifer to the stream, and other relatively constant discharges into the stream, such as releases from reservoirs. Annual mean direct runoff and base flow, by water year, at the four streamflow-gaging stations are shown in figures 3-2 through 3-5.

The annual mean base flow of the Maurice River at Norma ranged from 59 cfs in 1966 to 222 cfs in 1973, with a mean of 143 cfs, and from 74 percent of total flow in 1940 to 92 percent in 1947, with a mean of 87 percent. The annual mean base flow of Mercurio Creek near Millville ranged from 18 cfs in 1942 to 44 cfs in 1956, with a mean of 31 cfs, and from 75 percent of total flow in 1942 to 90 percent in 1952, with a mean of 86 percent. The annual mean base flow of the West Branch Cohansey River at Seelye ranged from 0.7 cfs in 1966 to 2.4 cfs in 1981, with a mean of 1.4 cfs, and from 68 percent of total flow in 1967 to 82 percent in 1982, with a mean of 83 percent. For the Cohansey River at Seelye, annual mean base flow ranged from 20 cfs in 1988 to 39 cfs in 1980, with a mean of 28 cfs, and from 72 percent of total flow in 1983 to 82 percent in 1986, with a mean of 81 percent.

A flow-duration curve is a cumulative-frequency curve that shows the percentage of time that any specified discharge is equaled or exceeded (Langhans and Ison, 1960, p. 11). The shape of the curve is determined by the hydrologic and geologic characteristics of the drainage basin. A curve with a gentle slope indicates that streamflow is derived largely from a steady supply of water from storage and, therefore, varies little. Water from storage can come from the ground-water system through the steady release of water from permeable deposits to hydraulic connection discharge, from surface storage from surface water bodies, or from the steady release of water from lakes and wetlands, or from a combination of the two sources. A steep curve indicates that a relatively small proportion of streamflow is from storage (little steady release of water from ground and surface water), and that flow is derived largely from direct runoff and tends to be variable. A streamflow-variability index for flow-duration curves, calculated as the discharge that is equaled or exceeded 20 percent of the time divided by the discharge that is equaled or exceeded 80 percent of the time, was proposed by Miller (1968, p. 24). Miller reported that the streamflow-variability index for New Jersey streams with drainage areas greater than 25 sq mi ranged from approximately 2 (low variability) to 20 (high variability). The streamflow-variability index reported by Miller (1968) for Coastal Plain streams ranged from 2.2 to 3.6.

Flow-duration curves for the streamflow-gaging stations at Maurice River at Norma, N.J., during water years 1933-84 and at Cohansey River at Seelye, N.J., during water years 1933-84 are shown in figure 3-10. The streamflow-variability indices at these gaging stations were 2.7 and 2.0, respectively, which indicates that these streams have uniform flow characteristics, even with respect to their Coastal Plain streams, and derive most of their flow from ground-water and surface-water storage. Curves for the Mercurio Creek near Millville, N.J., and West Branch Cohansey River at Seelye, N.J., are presented for the drainage basins of these streams upstream from the streamflow-gaging station are smaller than 25 sq mi. The discharges that were equaled or exceeded 5 percent and 20 percent of the time at Maurice River at Norma are 347 cfs and 67 cfs, respectively, and for Cohansey River at Seelye are 87 cfs and 20 cfs, respectively. The discharges that were equaled or exceeded 50 percent of the time are 146 cfs for Maurice River at Norma and 35 cfs for Cohansey River.

Discharge at Low-Flow Partial-Record Stations

The magnitude and frequency of streamflow at stations for which a continuous record is unavailable commonly are estimated by interpolating instantaneous flow discharge at the low-flow, partial-record station with the concurrent mean daily discharge at a streamflow-gaging station, or index station, in a similar hydrologic setting. In this study, in addition to the 14 low-flow, partial-record stations, 2 streamflow-gaging stations were used to describe the mean daily discharge at the index gaging station. Measured discharge values at each of these 17 low-flow, partial-record stations were correlated with mean discharge at four index gaging stations using equation 3-1. The correlation coefficient is reported to the index gaging station. The locations of the index gaging stations and low-flow, partial-record stations are shown in figure 3-1.

The low-flow correlations reported here were developed by use of the MOVE-1 (Maintenance of Variance Extension, Type 1) method, which makes use of geometric means to estimate the base of ordinary-least-squares regression (Hirsch, 1982), an example of a low-flow correlation is shown in figure 3-11. The "best-fit" line, or correlation equation, is drawn through the data points that represent the measured discharge at the low-flow, partial-record station, Q_{PR} , plotted against the mean daily discharge at the index gaging station, Q_I . The equation of the best fit line, $Q_{PR} = (0.3743) Q_I^{0.7698}$, is first used to estimate specific discharge statistics at the low-flow, partial-record station, Q_{PR} , on the basis of the values of the same discharge statistics measured at the index gaging station, Q_I . The low-flow, partial-record stations and their associated correlation equations are listed in table 3-2.

Two statistical indicators, the correlation coefficient and the standard error of estimation, are included in table 3-2 as an indication of the accuracy of the estimated discharge. The correlation coefficient is a number from -1.0 to 1.0 that measures the strength of the linear relation between the logarithm (base 10) of the discharge at the low-flow, partial-record station and that of the index gaging station. For low-flow correlations in this report, the nearer the correlation coefficient is to 1.0, the more reliable the predicted discharge, Q_{PR} . Although the correlation coefficient is used to describe the linear relation between the logarithm of the predicted discharge, Q_{PR} , and the logarithm of the measured discharge, Q_I , it is not used to describe the linear relation between the logarithm of the predicted discharge, Q_{PR} , and the logarithm of the mean daily discharge at the index gaging station, Q_I . The low-flow, partial-record stations and their associated correlation equations are listed in table 3-2.

Two statistical indicators, the correlation coefficient and the standard error of estimation, are included in table 3-2 as an indication of the accuracy of the estimated discharge. The correlation coefficient is a number from -1.0 to 1.0 that measures the strength of the linear relation between the logarithm (base 10) of the discharge at the low-flow, partial-record station and that of the index gaging station. For low-flow correlations in this report, the nearer the correlation coefficient is to 1.0, the more reliable the predicted discharge, Q_{PR} . Although the correlation coefficient is used to describe the linear relation between the logarithm of the predicted discharge, Q_{PR} , and the logarithm of the measured discharge, Q_I , it is not used to describe the linear relation between the logarithm of the predicted discharge, Q_{PR} , and the logarithm of the mean daily discharge at the index gaging station, Q_I . The low-flow, partial-record stations and their associated correlation equations are listed in table 3-2.

From these correlations, the 30-day, 5-year low-flow discharge; the 7-day, 10-year low-flow discharge; and the mean annual discharge were calculated for the 17 low-flow, partial-record stations. For example, to estimate 30-day, 5-year low-flow discharge at the low-flow, partial-record station near Millville, N.J. (01412000), 13.3 cfs is substituted in the correlation equation, which then is solved for the 30-day, 5-year low-flow discharge at the low-flow, partial-record station (Q_{PR}).

$Q_{PR} = (0.3743) (13.3 \text{ cfs})^{0.7698}$, and $Q_{PR} = 2.5 \text{ cfs}$.

Substituting the index-gaging station discharge values for 7-day, 10-year low flow (7.2 cfs) and mean annual flow (37.5 cfs) in the correlation equation, the appropriate respective flows, 1.6 cfs and 5.2 cfs, also are estimated for the low-flow, partial-record station. This same approach could be used to estimate the mean annual base flow at a low-flow, partial-record station for an eight-year period. For example, figure 3-7 shows that the mean base flow at Mercurio Creek near Millville, N.J. (01412000), in water year 1942 was the lowest on record. The 1942 mean base flow can be estimated for the low-flow, partial-record station Barrett Run near Bridgeton, N.J. (01413010) using equation 3-1. The predicted discharge at Barrett Run near Bridgeton, N.J. (01413010) for the 1942 mean base flow at Mercurio Creek near Millville, N.J. (01412000) is about 20 cfs (fig. 3-7). This value is substituted for Q_I in the prediction equation to yield a discharge value of about 20 cfs for Barrett Run near Bridgeton.

Low-flow correlation prediction equations were developed and used to estimate discharge statistics for all stations listed in table 3-2. Mean base flow was estimated in this study only for those low-flow, partial-record stations that were paired with an index gaging station within the Maurice River study area. Discharge statistics developed from correlation equations provide valuable information about sites for which those statistics would otherwise be unavailable; however, these values are considered to be less reliable than statistics based on direct measurements from a continuous-record streamflow-gaging station.

PRECIPITATION, DISCHARGE, AND EVAPOTRANSPIRATION

This section describes the influence of climatic factors on the hydrology of the unconfined aquifer system in the Maurice River study area. Precipitation is considered to be discharge, and potential evapotranspiration is estimated. These precipitation, discharge, and potential evapotranspiration values are used in the water-budget analysis on sheet 4 of this report.

Precipitation data from three National Oceanic and Atmospheric Administration weather stations (fig. 3-1) for the period 1933-84 were used: Wilmington, Del. (1932-62) (National Oceanic and Atmospheric Administration, 1928-95), and the average from the Gloucester, N.J., and Millville, N.J., weather stations (1933-55) (National Oceanic and Atmospheric Administration, 1928-95). Until 1963, data from the Wilmington, Del., station were considered to most closely represent precipitation in the study area on the basis of its proximity to the complete precipitation record. In 1963, uncorrelated precipitation records began at Gloucester, N.J., and Millville, N.J., weather stations (figs. 3-6 through 3-9) in the study area. The Wilmington precipitation record (1932-62) was adjusted slightly downward by using linear regression developed for the period of overlap (1963-64) between the record from the Wilmington station and the average of the records from the Gloucester and Millville stations. These adjusted values are used throughout this report for precipitation during 1932-62.

Total annual precipitation during 1932-84 ranged from a minimum of 31.2 in. in water year 1955 to a maximum of 58.2 in. in 1975, with a mean of 42.6 in/y. Monthly mean, minimum, and maximum precipitation values for the average of the records from the Gloucester and Millville weather stations for 10 water years (1955-64) are shown in figure 3-12. Monthly precipitation ranged from a minimum of 0.43 in. in October 1957 to a maximum of 8.85 in. in March 1957, with a mean of 3.58 in.

Most of the precipitation that falls on the Maurice River study area leaves as stream discharge (direct runoff plus base flow). Total annual discharge at the four streamflow-gaging stations in the study area was compared to total annual precipitation, which is assumed to be uniform over the study area. All values in figs. 3-6 through 3-9 are presented in units of inches of water over the area of the basin and units of cubic feet per second; values are discussed below only in units of inches of water over the area of the basin. The total annual discharge of the Maurice River at Norma, N.J. (01411500), ranged from 8.2 in. in water year 1966 to 30.2 in. in water year 1973 (fig. 3-6). The mean annual discharge was 20.0 in/y, or 47 percent of the mean annual precipitation for water years 1933-84. The total annual discharge of Mercurio Creek near Millville, N.J. (01412000), ranged from 12.6 in. in water year 1981 to 17.7 in. in water year 1973 (fig. 3-7). The mean annual discharge was 21.8 in/y, or 51 percent of the mean annual precipitation for water years 1933-84. The total annual discharge of West Branch Cohansey River at Seelye, N.J. (01412500), ranged from 4.1 in. in water year 1969 to 14.9 in. in water year 1981 (fig. 3-8). The mean annual discharge was 9.5 in/y, or 24 percent of the mean annual precipitation for water years 1932-84. The total annual discharge of Cohansey River at Seelye, N.J. (01412800), ranged from 7.8 in. in water year 1988 to 22.5 in. in water year 1979 (fig. 3-9). The mean annual discharge was 17.14 in/y, or 40 percent of the mean annual precipitation for water years 1979-88.

The percentage of mean annual streamflow that is base flow was similar for the four streamflow-gaging stations (80 to 87 percent of mean annual streamflow). In contrast, mean annual streamflow ranged from 40 to 51 percent of mean annual precipitation at three of the streamflow-gaging stations, but was 24 percent at West Branch Cohansey River at Seelye, N.J. (01412500). This difference is attributed to the fact that the stream reach above the West Branch Cohansey River gaging station is higher and is cut less deeply into the aquifer than the stream reaches above the other three gaging stations. Therefore, it is likely that proportionately more ground water underlies the West Branch Cohansey River than underlies the other three streams. Consequently, proportionately less ground water discharges as base flow. The ground water that flows beneath the stream ultimately discharges to stream reaches at lower elevations.

Most of the precipitation that does not discharge as streamflow leaves the Maurice River study area as evapotranspiration. Potential evapotranspiration was estimated by using the Thornthwaite and Mather (1927) method, which uses mean monthly air temperature and latitude as an index of the energy available for evapotranspiration. Potential evapotranspiration is the amount of water that is lost through transpiration from plants and evaporation from the soil if water is always unlimited. The average mean monthly air temperature at the Gloucester and Millville weather stations during 1935-84 (National Oceanic and Atmospheric Administration, 1928-95) is shown in figure 3-13. Estimated mean monthly potential evapotranspiration is shown in figure 3-14. The calculated mean annual potential evapotranspiration for the study area for the period of the water budget (1933-84) is 38.3 in/y.

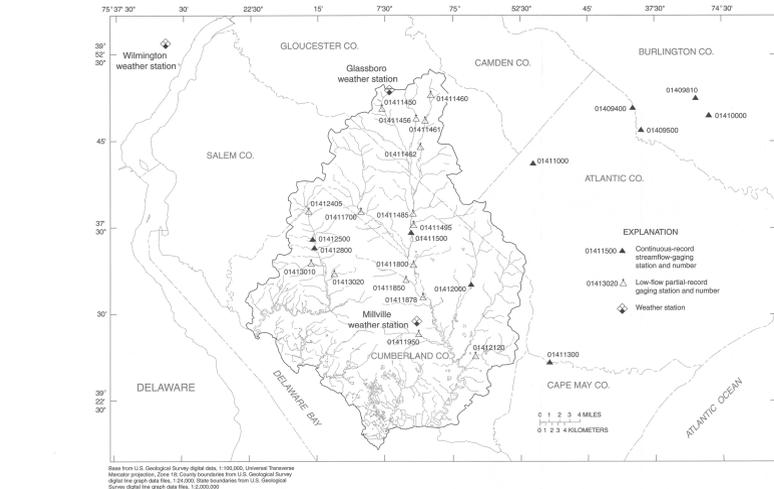


Figure 3-1. Locations of continuous-record streamflow-gaging stations, low-flow partial-record gaging stations, and weather stations in and near the Maurice River study area, New Jersey.

Table 3-1. Summary of discharge statistics for continuous-record streamflow-gaging stations in and near the Maurice River study area, New Jersey (Station locations shown in fig. 3-1; —, not calculated because streamflow-gaging station is not in study area)

Streamflow-gaging station number	Streamflow-gaging station name	Drainage area (square miles)	Period of record	Discharge (cubic feet per second)					Mean annual base flow ²		
				30-day	7-day	10-year	Maximum daily	Minimum daily	Cubic feet per second	Inches over the drainage area	
01411500	Maurice River near Norma, N.J.	46.7	September 1922 through September 1994	33	23	16	1,430	37	7.5	—	—
01412000	Mercurio Creek near Millville, N.J.	47.8	October 1933 through September 1994	42	49	41	2,000	122	5.7	—	—
01412500	West Branch Cohansey River near Seelye, N.J.	44.1	October 1974 through September 1994	16	37	28	1,200	143	23	—	—
01412800	Cohansey River near Seelye, N.J.	72.5	October 1979 through September 1994	60	29	22	1,220	86.8	4.0	—	—
01411000	Great Egg Harbor River near Fenwick, N.J.	57.1	September 1925 through September 1994	65	28	23	1,300	96.3	15	—	—
01411300	Tuckahoe River near Fenwick, N.J.	36.8	December 1949 through September 1994	20	11	6.0	464	43.8	1.3	—	—
01411700	Maurice River near Norma, N.J.	112	July 1972 through September 1994	58	32	38	5,200	365	23	143	17.3
01413010	Mercurio Creek near Millville, N.J.	23.2	June 1971 through September 1994	33	13	12	461	37.5	1.4	32	18.7
01412500	West Branch Cohansey River near Seelye, N.J.	2.50	May 1951 through September 1997	16	6	2	95	1.8	0	1.5	7.8
01412800	Cohansey River near Seelye, N.J.	28.0	October 1977 through September 1994	11	17	14	2,150	35.3	3	28	13.6

¹Low-flow statistics were calculated by using data for each complete climatic year. A climatic year is the 12-month period from April 1 through March 31, and is designated by the calendar year in which it begins. This period allows the entire low-water season to occur in one year. For the low-flow statistics in this study, the period of record begins with the earliest April 1 and ends with the latest March 31, for a total of 1994 climatic years. The base flow was estimated by using the 3-day sliding-interval method described by Pettiberry and Herring (1979) and adopted by Stoltz (1988). Base flow was calculated by using data for the water year in which the 12-month period of record begins with the earliest October 1 and ends with the latest September 30. Percentages were calculated from measured discharge values and base flow only and do not include the predicted discharge values from the correlation equations.

²Base flow is assumed to be uniform over the study area.

Table 3-2. Correlation equations relating instantaneous low-flow measurements at low-flow partial-record gaging stations to concurrent mean daily flow at continuous-record streamflow-gaging stations in and near the Maurice River study area, New Jersey (Station locations shown in fig. 3-1; —, predicted discharge at partial-record station; —, not calculated because mean base flow was predicted only using correlation equations developed from index stations located in the study area)

Low-flow partial-record gaging station number	Low-flow partial-record gaging station name	Drainage area (square miles)	Index gaging station number	Number of measurements at index station	Years of daily discharge record	Correlation coefficient	Standard error of estimation for 7-day, 10-year low flow (cubic feet per second)	Correlation equation	Predicted discharge (Q_{PR}) (cubic feet per second)		Cubic feet per second	Inches per year over the drainage area	Percentage of total flow
									30-day Q_{PR}	7-day, 10-year Q_{PR}			
01411400	Soil Run at Aera, N.J.	3.21	01409400	22	33	0.92	22.6	$Q_{PR} = 0.0203(Q_I^{1.7799})$	1.8	0.5	6.9	—	—
01411405	Little Run near Clinton, N.J.	9.77	01409400	21	33	0.92	22.6	$Q_{PR} = 0.0048(Q_I^{1.9149})$	4	0	10.3	—	—
01411460	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.0712(Q_I^{1.2863})$	1.9	1.1	10.1	—	—
01411461	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.00334(Q_I^{2.0475})$	0	0	9.5	71.8	76.8
01411462	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.0712(Q_I^{1.2863})$	1.9	1.1	10.1	—	—
01411463	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.00334(Q_I^{2.0475})$	0	0	9.5	71.8	76.8
01411464	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.0712(Q_I^{1.2863})$	1.9	1.1	10.1	—	—
01411465	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.00334(Q_I^{2.0475})$	0	0	9.5	71.8	76.8
01411466	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.0712(Q_I^{1.2863})$	1.9	1.1	10.1	—	—
01411467	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.00334(Q_I^{2.0475})$	0	0	9.5	71.8	76.8
01411468	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.0712(Q_I^{1.2863})$	1.9	1.1	10.1	—	—
01411469	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.00334(Q_I^{2.0475})$	0	0	9.5	71.8	76.8
01411470	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.0712(Q_I^{1.2863})$	1.9	1.1	10.1	—	—
01411471	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.00334(Q_I^{2.0475})$	0	0	9.5	71.8	76.8
01411472	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.0712(Q_I^{1.2863})$	1.9	1.1	10.1	—	—
01411473	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.00334(Q_I^{2.0475})$	0	0	9.5	71.8	76.8
01411474	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.0712(Q_I^{1.2863})$	1.9	1.1	10.1	—	—
01411475	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.00334(Q_I^{2.0475})$	0	0	9.5	71.8	76.8
01411476	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.0712(Q_I^{1.2863})$	1.9	1.1	10.1	—	—
01411477	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.00334(Q_I^{2.0475})$	0	0	9.5	71.8	76.8
01411478	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.0712(Q_I^{1.2863})$	1.9	1.1	10.1	—	—
01411479	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.00334(Q_I^{2.0475})$	0	0	9.5	71.8	76.8
01411480	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.0712(Q_I^{1.2863})$	1.9	1.1	10.1	—	—
01411481	Soledad Run at Franklinville, N.J.	3.94	01410000	22	45	0.85	24.8	$Q_{PR} = 0.00334(Q_I^{2.0475})$	0	0	9.5	71.8	76.8
01411482	So												