ESTIMATION OF FLOOD-FREQUENCY CHARACTERISTICS AND THE EFFECTS OF URBANIZATION FOR STREAMS IN THE PHILADELPHIA, PENNSYLVANIA AREA

By James F. Bailey, Wilbert O. Thomas, Jr., Kim L. Wetzel, and Thomas J. Ross

---

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 87-4194

Prepared in cooperation with the

PHILADELPHIA WATER DEPARTMENT

Harrisburg, Pennsylvania

1989

DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
4th Floor, Federal Building
P.O. Box 1107
Harrisburg, Pennsylvania 17108-1107

Copies of this report can be
purchased from:

U.S. Geological Survey
Books and Open-File Reports Section
Federal Center
Box 25425
Denver, Colorado 80225

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS IN APPENDIX A

TABLES

TABLES IN APPENDIX A

CONVERSION FACTORS AND ABBREVIATIONS

For use of readers who prefer to use metric (International System) units, conversion factors for the inch-pound terms used in this report are listed below:

Multipy inch-pound unit	By	To obtain metric units
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.0283	cubic meter per second (m^3/s)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
inch per square mile ($in./mi^2$)	9.807	millimeters per square kilometer (mm/km^2)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]
inch per hour (in./hr)	25.4	millimeter per hour (mm/hr)

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level of 1929".

ESTIMATION OF FLOOD-FREQUENCY CHARACTERISTICS AND THE EFFECTS OF URBANIZATION FOR STREAMS IN THE PHILADELPHIA, PENNSYLVANIA AREA

By James F. Bailey, Wilbert O. Thomas, Jr., Kim L. Wetzel and Thomas G. Ross

ABSTRACT

This report provides a method for estimating the magnitude and frequency of floods for small streams in the Philadelphia, Pennsylvania area. Data collected at 21 streamflow gaging stations were used in a multiple-regression analysis to develop equations for computation of peak-flow characteristics. The flood equations were determined by relating flood-frequency characteristics computed using observed flow data from 13 stations and synthetically derived flow data from 8 stations to measurable basin characteristics. Significant characteristics in the equations are drainage area and impervious cover. Standard errors of estimate for the regression equations ranged from 38 to 43 percent. The equations can be used to determine peak-flow characteristics and to estimate the effect of urbanization on small streams with drainage areas from 1.1 to 64 square miles. The analyses indicate that increasing impervious area can significantly increase peak flows. Examples are given for computing flood frequency for a site on an ungaged stream and for an ungaged site on a gaged stream.

INTRODUCTION

A study to define flood-frequency characteristics and evaluate the effects of urbanization on small streams in the Philadelphia area was begun in 1973 by the U.S. Geological Survey, in cooperation with the Philadelphia Water Department. The objective was to develop equations relating peak-flow characteristics to measurable basin characteristics. The equations are used to determine peak-flow characteristics at ungaged sites on small streams for a range of recurrence intervals and urban conditions. The information is necessary for designing culverts, bridges, flood-protection structures and for effective flood-plain management.

Purpose and Scope

The purpose of this report is to present techniques and procedures for estimating the probable magnitude and frequency of floods for ungaged streams in the Philadelphia, Pennsylvania area. The report is oriented toward engineers and planners where knowledge of flood potential is essential for efficient design of floodway structures and effective management of flood-prone lands.

Streamflow information from 21 gaging stations covering a range in drainage area from 1.1 to 64 mi^2 (square miles) and impervious area from 2 to 43 percent were available for analysis. The data were used in multiple-regression analyses to develop equations for estimating flood frequency in urban basins. Equations were developed for estimating peak flows corresponding to the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence-interval floods. The analysis indicate that drainage area and measured imperviousness are the most significant independent variables to use in estimating flood peak discharges for urban basins in the metropolitan Philadelphia, Pennsylvania area.

Approach

Flood frequency is best determined through analysis of long-term observed streamflow record where the development within the basin has been stable. Streamflow data that covers a wide range of drainage basin sizes and degree of development are needed for regional analysis. Streamflow data were available for analysis from 21 gaging stations in the Philadelphia area. The stations covered a wide range of basin sizes and development; however, many stations did not have adequate streamflow record. The reliability of flood-frequency relations at a site is directly related to the length of record. The lack of sufficient record at many gaged sites indicated the need to extend peak flow record in time to provide a more reliable frequency analysis.

Several digital computer models have been developed to synthesize peak-flow records. For this study, a rainfall-runoff model developed by Dawdy and others (1972) was used to synthesize peak-flow records. A brief description of the model and calibration results are given in Appendix A. Thirteen of the 21 gaging sites were instrumented to collect rainfall data (Appendix B). Concurrent rainfall and streamflow data collected at the sites were used to calibrate and verify a rainfall-runoff model for the 13 basins (Appendixes C and D). A 65-year rainfall record for Trenton, New Jersey (Appendix E) and a long-term daily evaporation record provided by the Newark University Farm near Newark, Delaware was used as input to the model for synthesis of long-term peak-flow record at each site.

The long-term synthetic-flow record was used to compute flood-frequency curves for the 13 basins. The synthetically produced curves at the 13 basins were then compared to flood-frequency curves computed from the observed streamflow record at the sites. The comparisons were made to determine which of the two curves is more appropriate for a particular basin. Flood frequency determined for the 21 gaging sites was used in a multiple-regression analysis relating peak flows to basin characteristics. The analysis provided equations that can be used to estimate peak discharges for selected recurrence intervals for ungaged urban basins.

Description of Study Area

The study area is located in southeastern Pennsylvania, in and on the outskirts of the Philadelphia metropolitan area, covering parts of Bucks, Montgomery, Chester, Delaware, and Philadelphia Counties (fig. 1). Elevations range from about 40 ft (feet) above sea level in the Little Crum Creek basin to somewhat above 500 ft along the divides in the Pigeon Run and Darby Creek basins.

The study area spans two physiographic provinces--the Piedmont and Coastal Plain. The Piedmont is extensively dissected low plateau underlain by deeply weathered crystalline rocks such as schist, gneiss, and granite. The southeastern edge of the Piedmont province is denoted as the Fall Line. Here, the more resistant rocks of the Piedmont gave way to the unconsolidated Coastal Plain sediments. The Poquessing, Pennypack, Tacony, Cobbs, and Crum Creek basins all have some type of Coastal Plain deposits, because the basins are in a transition zone in the vicinity of the Fall Line. The Coastal Plain deposits are of two distinct types: the Pennsauken Formation consisting of deeply weathered gravels and sandy gravels; and the Bryn Mawr Formation, which is a high-level terrace deposit consisting of sand and gravel with some silt. The Pennsauken Formation occupies an eroded discontinuous band about 2 mi (miles) wide roughly parallel to and about 1 mi northwest of the Delaware River. The Bryn Mawr Formation is present as remnants in the headwaters of the Tacony, Rock, Cobbs, and Naylor Creek basins.

The climate of the area is somewhat modified from the typical continental type--characterized by cold winters and warm to hot summers--by the nearby Delaware Bay and the Atlantic Ocean, which moderate temperatures. Average annual precipitation ranges from about 42 in. (inches) along the Delaware River to about 44 in. in the western part of the area. Almost half of the average annual precipitation falls from May through September--much of it during thunderstorms. The study area is located in a storm corridor frequently visited by tropical disturbances that move northward along the eastern coast of the United States. Storm patterns of this type have been known to deposit moderate to heavy rainfall over the area, which may cause severe flooding. Average annual lake evaporation in the area is about 35 in., of which approximately 75 percent occurs from May through October (Kohler and others, 1959).

Acknowledgments

Invaluable technical assistance during much of the data collection analysis and modeling process was furnished by George R. Dempster, Jr., Hydrologist, U.S. Geological Survey. William S. Alley, U.S. Geological Survey, provided assistance in the final stages of modeling. Nicholas J. Verna, a Drexel University cooperative-education student in Civil Engineering, screened rainfall-runoff data and maintained and edited the data base.

Basin characteristics were determined by employees of the Philadelphia Water Department (PWD) under the direction of Dennis Blair. Data were collected at two rain gages by the PWD during the entire period of the project and at all but 3 of the other 17 rain gages for the first year of the project. All but three of the rain gages were installed by PWD personnel. Michael M. Pence, PWD, assisted in the initial stages of the regression analysis.

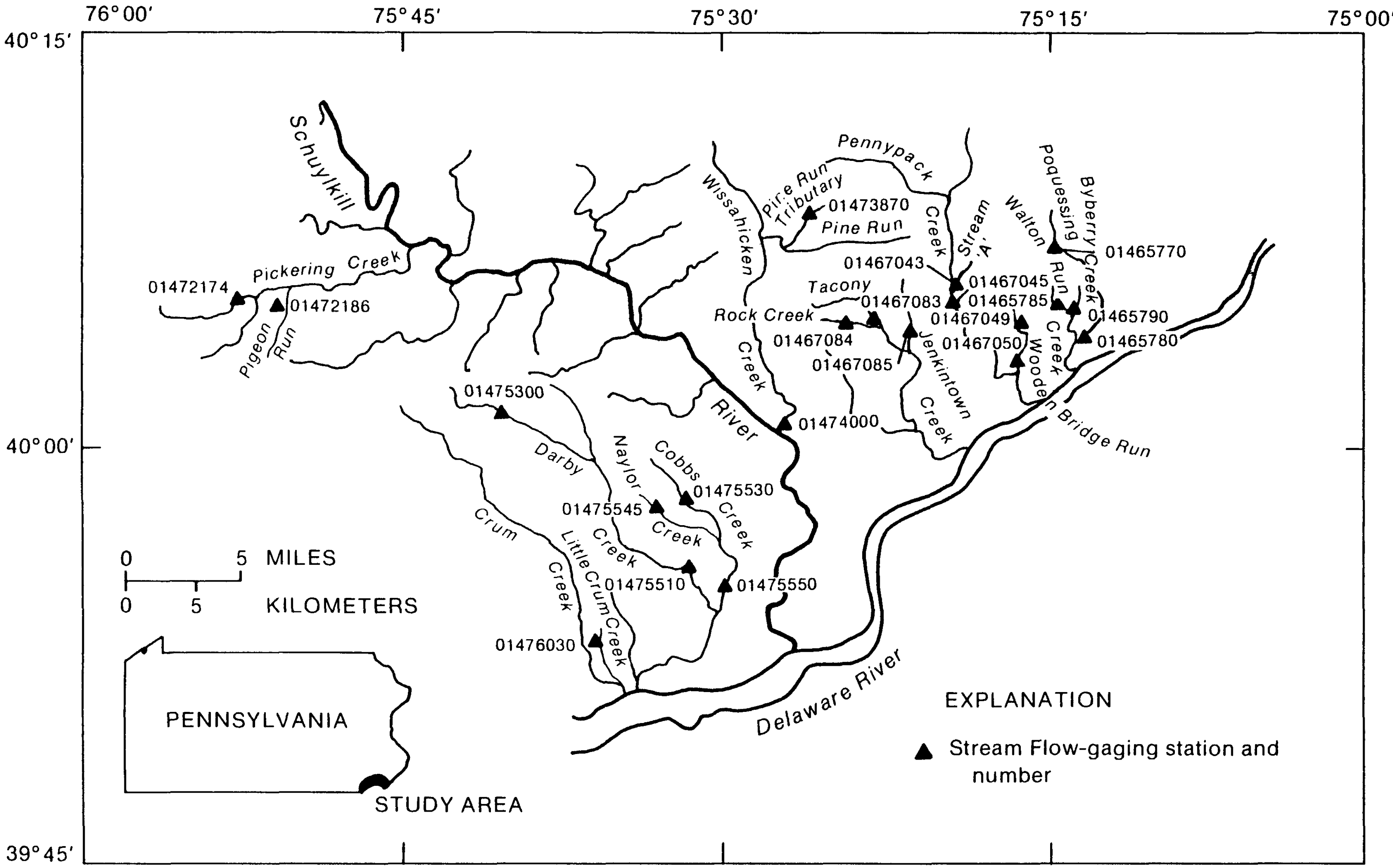


Figure 1.-- Study area showing location of stream flow-gaging stations.

DATA NETWORK AND BASIN CHARACTERISTICS

The data network consists of 21 gaging stations located in basins in and near the metropolitan Philadelphia area (fig. 1). The basins ranged from 1.1 to 64 mi^2 in size and contained different degrees and types of development. Continuous rainfall and runoff data were collected at 13 of the gaging stations. Data from the 13 stations represent the modeled basins (table 1). Each of these 13 basins was served by at least one rainfall gage and 4 basins had auxiliary gages, bringing the total number of rainfall gages operated to 17. Basin characteristics are defined in the Glossary and are shown in table 1 for the 21 gaged basins. Additional basin characteristic data on the modeled basins appear in the Appendixes F and G. The additional data include basin characteristics and impervious area determinations.

The basin characteristics ranged from those that are relatively easy to determine, such as drainage area, to those more difficult to determine, such as sewer inlet density and average permeability of the A horizon. Drainage-basin characteristics were determined from 1:4,800 aerial photographs made in 1970 and from topographic maps.

Land-use data were determined from aerial photographs made in 1970, to which basin outlines were transferred. Impervious area paved or covered by buildings and forested area were outlined and planimetered directly. The degree of development, as defined by the 1970 aerial photography, remained stable except for Poquessing and Byberry Creek basins. Impervious area for these two basins were redefined from aerial photography at a scale of 1:12,000 when an inspection of topographic maps of 1973 and 1979 revealed developments made after 1970. Imperviousness in the Poquessing Creek basin changed from 16.7 to 20.0 percent and, in the Byberry basin, from 24.2 to 29.7 percent.

Soil characteristics were determined by transferring basin outlines to soil maps contained in U.S. Department of Agriculture Soil Conservation Service soil-survey reports for Chester-Delaware (1963), Montgomery (1967) and Philadelphia-Bucks (1975) Counties. Soil types were planimetered and three characteristics were determined for all soils in each basin, except for those soils classified as made land--that is, land leveled, filled in, or otherwise disturbed by human activities.

Table 1.--Characteristics of gaged basins

Station number	Stream name	Station established	Years of record	Drainage area A	Slope S	Basin length BL	Elevation E	Forest F	$I_{24,2}$	Measured imperviousness MI
01465770	[1]Poquessing Creek at Trevose Rd., Phila., Pa.	1964	18	5.08	42.6	2.30	220	9	3.00	18.0
01465780	Poquessing Creek above Byberry Creek at Phila., Pa.	1965	16	13.2	18.4	8.57	150	7	2.95	20.0
01465785	Walton Run at Phila., Pa.	1964	14	2.17	48.3	2.79	150	11	3.00	24.0
01465790	[1]Byberry Creek at Chalfont Rd., Phila., Pa.	1965	13	5.34	33.1	4.07	130	8	3.00	29.7
01467043	Stream 'A'	1965	16	1.20	67.6	2.01	210	19	3.05	17.0
01467045	Pennypack Creek below Verree Rd., Phila., Pa.	1964	18	42.8	17.1	14.0	260	7	3.05	16.3
01467049	[1]Wooden Bridge Run at Grant Ave., Phila., Pa.	1973	5	1.06	58.5	1.49	130	1	2.95	32.5
01467050	Wooden Bridge Run at Phila., Pa.	1965	17	3.35	32.9	3.69	120	6	3.00	35.0
01467083	[1]Tacony Creek near Jenkintown, Pa.	1973	5	5.25	57.6	3.06	300	10	3.00	26.1
01467084	[1]Rock Creek above Curtis Arboretum near Phila., Pa.	1971	8	1.15	96.4	1.87	350	3	3.00	42.7
01467085	[1]Jenkintown Creek at Elkins Park, Pa.	1973	5	1.17	85.0	1.60	260	28	3.00	15.5
01472174	[1]Pickering Creek near Chester Springs, Pa.	1967	17	5.98	39.6	4.44	440	14	3.10	1.8
01472186	[1]Pigeon Run at Rapps Corner, Pa.	1974	5	1.06	218	1.76	490	39	3.20	2.4
01473870	[1]Pine Run tributary near Ambler, Pa.	1973	5	1.18	12.3	1.77	320	7	3.10	8.8
01474000	Wissahickon Creek at mouth, Phila., Pa.	1965	16	64.0	13.6	24.7	280	11	3.05	20.3
01475300	[1]Darby Creek at Waterloo Mills near Devon, Pa.	1972	10	5.15	40.0	3.91	430	26	3.10	10.4
01475510	Darby Creek near Darby, Pa.	1964	17	37.4	20.9	17.8	330	18	3.05	14.0
01475530	[1]Cobbs Creek at U.S. 1 at Phila., Pa.	1964	17	4.78	62.5	4.27	330	6	3.00	23.0
01475545	[1]Naylor Creek at West Chester Pike near Phila., Pa.	1972	7	1.10	76.2	1.91	390	1	3.00	31.4
01475550	Cobbs Creek at Darby, Pa.	1964	17	22.0	31.4	11.1	210	3	3.00	33.0
01476030	[1]Little Crum Creek at Michigan Ave., Swathmore, PA.	1971	9	1.15	66.7	1.60	150	33	3.05	16.4

[1]Modeled basin

ESTIMATION OF FLOOD-FREQUENCY CHARACTERISTICS AND THE EFFECTS OF URBANIZATION

Flood-Frequency Characteristics

Flood-frequency information often is desired for ungaged sites in urban areas. Therefore, available streamflow data must be interpreted and regional flood-frequency relations developed that are applicable to ungaged areas. Multiple-linear-regression analysis was used to define regional equations for selected recurrence intervals. The equations relate peak-flow characteristics to measurable basin characteristics.

Frequency Analysis

Observed flow data and synthetic flow data derived from rainfall-runoff modeling were available at the 21 stations for determination of flood frequency. Log-Pearson type III flood-frequency computations were made using a combination of observed record and synthetically derived flows at the 21 stations.

The log-Pearson type III method incorporates three statistical parameters and is of the form:

$$\log Q_T = M + KS \qquad (1)$$

where

Q_T = the peak discharge for a selected recurrence interval T,
M = the mean of the logarithms of the annual peaks,
K = a function of the coefficient of skew for the logarithms of the peaks and recurrence interval T, and
S = the standard deviation about the mean of the logarithms of the peaks.

Flood-frequency curves, computed using the synthetically derived peak discharges, were compared to flood-frequency curves computed using observed record at the 13 stations representing the modeled basins. This comparison revealed that 5 of the 13 stations have 10 or more years of record. More importantly, at two of the stations (01472174 and 01475530), the 100-year flood discharges, as estimated by the model, were exceeded at least once in the short observed records. At the other three stations, the 100-year-flood discharges were almost exceeded. Therefore, the observed record was assumed to be more representative of flood potential and was used to determine flood-frequency characteristics. The five stations are identified in table 2.

Flood-frequency curves at the eight other streamflow-gaging stations were determined using the synthetically derived peaks. Flood-frequency curves for eight gaging stations not in the modeled basins and five gaging stations in the modeled basins (noted in table 2) were determined from observed peaks. The annual peak series for the 13 stations using observed record were tested to make sure there was not a significant increase in the peaks due to urbanization as a function of time. Three different correlation coefficients--Pearson, Spearman rank order, and Kendall's Tau--were computed as a function of time. None of the 13 stations had a significant (at the 10-percent confidence level) upward trend in the annual peak data using the entire period of observed record. All frequency curves were computed using guidelines recommended in U.S. Water Resources Council (WRC) Bulletin 17B (1981). Flood-frequency characteristics used in the regression analysis are shown in table 2.

Table 2.--Flood-frequency characteristics used in regression analysis

Station number	Modeled	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}
01465770	Yes[1]	744	1,060	1,320	1,710	2,050	2,860
01465780	No	1,470	2,110	2,640	3,430	4,120	4,910
01465785	No	667	924	1,110	1,380	1,590	1,820
01465790	Yes[1]	812	1,160	1,420	1,790	2,110	2,450
01467043	No	280	471	622	843	1,030	1,230
01467045	No	2,770	3,990	4,910	6,220	7,300	8,470
01467049	Yes	582	881	1,100	1,400	1,630	1,880
01467050	No	880	1,310	1,660	2,150	2,570	3,030
01467083	Yes	2,260	3,470	4,370	5,610	6,600	7,660
01467084	Yes	684	936	1,110	1,330	1,500	1,680
01467085	Yes	207	339	454	638	807	1,010
01472174	Yes[1]	640	1,310	1,930	2,930	3,820	4,890
01472186	Yes	76	152	222	335	440	564
01473870	Yes	258	401	497	619	708	797
01474000	No	3,710	4,760	5,500	6,490	7,280	8,090
01475300	Yes[1]	609	1,050	1,430	2,020	2,550	3,160
01475510	No	3,070	4,470	5,470	6,820	7,890	9,000
01475530	Yes[1]	770	1,470	2,160	3,390	4,610	6,180
01475545	Yes	455	654	802	1,010	1,170	1,350
01475550	No	2,640	3,770	4,600	5,740	6,660	7,650
01476030	Yes	168	265	349	480	599	738

[1]Modeled station for which observed data were used to compute flood frequency.

Regression Analysis

Multiple-linear regression of the logarithms (base 10) of the variables was used to develop equations that relate basin characteristics to peak discharge (Q_T) for selected recurrence intervals T. The general form of a log-transform relation is

$$\log Q_T = \log a + b_1 \log X_1 + b_2 \log X_2 + \ldots + b_n \log X_n, \qquad (2)$$

where Q_T is the dependent variable (flood-frequency characteristic), X_1 to X_n are independent variables (basin characteristics), a is a regression constant, and b_1 to b_n are regression coefficients. An equivalent form of equation 2 used in this report is

$$Q_T = aX_1^{b_1} X_2^{b_2} \ldots X_n^{b_n} \qquad (3)$$

A computerized stepwise-regression program was used to relate the independent variables to the dependent variables. The basin characteristics shown in table 1 were used as independent variables, and the flood-frequency characteristics shown in table 2 were used as dependent variables with the regression constant, coefficients, standard error, and significance of each parameter calculated. The calculations were repeated omitting the least significant parameter until only the most significant parameters remained. All independent variables shown in an equation had regression coefficients significant at the 95-percent or better confidence level.

The best regression equations were those that related peak discharge to drainage area and measured imperviousness. Those equations gave the best estimates with a minimum number of independent variables. The equations found to give the best result at ungaged urban basins in the Philadelphia, Pennsylvania area are listed in table 3.

Table 3.--Summary of regression equations for peak discharges

Equation	Standard error (percent)	R^2	Standard error of prediction (percent)
$Q_2 = 74.9A^{0.65}MI^{0.48}$	38.3	0.88	48.9
$Q_5 = 166A^{0.62}MI^{0.36}$	39.3	.86	50.6
$Q_{10} = 255A^{0.60}MI^{0.30}$	40.0	.85	51.6
$Q_{25} = 406A^{0.59}MI^{0.24}$	41.2	.83	53.0
$Q_{50} = 548A^{0.58}MI^{0.21}$	42.2	.82	54.0
$Q_{100} = 724A^{0.58}MI^{0.18}$	43.4	.80	55.2

Accuracy and Limitations

Three indices of accuracy were computed and are shown for equations in table 3; the indices are standard error of estimate (SE), R^2, and the standard error of prediction (SEP). The standard error of estimate is a measure of how well the estimated values agree with the observed values for the stations used in the analysis. Approximately two out of three observed values will fall within one standard error of estimate of the computed values if the residuals are normally distributed. If the R^2 value is multiplied by 100, it defines the percentage of variation in the dependent variable that is explained by the independent variables. The SEP was computed using the PRESS statistic and is a measure of the predictive accuracy of the equations. The PRESS statistic is the prediction error sum of squares and is computed as follows. The regression equations are computed n times (number of stations), first using all the stations except station 1, then all stations except station 2, etc. The n residuals that result are all without that particular station in the computed analysis. Therefore, the residuals are indicative of a prediction at an ungaged site. The sum of squares of these residuals is the PRESS statistic. The SEP is approximated by dividing the PRESS statistic by n and taking the square root.

The equations can be used to compute the magnitude and frequency of floods in the Philadelphia area for drainage basins ranging in size from 1.1 to 64 mi^2, with impervious cover ranging from 1.8 to 42.7 percent. The equations are not applicable where flood flows are appreciably effected by natural or reservoir storage.

Illustrative Examples

<u>Sites on ungaged streams</u>

The following example illustrates how to estimate flood discharges for sites on ungaged streams.

Example (Hypothetical): Assume that 10-year and 100-year flood estimates are desired for a site on Frankfort Creek where the drainage area has been determined to be 15 mi^2 and measured imperviousness was determined to be 10 percent. Compute peak discharges using equations found in table 3.

$$Q_{10} = 255A^{0.60}MI^{0.30}$$

$$= 255(15)^{0.60}(10)^{0.30}$$

$$= 2{,}580 \text{ ft}^3\text{/s}$$

$$Q_{100} = 724A^{0.58}MI^{0.18}$$

$$= 724(15)^{0.58}(10)^{0.18}$$

$$= 5{,}270 \text{ ft}^3\text{/s}$$

Sites on gaged streams

For peak discharges for sites at a gaging station or on the same stream where the drainage area is within 5 percent of the drainage area at the gaging station, use the gaging station flood-frequency data shown in table 2.

If the drainage area for the site is 5 percent larger or smaller than the drainage area at the gage and is within ½ to 2 times that of the gaging-station area, peak discharges may be determined by computing a site-correction factor (Ks) and multiplying it by the site peak discharge computed by the regression equation. Regression equations should be used if site drainage area is less than one-half or more than twice the gaging-station drainage area. Site-correction factors (Hannum, 1976) are computed as follows:

For a site downstream from gage,

$$Ks = (Kg-1)\ (2-As/Ag) + 1$$

For a site upstream from gage,

$$Ks = (Kg-1)\ (2As/Ag-1) + 1$$

where Ks = ratio of flood frequency magnitude for the site to regression value for the site,

Kg = ratio of flood magnitude based on gage records to the corresponding regression value for the gage,

Ag = drainage area for gage, and

As = drainage area for site.

Example (Hypothetical): Assume the 100-year-flood estimate is desired at an ungaged site on Pennypack Creek upstream from the gaging station at Veree Road (01467045). The drainage area at the site has been determined to be 30 mi^2 and the measured imperviousness is 20 percent. Compute peak discharge using equation found in table 3.

$$Q_{100} = 724A^{0.58}MI^{0.18}$$

$$= 724\ (30)^{0.58}\ (20)^{0.18}$$

$$= 9{,}330\ ft^3/s$$

From table 2 the 100-year discharge at the Pennypack Creek gage (01467045) is given as 8,470 ft^3/s. The drainage area at the gage is 42.8 mi^2 and the measured imperviousness is 16.3 percent.

From table 3: $Q_{100} = 724\ A^{0.58}\ MI^{0.18}$

$$Q_{100} = 724\ (42.8)^{0.58}\ (16.3)^{0.18}$$

$$= 10{,}600\ ft^3/s$$

Ks for a site upstream from gage:

$$Ks = (Kg\text{-}1)\ (2As/Ag\text{-}1) + 1$$

$$= \left(\frac{8{,}470}{10{,}600} - 1\right)\left(2\ \frac{(30)}{42.8} - 1\right) + 1$$

$$= (0.80 - 1)\ (1.40 - 1) + 1$$

$$= 0.92$$

Final Q_{100} at site = 0.92 (9,330) = 8,580 ft^3/s

Effects of Urbanization

Frequently occurring floods are affected more by increased urbanization than are rare floods. An inspection of the equations in table 3 shows that the 2-year flood (Q_2) could be increased up to a maximum of about 4.4 times if development, as measured by imperviousness, were to increase from 2 to 43 percent. The 100-year flood (Q_{100}) would be increased up to a maximum of about 1.7 times for the same change in imperviousness. The approximate increase in peak discharge for selected recurrence intervals resulting from an increase in measured imperviousness is shown in table 4.

Table 4.--Ratio of discharge at selected percentages of measured imperviousness to discharge for 2 percent measured imperviousness for selected flood frequencies

Flood frequency (years)	Measured imperviousness (percent)			
	2	10	20	43
2	1	2.2	3.0	4.4
5	1	1.8	2.3	3.0
10	1	1.6	2.0	2.5
25	1	1.5	1.7	2.1
50	1	1.4	1.6	1.9
100	1	1.3	1.5	1.7

SUMMARY AND CONCLUSIONS

Urbanization results in replacement of the infiltration characteristics of native soils by the infiltration characteristics of concrete, blacktop, and other building materials that are generally characterized as impervious. This replacement reduces infiltration to the soil and increases rainfall available for runoff. Building storm sewers to carry runoff to existing stream channels and connecting impervious surfaces to each other or directly connecting them to storm sewers decreases the time between occurrence or rainfall excess and runoff. This reduction in time lag, accompanied by increased volume of runoff, are important effects of urbanization that result in higher peak discharges. The effects of urbanization on peak discharge are greatest for high-exceedance probabilities (frequent events), decreasing as exceedance probability decreases.

Flood frequency and basin characteristics were determined for 21 gaging sites in the Philadelphia area. Flood frequencies at 13 of the sites were computed by using observed record and at 8 sites by using synthetic data. Flood-frequency equations were developed from a multiple-regression analysis that related discharge to basin characteristics. The analysis indicates that peak flows could best be related to drainage size and measured imperviousness. The equations developed can be used to estimate peak flows for sites with drainage areas from 1.1 to 64 mi^2 having 1.8 to 42.7 percent impervious cover. Standard errors of estimate for the regression equations ranged from 38.3 to 43.4 percent. The equations indicate that the magnitude of frequently occurring floods can be increased by as much as 4.4 times, whereas the magnitude of rarely occurring floods will increase by 1.7 times.

REFERENCES CITED

Clark, C. O., 1945, Storage and the unit hydrograph: American Society of Civil Engineers Transactions, v. 110, p. 1419-1488.

Dawdy, D. R., Lichty, R. W., and Bergman, J. M., 1972, A rainfall-runoff simulation model for estimation of flood peaks for small drainage basins: U.S. Geological Survey Professional Paper 506-B, 28 p.

Hannum, C. H., 1976, Technique for estimating magnitude and frequency of floods in Kentucky: U.S. Geological Survey Water-Resources Investigations Report 76-62, 70 p.

Kirby, W. H., 1975, Model smoothing effect diminishes simulated flood peak variance, Abstract, EOS, Transactions of AGU, vol. 56, no. 6, p. 361.

Kohler, M. A., Nordenson, T. J., and Baker, D. R., 1959, Evaporation maps for the United States: U.S. Department of Commerce Weather Bureau Technical Paper No. 37, 13 p.

Mockus, Victor, 1969, Hydrologic soil groups (chapter 7): in SCS National Engineering Handbook, Section 4, Hydrology, Part I--Watershed planning.

Phillip, J. R., 1954, An infiltration equation with physical significance: Soil Science Society American Proceedings, v. 77, p. 153-157.

U.S. Soil Conservation Service, 1963, Soil survey Chester and Delaware Counties, Pennsylvania: U.S. Department of Agriculture Series 1959, No. 19, 124 p.

-----1967, Soil survey Montgomery County, Pennsylvania: U.S. Department of Agriculture, 187 p.

-----1975, Soil survey of Bucks and Philadelphia Counties, Pennsylvania: U.S. Department of Agriculture, 130 p.

U.S. Water Resources Council, 1981, A uniform technique for determining flood-flow frequency: Washington, D.C., Bulletin 17B of the Hydrology Committee, 161 p.

GLOSSARY

All drainage channels (ADC)--The sum, in miles, of the length of sewered streets (SS) and natural stream channels (NSC) within a basin.

Average available water capacity--Inches of water per inch of soil, determined by subtracting the moisture content at the wilting point from the moisture content at field capacity from data given for capacity and thickness weighted by the measured area for each soil type.

Average channel slope (SAL)--The average slope, in feet per mile, of the main channel, as determined by averaging the slopes determined at distances of 20, 40, 60, and 80 percent of the distance from the stream-gaging station to the end of the channel.

Average permeability--Infiltration capacity, in inches per hour, calculated for each soil type from data on thickness and permeability weighted by the measured area for each soil type.

Average permeability of the A horizon--Infiltration capacity, in inches per hour, calculated in the same manner as average permeability but for the A horizon of the soil only.

Basin length (BL)--The straight-line distance, in miles, from the stream-gaging station to the most distant point on the basin divide.

Basin slope (BS)--In feet per mile, was determined by preparing an overlay on which the stream system, the outline of the basin, and the natural runoff divides between tributaries were traced from U.S. Geological Survey 7½-minute topographic maps. The traced basin was then divided by 20 concentric arcs of constant change in radius equal to 0.05BL. Within each subbasin formed by the natural runoff divides within the basin, the point of highest elevation on each arc that crosses the stream was noted (one on each side of the stream), and the distance along the arc from this point to the stream was determined. When two or more points qualified as the point of highest elevation, the point nearest to the stream was used. The elevation of the stream channel where each arc crossed was determined from the stream profile. Two slope values per arc intersecting the stream were determined for each subbasin. In the area where the stream no longer crossed the arcs, one slope value was determined by finding the point of highest elevation within the upper part of the basin between the divides for that stream, then calculating the slope to the stream origin using the straight-line distance between the two points. Basin slope is the average of all of the slope values within the basin as determined in this manner.

Capillary potential (PSP)--An infiltration component of soils at field moisture capacity equal to the product of the moisture deficit and suction at the wetted front, in inches.

Cubic feet per second (ft^3/s)--The rate of discharge, one cubic foot per second is equal to the discharge of a stream of rectangular cross section 1 foot wide and 1 foot deep flowing at an average velocity of 1 foot per second.

Detention storage--Storage of storm runoff from roofs, parking lots, and other impervious surfaces especially designed to reduce peak flows. Detention-storage areas normally have constricted outlets so that water will flood designated areas and flow out slowly, thereby reducing the flood peak.

Discharge (Q_T)--The peak discharge, in cubic feet per second, for an event of recurrence interval T.

Drainage area (A)--Area of the basin, in square miles, planimetered from basin outlines drawn on U.S. Geological Survey 7½-minute topographic maps. Basin boundaries were adjusted for manmade modifications.

Drainage coefficient (DRN)--Antecedent moisture accounting component, in inches per hour, providing a constant drainage rate for redistribution of soil moisture.

Effective imperviousness (EI)--The percentage of total drainage area that has a direct hydraulic link to the stream and is impervious to the infiltration of rain.

Elevation (E)--Average basin elevation, in feet above sea level, computed by averaging the elevations at the 10- and 85-percent distance points along the channel, as determined from topographic maps.

Evaporation coefficient (EVC)--An antecedent-moisture-accounting component used to convert pan evaporation to potential evapotranspiration values.

Exceedance probability--Probability that a random event will exceed a specific magnitude in a given time period. For example, a flood with a 0.01 exceedance probability is a flood that has one chance in one hundred of being exceeded in any given year. This is a "100-year flood" in recurrence-interval terminology. Exceedance probability is used without the decimal point for the sake of brevity and can be read as percent chance (.01=1, .02=2, ..., .99=99).

Forest cover (F)--The percentage of the total drainage area occupied by forest cover, as determined from topographic maps.

F statistic--A test that defines the significance of the independent variables. The larger the F value, the more significant is the regression coefficient in the equation. Unless otherwise shown, all F statistics fall within the 95-percent-confidence limit.

Hydraulic conductivity of transmission zone (KSAT)--An infiltration component, in inches per hour, equal to the minimum (saturated) hydraulic conductivity used to determine infiltration rates.

Lagtime (T)--The sum, in time, of the routing components for linear reservoir routing (KSW) and one half the length of the base of the triangular translation hydrograph (TC).

Longest channel length (LCL)--The length, in miles, of the longest channel in the basin measured from U.S. Geological Survey 7½-minute topographic maps.

Main channel length (MCL)--The length, in miles, of that channel that makes the least angle to the stream at the confluence of two branches; it is measured from U.S. Geological Survey 7½-minute topographic maps.

Measured imperviousness (MI)--The percentage of the total area that is impervious to the infiltration of rain. It is measured directly by planimetering impervious areas outlined on aerial photography.

Natural stream channels (NSC)--The total length, in miles, of continuously flowing (solid blue lines) and intermittent (dash-dot blue lines) streams in a basin, as shown on U.S. Geological Survey 7½-minute topographic maps.

Precipitation index ($^{I}24,2$)--The maximum 24-hour rainfall, in inches, having a recurrence interval of 2 years, as determined from U.S. Weather Bureau Technical Paper 40 (1961).

Rainfall ration (RR)--The proportion of daily rainfall that infiltrates the soil.

Ratio (RGF)--An infiltration component, equal to the ratio of the product of moisture deficit and suction at the wetted front for soil moisture at wilting point to that at field capacity.

R-square--The coefficient of determination. It is a measure of the variation explained by the regression equation. The R-square multiplied by 100 defines the percentage of variation explained by the independent variables.

Sewer inlet density (SID)--The equivalent inlet per square mile, using weighting factors, for the following types of inlets, curb, grate, and open-mouth grate inlets in a sump; grate and open-mouth inlet on a slope.

Sewered streets (SS)--The total length, in miles, of sewered streets measured on aerial photographs. Sewered streets were defined as all streets that could channel water to storm-sewer inlets. This includes curb or guttered streets that slope to inletted streets, as well as those that actually have inlets along their length. This characteristic was determined by driving along every street in the basin and noting streets that could be considered sewered.

Slope (S)--The slope, in feet per mile, is the slope of the stream between points that are 10 and 85 percent of the distance along the channel from the gaging station to the basin divide, determined from topographic maps.

Soil moisture volume (BMS)--An infiltration component, in inches, equal to the soil moisture storage volume at field capacity.

Standard error of estimate (SE)--A statistical measure of accuracy based on population scatter about the curve only. It is the square root of the variance and is graphically defined as having two-thirds of the data points falling within its limits.

Standard error of prediction (SEP)--A statistical measure of the predictive accuracy of the equations.

Stream magnitude (SM)--Calculated by designating all channels without tributaries on a U.S. Geological Survey 7½-minute topographic map as magnitude 1; thereafter, whenever two channels come together, the channel downstream from the confluence is of a magnitude equal to sum of the tributary magnitudes.

Time characteristic (KSW)--A routing component, in hours, equal to the time characteristic for linear reservoir routing.

Time characteristic (TC)--A routing component, in minutes, equal to the length of the base of the triangular translation hydrograph.

Total outfall area (TOA)--The total area, in square feet, of all storm-sewer outfalls into basin streams. TOA was determined in the field for basins where maps of sewer systems were not available.

APPENDIX A

RAINFALL-RUNOFF SIMULATION MODELING

A major use of digital rainfall-runoff simulation modeling is to extend streamflow record in time. Simulation modeling was a particularly attractive alternative to long-term stream gaging in the Philadelphia area, because information on peak flows for streams less than 6 mi^2 in drainage area for a range of urbanized conditions were lacking. The simulation modeling described herein employs digital-computer solutions of mathematical relations to approximate the hydrological process of infiltration, soil-moisture storage, and surface-runoff routing.

Purpose

The purpose of rainfall-runoff simulation modeling was to synthesize peak flow record at 13 gaging stations where observed record varied in length from 1-18 years. The synthetically derived peak flows were used to compute flood-frequency curves at the gaging sites. The curves covered a range of recurrence intervals from 2 to 100 years.

Description

The digital rainfall-runoff model developed by Dawdy and others (1972) and used in this study is a simplified conceptualization of watershed response to storm rainfall. The three components of the model simulate antecedent soil moisture, storm infiltration, and surface-runoff routing. Figure A1 shows the general sequence of computations and shows that the output from one component is the input to the next. The most complex component of the model deals with infiltration; the surface-runoff component is the least complex.

Antecedent soil-moisture accounting, which measures the effects of antecedent conditions on the infiltration component, is done on a daily basis up to the onset of a storm day. The infiltration component (Philip, 1954) computes infiltration rates as a function of soil moisture and rainfall intensity. The surface-runoff component transforms the rainfall excess (the difference between rainfall rate and infiltration rate) into a flood hydrograph by translation and linear storage attenuation (Clark, 1954) using distance-area histograms. The modeling process is described as a variable optimization scheme, but the goodness of fit of the optimized variables is evaluated on the basis of minimizing the error of the simulated volumes and peaks.

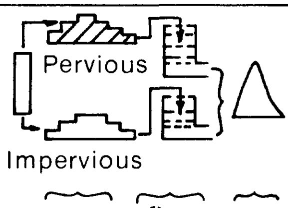
The values of selected model variables are determined by an optimization technique (Dawdy and others, 1972) in which the variables are constrained within preselected limits. Ranges for KSAT, PSP, RGF, and BMSM for each basin were based on guidelines suggested by Alley (written commun., 1980). Ranges for both KSAT and PSP can be estimated from U.S. Soil Conservation Service Hydrologic Soil Group classifications (A, B, C, D). Soils were determined from county reports and the Hydrologic Soil Groups abstracted from Mockus (1969). Values of KSAT range from 1.2 to 0.05 in./hr (inches per hour) for Hydrologic Soil Groups A to D. Corresponding values for PSP range from 0.5 to 4.0 in. Model estimates of infiltration are very sensitive to PSP. Although the relationship of RGF to soil properties is not well established, values of RGF should generally range

ANTECEDENT-MOISTURE ACCOUNTING COMPONENT	INFILTRATION COMPONENT	ROUTING COMPONENT

INPUT DATA

Daily rainfall Daily pan evaporation	Unit rainfall BMS SMS (from moisture accounting component)	Rainfall excesses (from pervious area infiltration and impervious area retention component)

COMPUTATIONAL OPERATION AND OPTIMIZED VARIABLES

Saturated-unsaturated soil moisture levels for pervious area	Average pervious area infiltration and impervious area retention	Instantaneous hydrographs from pervious and impervious areas
Non-optimized variable DRN Model-optimized variable BMSM Trial and error optimized variable EVC RR	Variables BMS SMS Model-optimized variable PSP KSAT RGF Trial and error optimized variable I	 Rainfall excesses Lag by distance (time)-area histograms Attenuation by proportionate linear-storage routing Flood hydrograph TC KSW

OUTPUT DATA

Variables BMS-Base-moisture storage available SMS-Surface-moisture content from infiltration	Rainfall excess (volume of runoff)	Peak discharge and plotted hydrographs of observed and simulated flows

Figure A1.-- Schematic diagram of the rainfall-runoff simulation model (adapted from Dempster, 1974).

from 5 to 20. The sensitivity of infiltration estimates to antecedent soil moisture conditions increases as RGF increases. Values for BMSM were constrained between 2.0 and 6.0 in. BMSM will generally increase with increasing development of the soil to the depth of the root zone.

The remaining variables--DRN, EVC, and RR--were held at constant values. DRN effects the redistribution of soil moisture and was set equal to one. EVC was held constant at 0.75, a value determined from Kohler and others (1959). The value of RR was varied from 0.70 to 0.90 for each basin to find the optimal value and held constant for model calibrations used to optimize the remaining model variables. The optimal value of RR was that which minimized the error of estimate for runoff volumes.

The routing component of the model uses pervious-impervious area distribution in each basin. This distribution is calculated by outlining pervious and impervious areas on a map of the basin and dividing the basin into 20 subareas by measuring basin length (BL) then drawing concentric arcs across the basin at increments of 0.05 BL with the gage site as the center point. The model uses the cumulative pervious and impervious areas (beginning at the basin outlet) to define travel time (TC and KSW) from this distance-area histogram on the assumption that travel time is proportional to distance.

Impervious area should have a direct hydraulic link to a stream channel to be totally effective but directly connected impervious area is difficult to quantify. The measured imperviousness for each basin was varied in model calibration in small decrements to determine the effective imperviousness, which should approximate directly connected imperviousness. Effective imperviousness was taken as the imperviousness that minimized the error of estimate for runoff volumes. Effective imperviousness was determined for all basins except those of Pickering Creek and Pigeon Run. The measured imperviousness for these two basins was so small that using values other than the measured value did not change runoff volumes.

The values of imperviousness and RR affect runoff volumes. RR affects antecedent soil-moisture conditions, and thus SMS and BMS, when the model computes infiltration during a storm. Impervious-area runoff is computed only during storms and determines the volume of precipitation available for immediate runoff after subtraction of impervious retention, which was held constant at 0.05 in. in this study.

Calibration and Verification

Rainfall-runoff data were screened as they were processed to eliminate those events for which runoff was greater than rainfall and those events for which runoff was less than about 10 percent of rainfall. The screening limited events in the data base to those that were hydrologically feasible. About one-third of all events were eliminated. The remaining data were included in either the calibration or verification data sets, but those storms for which simulated volumes or peaks were significantly different than observed volumes or peaks were not used to optimize the model variables.

The data for each basin were split as evenly as possible into calibration and verification sets with each set spanning the entire period of data collection. Constraining values for parameters were adopted. Final parameter values were within 25 percent of the limiting value, except KSAT values for Wooden Bridge Run, Pickering Creek, and Pine Run Tributary basins. The anomalous values of KSAT are not readily explainable, but they are the values that best fit synthesized data to observed data.

Verification of the model for each basin consisted of running the model, with no optimization of parameter values, using the other half of the data for the period of record. Data collected on Pigeon Run and Pine Run Tributary were insufficient to verify the digital model although simulated volumes and peaks appear reasonable if the data are compared to that computed for other basins. A summary of the modeling results is shown in table 3, whereas figures A2 and A3 show plots of the relation of simulated to observed peak discharges for both calibration and verification storms for basins with drainage areas near 1 and 5 mi^2. The plots show that the methodology used to produce the synthesized record was not biased.

The use of the full span of data from 1974-78 to calibrate and verify the rainfall-runoff model ensured that the full range of rainfall and soil moisture conditions occuring during the study would be adequately represented in both sets of data. Both sets, therefore, depend on the same daily soil-moisture accounting, but there was no other way to encompass the full range of conditions occurring during the short data collection period.

Synthesis of Flood Data and Frequency Analysis

The rainfall-runoff model was used to synthesize flood peaks resulting from storm rainfall and antecedent moisture conditions. Input to the synthesis model was rainfall and evaporation record and the optimized variables and distance-area histograms from the rainfall-runoff simulation model. Long-term rainfall and daily evaporation record are required to generate a long series of flood peaks. Daily precipitation are required for nonstorm periods, and unit data (intervals of 5 minutes) are required for storm periods. The 65-year rainfall record for Trenton, New Jersey was used as input. Daily and unit precipitation data for the Trenton station were obtained from the U.S. Weather Service. Unit precipitation data were obtained only for those periods likely to produce the annual peak for a given year. The 65-year rainfall record at Trenton was considered to be typical of the Philadelphia area. The long-term daily evaporation record from the Newark University Farm near Newark, Delaware was used in the synthesis. Output of the synthesis model was runoff volume and peak discharge for each storm.

A log-Pearson Type III flood frequency analysis, as described earlier, was made of the annual series of synthesized peak discharges. Bias in the synthetically determined flood frequency caused by the calibration regression effect (a loss of variance) (Kirby, 1975) was corrected by dividing the standard deviation (S in equation 1) by the correlation coefficient determined in calibrating the simulation model (table A1). Peak discharges for selected flood frequencies computed using synthetic record are shown in table A2 for the 13 basins modeled.

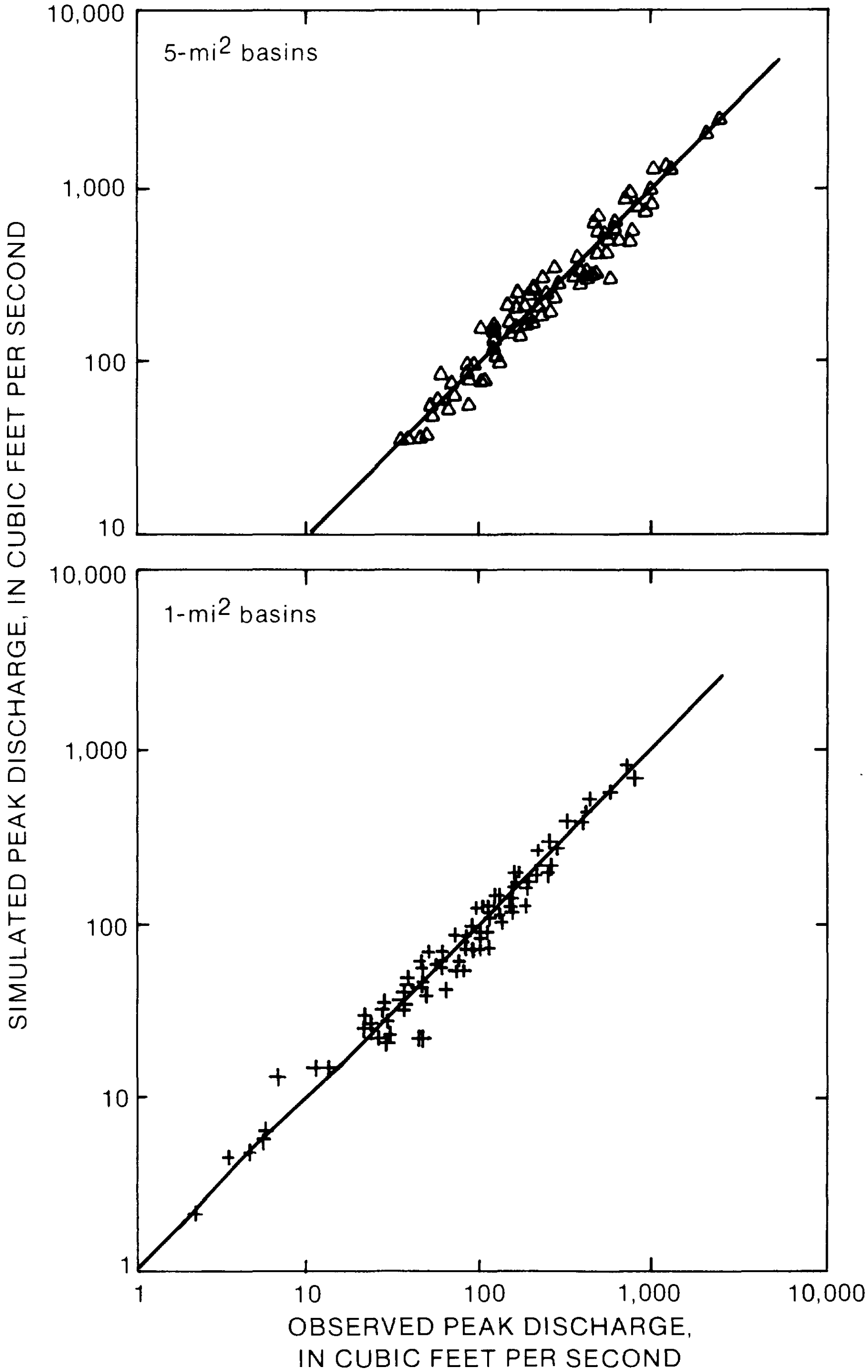


Figure A2.-- Relation of simulated to observed peak discharge for storms used in calibration.

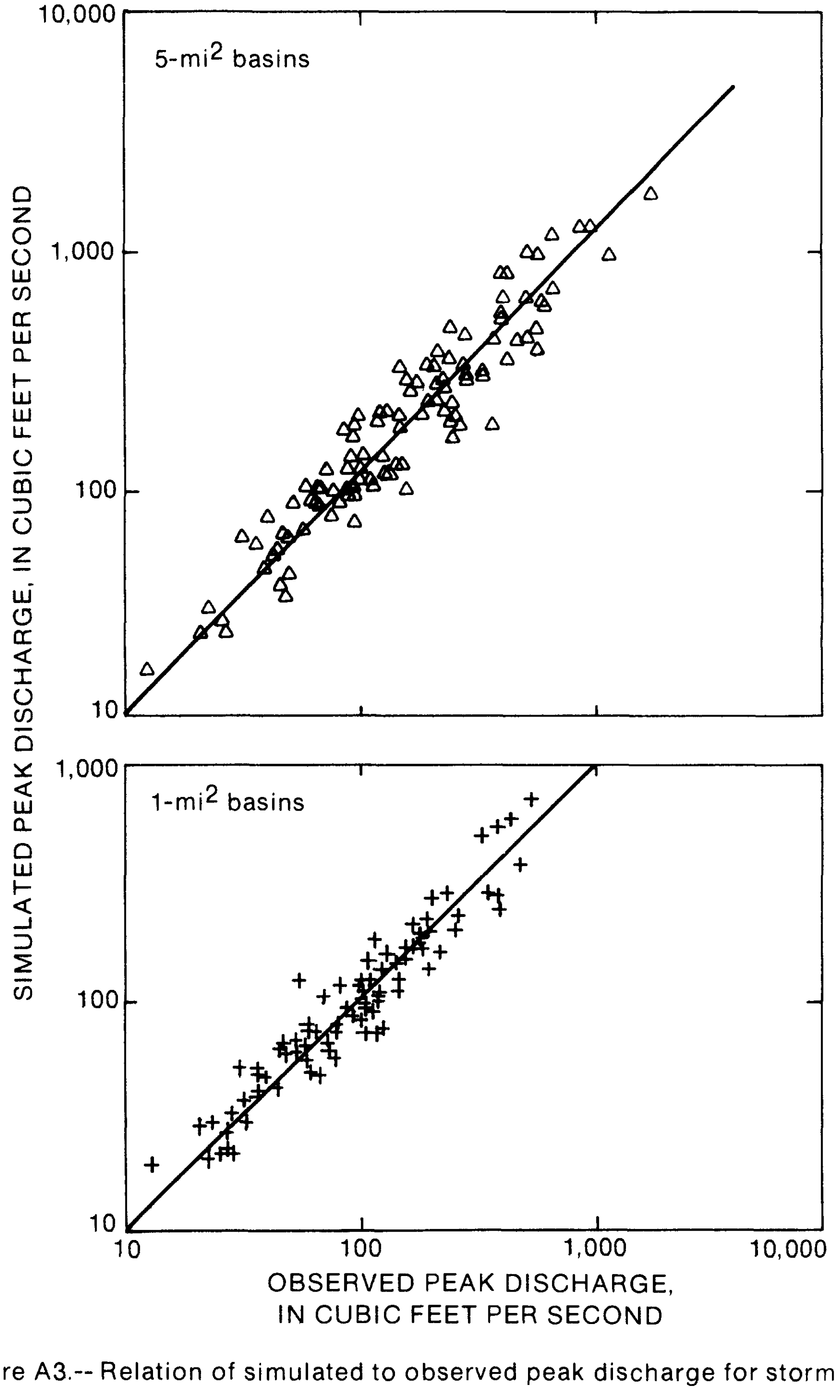


Figure A3.-- Relation of simulated to observed peak discharge for storms used in verification.

Table A1.--Results of simulation model calibration and verification

[PSP, Capillary potential;
KSAT, Hydraulic conductivity of transmission zone;
RGF, Ratio;
BMS, Soil moisture volume;
TC, Time characteristic;
KSW, Time Characteristic;

Lag time is computed as one-half TC (in hours) plus KSW]

		Optimized Variables								Statistics									
		Soil moisture				Timing				Calibration					Verification				
Station number	Drainage area (mi^2)	PSP (in.)	KSAT (in./hr)	RGF	BMS (in.)	TC (min)	KSW (h)	Lag time (h)	Effective impervious area (percent)	Number of events	R^2	Slope of regression line	Standard error of estimate (percent) Volume	Standard error of estimate (percent) Peak	Number of Events	R^2	Slope of regression line	Standard error of estimate (percent) Volume	Standard error of estimate (percent) Peak
01465770	5.08	3.11	0.372	7.08	5.87	134.0	0.760	1.88	17.7	13	0.974	0.956	20.1	17.3	14	0.822	0.900	36.2	38.1
01465790	5.34	2.10	.406	19.3	3.79	107.	1.22	2.11	23.7	16	.981	.964	18.3	13.6	17	.935	.933	29.0	24.4
01467049	.908	1.17	.288	7.47	2.73	31.2	.201	.461	25.2	16	.990	.994	22.7	11.2	19	.957	.976	23.4	27.6
01467083	5.25	1.04	.407	5.13	3.91	71.7	.209	.807	20.5	23	.972	1.034	25.4	24.1	21	.971	.957	27.1	26.6
01467084	1.15	2.82	.593	19.0	2.51	28.2	.032	.267	32.1	20	.978	.969	16.0	14.5	19	.955	.897	22.2	18.6
01467085	1.17	2.68	.532	20.0	3.57	18.6	.550	.705	10.5	18	.962	1.003	30.0	19.7	19	.956	.964	32.9	23.8
01472174*	5.98	.835	.075	8.28	4.43	397.	2.54	5.85	†1.77	12	.963	.971	23.8	24.5	21*	.973	.936	64.6	30.1
01472186	1.06	1.07	.423	18.6	4.48	51.0	2.43	2.86	†2.39	13	.946	1.015	44.8	35.4	a	--	--	--	--
01473870	1.18	1.07	.150	13.3	3.01	146.	.319	1.54	5.96	13	.972	.983	26.2	23.7	a	--	--	--	--
01475300	5.15	1.33	.433	10.7	2.45	122.	1.58	2.59	7.91	14	.987	.993	23.2	14.8	26*	.900	.946	33.6	36.0
01475530*	4.78	1.94	.387	16.7	2.06	106.	.827	1.71	15.6	18	.976	.979	25.1	20.5	19	.968	1.023	34.5	24.5
01475545	1.10	2.19	.648	17.7	2.36	35.1	.148	.440	25.2	14	.943	.949	17.2	21.8	22	.936	.916	32.0	27.5
01476030	1.15	2.92	.650	18.0	3.76	13.2	.916	1.03	11.2	20	.960	1.016	22.4	18.0	18	.937	1.014	23.2	20.7

† Measured impervious area

* Single rain gage verification

a Insufficient data for verification

Table A2.--Peak discharges for selected flood frequencies computed using synthetic record

Station number	Flood frequency (years) Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}
01465770	765	1,150	1,440	1,850	2,180	2,530
01465790	725	1,030	1,260	1,570	1,820	2,090
01467049	582	881	1,100	1,400	1,630	1,880
01467083	2,260	3,470	4,370	5,610	6,600	7,660
01467084	684	936	1,110	1,330	1,500	1,680
01467085	207	339	454	638	807	1,010
01472174	723	1,090	1,350	1,670	1,920	2,160
01472186	76	152	222	335	440	564
01473870	258	401	497	619	708	797
01475300	529	904	1,200	1,640	2,020	2,430
01475530	589	913	1,170	1,560	1,980	2,050
01475545	455	654	802	1,010	1,170	1,350
01476030	168	265	349	480	599	738

Appendix B.--Station descriptions for streamflow-gaging stations in the modeled basins and corresponding rainfall stations with period-of-record rainfall intensity data for rainfall stations

POQUESSING CREEK BASIN

01465770 POQUESSING CREEK AT TREVOSE ROAD, PHILADELPHIA, PA

LOCATION.--Lat 40°07'55", long 74°59'40", Bucks County, Hydrologic Unit 02040202, on right bank 30 ft (9 m) downstream from Trevose Road Bridge, 1 mi (1.6 km) southwest of Trevose.

DRAINAGE AREA.--5.08 mi^2 (13.2 km^2).

PERIOD OF RECORD.--July 1964 to September 1981 (discontinued).

GAGE.--Water-stage recorder and concrete control. Altitude of gage is 120 ft (37 m), from topographic map.

400817075021366 PINE ROAD SCHOOL RAIN GAGE

LOCATION.--Lat 40°08'17", long 75°02'13", Montgomery County, on Pine Road School.

PERIOD OF RECORD.--July 1975 to September 1978 (discontinued).

GAGE.--Tipping bucket (.01 in.). Altitude of gage is 270 ft (82 m), from topographic map.

400904075001165 TREVOSE FIRE COMPANY RAIN GAGE

LOCATION.--Lat 40°09'04", long 75°00'11", Bucks County, on Trevose Fire Company.

PERIOD OF RECORD.--June 1975 to September 1978 (discontinued).

GAGE.--Tiping bucket (.01 in.). Altitude of gage is 250 ft (76 m), from topographic map.

Annual maximum precipitation, in inches, for time interval indicated and date on which it occurred

Water year	Rain gage	5 min	15 min	30 min	60 min	120 min	180 min
1975	Pine Rd.	0.31 (7/14)	0.92 (7/14)	1.38 (7/14)	1.66 (7/14)	1.91 (7/14)	2.26 (7/14)
	Trevose	.28 (7/14)	.85 (7/14)	1.38 (7/20)	1.67 (7/20)	2.10 (7/20)	2.48 (7/20)
1976	Pine Rd.	.14 (8/8)	.42 (8/8)	.60 (8/8)	.64(11/12)	.83(11/12)	1.10(11/12)
	Trevose	.08(11/12)	.25(11/12)	.48(11/12)	.73(11/12)	1.04(11/12)	1.36(11/12)
1977	Pine Rd.	.19 (7/12)	.57 (7/12)	.96 (7/12)	1.44 (7/12)	1.54 (7/12)	1.54 (7/12)
	Trevose	.23 (9/6)	.70 (9/6)	1.21 (9/6)	1.49 (8/1)	1.94 (8/1)	2.00 (8/1)
1978	Pine Rd.	.19 (8/28)	.58 (8/28)	1.02 (8/28)	1.71 (8/28)	1.98 (8/28)	2.34 (8/28)
	Trevose	.18 (6/27)	.55 (6/27)	.69 (6/26)	.89 (8/28)	1.40 (7/3)	1.87 (7/3)

Appendix B.--Station descriptions for streamflow-gaging stations in the modeled basins and corresponding rainfall stations with period-of-record rainfall intensity data for rainfall stations--Continued

POQUESSING CREEK BASIN

01465790 BYBERRY CREEK AT CHALFONT ROAD, PHILADELPHIA, PA

LOCATION.--Lat 40°05'01", long 74°58'57", Philadelphia County, Hydrologic Unit 02040202, on right bank 200 ft (61 m) downstream from Chalfont Road Bridge, 0.2 mi (0.3 km) downstream from Walton Run, Philadelphia.

DRAINAGE AREA.--5.34 mi^2 (13.8 km^2).

PERIOD OF RECORD.--June 1965 to September 1978 (discontinued).

GAGE.--Water-stage recorder and concrete control. Datum of gage is 46.84 ft (14.277 m) National Geodetic Vertical Datum of 1929.

400645074595127 BYBERRY HOSPITAL RAIN GAGE

LOCATION.-Lat 40°06'45", long 74°59'51", Philadelphia County on Byberry Hospital on Roosevelt Boulevard.

PERIOD OF RECORD.--January 1975 to September 1978 (discontinued).

GAGE.--Tipping bucket (.01 in.). Altitude of gage is 150 ft (46 m), from topographic map.

400546075001728 FILM CORPORATION OF AMERICA RAIN GAGE

LOCATION.--Lat 40°05'46", long 75°00'17", Philadelphia County, at Film Corporation of America building at North Philadelphia Airport Industrial Park.

PERIOD OF RECORD.--January 1975 to September 1978 (discontinued).

GAGE.--Tipping bucket (.01 in.). Altitude of gage is 140 ft (43 m), from topographic map.

Annual maximum precipitation, in inches, for time interval indicated and date on which it occurred

Water year	Rain gage	5 min	15 min	30 min	60 min	120 min	180 min
1975	Byberry	0.30 (9/26)	0.90 (9/26)	1.08 (9/26)	1.12 (9/26)	1.22 (6/1)	1.66 (3/19)
	Film Corp.	.16 (7/13)	.48 (7/13)	.76 (7/13)	1.10 (7/13)	1.37 (7/13)	1.55 (5/31)
1976	Byberry	.07 (11/8)	.22 (11/8)	.35 (11/8)	.43 (10/18)	.66 (11/12)	.89 (11/12)
	Film Corp.	.07 (11/12)	.21 (11/12)	.27 (11/12)	.43 (10/18)	.66 (11/12)	.88 (11/12)
1977	Byberry	.13 (6/1)	.39 (6/1)	.71 (6/1)	.94 (6/1)	.97 (6/1)	1.03 (3/22)
	Film Corp.	.09 (4/26)	.27 (4/26)	.36 (4/26)	.49 (3/22)	.84 (4/29)	1.07 (4/29)
1978	Byberry	.35 (8/11)	1.05 (8/11)	1.69 (8/11)	1.77 (8/11)	2.23 (8/28)	2.47 (8/28)
	Film Corp.	.34 (8/11)	1.03 (8/11)	1.94 (8/11)	2.30 (8/11)	2.61 (8/11)	2.64 (8/11)

Appendix B.--Station descriptions for streamflow-gaging stations in the modeled basins and corresponding rainfall stations with period-of-record rainfall intensity data for rainfall stations--Continued

PENNYPACK CREEK BASIN

01467049 WOODEN BRIDGE RUN AT GRANT AVENUE, PHILADELPHIA, PA

LOCATION.--Lat 40°04'36", long 75°01'19", Philadelphia County, Hydrologic Unit 02040202, on left bank 20 ft (6 m) downstream from Grant Avenue Bridge in northeast Philadelphia.

DRAINAGE AREA.--1.06 mi^2 (2.36 km^2).

PERIOD OF RECORD.--October 1973 to September 1978 (discontinued).

GAGE.--Water stage recorder, concrete control, and crest-stage gage. Altitude of gage is 80 ft (24 m), from topographic map.

400505075012426 ALMO ELECTRONICS RAIN GAGE

LOCATION.--Lat 40°05'05", long 75°01'24", Philadelphia County, on Almo Electronics building on Roosevelt Boulevard.

PERIOD OF RECORD.--October 1973 to September 1978 (discontinued).

GAGE.--Tipping bucket (.01 in.). Altitude of gage is 135 ft (41 m) from topographic map.

Annual maximum precipitation, in inches, for time interval indicated and date on which it occurred

Water year	5 min	15 min	30 min	60 min	120 min	180 min
1974	0.37 (8/2)	0.62 (8/2)	0.77 (8/2)	0.83 (9/3)	1.03 (8/23)	1.09 (8/23)
1975	.18 (9/21)	.42 (7/13)	.63 (7/13)	.80 (7/13)	1.05 (7/13)	1.16 (7/20)
1976	.10(11/8)	.17(11/8)	.25(10/18)	.41(10/17)	.56(10/17)	.77(10/18)
1977	.39 (8/1)	1.04 (8/1)	1.74 (8/1)	2.51 (8/1)	2.90 (8/1)	3.14 (8/1)
1978	.31 (8/6)	.85 (8/6)	1.50 (8/6)	1.72 (8/6)	1.72 (8/6)	1.76 (8/28)

Appendix B.--Station descriptions for streamflow-gaging stations in the modeled basins and corresponding rainfall stations with period-of-record rainfall intensity data for rainfall stations--Continued

FRANKFORD CREEK BASIN

01467083 TACONY CREEK NEAR JENKINTOWN, PA

LOCATION.--Lat 40°05'08", long 75°08'08", Montgomery County, Hydrologic Unit 02040202, on right bank 700 ft (213 m) downstream from State Highway 73 (Washington Lane) and 0.5 mi (0.8 km) south of Jenkintown Railroad station.

DRAINAGE AREA.--5.25 mi^2 (13.6 km^2).

PERIOD OF RECORD.--October 1973 to September 1978 (discontinued).

GAGE.--Water-stage recorder. Altitude of gage is 200 ft (61 m), from topographic map.

400732075071550 ABINGTON RAIN GAGE

LOCATION.--Lat 40°07'32", long 75°07'15", Montgomery County, on Highland Avenue in Abington.

PERIOD OF RECORD.--June 1966 to current year (1983).

GAGE.--Weighing gage operated by Philadelphia Water Department. Altitude of gage is 370 ft (113 m), from topographic map.

400540075092460 BISHOP MCDEVITT HIGH SCHOOL RAIN GAGE

LOCATION.--Lat 40°05'40", long 75°09'24", Montgomery County, on Bishop McDevitt High School building on Royal Avenue in Wyncote.

PERIOD OF RECORD.--January 1974 to September 1978 (discontinued).

GAGE.--Tipping bucket (.01 in.). Altitude of gage is 320 ft (98 m) from topographic map.

Annual maximum precipitation, in inches, for time interval indicated and date on which it occurred

Water year	Rain gage	5 min	15 min	30 min	60 min	120 min	180 min
1974	Abington	0.17 (8/23)	0.52 (8/23)	0.79 (8/23)	1.08 (8/23)	1.56 (8/23)	1.70 (8/23)
	McDevitt	.27 (8/23)	.82 (8/23)	1.05 (8/23)	1.50 (8/23)	2.49 (8/23)	2.71 (8/23)
1975	Abington	.30 (7/14)	.90 (7/14)	1.01 (7/14)	1.28 (7/25)	1.60 (7/25)	1.60 (7/25)
	McDevitt	.21 (6/19)	.62 (6/19)	.86 (6/19)	1.06 (7/12)	1.42 (6/1)	1.43 (6/1)
1976	Abington	.20 (8/8)	.60 (8/8)	.78 (8/8)	.88 (8/8)	1.00 (5/1)	1.19 (5/1)
	McDevitt	.14 (8/14)	.43 (8/14)	.45 (8/14)	.52 (5/1)	.91 (5/1)	1.12 (5/1)
1977	Abington	.19 (9/19)	.56 (9/19)	.98 (9/19)	1.49 (9/19)	1.61 (9/19)	1.63 (9/19)
	McDevitt	.17 (9/25)	.52 (9/25)	.77 (7/12)	.98 (7/12)	.99 (7/12)	1.09 (3/22)
1978	Abington	.20 (9/12)	.61 (9/12)	.94 (8/28)	1.48 (8/28)	1.75 (8/28)	2.00 (8/28)
	McDevitt	.12 (5/24)	.36 (5/24)	.69 (8/28)	1.35 (8/28)	1.84 (8/28)	2.16 (8/28)

Appendix B.--Station descriptions for streamflow-gaging stations in the modeled basins and corresponding rainfall stations with period-of-record rainfall intensity data for rainfall stations--Continued

FRANKFORD CREEK BASIN

01467084 ROCK CREEK ABOVE CURTIS ARBORETUM NEAR PHILADELPHIA, PA

LOCATION.--Lat 40°04'54", long 75°09'03", Montgomery County, Hydrologic Unit 02040203, on right bank 60 ft (18 m) upstream from stone arch bridge, 1,600 ft (488 m), upstream from Washington Lane, Cheltenham Township and about 1.2 mi (1.9 km) upstream from mouth.

DRAINAGE AREA.--1.15 mi^2 (2.98 km^2).

PERIOD OF RECORD.-May 1971 to September 1978 (discontinued).

GAGE.--Water stage recorder, and concrete control. Altitude of gage is 245 ft (75 m) from topographic map.

400442075093756 CEDAR BROOK JUNIOR HIGH SCHOOL RAIN GAGE

LOCATION.--Lat 40°04'42", long 75°09'37", Montgomery County, on Cedar Brook Junior High School on Ogontz Avenue in Cedar Brook.

PERIOD OF RECORD.--October 1973 to November 1978 (discontinued).

GAGE.--Weighing gage operated by Philadelphia Water Department. Altitude of gage is 320 ft (98 m) from topographic map.

Annual maximum precipitation, in inches, for time interval indicated and date on which it occurred

Water year	5 min	15 min	30 min	60 min	120 min	180 min
1974	0.32 (8/4)	0.82 (8/23)	1.05 (8/23)	1.50 (8/23)	2.49 (8/23)	2.73 (8/23)
1975	.17 (5/30)	.32 (5/30)	.56 (5/22)	.92 (5/22)	1.20 (5/30)	1.42 (3/19)
1976	.21 (6/1)	.51 (6/1)	.75 (6/1)	.80 (6/1)	.91 (5/1)	1.16 (5/1)
1977	.11 (6/28)	.32 (6/28)	.60 (6/28)	.85 (6/28)	1.01 (6/28)	1.15 (6/28)
1978	.05(12/1)	.13(12/1)	.23(12/1)	.34(11/30)	.51(11/30)	.65(11/30)

Appendix B.--Station descriptions for streamflow-gaging stations in the modeled basins and corresponding rainfall stations with period-of-record rainfall intensity data for rainfall stations--Continued

FRANKFORD CREEK BASIN

01467085 JENKINTOWN CREEK AT ELKINS PARK, PA

LOCATION.--Lat 40°04'45", long 75°06'36", Montgomery County, Hydrologic Unit 02040202, on right bank 20 ft (6 m) downstream from Cedar Road bridge, 0.5 mi (0.8 km), east of Elkins Park, and 1 mi (1.6 km) west of Rockledge.

DRAINAGE AREA.--1.17 mi^2 (3.03 km^2).

PERIOD OF RECORD.--October 1973 to September 1978 (discontinued).

GAGE.--Water stage recorder. Altitude of gage is 180 ft (55 m) from topographic map.

400512075062757 MANOR JUNIOR COLLEGE RAIN GAGE

LOCATION.--Lat 40°05'12", long 75°06'27", Montgomery County, on Manor Junior College in Jenkintown.

PERIOD OF RECORD.--October 1973 to September 1978 (discontinued).

GAGE.--Tipping bucket (.01 in.). Altitude of gage is 240 ft (73 m) from topographic map.

Annual maximum precipitation, in inches, for time interval indicated and date on which it occurred

Water year	5 min	15 min	30 min	60 min	120 min	180 min
1974	0.60 (5/10)	1.13 (8/2)	1.26 (8/4)	1.56 (8/4)	1.73 (8/23)	1.95 (8/2)
1975	.28 (7/9)	.58 (6/1)	.79 (6/1)	1.11 (5/30)	1.71 (6/1)	1.86 (6/1)
1976	.37 (8/8)	.73 (8/8)	1.02 (8/8)	1.04 (8/8)	1.04 (8/8)	1.12 (8/8)
1977	.62 (6/9)	.73 (8/10)	.82 (9/19)	1.04 (9/19)	1.53 (8/1)	1.60 (8/1)
1978	.13 (11/7)	.24 (11/7)	.32 (11/7)	.56 (11/7)	.89 (11/7)	1.29 (11/7)

Appendix B.--Station descriptions for streamflow-gaging stations in the modeled basins and corresponding rainfall stations with period-of-record rainfall intensity data for rainfall stations--Continued

SCHUYLKILL RIVER BASIN

01472174 PICKERING CREEK NEAR CHESTER SPRINGS, PA

LOCATION.--Lat 40°05'22", long 75°37'50", Chester County, Hydrologic Unit 02040203, on left bank 30 ft (9.1 m) downstream from bridge on Horseshoe Trail Road, 0.45 mi (0.72 km) downstream from unnamed tributary, and 0.75 mi (1.21 km) southwest of Chester Springs.

DRAINAGE AREA.--5.98 mi^2 (15.49 km^2).

PERIOD OF RECORD.--January 1967 to current year (1983).

GAGE.--Water-stage recorder and crest-stage gage. Altitude of gage is 280 ft (85 m), from topographic map.

400430075401202 DEWEES RAIN GAGE

LOCATION.--Lat 40°04'30", long 75°40'12", Chester County, on Dewees farm at Byers.

PERIOD OF RECORD.--August 1975 to September 1978 (discontinued).

GAGE.--Tipping bucket (.01 in.). Altitude of gage is 450 ft (137 m), from topographic map.

01472174 PICKERING CREEK RAIN GAGE

LOCATION.--Lat 40°05'22", long 75°37'50", Chester County, at stream-gaging station.

PERIOD OF RECORD.--March 1974 to current year (1983).

GAGE.--Tipping bucket (.01 in.). Altitude of gage is 280 ft (85 m) from topographic map.

Annual maximum precipitation, in inches, for time interval indicated and date on which it occurred

Water year	Rain gage	5 min	15 min	30 min	60 min	120 min	180 min
1974	Dewees	No record					
	Pickering	0.34 (6/21)	1.03 (6/21)	1.16 (6/21)	1.19 (6/21)	1.28 (9/3)	1.32 (9/3)
1975	Dewees	.14 (9/20)	.43 (9/20)	.69 (9/20)	.76 (9/20)	.78 (9/20)	.83 (8/16)
	Pickering	.15 (9/20)	.44 (9/20)	.53 (9/20)	.59 (9/20)	.60(12/16)	.78(12/16)
1976	Dewees	.08 10/19	.25 10/19	.48 10/19	.84 10/19	1.11 10/19	1.23 10/19
	Pickering	.13 (7/11)	.39 (7/11)	.42 (7/11)	.43 (7/11)	.50 (6/1)	.52 (6/1)
1977	Dewees	.11 (6/9)	.32 (6/9)	.64 (6/9)	.96 (6/9)	1.19 (6/9)	1.19 (6/9)
	Pickering	.17(10/2)	.50(10/2)	.57(10/2)	.73 (2/24)	.84 (2/24)	1.17 (3/22)
1978	Dewees	.16 (8/31)	.48 (8/31)	.60 (8/31)	.76 (8/28)	.91 (8/28)	.95 (8/28)
	Pickering	.11 (7/3)	.32 (7/3)	.54 (7/3)	.74 (7/3)	1.02 (7/3)	1.62 (7/3)

Appendix B.--Station descriptions for streamflow-gaging stations in the modeled basins and corresponding rainfall stations with period-of-record rainfall intensity data for rainfall stations--Continued

SCHUYLKILL RIVER BASIN

01472186 PIGEON RUN AT RAPPS CORNER, PA

LOCATION.--Lat 40°04'58", long 75°35'31", Chester County, Hydrologic Unit 02040203, on left bank 5 ft (2 m) upstream from Yellow Springs Road, 0.6 mi (1.0 km) southeast of Rapps Corner, 1.6 mi (2.6 km) southeast of Chester Springs and 3 mi (4.8 km) west of Devault.

DRAINAGE AREA.--1.06 mi^2 (2.75 km^2).

PERIOD OF RECORD.--March 1974 to September 1978 (discontinued).

GAGE.--Water-stage recorder. Altitude of gage is 280 ft (85 m), from topographic map.

400411075353300 ARMSTRONG RAIN GAGE

LOCATION.--Lat 40°04'11", long 75°35'33", Chester County, on Armstrong property at Rapps Corner.

PERIOD OF RECORD.--August 1975 to September 1978 (discontinued).

GAGE.--Tipping bucket (.01 in.). Altitude of gage is 520 ft (158 m), from topographic map.

Annual maximum precipitation, in inches, for time interval indicated and date on which it occurred

Water year	5 min	15 min	30 min	60 min	120 min	180 min
1977	0.30 (8/1)	0.65 (8/1)	0.80 (8/1)	0.81 (8/1)	0.84 (3/22)	1.15 (3/22)
1978	.14 (3/14)	.28 (3/14)	.44 (5/14)	.63 (5/14)	.69 (5/14)	.90 (5.14)

Appendix B.--Station descriptions for streamflow-gaging stations in the modeled basins and corresponding rainfall stations with period-of-record rainfall intensity data for rainfall stations--Continued

SCHUYLKILL RIVER BASIN

01473870 PINE RUN TRIBUTARY NEAR AMBLER, PA

LOCATION.--Lat 40°08'56", long 75°10'50", Montgomery County, Hydrologic Unit 02040203, on left bank 20 ft (6 m) upstream from Susquehanna Road, 1.5 mi (2.4 km) east of Fort Washington, 2.2 mi (3.5 km) west of Ambler, and 3 mi (4.8 km) northwest of Roslyn.

DRAINAGE AREA.--1.18 mi^2 (3.06 km^2).

PERIOD OF RECORD.--October 1973 to September 1978 (discontinued).

GAGE.--Water-stage recorder and crest-stage gage. Altitude of gage is 200 ft (61 m), from topographic map.

400926075104358 TEMPLE SINAI NURSERY RAIN GAGE

LOCATION.-Lat 40°09'26", long 75°10'43", Montgomery County, on Temple Sinai Nursery on Dillon Road in Upper Dublin Township.

PERIOD OF RECORD.--November 1973 to September 1978 (discontinued).

GAGE.--Tipping bucket (.01 in.). Altitude of gage is 280 ft (85 m), from topographic map.

Annual maximum precipitation, in inches, for time interval indicated and date on which it occurred

Water year	5 min	15 min	30 min	60 min	120 min	180 min
1974	0.22 (9/28)	0.34 (9/28)	0.57 (9/28)	0.99 (9/28)	1.35 (9/28)	1.40 (9/28)
1975	.43 (5/31)	.64 (5/31)	.91 (5/22)	1.12 (9/12)	1.24 (9/12)	1.3 (3/19)
1976	NO UNIT Q DAYS--DATA NOT USED					
1977	.29 (8/22)	.54 (8/1)	.56 (8/1)	.58 (8/1)	.82 (3/22)	1.09 (3/22)
1978	.25 (8/28)	.48 (8/28)	.93 (8/28)	1.61 (8/28)	2.05 (8/28)	2.20 (8/28)

Appendix B.--Station descriptions for streamflow-gaging stations in the modeled basins and corresponding rainfall stations with period-of-record rainfall intensity data for rainfall stations--Continued

DARBY CREEK BASIN

01475300 DARBY CREEK AT WATERLOO MILLS NEAR DEVON, PA

LOCATION.--Lat 40°01'21", long 75°25'20", Chester County, Hydrologic Unit 02040202, on left bank 125 ft (38 m) upstream from bridge on Waterloo Road, 2 mi (3.2 km) south of Devon, and 2.5 mi (4.0 km) northwest of Newtown Square.

DRAINAGE AREA.--5.15 mi^2 (13.3 km^2).

PERIOD OF RECORD.--May 1972 to September 1981 (discontinued)

GAGE.--Water-stage recorder. Altitude of gage is 310 ft (94 m), from topographic map.

400243075264264 BERWYN FIRE COMPANY RAIN GAGE

LOCATION.--Lat 40°02'43", long 75°26'42", Chester County, on Berwyn Fire Company building on Bridge Avenue in Berwyn.

PERIOD OF RECORD.--February 1975 to September 1978 (discontinued).

GAGE.--Tipping bucket (.01 in.). Altitude of gage is 530 ft (162 m) from topographic map.

400121075251955 MCCORMACK ASSOCIATES RAIN GAGE

LOCATION.--Lat 40°01'21", long 75°25'19", Chester County, on north side of Waterloo Road at stream-gaging station.

PERIOD OF RECORD.--July 1973 to June 1976 (discontinued).

GAGE.--Weighing gage operated by Philadelphia Water Department. Altitude of gage is 320 ft (98 m), from topographic map.

Annual maximum precipitation, in inches, for time interval indicated and date on which it occurred

Water year	Rain gage	5 min	15 min	30 min	60 min	120 min	180 min
1973	Berwyn	NO RECORD					
	McCormack	0.25 (8/2)	0.75 (8/2)	1.17 (8/2)	1.27 (8/2)	1.41 (8/2)	1.67 (8/2)
1974	Berwyn	NO RECORD					
	McCormack	.12 (6/16)	.35 (6/16)	.65 (6/16)	.66 (6/16)	.87 (5/12)	1.10 (5/12)
1975	Berwyn	.24 (7/9)	.71 (7/9)	.90 (7/20)	1.38 (7/13)	1.98 (7/13)	2.34 (7/13)
	McCormack	.14 (7/12)	.42 (7/12)	.72 (5/30)	1.03 (5/30)	1.46 (5/30)	1.88 (7/12)
1976	Berwyn	.28 (7/11)	.83 (7/11)	1.00 (7/11)	1.06 (7/11)	1.40 (7/11)	1.58 (7/11)
	McCormack	.05(10/17)	.15 (3/31)	.26 (3/31)	.35 (3/31)	.52 (3/31)	.73 (3/31)
1977	Berwyn	.20 (9/19)	.59 (9/19)	1.13 (9/19)	1.34 (9/19	1.40 (9/19)	1.50 (9/19)
	McCormack	NO RECORD					

Appendix B.--Station descriptions for streamflow-gaging stations in the modeled basins and corresponding rainfall stations with period-of-record rainfall intensity data for rainfall stations--Continued

DARBY CREEK BASIN

01475530 COBBS CREEK AT U.S. HIGHWAY NO. 1 AT PHILADELPHIA, PA

LOCATION.--Lat 39°59'29", long 75°16'49", Philadelphia County, Hydrologic Unit 02040203, on left bank 30 ft (9 m) downstream from bridge on U.S. Highway No. 1 and 50 ft (15 m) upstream from unnamed tributary at west city limits of Philadelphia.

DRAINAGE AREA.--4.78 mi^2 (12.4 km^2).

PERIOD OF RECORD.--October 1964 to September 1981 (discontinued). Prior to October 1973 as "near Philadelphia."

GAGE.--Water-stage recorder, concrete control, and crest-stage gage. Datum of gage is 121.76 ft (37.112 m) National Geodetic Vertical Datum of 1929.

400037075183061 HAVERFORD COLLEGE RAIN GAGE

LOCATION.--Lat 40°00'37", long 75°18'30", Montgomery County, on Sharpless Hall building of Harverford College in Harverford Township.

PERIOD OF RECORD.--December 1974 to September 1978 (discontinued).

GAGE.--Tipping bucket (.01 in.). Altitude of gage is 400 ft (122 m), from topographic map.

395913075173962 SUBURBAN JEWISH COMMUNITY CENTER RAIN GAGE

LOCATION.--Lat 39°59'13", long 75°17'39", Montgomery County, on Suburban Jewish Community Center bulding on Mill Road in Harverford.

PERIOD OF RECORD.--January 1975 to September 1978 (discontinued).

GAGE.--Tipping bucket (.01 in.). Altitude of gage is 250 ft (76 m), from topogrpahic map.

Annual maximum precipitation, in inches, for time interval indicated and date on which it occurred

Water year	Rain gage	5 min	15 min	30 min	60 min	120 min	180 min
1975	Harverford	0.07 (8/16)	0.22 (8/16)	0.43 (3/19)	0.61 (3/19)	0.78 (3/19)	1.12 (3/19)
	Community Center	.32 (6/24)	.96 (6/24)	1.84 (6/24)	2.08 (6/24)	2.16 (7/13)	2.43 (7/13)
1976	Harverford	.23 (7/11)	.70 (7/11)	.73 (7/11)	.74 (7/11)	.76 (7/11)	.77 (7/11)
	Community Center	.17 (7/11)	.51 (7/11)	.67 (7/11)	.76 (7/11)	.81 (7/11)	.92 (7/11)
1977	Harverford	.16 (6/28)	.48 (6/28)	.84 (6/28)	.88 (6/28)	.92 (6/28)	.92 (6/28)
	Community Center	.26 (9/19)	.78 (9/19)	1.45 (9/19)	2.12 (9/19)	2.20 (9/19)	2.70 (9/19)
1978	Harverford	.15 (9/12)	.45 (9/12)	.83 (9/12)	1.07 (9/12)	1.08 (9/12)	1.08 (9/12)
	Community Center	.32 (8/28)	.95 (8/28)	1.31 (8/28)	1.85 (8/28)	2.21 (8/28)	2.42 (8/28)

Appendix B.--Station descriptions for streamflow-gaging stations in the modeled basins and corresponding rainfall stations with period-of-record rainfall intensity data for rainfall stations--Continued

DARBY CREEK BASIN

01475545 NAYLOR CREEK AT WEST CHESTER PIKE NEAR PHILADELPHIA, PA

LOCATION.--Lat 39°58'13", long 75°18'11", Delaware County, Hydrologic Unit 02040203, on right bank 200 ft (60 m) north of West Chester Pike 0.4 mi (0.6 km) west of intersection of West Chester Pike and U.S. Highway 1 and 8 mi (13 km) west of City Hall, Philadelphia.

DRAINAGE AREA.--1.10 mi^2 (2.85 km^2).

PERIOD OF RECORD.--June 1972 to September 1978 (discontinued).

GAGE.--Water-stage recorder, concrete control, and crest-stage gage. Altitude of gage is 215 ft (65 m).

395913075183759 OAKMONT FIRE COMPANY RAIN GAGE

LOCATION.--Lat 39°59'13", long 75°18'37", Delaware County, on Oakmont Fire Company building on Benedict Avenue in Harverford Township.

PERIOD OF RECORD.--January 1975 to September 1978 (discontinued).

GAGE.--Tipping bucket (.01 in.). Altitude of gage is 330 ft (101 m), from topographic map.

Annual maximum precipitation, in inches, for time interval indicated and date on which it occurred

Water year	5 min	15 min	30 min	60 min	120 min	180 min
1975	0.45 (6/24)	1.24 (6/24)	1.95 (6/24)	2.16 (6/24)	2.17 (6/24)	2.25 (5/31)
1976	.36 (7/11)	.88 (7/11)	1.24 (7/11)	1.30 (7/11)	1.42 (7/11)	1.62 (7/11)
1977	.48 (9/19)	1.09 (9/19)	1.28 (9/19)	1.89 (9/19)	2.04 (6/28)	2.56 (9/19)
1978	.41 (5/31)	.49 (5/31)	.63 (7/27)	.95 (7/27)	1.36 (7/27)	1.50 (7/3)

Appendix B.--Station descriptions for streamflow-gaging stations in the modeled basins and corresponding rainfall stations with period-of-record rainfall intensity data for rainfall stations--Continued

CRUM CREEK BASIN

01476030 LITTLE CRUM CREEK AT MICHIGAN AVENUE, SWARTHMORE, PA

LOCATION.--Lat 39°53'42", long 75°20'19", Delaware County, Hydrologic Unit 02040202, on left bridge abutment at Michigan Avenue, Ridley Township, Swarthmore.

DRAINAGE AREA.--1.15 mi^2 (2.98 km^2)

PERIOD OF RECORD.--May 1971 to September 1978 (discontinued).

GAGE.--Water-stage recorder and concrete and rock control. Altitude of gage is 40 ft (12 m), from topographic map.

395425075200363 SWARTHMORE COLLEGE RAIN GAGE

LOCATION.--Lat 39°54'25", long 75°20'03", Delaware County, on Swarthmore College in Swarthmore.

PERIOD OF RECORD.--May 1975 to September 1978 (discontinued).

GAGE.--Tipping bucket (.01 in.). Altitude of gage is 140 ft (43 m) from topographic map.

Annual maximum precipitation, in inches, for time interval indicated and date on which it occurred

Water year	5 min	15 min	30 min	60 min	120 min	180 min
1975	0.37 (6/1)	1.00 (6/13)	1.42 (6/13)	1.43 (6/13)	1.95 (5/30)	2.00 (5/30)
1976	.27 (6/27)	.51 (8/14)	.55 (8/14)	.73 (5/1)	1.14 (5/1)	1.41 (5/1)
1977	.71 (8/31)	1.31 (8/31)	1.76 (8/31)	1.89 (8/31)	1.90 (8/31)	1.90 (8/31)
1978	.21 (6/7)	.46 (8/28)	.85 (8/28)	1.55 (8/28)	1.82 (8/28)	2.14 (8/28)

Appendix C.--Model calibration data sets

01465770 Poquessing Creek at Trevose Road, Philadelphia, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*07/09/75	0.73	0.12	0.13	277	242	3.8
*07/13/75	2.95	.96	.85	759	955	8.7
*07/14/75	.68	.26	.16	434	326	14
*07/14/75	2.20	1.16	1.02	1,053	1,312	27
*09/20/75	.73	.11	.14	247	254	2.5
09/22/75	5.92	1.87	1.14	318	154	2.5
09/26/75	1.25	.68	.29	553	247	13
*03/12/76	.56	.11	.10	115	112	6.4
*02/24/77	1.44	.22	.26	185	219	1.7
03/13/77	1.54	.32	.29	247	133	1.6
*06/09/77	1.39	.21	.25	143	156	1.4
*07/12/77	2.19	.43	.46	623	644	.8
*12/05/77	.64	.10	.13	121	153	4
12/18/77	1.42	.50	.30	291	177	9
*03/26/78	2.22	.33	.41	205	170	35
*05/24/78	2.52	.77	.63	547	431	4
*08/28/78	1.76	.54	.49	853	811	2.2
08/28/78	.62	.19	.12	431	282	5.4
Total number of calibration storms = 13						
Means based on calibration storms		.41	.39	428	445	8.6

* - Events used in calibration

Note: Storm rainfall is weighted.

Appendix C.--Model calibration data sets--Continued

01465790 Byberry Creek at Chalfont Road at Philadelphia, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*05/04/75	1.20	.28	.28	233	198	4.2
*05/16/75	.60	.10	.13	122	150	4.6
*05/30/75	1.21	.21	.28	165	162	3.3
*05/31/75	1.77	.68	.69	603	607	4.9
*06/11/75	1.53	.38	.35	176	147	5.3
06/13/75	.31	.07	.07	143	87	22
*08/16/75	.74	.12	.16	192	211	2.4
*09/22/75	5.70	1.67	1.49	538	569	2.6
*09/25/75	.84	.29	.20	192	172	26
*11/08/75	.47	.09	.10	152	171	3.1
11/12/75	2.36	.87	.58	400	261	2.8
*03/31/76	.81	.18	.18	152	149	3.1
*03/13/77	.81	.20	.18	258	201	1.6
*03/13/77	.26	.07	.05	123	109	22
*03/18/77	.49	.09	.10	121	142	2.1
03/22/77	1.97	.80	.48	608	345	2.1
04/04/77	1.12	.39	.26	222	157	2.2
*10/14/77	.34	.08	.08	76	78	3
10/15/77	.57	.18	.13	229	154	17
*08/11/78	2.32	.84	.79	1,238	1,365	2.1
*08/12/78	.54	.16	.14	230	187	16
Total number of calibration storms = 16						
Means based on calibration storms		.34	.33	286	289	6.6

* - Events used in calibration

Note: Storm rainfall is weighted.

Appendix C.--Model calibration data sets--Continued

01467049 Wooden Bridge Run at Grant Avenue at Philadelphia, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*06/23/74	0.61	0.14	0.15	89	86	0.5
*06/23/74	.27	.05	.07	81	87	2.1
*09/28/74	.74	.24	.23	150	131	.2
06/19/75	.48	.15	.14	205	130	.5
*07/25/75	.44	.10	.13	144	138	.5
*09/12/75	.62	.13	.16	122	113	.8
*11/08/75	.37	.07	.09	53	60	.4
*07/08/77	.17	.04	.03	34	41	.1
*07/12/77	.78	.24	.21	165	126	.1
08/01/77	3.22	1.56	1.83	817	1,391	.2
*08/03/77	1.06	.47	.53	584	583	.2
*08/06/77	.41	.13	.13	181	164	.2
*08/10/77	.34	.10	.10	127	128	.1
*08/13/77	.28	.10	.07	78	74	.2
*08/13/77	.39	.19	.11	113	112	.2
*05/24/78	.74	.23	.30	230	227	42
*08/06/78	1.72	.77	.87	718	832	.3
*08/28/78	1.78	.68	.77	413	451	.2
Total number of calibration storms = 16						
Means based on calibration storms		.23	.25	205	210	3.0

* - Events used in calibration

Appendix C.--Model calibration data sets--Continued

01467083 Tacony Creek near Jenkintown, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*05/09/74	0.71	0.11	0.15	209	264	5.7
*05/10/74	.77	.20	.17	210	193	8.2
*05/12/74	.88	.19	.26	472	657	6.7
*08/23/74	2.65	1.40	1.17	2,558	2,525	2.3
*09/03/74	.40	.06	.09	236	314	3.6
*09/03/74	1.14	.27	.30	585	615	3.9
*09/06/74	1.19	.23	.27	168	215	4.5
*12/16/74	1.76	.66	.47	662	524	3.6
*03/19/75	2.32	.82	.93	1,293	1,323	6.7
*05/22/75	.83	.19	.24	492	712	7.2
*06/05/75	.97	.20	.23	406	326	9.7
*03/04/77	.59	.13	.11	119	116	3.6
*03/22/77	1.99	.68	.53	786	582	5.2
*06/20/77	.42	.10	.10	464	338	2.6
*07/12/77	.97	.18	.28	713	899	2.4
*08/01/77	.52	.07	.09	148	218	2.3
*08/13/77	.09	.02	.01	39	37	2.3
*08/13/77	.31	.04	.06	121	165	2.3
*08/14/77	.25	.04	.04	59	87	2.3
*08/22/77	1.02	.22	.25	565	535	2.3
09/19/77	1.37	.29	.43	708	1330	2
*09/25/77	1.05	.34	.34	1,018	1,028	2.3
*11/30/77	1.01	.25	.24	380	293	8.2
*05/24/78	2.32	.72	.72	941	763	9.2
Total number of calibration storms = 23						
Means based on calibration storms		.31	.31	550	553	4.7

* - Events used in calibration

Note: Storm rainfall is weighted.

Appendix C.--Model calibration data sets--Continued

01467084 Rock Creek above Curtis Arboretum near Philadelphia, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*03/08/74	0.42	0.10	0.12	54	56	1.2
*05/22/74	.35	.10	.10	162	179	1.3
*05/23/74	.29	.09	.08	190	184	1.5
*06/02/74	.41	.12	.12	58	57	3.7
*06/21/74	.33	.10	.09	155	119	1
*07/24/74	.32	.08	.10	152	170	3.7
*08/23/74	3.20	1.34	1.10	795	696	1.1
*09/03/74	.40	.13	.12	171	182	.9
09/03/74	1.10	.45	.36	199	275	1
*09/04/74	.28	.06	.09	35	36	2.7
*09/07/74	.98	.37	.32	90	75	6.6
*03/19/75	2.19	.90	.81	249	307	2.9
*05/16/75	.49	.16	.14	101	93	1.2
*06/05/75	.95	.29	.29	141	131	1.8
09/21/75	.94	.24	.33	467	585	3.2
*10/17/75	.67	.18	.22	102	129	7
*10/18/75	1.26	.32	.38	69	89	1.6
*11/21/75	.61	.17	.20	101	85	6
*03/12/76	.54	.13	.16	58	63	2.8
*06/01/76	.79	.20	.24	314	399	.6
*04/26/77	.45	.13	.13	213	197	2.6
*03/26/78	1.71	.57	.55	112	110	2.1
Total number of calibration storms = 20						
Means based on calibration storms		.28	.27	166	168	2.6

* - Events used in calibration

Appendix C.--Model calibration data sets--Continued

01467085 Jenkintown Creek at Elkins Park, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*04/09/74	0.75	0.09	0.09	27	36	3.8
*08/02/74	1.93	.24	.25	162	204	2.2
*08/23/74	1.85	.41	.28	182	169	.8
*09/28/74	1.01	.15	.14	81	88	3.5
09/29/74	.21	.01	.03	24	36	.9
*12/02/74	.56	.05	.06	43	43	3.8
*04/24/75	1.01	.10	.11	22	27	2.7
*04/25/75	1.30	.25	.15	62	43	2.2
*06/05/75	.37	.02	.04	32	37	2.7
*08/16/75	.28	.02	.03	29	34	3
*04/26/77	.77	.07	.08	37	46	1.3
*06/01/77	.83	.08	.09	76	71	.3
*08/10/77	.76	.07	.09	115	119	.1
08/24/77	.70	.05	.07	44	61	.4
*09/19/77	1.74	.16	.20	96	126	.3
*11/07/77	2.24	.45	.38	106	111	4.4
*11/07/77	1.93	.57	.38	126	119	4
*11/23/77	.84	.10	.10	25	22	1.8
*11/30/77	1.15	.21	.16	70	54	1.8
*12/05/77	0.66	.05	.07	21	30	1.6
Total number of calibration storms = 18						
Means based on calibration storms		.17	.15	73	77	2.2

* - Events used in calibration

Appendix C.--Model calibration data sets--Continued

01472174 Pickering Creek near Chester Springs, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*09/22/75	3.71	.74	.90	102	162	5.7
*10/17/75	.96	.11	.11	68	78	5.9
*10/18/75	1.25	.66	.57	490	442	9.6
*11/12/75	.99	.27	.17	85	58	6.5
*03/12/76	.36	.05	.05	44	37	10.8
*04/01/76	1.00	.32	.41	208	274	13
10/20/76	.68	.26	.07	190	45	4
*02/24/77	1.09	.59	.43	486	338	4.8
*03/13/77	1.45	.41	.53	188	192	5.7
*03/22/77	1.27	.61	.51	413	346	5.9
06/09/77	1.13	.13	.33	160	301	5.5
*09/25/77	.36	.05	.07	51	56	4.6
*12/18/77	1.94	.80	.96	490	593	21
*07/03/78	1.39	.55	.51	383	345	13
Total number of calibration storms = 12						
Means based on calibration storms		.43	.44	251	243	8.9

* - Events used in calibration

Note: Storm rainfall is weighted.

Appendix C.--Model calibration data sets--Continued

01472186 Pigeon Run at Rapps Corner, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*10/31/76	0.75	0.04	0.05	13	15	0.9
*12/07/76	1.61	.13	.09	29	23	.8
*03/13/77	1.29	.10	.12	26	33	1
*03/13/77	0.77	.13	.19	44	62	4.2
*03/22/77	1.94	.30	.29	55	59	1.3
*04/02/77	.98	.03	.03	5.80	5.81	1.1
*04/04/77	1.74	.26	.15	43	22	1.5
*04/24/77	.62	.01	.02	3.50	4.49	2.1
*04/26/77	.36	.01	.01	2.20	2.14	2.2
*06/28/77	.91	.02	.04	6.82	13.15	.8
08/01/77	.82	.02	.06	7.97	20.13	.4
08/03/77	.66	.01	.02	5.98	7.56	.5
*12/05/77	.49	.02	.02	4.80	4.77	2.8
*12/14/77	.96	.06	.04	5.90	6.42	2.7
*03/14/78	.40	.15	.06	42	22	11
05/14/78	2.24	.35	.15	53	18	5.1
Total number of calibration storms = 13						
Means based on calibration storms		.10	.09	22	21	2.5

* - Events used in calibration

Appendix C.--Model calibration data sets--Continued

01473870 Pine Run Tributary near Ambler, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
10/15/74	1.15	.04	.17	11	57	.3
*10/16/74	1.16	.14	.16	28	28	4
*03/19/75	2.28	.68	1.10	153	205	1.3
*04/25/75	1.03	.16	.12	28	21	1.8
*05/31/75	1.48	.33	.36	105	119	1.7
*06/05/75	.56	.11	.08	20	25	2.4
*06/12/75	.54	.08	.06	27	21	5.1
*06/12/75	1.24	.63	.58	159	162	9
*06/13/75	.23	.07	.07	35	33	11
*03/13/77	.33	.03	.03	11	15	1.2
*03/22/77	1.77	.68	.54	181	131	.2
08/01/77	.46	.14	.07	101	37	1.3
11/30/77	.68	.16	.10	34	24	1.2
03/26/78	.47	.18	.07	60	26	11
03/27/78	.49	.26	.05	40	11	12
*08/28/78	2.20	.59	.75	213	273	.2
*08/28/78	.77	.29	.24	134	106	.7
*09/12/78	.46	.03	.04	21	26	.3
Total number of calibration storms = 13						
Means based on calibration storms		.29	.32	86	90	3

* - Events used in calibration

Appendix C.--Model calibration data sets--Continued

01475300 Darby Creek at Waterloo Mills near Devon, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*02/24/75	0.55	0.05	0.06	53	51	22
07/20/75	1.46	.18	.29	284	392	13
*09/22/75	3.27	.44	.39	118	129	11
*09/24/75	1.15	.37	.26	429	336	36
*11/12/75	1.34	.16	.14	97	88	8.9
*04/01/76	1.19	.12	.12	88	86	12
08/09/76	1.90	.15	.20	107	155	3.4
*06/28/77	1.42	.16	.15	195	182	3.8
*09/19/77	1.50	.18	.22	348	321	2.1
09/25/77	1.61	.13	.28	154	339	4.5
*10/09/77	.63	.04	.06	49	39	11
*11/25/77	.80	.10	.10	94	96	16
05/09/78	.73	.07	.10	101	164	11
*05/13/78	.97	.08	.09	86	90	7.5
*05/14/78	.78	.10	.09	65	55	28
*06/08/78	.54	.04	.03	93	97	9.6
*07/27/78	1.85	.17	.28	272	366	3.2
*08/28/78	2.99	.68	.63	1,035	845	4.7
Total number of calibration storms = 14						
Means based on calibration storms		.19	.19	216	199	12.6

* - Events used in calibration

Appendix C.--Model calibration data sets--Continued

01475530 Cobbs Creek at U.S. Highway 1, at Philadelphia, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*05/16/75	0.58	0.09	0.09	130	103	5.5
*07/09/75	.84	.11	.15	197	258	3.2
*07/12/75	.34	.04	.05	86	81	4.4
*07/12/75	4.29	1.46	1.84	2,105	2,129	4.7
*07/20/75	1.93	.43	.44	765	514	5.5
08/09/76	.67	.22	.10	184	92	2.2
08/14/76	.18	.04	.01	70	37	3
*07/12/77	.73	.10	.11	209	186	1.6
*08/01/77	.78	.11	.12	122	148	1.4
08/31/77	.45	.08	.05	132	60	1.5
*10/16/77	.94	.15	.17	142	162	3.2
*11/06/77	2.37	.48	.46	170	261	2.9
*11/07/77	2.04	.35	.55	363	417	62
*12/18/77	1.85	.41	.38	145	172	5.2
*03/14/78	.33	.07	.05	102	80	18
*04/19/78	.49	.04	.07	35	37	5.5
04/19/78	.17	.01	.03	32	43	8.9
*05/13/78	1.20	.21	.18	85	99	5.4
*05/14/78	.23	.03	.03	57	62	10
*05/16/78	.53	.11	.08	71	64	6.3
*05/17/78	.49	.11	.08	105	83	7.9
06/07/78	1.13	.11	.19	146	217	4.4
*07/03/78	3.64	.70	.65	287	291	3.7
Total number of calibration storms = 18						
Means based on calibration storms		.28	.30	288	286	8.7

* - Events used in calibration

Note: Storm rainfall is weighted.

Appendix C.--Model calibration data sets--Continued

01475545 Naylor Creek at West Chester Pike near Philadelphia, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*03/19/75	2.18	0.81	0.68	260	227	9.5
*05/21/75	.17	.04	.03	79	55	1
*05/30/75	.58	.11	.13	49	71	1
*05/30/75	.30	.07	.08	102	131	2.5
*05/31/75	2.74	.93	.99	430	531	1.1
*06/05/75	1.33	.40	.35	241	207	1.1
*11/12/75	1.49	.37	.38	111	92	.6
*05/01/76	2.56	.77	.66	248	203	.8
05/12/76	.42	.04	.11	51	73	9.8
06/27/76	.58	.07	.14	177	221	.6
*07/08/76	.36	.07	.08	118	135	.6
03/22/77	1.99	.79	.57	227	154	1
*04/04/77	1.38	.42	.35	98	74	1.2
*06/28/77	2.71	.83	.73	386	395	.5
08/01/77	.46	.06	.11	131	212	.3
08/06/77	.85	.10	.22	204	302	.4
*08/06/77	.25	.06	.06	115	122	8
*08/22/77	1.12	.20	.27	128	154	.3
03/14/78	.28	.13	.08	216	153	22
05/08/78	.95	.13	.24	50	55	.8
05/09/78	.24	.03	.05	33	57	1.3
*05/16/78	.36	.06	.08	59	72	.9
05/24/78	.63	.22	.16	177	125	.9
05/24/78	.30	.08	.08	177	126	8
Total number of calibration storms = 14						
Means based on calibration storms		.37	.35	173	176	2.1

* - Events used in calibration

Appendix C.--Model calibration data sets--Continued

01476030 Little Crum Creek at Michigan Avenue, Swarthmore, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*05/30/75	2.02	0.38	0.30	185	166	1.6
*05/30/75	.35	.08	.06	67	63	13.4
*06/01/75	.97	.21	.17	130	125	2.4
*06/05/75	.85	.14	.17	120	152	1.7
*08/13/75	.51	.04	.05	35	38	.3
*10/19/75	.62	.06	.08	23	25	6.8
*05/01/76	2.50	.31	.30	87	89	.2
*06/30/76	.50	.04	.05	45	57	.2
*07/23/76	.35	.04	.04	39	41	0
*08/13/76	.48	.06	.05	71	55	.1
*08/14/76	.55	.05	.06	47	63	.2
*10/31/76	.77	.08	.09	35	35	1.2
*02/24/77	1.15	.20	.14	111	76	28
*06/01/77	1.22	.13	.14	88	101	.3
*06/09/77	1.29	.10	.14	45	47	.4
*08/01/77	.91	.06	.10	36	50	.3
*08/03/77	.36	.04	.04	47	39	.3
*08/31/77	1.90	.39	.32	276	283	2.4
*09/25/77	.77	.08	.10	72	62	.1
03/14/78	.34	.05	.04	51	31	5.8
05/24/78	1.61	.12	.20	58	71	1.1
*08/28/78	2.14	.23	.28	152	146	.7
Total number of calibration storms = 20						
Means based on calibration storms		.14	.13	86	86	3

* - Events used in calibration

Appendix D.--Model verification data sets

01465770 Poquessing Creek at Trevose Road, Philadelphia, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
07/20/75	3.00	1.17	1.19	864	1,335	5.4
07/25/75	1.23	.28	.36	465	675	5.4
*10/17/75	1.16	.18	.22	204	195	3.6
*10/18/75	1.40	.43	.28	294	174	8.0
*11/12/75	2.32	.77	.53	527	397	3.8
*03/31/76	1.37	.25	.26	168	175	7.7
*03/22/77	2.30	.86	.50	637	365	2.2
*04/04/77	1.51	.43	.30	272	155	2.7
*08/01/77	2.09	.56	.47	746	649	1.1
*08/03/77	.62	.06	.11	111	193	11.0
*08/03/77	.29	.08	.05	176	93	1.0
*08/22/77	1.28	.24	.25	301	315	1.5
*08/24/77	.63	.10	.10	165	175	1.9
*12/21/77	1.39	.48	.30	283	189	9.0
*05/08/78	1.26	.19	.23	141	111	3.4
*05/14/78	1.80	.39	.37	314	284	4.0
06/08/78	.06	.07	.01	128	31	1.0
Total number of verification storms = 14						
Means based on verification storms		.36	.28	310	248	4.3

* - Events used in verification

Note: Storm rainfall is weighted.

Appendix D.--Model verification data sets--Continued

01465790 Byberry Creek at Chalfont Road at Philadelphia, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*02/23/75	0.61	0.11	0.14	167	174	3.9
*03/19/75	1.91	.79	.59	691	554	3.1
*05/12/75	1.09	.21	.25	214	221	4.2
*06/05/75	1.00	.28	.25	236	224	6.6
*06/06/75	.29	.05	.06	112	104	13.0
*07/24/75	.52	.09	.12	178	273	4.9
*09/12/75	.66	.09	.15	167	308	2.1
*09/21/75	.51	.10	.07	232	249	2.8
09/26/75	1.69	.72	.76	667	1,404	11.0
*09/26/75	.24	.05	.06	99	116	36.0
*10/17/75	1.15	.24	.27	232	260	2.8
*10/18/75	.97	.36	.25	363	294	10.0
*10/19/75	.54	.15	.14	248	201	21.0
*11/21/75	.58	.11	.13	102	128	3.1
*03/04/77	.69	.20	.15	134	185	2.1
*04/26/77	.11	.03	.02	29	26	2.1
*04/26/77	1.05	.24	.24	250	275	5.3
*10/08/77	.91	.28	.20	127	98	.7
08/28/78	2.53	.52	.77	696	1,441	42.0
Total number of verification storms = 17						
Means based on verification storms		.20	.18	211	217	7.3

* - Events used in verification

Note: Storm rainfall is weighted.

Appendix D.--Model verification data sets--Continued

01467049 Wooden Bridge Run at Grant Avenue at Philadelphia, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*03/21/74	1.32	0.67	0.55	219	161	0.5
03/30/74	.89	.42	.27	177	96	.5
*07/30/74	.73	.18	.19	107	95	.4
08/02/74	.81	.38	.26	538	288	.3
*08/23/74	1.08	.33	.33	184	167	.4
*08/28/74	.63	.20	.21	391	281	.2
*09/02/74	.52	.14	.16	257	198	.4
*09/03/74	.88	.35	.35	492	383	.5
*10/15/74	.34	.06	.07	34	36	.4
*10/16/74	1.31	.46	.34	80	55	1.4
*04/24/75	1.02	.26	.25	59	59	.8
*04/25/75	1.30	.50	.38	147	108	.6
*06/13/75	.31	.10	.11	125	134	1.3
*07/20/75	1.35	.57	.52	396	243	.5
*07/21/75	.19	.07	.07	126	74	17.0
*09/21/75	.40	.11	.10	199	135	.5
*04/26/77	1.16	.38	.33	110	112	.4
*06/28/77	.94	.31	.26	169	168	.1
*07/25/77	.37	.15	.08	75	70	.1
*08/22/77	.99	.41	.28	116	89	.2
*08/11/78	1.18	.50	.71	550	720	.2
Total number of verification storms = 19						
Means based on verification storms		.30	.28	202	173	1.4

* - Events used in verification

Appendix D.--Model verification data sets--Continued

01467083 Tacony Creek near Jenkintown, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*07/05/74	0.56	0.11	0.08	413	403	2.8
*08/02/74	1.27	.26	.31	441	489	3.3
*08/04/74	1.19	.21	.34	738	1,099	2.4
*09/28/74	.34	.04	.06	102	131	3.9
*09/28/74	1.56	.48	.55	1,093	1,186	6.7
*05/30/75	1.59	.32	.46	646	908	6.2
*06/01/75	1.50	.58	.69	987	1,187	7.7
*06/01/75	.16	.03	.03	71	82	25.0
*07/07/75	.94	.19	.28	579	930	6.2
07/12/75	1.10	.14	.39	449	1,155	5.7
*07/13/75	2.27	.67	.63	576	596	8.7
*10/17/75	1.11	.16	.26	214	319	9.2
*11/12/75	2.17	.47	.57	269	454	7.2
*05/01/76	2.24	.49	.57	442	519	6.2
*03/13/77	.90	.16	.18	146	203	3.9
*03/13/77	.21	.08	.05	142	131	3.9
*03/18/77	.44	.08	.08	115	131	4.7
*04/04/77	1.24	.31	.28	264	193	5.7
*06/14/77	.35	.07	.06	112	116	2.6
*06/28/77	1.34	.23	.30	457	602	2.4
*08/03/77	.37	.06	.07	241	258	2.3
*08/28/78	2.17	.78	.79	2,046	1,639	3.6
Total number of verification storms = 21						
Means based on verification storms		.28	.32	481	551	5.9

* - Events used in verification

Note: Storm rainfall is weighted.

Appendix D.--Model verification data sets--Continued

01467084 Rock Creek above Curtis Arboretum near Philadelphia, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*12/13/73	0.88	0.23	0.27	54	59	0.7
05/03/74	.38	.09	.10	59	85	2.0
*05/12/74	.87	.30	.27	205	277	1.5
*06/16/74	.55	.22	.16	178	173	1.7
*06/23/74	.61	.19	.18	110	90	1.1
*06/23/74	.28	.07	.08	120	98	2.0
06/23/74	.22	.03	.06	31	33	2.9
*07/30/74	.60	.18	.18	132	155	.9
*08/09/74	.27	.06	.07	88	92	.9
*09/21/74	.45	.12	.13	112	120	1.0
*09/28/74	.35	.08	.10	61	54	.9
09/28/74	1.45	.42	.49	258	367	1.8
*03/14/75	.34	.13	.11	74	64	5.3
06/01/75	2.09	.56	.88	318	633	2.2
*06/19/75	.93	.16	.31	444	593	1.5
07/07/75	1.06	.19	.33	153	506	1.4
07/12/75	1.34	.23	.44	149	352	1.3
*07/13/75	1.46	.63	.50	170	211	4.0
*07/13/75	.36	.11	.12	81	71	7.5
*10/11/75	.21	.05	.05	62	73	1.5
*11/12/75	1.52	.55	.48	148	122	1.6
*05/01/76	.24	.85	.70	186	166	.7
*06/09/77	1.18	.26	.36	102	81	.8
*06/15/77	.24	.07	.08	49	64	2.8
*06/28/77	1.42	.56	.44	356	289	.7
11/30/77	.99	.42	.33	213	129	1.3
Total number of verification storms = 19						
Means based on verification storms		.25	.24	144	150	2.0

* - Events used in verification

Appendix D.--Model verification data sets--Continued

01467085 Jenkintown Creek at Elkins Park, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*05/10/74	0.97	0.14	0.11	81	77	4.9
*05/12/74	.75	.11	.10	60	77	1.8
*09/06/74	1.08	.16	.13	28	26	1.3
*12/08/74	.97	.12	.10	30	21	1.3
*05/21/75	.54	.04	.08	71	102	1.6
*05/22/75	.51	.07	.06	64	48	2.0
*05/30/75	1.27	.17	.16	122	123	1.3
*06/01/75	1.71	.47	.44	265	230	2.2
*06/12/75	.56	.07	.06	23	20	5.5
*06/13/75	.16	.01	.02	13	19	4.1
*07/24/75	1.07	.12	.17	132	159	2.2
*07/03/76	.23	.01	.02	24	29	.2
*08/01/77	1.60	.20	.19	122	103	2.0
*08/13/77	.39	.03	.04	39	47	.2
*08/22/77	1.52	.18	.18	94	84	.1
*08/31/77	.49	.03	.05	48	61	.3
*08/31/77	.25	.02	.03	21	28	.9
*09/06/77	.53	.04	.06	76	73	.4
09/24/77	.76	.16	.11	157	104	.6
*09/25/77	1.03	.17	.22	117	182	.4
12/21/77	1.54	.38	.22	69	48	2.7

Total number of verification storms = 19

Means based on verification storms		.11	.12	75	79	1.7

* - Events used in verification

Appendix D.--Model verification data sets--Continued

01472174 Pickering Creek near Chester Springs, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*03/29/74	1.09	0.08	0.15	41	55	7.8
03/30/74	1.07	.23	.53	158	277	33.0
04/05/74	.32	.03	.03	28	16	14.0
*04/08/74	1.25	.21	.36	167	182	13.0
*05/12/74	.24	.01	.03	13	16	8.0
*05/12/74	1.28	.23	.53	229	312	11.0
*10/16/74	1.55	.14	.27	80	116	4.1
*12/08/74	2.10	.56	.62	316	270	12.0
*12/16/74	1.67	.44	.64	266	338	5.7
*04/24/75	1.10	.12	.18	75	96	11.0
*06/01/76	1.05	.10	.10	56	41	4.5
*10/09/76	1.47	.23	.31	105	99	4.5
*04/04/77	2.07	.60	.87	311	421	11.0
*04/24/77	.74	.03	.10	36	59	5.7
11/03/77	.75	.06	.15	35	80	9.6
*11/07/77	3.38	1.06	1.89	475	761	16.0
*11/25/77	1.09	.21	.36	136	197	16.0
*11/30/77	.75	.13	.19	73	97	22.0
*12/05/77	.42	.04	.05	25	29	19.0
*12/14/77	1.01	.13	.23	59	83	15.0
*03/26/78	3.12	1.09	1.35	469	329	31.0
04/19/78	.53	.03	.02	14	7	22.0
*04/19/78	.42	.03	.04	30	23	30.0
*04/20/78	.35	.02	.04	23	23	41.0
*05/09/78	1.00	.18	.59	237	358	23.0

Total number of verification storms = 21

Means based on verification storms		.27	.42	153	186	14.8

* - Events used in verification

Appendix D.--Model verification data sets--Continued

01475300 Darby Creek at Waterloo Mills near Devon, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*04/24/75	1.08	0.11	0.10	75	81	7.5
*04/25/75	1.74	.41	.31	365	284	16.0
*05/16/75	.77	.07	.07	46	73	9.6
*05/31/75	1.53	.16	.19	167	176	7.5
*06/05/75	.78	.09	.07	50	52	9.2
*06/12/75	2.34	.28	.28	146	109	8.2
*06/13/75	.49	.08	.12	135	182	27.0
*07/13/75	3.62	.76	.85	448	760	7.2
*10/17/75	.88	.07	.07	53	61	7.8
*10/18/75	1.32	.17	.18	105	157	10.0
*11/21/75	.82	.08	.08	55	58	8.9
*05/01/76	1.86	.18	.17	92	82	6.6
*10/20/76	1.39	.11	.14	66	97	4.1
*02/24/77	1.76	.49	.22	405	174	5.2
*04/26/77	1.64	.21	.14	100	94	8.5
*06/01/77	1.10	.08	.12	107	179	4.0
*08/31/77	1.31	.07	.11	96	167	1.4
*11/06/77	1.97	.23	.33	195	264	4.7
*11/07/77	1.43	.36	.39	633	445	66.0
*11/23/77	.47	.08	.04	54	33	10.0
*11/30/77	.69	.11	.07	51	36	11.0
*12/21/77	1.08	.21	.13	86	92	24.0
*05/17/78	.65	.06	.07	64	63	14.0
*06/21/78	2.15	.43	.32	577	408	5.5
*07/03/78	3.32	.51	.39	276	195	4.5
*07/31/78	.99	.05	.09	70	85	4.5
Total number of verification storms = 26						
Means based on verification storms		.21	.19	174	170	11.3

* - Events used in verification

Appendix D.--Model verification data sets--Continued

01475530 Cobbs Creek at U.S. Highway 1, at Philadelphia, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*05/04/75	1.18	0.22	0.18	100	88	5.5
*05/12/75	1.03	.15	.16	124	104	5.8
05/21/75	.26	.05	.03	113	61	4.9
*05/21/75	.21	.02	.01	48	49	5.8
*06/24/75	2.10	.26	.55	1,325	906	4.7
*06/26/75	.59	.08	.09	81	114	5.8
*06/27/76	.31	.05	.04	105	67	1.5
*07/11/76	.95	.21	.15	273	217	2.2
*06/28/77	2.73	.38	.53	664	575	1.3
*07/25/77	.54	.65	.08	85	73	.9
*08/03/77	.46	.07	.07	159	119	1.5
*08/06/77	1.10	.12	.15	253	250	1.3
*08/22/77	1.12	.24	.18	266	183	2.3
*09/06/77	1.14	.13	.19	185	245	2.2
11/25/77	.36	.10	.06	106	49	8.9
*12/21/77	1.38	.32	.28	126	104	16.0
*03/26/78	2.64	.74	.43	169	120	6.8
*05/08/78	1.20	.22	.18	85	73	4.9
*05/24/78	1.35	.33	.22	165	171	5.5
*06/21/78	.36	.04	.05	44	43	6.5
*07/31/78	.48	.07	.07	106	88	5.0

Total number of verification storms = 19

Means based on verification storms		.23	.19	230	189	4.5

* - Events used in verification

Appendix D.--Model verification data sets--Continued

01475545 Naylor Creek at West Chester Pike near Philadelphia, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*04/03/75	0.45	0.07	0.12	67	72	11.0
*04/24/75	.93	.22	.23	62	78	.8
04/25/75	1.48	.48	.40	243	177	.8
06/24/75	2.17	.47	.69	503	901	1.3
*06/26/75	.48	.09	.13	100	115	2.5
*06/29/75	.34	.08	.10	158	168	1.3
*05/18/76	.46	.08	.10	55	66	.8
*05/18/76	.75	.18	.18	201	197	.6
*06/01/76	1.06	.21	.25	111	146	.9
06/30/76	.34	.06	.08	93	137	.6
07/04/76	.69	.09	.16	130	174	.6
*07/11/76	1.62	.34	.44	332	504	.6
*08/08/76	.43	.07	.10	84	114	.6
*08/09/76	1.70	.35	.42	101	100	.6
*08/13/76	.65	.14	.17	237	288	.6
*08/14/76	.42	.10	.11	181	183	.6
*07/25/77	.28	.03	.07	56	121	.3
*07/25/77	.19	.03	.05	32	50	1.7
*08/03/77	.47	.09	.11	185	186	.6
*09/19/77	1.90	.45	.53	390	551	.3
*09/19/77	.67	.21	.19	185	193	17.0
*09/20/77	.51	.12	.15	195	224	17.0
*03/26/78	.40	.13	.11	105	71	16.0
*03/27/78	.45	.14	.11	46	41	8.0
*04/20/78	.42	.09	.11	145	142	1.0
*05/14/78	.43	.09	.11	101	120	2.7
Total number of verification storms = 22						
Means based on verification storms		.15	.18	142	170	3.9

* - Events used in verification

Appendix D.--Model verification data sets--Continued

01476030 Little Crum Creek at Michigan Avenue, Swarthmore, PA

Date	Storm rainfall (inches)	Direct runoff (inches)	Simulated direct runoff (inches)	Peak discharge (cubic feet per second)	Simulated peak discharge (cubic feet per second)	Base flow (cubic feet per second)
*06/12/75	1.08	0.14	0.12	28	22	1.7
*06/12/75	.41	.06	.04	26	21	7.2
06/13/75	1.43	.40	.57	251	569	4.4
*07/09/75	.31	.03	.03	34	29	.1
07/13/75	2.43	.43	.28	153	80	.6
*08/16/75	.94	.07	.10	38	50	.4
*06/27/76	.49	.05	.05	51	58	.1
*07/11/76	1.36	.11	.16	61	62	6.0
*08/09/76	1.50	.14	.17	29	32	.2
*10/20/76	1.70	.13	.19	38	40	.5
*03/22/77	2.31	.50	.42	159	150	1.0
*04/26/77	.81	.09	.09	33	36	1.0
*06/28/77	1.60	.17	.19	124	106	.8
*07/25/77	.57	.04	.06	41	46	.6
*08/06/77	.49	.06	.05	75	59	.2
*08/14/77	.39	.04	.04	36	37	.4
*08/17/77	.56	.05	.06	44	41	.3
*09/06/77	.52	.05	.06	69	47	.2
*06/07/78	1.21	.21	.14	121	71	1.0
*07/03/78	4.39	.54	.60	110	108	.6
Total number of verification storms = 18						
Means based on verification storms		.14	.14	62	56	1.2

* - Events used in verification

Appendix E.--Station description and rainfall intensities for selected storms for the Trenton, N.J. NOAA rain gage, 1913-77

401300074460000 NOAA RAIN GAGE AT TRENTON, NJ

LOCATION.--Lat 40°13', long 74°46', Mercer County, on Federal Building at State and Carrol Streets in Trenton, NJ

PERIOD OF RECORD.--June 1865 to March 1881, September 1887 to current year (1978).

GAGE.--Weighing gage operated by National Oceanic and Atmospheric Administration. Non-recording gage prior to April 1913. Altitude of gage is 140 ft, from NOAA annual summary. At site 1,500 ft east and 15 ft higher July 1924 to December 1932, same site 47 ft higher April 1913 to July 1924.

EXCESSIVE PRECIPITATION.--Listed below are precipitation amounts classified as excessive by NOAA for all data reduced to five-minute rainfall amounts by NOAA and filed on the USGS WATSTORE system.

Water		Precipitation, in inches, for time interval indicated				
year	Date	5 min	10 min	15 min	30 min	60 min
1913	9/5	0.08	0.23	0.42	1.00	
	9/21	.32	.45	.63	.96	
1914	7/29	.25	.41	.44		
	8/21	.21	.43	.58		
1915	7/2	.16	.46	.85		
	7/2	.26	.30			
	8/4	.09	.22	.46	.82	
	8/5	.10	.29	.52		
1916	7/2-3	.08	.26	.38	.59	
	7/17	.14	.21	.22	.61	
	7/26	.05	.16	.44		
1917	8/16	.15	.40	.79		
	9/1	.06	.10	.28	.75	
1918	7/30	.26	.47	.52	.62	1.30
	8/12	.20	.31	.55	.90	
1919	7/13	.05	.14	.24	.72	
	7/13	.17	.21	.30	.73	
	7/19	.14	.23	.28	.59	
	7/20	.28	.38			
	7/20	.45	.74	.99		
	7/21	.10	.21	.34	.56	
1920	6/17	.31	.63	.71		
	6/30	.19	.50	.96	1.69	
1921	6/27	.08	.30	.74		
		.08	.16	.41	.75	
	8/7	.08	.17	.26	.52	
		.19	.32	.63	.91	
		.08	.17	.44	1.23	
		.11	.18	.34	.64	

Appendix E.--Station description and rainfall intensities for selected storms for the Trenton, N.J. NOAA rain gage, 1913-77--Continued

401300074460000 NOAA RAIN GAGE AT TRENTON, NJ

Water year	Date	Precipitation, in inches, for time interval indicated 5 min	10 min	15 min	30 min	60 min
1922	6/3	0.06	0.13	0.22	0.60	
	8/1	.15	.18	.24	.51	1.09
	8/31	.19	.50	.61		
	9/4	.44	.64	.73		
1923	8/19	.17	.35	.48	1.14	
1924	7/8	.25	.33	.58	.92	1.49
	8/12a	.12	.17	.21	.62	1.30
	9/9	.11	.58	.77	1.20	
1925	9/16	.19	.30			
	9/16	.56	.94			
1926	8/12	.21	.60	.83	1.04	
	8/13	.15	.39	.55		
	8/13	.18	.46	.49		
1927	11/16	.19	.49	.70		
	4/21	.08	.28	.36	.64	1.10
	8/8	.30	.35			
	8/8	.21	.32	.55		
	8/8-9	.05	.20	.43		
1928	6/19	.23	.47	.54		
	7/13	.20	.42	.52		
1929	6/20	.31	.81	1.06		
	9/7	.20	.38	.46	.75	1.47
	9/8	.15	.38	.68		
1930	6/10	.05	.15	.28	.43	1.11
	7/3	.18	.51	.81		
	7/9	.20	.58	.65		
1931	7/10	.25	.57	.78		
	7/10	.18	.39	.49	.65	1.12
	8/10	.38	.77	.96	1.26	1.70
1932	6/27	.25				
	6/27	.26	.65	.89		
	8/18a	.14	.23	.36	1.13	1.90
	8/31	.17	.53	.79	1.08	
	9/2	.28	.63	.87	1.50	
1933	11/1	.07	.20	.27	.44	1.06
	6/12	.33	.55	.70	1.05	1.32
	8/18	.15	.35	.66	1.18	1.25
1934	5/22	.29	.49	.63	.71	.88
	6/12	.17	.27	.46	.49	.49
	6/12	.18	.40	.50	.54	.59
	7/20	.25	.65	.81	.90	.90
	9/17	.10	.22	.35	.73	1.35
	9/23	.17	.35	.53	.84	1.12

Appendix E.--Station description and rainfall intensities for selected storms for the Trenton, N.J. NOAA rain gage, 1913-77--Continued

401300074460000 NOAA RAIN GAGE AT TRENTON, NJ

Water year	Date	Precipitation, in inches, for time interval indicated 5 min	10 min	15 min	30 min	60 min
1935	8/15	0.27	0.88	1.14	1.32	1.35
	9/6	.13	.27	.30	.42	.81
1936	5/13	.29	.47	b	.60	.61
	8/24	.14	.27	b	.57	.71
	9/20	.15	.25	b	.64	.77
1937	6/6	.27	.40	b	.91	1.15
1938	6/26	.28	.50	b	.65	.86
	6/27	.15	.24	b	.50	.55
	7/20	.25	.39	b	.84	1.07
	9/19	.40	.68	b	1.22	1.36
1939	6/30	.48	.88	b	1.68	2.34
	8/18	.59	1.08	b	1.93	1.99
	8/19	.16	.23	b	.45	.90
1940	9/1	.34	.56	b	1.57	2.30
1941	6/17	.42	.76	b	1.45	1.69
1942	7/18	.43	.56	b	.64	.67
	8/16	.30	.44	b	.69	.71
1943	10/17	.16	.29	b	.69	.86
	6/17	.27	.43	b	.65	.70
	8/14	.39	.73	b	.94	.96
1944	6/10	.23	.37	.54	.75	1.40
	9/13	.20	.30	.46	.64	.93
1945	7/2	.48	.85	1.16	1.38	1.58
	7/17	.28	.51	.73	.93	.96
	7/18	.25	.47	.51	.55	.55
	9/11	.51	.81	.88	.88	.88
	9/14	.40	.55	.65	.74	.75
1946	6/11	.28	.44	.50	.78	1.10
	7/22	.33	.53	.63	.63	.68
		.26	.32	.53	.61	.68
	9/24	.29	.53	.72	.94	1.03
1947	6/20	.34	.46	.61	.81	.86
	8/16	.23	.44	.59	1.02	1.98
1948	10/29	.23	.43	.50	.71	1.06
	6/12	.17	.33	.43	.83	1.14
	7/23	.28	.46	.50	.66	.72
1949	7/17	.23	.45	.67	1.20	2.05
	9/5	.36	.56	.72	.94	1.31
1950	7/10	.25	.46	.64	1.13	1.38
	8/3	.20	.34	.45	.76	1.31

Appendix E.--Station description and rainfall intensities for selected storms for the Trenton, N.J. NOAA rain gage, 1913-77--Continued

401300074460000 NOAA RAIN GAGE AT TRENTON, NJ

Water year	Date	Precipitation, in inches, for time interval indicated 5 min	10 min	15 min	30 min	60 min
1951	11/4	0.21	0.33	0.42	0.66	1.22
	7/17	.27	.45	.61	.95	1.00
	8/12	.31	.56	.69	1.00	1.30
	8/21	.33	.55	.65	1.00	1.06
1952	10/7	.21	.30	.32	.45	.51
	10/7	.19	.28	.42	.69	.96
	11/1	.18	.30	.39	.60	.85
	7/20	.34	.52	.61	.89	1.17
	7/21	.35	.60	.82	.92	.98
	8/16	.38	.66	.90	1.21	1.39
	8/16	.30	.45	.47	.48	.48
1953	11/22	.20	.36	.46	.60	.72
	7/6	.29	.57	.83	.93	1.13
	7/19	.46	.69	.80	1.12	1.21
	7/20	.47	.66	.69	.83	.84
	7/23	.19	.24	.30	.54	.96
1954	8/9	.17	.26	.34	.53	.87
	9/11	.16	.30	.36	.57	.86
1955	8/7	.71	1.17	1.68	2.57	2.90
	8/11	.26	.43	.55	.56	.59
	8/13	.14	.21	.29	.55	.91
	8/18	.21	.33	.46	.67	.78
1956	10/14	.21	.35	.43	.67	1.13
	6/17	.34	.53	.55	.63	.72
1957	5/20	.15	.27	.38	.66	.81
	5/26	.25	.29	.32	.33	.33
1958	4/6	.19	.31	.40	.62	1.00
	4/29	.16	.27	.37	.49	.58
	7/27	.20	.37	.52	.60	.90
	8/25	.16	.29	.42	.60	.67
	8/25	.12	.22	.31	.50	.69
1959	6/28	.34	.57	.79	.84	.88
	8/8-9	.38	.50	.62	.80	.95
	8/29	.31	.51	.66	1.01	1.62
	8/30	.24	.32	.38	.44	.52
1960	7/14	.44	.67	.88	1.20	1.45
	7/30	.16	.28	.42	.72	1.27
	9/11-12	.28	.39	.43	.61	.68
1961	7/15	.35	.61	.89	1.60	1.99
1962	8/9	.27	.50	.68	1.08	1.78
	8/28	.28	.50	.72	1.00	1.41
1963	7/20	.65	1.16	1.26	1.32	1.32
		.30	.46	.57	.62	.66

Appendix E.--Station description and rainfall intensities for selected storms for the Trenton, N.J. NOAA rain gage, 1913-77--Continued

401300074460000 NOAA RAIN GAGE AT TRENTON, NJ

Water		Precipitation, in inches, for time interval indicated				
year	Date	5 min	10 min	15 min	30 min	60 min
1964	7/8	0.18	0.32	0.44	0.76	1.26
	7/13	.44	.76	.80	1.10	1.45
	9/11	.19	.30	.41	.63	1.18
1965	7/11	.15	.26	.38	.64	1.05
	7/17	.67	1.17	1.43	1.99	2.20
	8/8	.35	.60	.68	.69	.70
	8/9	.30	.41	.50	.92	1.41
1966	5/19	.15	.25	.36	.56	.81
	5/19	.25	.40	.40	.51	.51
	9/14	.20	.29	.40	.72	.96
	9/21	.21	.27	.30	.57	.86
	9/22	.22	.36	.39	.42	.42
1967	7/10	.27	.34	.38	.70	.94
	7/11	.25	.43	.65	.82	.85
	7/21	.36	.56	.67	1.00	1.72
	8/3	.49	.82	.93	1.41	1.45
1968	6/12	.23	.37	.53	.82	1.14
	6/12	.21	.33	.46	.82	1.12
	8/3	.25	.45	.57	1.08	1.39
1969	6/14	.56	.88	1.11	1.34	1.34
	7/26	.28	.38	.43	.61	.68
	7/27	.21	.35	.51	.82	.89
	9/3	.25	.35	.44	.59	.74
	9/17	.27	.47.	.73	.91	1.01
1970	6/18	.42	.53	.54	.54	.54
	8/23	.24	.36	.44	.79	.95
1971	8/27	.35	.70	.78	1.03	1.25
	8/28	.23	.40	.50	.98	1.60
	9/11	.45	.73	.92	1.00	1.01
	9/13	.26	.37	.41	.46	.63
	9/13	.22	.38	.48	.85	1.34
1972	3/3	.18	.35	.38	.56	.69
	7/13	.18	.26	.29	.52	.73
1973	6/29	.32	.61	.68	.72	.73
	8/15	.36	.53	.55	.60	.70
	9/14			.20	.39	.65
1974	10/29	.11	.22	.24	.38	.54
	7/5	.37	.59	.68	1.09	1.77
	8/9	.29	.51	.61	.82	1.34
1975	7/14	.37		.56		
	7/20		.52		.97	1.50
	9/24			.58	.81	.95
	9/26	.33	.54			

Appendix E.--Station description and rainfall intensities for selected storms for the Trenton, N.J. NOAA rain gage, 1913-77--Continued

401300074460000 NOAA RAIN GAGE AT TRENTON, NJ

Water year	Date	Precipitation, in inches, for time interval indicated 5 min	10 min	15 min	30 min	60 min
1976	10/18	0.18	0.35	0.38	0.76	1.00
	5/11				.42	.69
	5/31	.19	.25	.25		
	6/1	.30	.57	.64	.77	.86
1977	7/12	.31	.57	.60	1.08	1.56
	8/1	.30	.60	.82	1.40	1.81
	9/19	.37	.73	.79	1.01	1.23

a. Defective record not reduceable to five minute intervals.

b. Not computed.

Appendix F.--Supplementary characteristics determined for gaged basins

Characteristic	Station number: 01465770	01465790	01467049	01467083	01467084	01467085	01472174	01472186	01473870	01475300	01475530	01475545	01476030
All drainage channels	35.1	49.7	10.5	73.7	18.4	12.5	10.5	2.9	7.8	34.1	73.9	21.7	13.3
Average available water capacity	7.3	8.1	9.2	7.6	12.5	8.2	8.7	8.2	9.1	8.8	9.3	13.3	10.0
Average channel slope	40	22	35	29	79	66	123	147	77	25	37	55	41
Averave permeability	1.4	1.0	1.3	2.5	2.8	2.5	1.3	1.5	1.7	1.3	1.4	1.3	1.1
Average permeability of A horizen	1.8	1.2	1.3	4.2	4.2	1.4	2.1	3.6	1.4	1.5	1.3	1.3	2.0
Basin slope	194	88	82	202	206	166	286	352	193	160	170	192	158
Longest channel length	3.1	3.5	.6	3.3	1.2	1.3	4.1	1.3	1.4	3.4	3.7	.9	1.1
Main channel length	1.4	2.9	.6	2.8	1.2	1.3	2.3	1.3	1.4	3.4	3.7	.9	1.1
Natural stream channels	6.1	9.7	.6	6.3	1.2	2.1	9.6	2.4	2.5	9.3	4.3	.9	1.1
Sewer inlet density	188	274	339	179	442	57	14	16	153	68	144	219	136
Sewered streets	29.0	40	10	67.4	17.2	10.4	.9	.5	5.3	24.8	69.6	20.8	12.2
Stream magnitude	4	6	1	6	1	1	7	2	2	9	2	1	1
Total outfall area	158	355	98	323	101	38	27	10	4	84	196	84	33

Appendix G.--Cumulative percent area (A), measured impervious area (MI), and effective impervious area (EI) from distance-area histograms

Station number	Area type	Cumulative percent of area type for selected percent of distance from gage to most distant divide																			Summation 5-95
		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	
01465770	A	0.405	1.66	5.59	8.85	12.3	16.2	20.8	26.2	32	38.6	45.3	53	61.8	71.3	80.3	87.2	93.2	97.2	99.2	851
	MI	.280	1.18	4.06	6.61	9.46	13	17.6	23.5	31	40	48.4	56.3	64.4	74.1	83.1	89.4	93.7	97.1	99.1	852
	EI	.267	1.12	4.07	6.55	9.23	12.6	17	22.7	29.7	38.6	46.6	54	61.6	71.2	80.8	86.9	92.1	97.3	99.2	832
01465790	A	.696	3.25	7.29	12.8	18.7	24.9	31.2	37.3	43.1	48.9	55	61.9	68.5	75.5	82.1	87.1	92	96.1	99	945
	MI	.933	3.18	6.39	11.9	18.8	24.6	28	30.4	36.1	46.4	54.8	63	69.2	80.5	85.3	86.2	90.4	96.2	99.1	931
	EI	.933	3.18	6.39	11.9	18.8	24.6	28	30.4	36.1	46.4	54.8	63	69.2	80.5	85.3	86.2	90.4	96.2	99.1	931
01467049	A	1.20	3.61	8.09	13.8	21.9	28.6	36	43.9	50.6	57.1	63.9	70.4	76.4	82.9	89.2	92.8	96	98.4	99.5	1,034
	MI	1.59	4.76	10.6	18.0	28.6	37	45.5	54	59.3	63.5	67.2	70.4	73.5	79.4	85.7	90.5	94.7	97.9	99.5	1,080
	EI	1.37	4.79	11	18.5	29.5	37.7	47.2	56.2	61	64.4	67.8	70.5	73.2	78.8	85.6	90.4	94.5	97.9	99.3	1,090
01467083	A	.477	1.82	3.81	7	10.2	14.2	19	24.5	29.8	35.9	42.7	50.3	58.9	68.2	78.2	87.9	95.1	98.3	99.4	826
	MI	0	.276	2.50	6.10	9.11	14.2	20.2	26.9	31.1	39.3	46.7	54.2	61.5	70.7	80.2	88.8	94.8	98	99.3	844
	EI	0	.276	2.50	6.10	9.11	14.2	20.2	26.9	32.6	39.2	46.7	54.2	61.5	70.7	80.2	88.8	94.8	98	99.3	845
01467084	A	.742	2.52	4.75	7.57	11.3	15.6	20.6	25.7	31.3	37.8	44.8	52.5	60.1	68	75.8	82.3	87.5	92.3	97.1	818
	MI	.694	2.08	3.82	5.56	7.99	11.5	17	22.2	27.8	33.3	39.6	49	58	66.7	74	80.2	85.4	91.7	96.5	773
	EI	.600	2.08	3.92	5.77	7.89	11.1	16.7	21.9	27	32.2	38.2	47.7	57	65.7	73	79.3	84.4	88.8	96.2	759
01467085	A	.664	2.52	5.44	10.7	15	19.9	25.4	31.5	38.8	46.3	54.1	61.6	68.2	74.2	79.4	84.2	88.4	92.4	96.5	895
	MI	.855	4.27	10.3	17.1	23.1	28.2	33.3	37.6	43.6	48.7	55.6	62.4	67.5	71.8	76.1	81.2	86.3	91.5	95.7	935
	EI	1.14	4.42	9.97	17.9	24.8	31	36.4	41.3	47.3	52.8	59.2	65	68.6	71.8	75	79.9	84.6	89.1	94.6	955
01472174	A	.702	2.76	6.51	11.8	17.8	23.2	29.1	35.7	42.5	48.3	55.1	62.4	69.5	76.6	82.5	87.6	92	96.1	98.9	939
	MI	.595	2.23	5.80	11.2	17.1	21.9	29.2	37.4	44.2	46.3	51.3	55.5	59.5	63.5	68.5	73	79.6	89.1	95.3	851
	EI	.595	2.23	5.80	11.2	17.1	21.9	29.2	37.4	44.2	46.3	51.3	55.5	59.5	63.5	68.5	73	79.6	89.1	95.3	851
01472186	A	.752	2.83	5.68	9.28	13.1	17.4	22.9	28.8	36.6	44.3	51.9	60.2	68.6	75.4	81.3	87.9	93.4	97.9	99.2	897
	MI	.606	2.42	5.45	9.09	12.7	17	22.4	28.5	36.4	44.2	51.5	60	68.5	75.2	81.2	87.9	93.3	98.2	99.4	894
	EI	.606	2.42	5.45	9.09	12.7	17	22.4	28.5	36.4	44.2	51.5	60	68.5	75.2	81.2	87.9	93.3	98.2	99.4	894
01473870	A	.678	2.98	5.96	9.49	14.1	18.6	25.1	31	35.5	41.5	47.6	53.7	60.6	66.9	74.1	82.1	89.2	94.6	98.4	852
	MI	0	1.54	3.08	4.62	6.15	7.69	12.3	16.9	21.5	26.2	30.8	35.4	43.1	50.8	63.1	75.4	86.2	92.3	96.9	674
	EI	0	0	0	0	0	0	0	0	2.27	4.55	6.82	11.4	18.2	29.5	45.5	63.6	79.5	88.6	95.5	445
01475300	A	.559	2.40	5.44	9.67	14.9	20.7	27	33.7	40.5	47.9	54.5	61.8	68.9	78	85.8	91.8	96.9	98	99.4	938
	MI	.264	1.20	2.73	4.96	7.72	10.9	14.9	19.4	24.3	29.7	35.7	46.2	55.9	70.3	82	89.9	94.9	97.6	99.3	778
	EI	.116	.579	1.31	2.55	4.13	5.95	9.19	13.4	17.5	22.6	28.4	39.2	48.7	64.8	78.3	86.9	93.2	96.8	99	713
01475530	A	.873	3.14	6.57	10	13.7	19.4	23.8	29.3	33.6	38.4	44.5	52.3	59.2	66.6	73.9	80.9	87.9	94	98.2	836
	MI	1.05	3.53	7.01	10.5	14.3	18.9	23.8	28.7	32.9	37.4	43.4	50.5	57.1	65.1	73.3	81.1	88.5	94.4	98.5	830
	EI	.300	.682	50.2	8.82	11.7	17.3	24.2	31.2	36.6	42.5	51.1	60.7	68.5	73.5	76.7	80.4	85.3	92.1	96.9	865
01475545	A	.615	2.75	5.34	8.69	12.5	16.6	20.9	25	30.8	38.4	46.9	56.6	68	77.9	86.3	91.3	94.8	97.1	99	879
	MI	.652	2.98	5.78	9.22	11.9	15	18.5	22.3	27.9	36	45.2	55.7	68.2	79.8	89.3	93.6	96.7	98.6	99.6	877
	EI	.639	2.97	5.76	9.19	11.9	15	18.5	22.3	27.8	35.9	45.1	55.6	68.1	79.7	89	93.6	96.7	98.7	99.6	876
01476030	A	.471	2.17	4.24	6.97	10.7	14.9	19.9	25.4	31.4	38.2	45	52.3	59.1	66.1	73.6	79.8	86.8	93	98.4	808
	MI	.546	2.52	4.94	8.11	12.5	17.3	23.3	30.4	38.1	41.4	49.2	56.3	63	68.5	74.3	79.9	86.8	92.9	98.2	848
	EI	.591	2.62	5.07	8.27	12.8	17.9	24.1	31.3	39.2	48.1	54.6	59.7	64.5	69.5	75	80.2	87	93	98.1	872