APPLICATION OF REMOTELY SENSED LAND-USE INFORMATION TO IMPROVE ESTIMATES OF STREAMFLOW CHARACTERISTICS

By Edward J. Pluhowski

U.S. Geological Survey
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Land-use data derived from high-altitude photography and satellite imagery are presented for 49 basins in Delaware, and eastern Maryland and Virginia. Applying multiple regression techniques to a network of gaging stations monitoring runoff from 39 of the basins, it was demonstrated that land-use data from high-altitude photography provides an effective means of significantly improving estimates of streamflow. Forty streamflow-characteristic equations for incorporating remotely sensed land-use information, were compared with a control set of equations using map derived land cover. Significant improvement was detected in six equations where Level I data was added and in five equations where Level II information was utilized. Only four equations were improved significantly using land-use data derived from Landsat imagery Significant losses in accuracy due to the use of remotely sensed land-use information were detected only in estimates of flood peaks. Losses in accuracy for flood peaks were probably due to land cover changes associated with temporal differences among the primary land-use data sources.

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2. NORFOLK AND ENVIRONS: A LAND USE PERSPECTIVE by Robert H. Alexander, Peter J. Buzzanell, Katherine A. Fitzpatrick, Harry F. Lins, Jr., and Herbert K. McGinty III.

3. TOWARD A NATIONAL LAND USE INFORMATION SYSTEM by Edward A. Ackerman and Robert H. Alexander.

4. GEOGRAPHIC INFORMATION SYSTEM DEVELOPMENTS ASSOCIATED WITH THE CARETS PROJECT by Robin G. Fegeas, Katherine A. Fitzpatrick, Cheryl A. Hallam, and William B. Mitchell.

5. INTERPRETATION, COMPILATION AND FIELD VERIFICATION PROCEDURES IN THE CARETS PROJECT by Robert H. Alexander, Peter W. DeForth, Katherine A. Fitzpatrick, Harry F. Lins, Jr., and Herbert K. McGinty III.

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7. LAND USE INFORMATION AND AIR QUALITY PLANNING: AN EXAMPLE OF ENVIRONMENTAL ANALYSIS USING A PILOT NATIONAL LAND USE INFORMATION SYSTEM by Wallace E. Reed and John E. Lewis.

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12. USER EVALUATION OF EXPERIMENTAL LAND USE MAPS AND RELATED PRODUCTS FROM THE CENTRAL ATLANTIC TEST SITE by Herbert K. McGinty III.

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Multiply English units	*by*	*To obtain SI units*
in (inches)	25.4	mm (millimeters)
ft (feet)	3.048×10^{-1}	m (meters)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.59	km^2 (square kilometers)
acres	4.047×10^{-1}	ha (hectares)
ft^3/s (cubic feet per second)	2.832×10^{-2}	m^3/s (cubic meters per second)
^oF (degrees Fahrenheit)	5/9 after subtracting 32	^oC (degrees Celsius)

APPLICATION OF REMOTELY SENSED LAND-USE INFORMATION TO IMPROVE ESTIMATES OF STREAMFLOW CHARACTERISTICS

by Edward J. Pluhowski

Abstract

Land-use data derived from high-altitude photography and satellite imagery are presented for 49 basins in Delaware, and eastern Maryland and Virginia. Based on 1:100,000 scale maps from high-altitude photography, basin land cover was extracted at the generalized Level I and the more detailed Level II classification categories. Level I land-use data summaries were prepared for 46 of the basins using the 1:250,000 scale maps derived from Landsat imagery. Land cover in the basins ranged from 93.9 percent urban at Little Falls Branch near Bethesda, Maryland, to 96.2 percent agricultural at Morgan Creek near Kennedyville, Maryland.

Applying multiple regression techniques to a network of gaging stations monitoring runoff from 39 of the basins, it was demonstrated that land-use data from high-altitude photography provides an effective means of significantly improving estimates of streamflow. Forty streamflow-characteristics equations incorporating remotely sensed land-use information, were compared with a control set of equations using map derived land cover. Siginificant improvement was detected in six equations where Level I data was added and in five equations where Level II information was utilized. Only four equations were improved significantly using land-use data derived from Landsat imagery. Significant losses in accuracy due to the use of remotely sensed land-use information were detected only in estimates of flood peaks. Losses in accuracy for flood peaks were probably due to land cover changes associated with temporal differences among the primary land-use data sources.

INTRODUCTION

Since 1888 when systematic streamflow records were first collected by the U.S. Geological Survey, more than 16,000 sites have been gaged in the United States (Carter and Davidian, 1968). Surface-water data are used for many purposes such as evaluating the water supply available to a town or city, designing bridges and culverts, or assessing the flood potential along a particular watercourse. A well designed stream-gaging network is of considerable value in studies attempting to assess man's impact on the hydrologic cycle. For example, urbanization will change streamflow patterns because of street paving, home and building construction, and the installation of storm sewers. These and other activities needed to develop urban environments alter important basin characteristics such as infiltration rates, generated volume of storm flow, and the time required for water to move from any point in the basin to stream channels. Ideally, continuous streamflow monitoring would be required before, during, and after development to appraise the impact of urbanization on a particular watercourse.

The general objective of the streamflow data program is to provide users with water data at any site on any stream. Clearly, it is neither practical nor desirable to gage every site where data are required. It is, however, frequently possible to transfer streamflow information on unregulated streams to other natural stream sites in areas of similar climatic and geologic settings. Thomas and Benson (1970) outlined a multiple-regression method of streamflow generalization. This procedure involves regressing a single streamflow characteristic (such as mean annual discharge) against the physiographic and climatologic characteristics of gaged basins within a selected region. Equations obtained from the multiple-regression procedure contain only statistically significant basin characteristics, and the regression equations enable users to compute streamflow patterns at any site on natural streams within the region.

Using basin characteristics derived from climatologic data and maps, detailed formulas were obtained by the multiple-regression procedure for a wide range of streamflow characteristics throughout the Nation. The results of these investigations, published in open-file reports, are available at the 46 district offices of the U.S. Geological Survey except Hawaii (Benson and Carter, 1973). The purpose of this investigation is to investigate the potential improvement of streamflow estimates by using land-use information obtained from high-altitude photographs and satellite images. Remotely sensed data to be tested were obtained from U.S. Geological Survey land-use maps compiled by the Central Atlantic Regional Ecological Test Site (CARETS) project.

CARETS PROJECT

The CARETS project was sponsored jointly by the National Aeronautics and Space Administration (NASA) and the U.S. Geological Survey. The principal objective of CARETS was to test the extent to which various remote sensor data systems could be used as input to a regional land-resources information data base (Alexander, 1974). The CARETS region covers 46,434 mi^2 (74,712 km^2) which includes Delaware, southern New Jersey, southeastern Pennsylvania, District of Columbia, and eastern Maryland and Virginia (fig. 1).

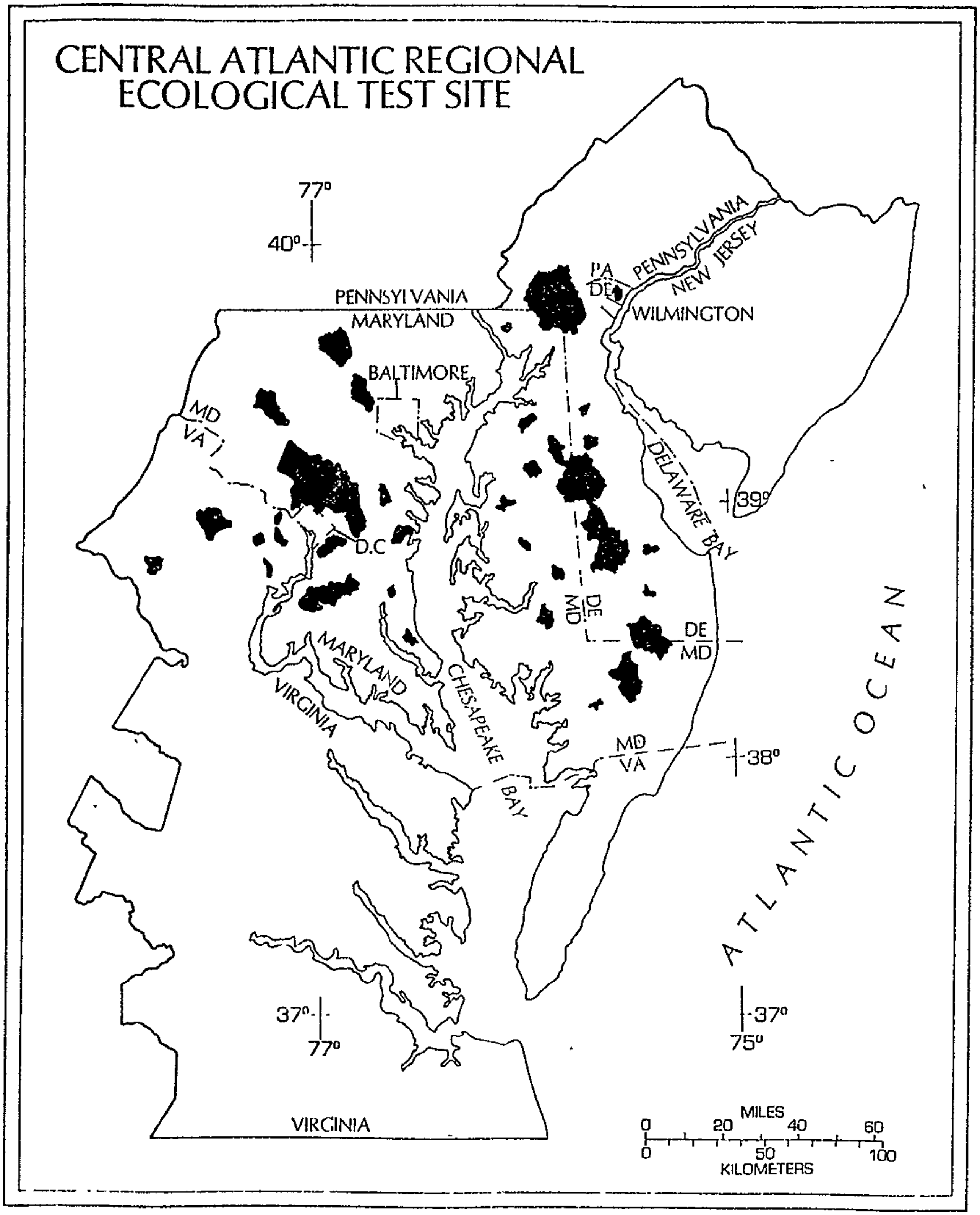

Figure 1. -- Map of CARETS area showing location of basins for which land use was delineated.

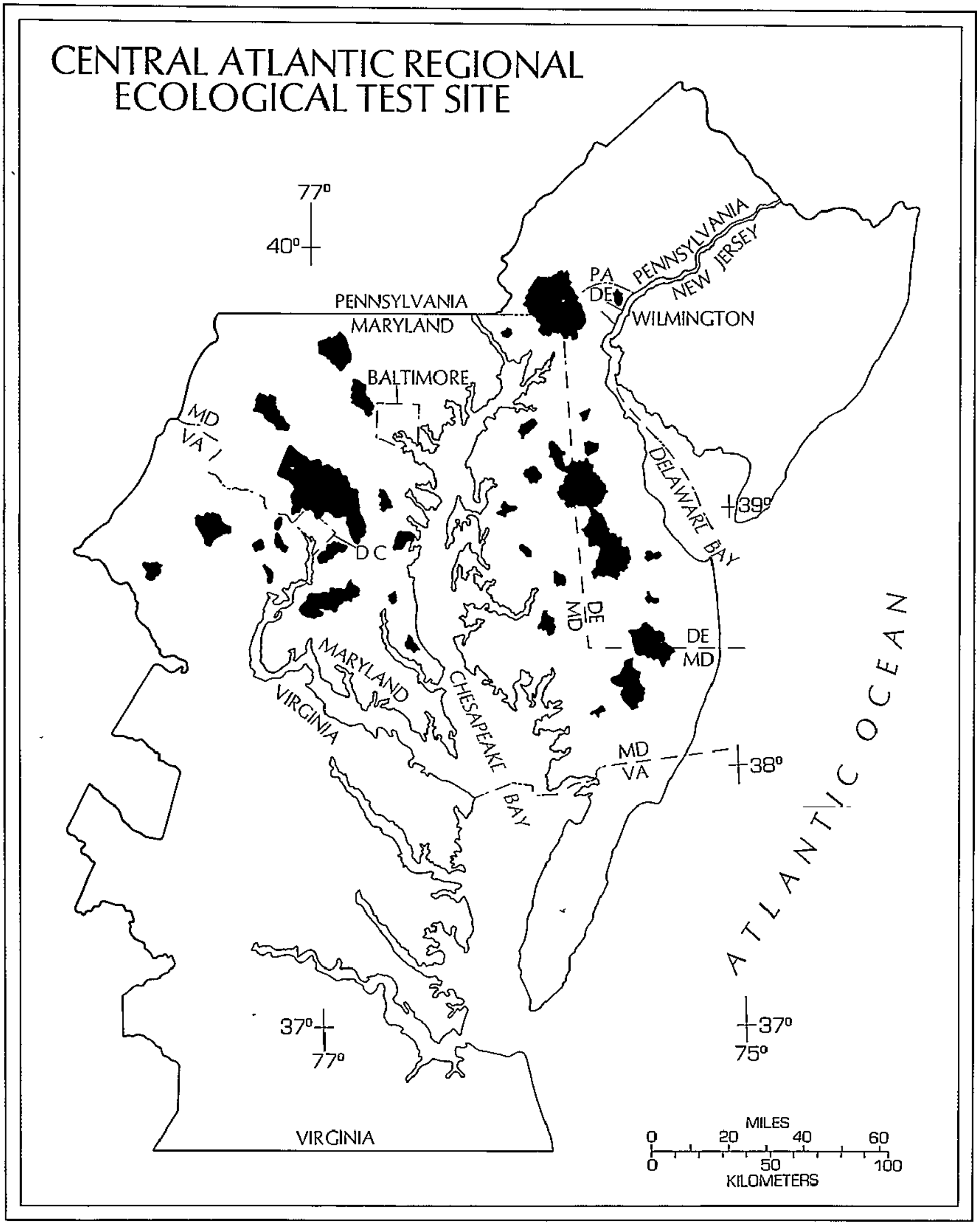

Figure 1. -- Map of CARETS area showing location of basins for which land use was delineated.

NASA aircraft flown at altitudes of about 60,000 ft (18,300 m) provided color and color infrared photographs of the site in 1970 and again in 1972. The bulk of the high-altitude land-use analysis was done using the 1970 aerial photographs. However, parts of the site were masked by clouds in the 1970 high-altitude photographs and other aerial photographs taken as close as possible to the dates of the 1970 missions were required to complete land-use mapping of the site. Landsat-1 imagery was available at 18-day intervals following launching of the satellite in July 1972. Land-use mapping predicated on satellite imagery was derived from Landsat-1 data obtained principally during September and October 1972 (K. Fitzpatrick, oral commun., 1976).

Photointerpreters examined each piece of film or imagery for the major land-use types such as urban land, agricultural land, forests, wetlands, or water. Urban land is recognized by the patterns of buildings, houses, road networks, railroads, and other man-made features. The complex urban setting contrasts strongly on high-altitude photographs and images with the less complicated appearance of agricultural fields, forests, wetlands, and water.

Land-use maps based on high-altitude photographs were produced at a scale of 1:100,000. Owing to resolution differences between Landsat imagery and high-altitude photographs, land-use maps derived from satellite imagery were prepared at a scale of 1:250,000. Forty eight sheets depicting land use of the CARETS area at a scale of 1:100,000 and eight sheets at a scale of 1:250,000 have been released to the U.S. Geological Survey open files, along with many additional map types to assist users in applying the data to land-use planning and environmental interpretation (Alexander and others, 1975).

LAND-USE CLASSIFICATION SYSTEM

The classification system used in the CARETS project was one developed by a special interagency committee (R. Alexander, written commun., 1976) later slightly modified into the USGS Land-Use Classification System for use with remote-sensor data (Anderson and others, 1972). The scheme is a multilevel, hierarchical classification system which specifies the first two levels (table 1), and leaves the more detailed levels for later definition. Level I contains generalized categories suitable for delineation from satellite imagery. Level II yields greater detail within each Level I category and is most suitably obtained using high-altitude photographs as a primary source.

Table 1. -- Land-use categories used in CARETS data base

Level I Categories	Level II Category Numbers and Titles
URBAN & BUILT-UP	11-Residential 12-Commercial and services 13-Industrial 14-Extractive 15-Transportation, communications, and utilities 16-Institutional 17-Strip and clustered settlement 18-Mixed 19-Open and other
AGRICULTURAL	21-Cropland and pasture 22-Orchards, groves, bush fruits, vineyards, and horticultural areas 23-Feeding operations 24-Other
FOREST LAND	41-Heavy crown cover (40% & over) 42-Light crown cover (10% to 40%)
WATER	51-Streams and waterways 52-Lakes 53-Reservoirs 54-Bays and estuaries 55-Other
NONFORESTED WETLAND	61-Vegetated 62-Bare
BARREN LAND	72-Sand other than beaches 73-Bare exposed rock 74-Beaches 75-Other

LAND USE IN SELECTED BASINS

Using maps prepared in accordance with the CARETS classification system (table 1), land use was defined for selected basins listed in table 2. The basins for which land-use information is presented are in the northwest and north-central part of the CARETS region (fig. 1). They represent a broad spectrum of land cover ranging from predominantly agricultural in the Delmarva Peninsula to urban in the Washington-Baltimore-Wilmington corridor. Land-use data were obtained by drawing the boundaries of each selected basin on clear plastic sheets. These basin outlines, prepared at scales of 1:100,000 or 1:250,000, were used as overlays on CARETS land-use maps. The percentage of a basin ascribed to any particular category was determined manually using a dot planimeter. The dot planimeter is a uniform grid of dots on a clear plastic sheet which was placed over the basin boundary overlay. Land use beneath each dot was recorded, the number of dots subtotaled by category, each category subtotal was then divided by the sum total of dots within the basin boundaries, and the result multiplied by 100 to yield percent.

Land Use Based on High-Altitude Photographs

Land-use information for 49 basins based on high-altitude photographs is summarized in tables 3 and 4 at Levels I and II respectively. At the 1:100,000 scale used to compile tables 3 and 4, the smallest depictable area is about 10 acres (4 hectares), or the equivalent of a square 656 ft (200 m) on a side (Alexander, 1975, written communication). Table 3, which shows generalized Level I land-use categories, is a compilation of the more detailed Level II category listings in table 4.

Table 2. -- Drainage basins analyzed for land use and gaging stations used in multiple regression analysis.

Station No.	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record analyzed (water years)
01477800	Shellpot Creek at Wilmington, Del.*	39°45'39"	75°31'10"	7.46	1945-67
01478000	Christina R. at Coochs Bridge Del.*	39°38'16"	75°43'46"	20.5	1943-67
01478500	White Clay Creek above Newark, Del.*	39°42'50"	75°45'35"	66.7	1952-59, 1962-67
01479000	White Clay Creek nr. Newark, Del.	39°42'00"	75°41'10"	87.8	
01483200	Blackbird Creek at Blackbird, Del.*	39°21'58"	75°40'10"	3.85	1952-56**,1957-67
01483500	Leipsic River nr. Cheswold, Del.*	39°13'58"	75°37'57"	9.35	1932-33,1943-57, 1958-67**
01484300	Sowbridge Branch nr. Milton, Del.*	38°48'51"	75°19'39"	7.08	1956-67
01484500	Stockley Branch nr. Stockley, Del.*	38°38'19"	75°20'31"	5.24	1943-67
01485000	Pocomoke River nr. Willards, Md.*	38°23'20"	75°19'30"	60.5	1949-67
01485500	Nassawango Creek nr. Snow Hill, Md.*	38°13'45"	75°28'20"	44.9	1949-67
01486000	Nanokin Brook nr. Princess Ann, Md.*	38°12'50"	75°40'18"	5.8	1951-67
01486500	Beaverdam Creek nr. Salisbury, Md.*	38°21'05"	75°34'11"	19.5	1930-33,1934-35,1936-67
01487000	Nanticoke River nr. Bridgeville, Del.*	38°43'42"	75°33'44"	75.4	1943-67
01487500	Trap Pond Outlet nr. Laurel, Del.*	38°31'40"	75°29'00"	16.7	1951-67
01488500	Marshy Hope Creek nr. Adamsville, Del.*	38°51'00"	75°40'29"	44.8	1943-67
01489000	Faulkner Br. at Federalsburg, Md.*	38°42'45"	75°47'35"	7.1	1950-67
01490000	Chicamacomico River nr. Salem, Md.*	38°30'45"	75°52'50"	15.0	1951-67
01491000	Choptank River nr. Greensboro, Md.*	38°59'50"	75°47'10"	113	1948-67
01492000	Beaverdam Branch at Matthews, Md.*	38°48'40"	75°58'15"	5.85	1950-67
01492500	Salle Harris Cr. nr. Carmichael, Md.*	38°57'55"	76°06'30"	8.09	1951-56,1957-67**
01493000	Unicorn Branch nr. Millington, Md.*	39°15'00'	75°51'40"	22.3	1948-67
01493500	Morgan Creek nr. Kennedyville, Md.*	39°16'50"	76°00'55"	10.5	1951-67
01494000	Southeast Creek at Church Hill, Md.*	39°07'57"	75°58'51"	12.5	1951-56,1957-65**

Table 2. -- Drainage basins analyzed for land use -- Continued

Station No.	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record analyzed (water years)
01495000	Big Elk Creek at Elk Mills, Md.*	39°39'26"	75°49'20"	52.6	1932-67
01495500	Little Elk Creek at Childs, Md.*	39°38'30"	75°52'00"	26.8	1949-58
01496000	Northeast Creek nr. Leslie, Md.	39°37'40"	75°56'40"	24.3	
01579000	Basin Run at Liberty Grove, Md.*	39°39'30"	76°06'10"	5.31	1948-58,1965-67**
01586000	N. Br. Patapsco R. at Cedarhurst, Md.*	39°30'00"	76°53'00"	56.6	1945-67
01589300	Gwynns Falls at Villa Nova, Md.*	39°20'43"	76°44'01"	32.5	1957-67
01590000	North River nr. Annapolis, Md.*	38°59'09"	76°37'2[illegible]"	8.5	1932-67
No gage	Rhode River nr. Galesville, Md.	38°52'00"	76°31'00"	14.8+	
01591000	Patuxent River nr. Unity, Md.*	39°14'18"	77°03'23"	34.8	1944-67
01594500	Western Branch nr. Largo, Md.*	38°52'34"	76°47'54"	30.2	1950-67
01594600	Cocktown Cr. nr. Huntington, Md.*	38°38'27"	76°38'07"	3.85	1957-67
01594800	St. Leonard Cr. nr. St. Leonard, Md.	38°26'57"	76°29'43"	6.73	
01645200	Watts Branch at Rockville, Md.*	39°05'03"	77°10'38"	3.70	1957-67
01646200	Scott Run nr. McLean, Va.	38°57'32"	77°12'21"	4.69	
01646550	Little Falls Br. nr. Bethesda, Md.*	38°57'27"	77°06'31"	4.1	1944-59,1960-61,**1961-67
01648000	Rock Cr. at Sherrill Dr., Washington, D.C.*	38°58'21"	77°02'25"	62.2	1928-67
01649500	N.E. Br. Anacostia R. at Riverdale, Md.*	38°57'37"	76°55'34"	72.8	1938-67
01650500	N.W. Br. Anacostia R. nr. Colesville, Md.*	39°03'55"	77°01'48"	21.1	1924-67
01652610	Holmes Run nr. Annandale, Va.	38°50'47"	77°10'28"	7.10	
01653500	Henson Creek at Oxon Hill, Md.*	38°47'05"	76°58'42"	16.7	1948-67
01653900	Accotink Cr. nr. Fairfax, Va.	38°48'46"	77°13'43"	23.5	
01655500	Cedar Run nr. Warrenton, Va.*	38°44'30"	77°47'15"	13.0	1950-67
01656800	Cub Run nr. Chantilly, Va.	38°54'30"	77°28'01"	7.13	
01656940	Cub Run at Lee Highway nr. Chantilly, Va.	38°49'59"	77°27'50"	39.6	

Table 2. -- Drainage basins analyzed for land use -- Continued

Station No.	Station name	Latitude	Longitude	Drainage area (mi²)	Period of record analyzed (water years)
01657800	Giles Run nr. Woodbridge, Va.	38°40'48"	77°13'36"	4.54	
01658000	Mattawoman Cr. nr. Pomonkey, Md.*	38°35'45"	77°03'25"	57.7	1950-67

*Station used in regression analyses.

**Annual maximum discharge only.

+ Includes entire drainage basin above confluence with West River.

Table 3.--Level I land-use classifications, in percent, for selected basins in Delaware, eastern Maryland and Virginia. (Based on high-altitude photography).

Index No. (fig. 2)	STATION NAME	LEVEL I Categories					
		URBAN	AGRICUL-TURE	FOREST	WATER	WETLAND	BARREN
4778	Shellpot Creek at Wilmington, Del.*	84.9	3.5	11.0	0.6	0	0
4780	Christiana River at Coochs Bridge, Del.*	20.9	59.9	19.2	0	0	0
4785	White Clay Creek above Newark, Del.*	3.0	78.0	19.0	0.05	0	0
4790	White Clay Creek nr. Newark, Del.	11.1	69.7	19.1	0	0	0
4832	Blackbird Creek at Blackbird, Del.*	0	61.6	37.6	0.8	0	0
4835	Leipsic River near Cheswold, Del.*	0	82.3	17.7	0	0	0
4843	Sowbridge Branch near Milton, Del*	0	46.9	52.5	0.6	0	0
4845	Stockley Branch at Stockley, Del.*	1.3	56.5	42.2	0	0	0
4850	Pocomoke River near Willards, Md *	0.2	49.6	50.2	0	0	0
4855	Nassawango Creek near Snow Hill, Md.*	0.2	20.2	79.6	0	0	0
4860	Manokin Br. near Princess Ann, Md.*	0	31.6	68.4	0	0	0
4865	Beaverdam Creek near Salisbury, Md.*	5.1	44.7	49.8	0.4	0	0
4870	Nanticoke River near Bridgeville, Del.*	1.1	57.6	41.3	0	0	0

Table 3. --Level I land-use classifications, in percent, for selected basins in Delaware, eastern Maryland and Virginia--continued

Index No. (fig.2)	STATION NAME	LEVEL I Categories					
		URBAN	AGRICUL-TURE	FOREST	WATER	WETLAND	BARREN
4875	Trap Pond Outlet near Laurel, Del.*	0	26.3	72.8	0.6	0.3	0
4885	Marshy Hope Cr near Adamsville, Del.*	0.1	58.0	41.9	0	0	0
4890	Faulkner Branch at Federalsburg, Md.*	0	72.5	27.5	0	0	0
4900	Chicamacomico River, near Salem, Md.*	0	53.0	46.8	0.2	0	0
4910	Choptank River near Greensboro, Md.*	0.1	55.8	43.9	0	0.2	0
4920	Beaverdam Branch at Matthews, Md.*	0	71.2	28.8	0	0	0
4925	Sallie Harris Cr.near Carmichael, Md.*	0	67.9	32.1	0	0	0
4930	Unicorn Branch near Millington, Md.*	0.4	70.1	29.2	0.3	0	0
4935	Morgan Creek near Kennedyville, Md.*	0	96.2	3.8	0	0	0
4940	Southeast Cr.at Church Hill, Md.*	0	73.5	26.5	0	0	0
4950	Big Elk Creek at Elk Mills,Md.*	1.1	85.9	13.0	0	0	0
4955	Little Elk Cr. at Childs, Md.*	1.2	79.5	18.3	0 1	0.9	0

Table 3. --Level I land-use classifications, in percent, for selected basins in Delaware, eastern Maryland and Virginia--Continued

Index No. (fig. 2)	STATION NAME	LEVEL I Categories					
		URBAN	AGRICULTURE	FOREST	WATER	WETLAND	BARREN
4960	Northeast Creek nr. Leslie, Md.	4.0	80.1	15.9	0	0	0
5790	Basin Run at Liberty Grove, Md.*	1.9	73.4	24.7	0	0	0
5860	North Branch Patapsco River at Cedarhurst, Md.*	3.6	70.9	25.3	0.1	0	0.1
5893	Gwynns Falls at Villa Nova, Md.*	35.4	23.7	40.0	0	0	0.9
5900	North River near Annapolis, Md.*	0	33.0	67.0	0	0	0
5905	Rhode River nr. Galesville, Md.+	3.7	39.7	42.9	12.2	1.5	0
5910	Patuxent River near Unity, Md.*	1.5	66.3	32.2	0	0	0
5945	Western Branch near Largo, Md.*	18.5	38.6	42.9	0	0	0
5946	Cocktown Creek near Huntington, Md.*	1.6	57.7	40.7	0	0	0
5948	St. Leonard Creek near St. Leonard, Md.*	0	18.9	81.1	0	0	0
6452	Watts Branch at Rockville, Md.*	42.5	40.9	16.6	0	0	0
6462	Scott Run near McLean, Va.	55.6	9.6	34.8	0	0	0
64655	Little Falls Branch near Bethesda, Md.*	93.9	0	6.1	0	0	0
6480	Rock Creek at Sherrill Drive, Washington, D.C.*	53.3	26.1	20.3	0.3	0	0

Table 3. --Level I land-use classifications, in percent, for selected basins in Delaware, eastern Maryland and Virginia--Continued

Index No. (fig.2)	STATION NAME	LEVEL I Categories					
		URBAN	AGRICUL-TURE	FOREST	WATER	WETLAND	BARREN
6495	N.E. Br. Anacostia River at Riverdale, Md.*	45.1	15.8	38.9	0.2	0	0
6505	N.W Br. Anacostia River near Colesville, Md.*	26.0	42.4	31.6	0	0	0
65261	Holmes Run near Annandale, Va.	67.9	1.3	30.8	0	0	0
6535	Henson Creek at Oxon Hill, Md.*	63.2	4.8	32.0	0	0	0
6539	Accotink Cr. near Fairfax, Va.	71.1	8.6	20.2	0	0	0
65[illegible]	Cedar Run near Warrenton, Va.*	1.9	63.1	3[illegible]	0.4	0	0
6568	Cub Run near Chantilly, Va.	49.9	28.0	22.1	0	0	0
65694	Cub Run at Lee Highway near Chantilly, Va.	18.5	46.9	34.0	0	0	0
6578	Giles Run near Woodbridge, Va.	11.8	33.3	54.9	0	0	0
6580	Mattawoman Cr.nr. Pomonkey,Md.*	7.2	24 7	68.0	0.1	0	0

*Station used in regression analyses

+Includes entire drainage basin above confluence with West River.

Table 4. — Level II land-use classifications, in percent, for selected basins in Delaware, eastern Maryland and Virginia (Based on high-altitude photography).

Category Number	Level II Category Description	Shellpot Cr. at Wilmington, Del. #4778	Christiana R. at Coochs Br. Del. #4780	White Clay Cr. above Newark, Del. #4785	White Clay Cr. near Newark, Del. #4790	Blackbird Cr. at Blackbird, Del. #4832	Leipsic R. nr. Chreswald, Del. #4835	Sowbridge Br. nr. Milton, Del. #4843	Stockley Br. at Stockley, Del. #4845	Pocomoke R. nr Willards, Md. #4850	Nassawango Cr. nr. Snow Hill, Md. #4855	Manokin Br. nr. Princess Anne, Md. #4860	Beaverdam Cr. nr. Salisbury, Md. #4865
////	URBAN	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
11	Residential	69.8	15.0	1.8	7.1						0.1		1 1
12	Commercial	2.9	0.3	0.3	0.8								
13	Industrial		2.0	0.3	1.3								
14	Extractive		0.1										
15	Transportation	1.5	1.5	0.1	0.1								3.2
16	Institutional	5.4	0.9	0.2	0.9				1.3				
17	Strip or clustered		0.4							0.2	0.1		0.8
18	Mixed	0.7			0.3								
19	Open or other	4 6	0.7	0.3	0.5								
////	AGRICULTURE	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
21	Cropland & pasture	3.5	59.9	78.0	69.7	61.6	82.3	46.5	56.5	49.4	19.2	31.6	44.3
22	Orchards												
23	Feeding operations										1.0		0.4
24	Other							0.4		0 2			
////	FORESTLAND	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
41	Heavy crown cover	10.1	18.2	18.5	18.7	37 6	17.5	51.8	42.2	49.3	74.3	67.9	47.9
42	Light crown cover	0.9	1.0	0.5	0.4		0.2	0.7		0 9	5.3	0.5	1.9
////	WATER	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
52	Lakes							0.6					
53	Reservoirs	0.6		0.05	0.1	0.8							0.4
54	Bays and estuaries												
////	WETLANDS	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
61	Vegetated				0 1								
////	BARREN LAND	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
75	"Other"												

Table 4. -- Level II land-use classifications, in percent, for selected basins in Delaware, eastern Maryland and Virginia (Based on high-altitude photography). -- Continued.

Category Number	Level II Category Description	Nanticoke R. nr. Bridgeville Del. #4870	Trap Pond outlet nr. Laurel, Del. #4875	Marshyhope Cr. nr. Adamsville Del. #4885	Faulkner Br. at Federalsburg Md. #4890	Chicamacomico R. nr. Salem Md. #4900	Choptank R. nr. Greensboro Md. #4910	Beaverdam Br. at Matthews Md. #4920	Sallie Harris nr. Carmichael Md. 4925	Unicorn Br. nr. Millington Md. #4930	Morgan Cr. nr. Kennedyville Md. #4935	Southeast Cr. at Church Hill Md. #4940	Big Elk Cr. at Elk Mills Md. #4950
////	URBAN	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
11	Residential	0.6											0.3
12	Commercial	0.1											
13	Industrial												
14	Extractive												
15	Transportation												
16	Institutional												0.2
17	Strip or clustered	0.4		0.1			0.1			0.4			0.6
18	Mixed												
19	Open or other												
////	AGRICULTURE	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
21	Cropland & pasture	57 4	26.1	58.0	72.5	53.0	55.8	71.2	67 9	70.1	96.2	73.5	85.9
22	Orchards	0.1											
23	Feeding operations												
24	Other	0.1	0.2										
////	FORESTLAND	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
41	Heavy crown cover	41.2	63.1	41 7	27.5	44.0	43.0	28.8	32.1	27.7	3.8	26.3	12.9
42	Light crown cover	0.1	9 7	0.2		2.8	0.9			1.5		0.2	0.1
////	WATER	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
52	Lakes					0.2				0.3			
53	Reservoirs		0.6										
54	Bays and estuaries												
////	WETLANDS	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
61	Vegetated		0.3				0.2						
////	BARREN LAND	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
75	"Other"												

Table 4. -- Level II land-use classifications, in percent, for selected basins in Delaware, eastern Maryland and Virginia (Based on high-altitude photography) -- Continued.

Category Number	Level II Category Description	Little Elk Cr at Childs Md. #4955	Northeast Cr nr Leslie Md. #4960	Basin Run at Liberty Grove Md #5790	N Br. Patapsco R. at Cedarhurst Md. #5860	Gwynns Falls at Villa Nova Md. #5893	North River nr Annapolis Md. #5900	Rhode River nr Galesville Md. #5905	Patuxent R. nr Largo Md. #5910	Western Br. nr Largo Md. #5945	Cocktown Cr. nr Huntington Md. #5946	St. Leonard Cr. nr St. Leonard Md. #5948	Watts Branch at Rockville Md. #6452
////	URBAN	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
11	Residential	0.4	0 5	1.9	1 7	26.9		3.5	1.0	12.3			26.2
12	Commercial				0.6	2 8			0.1	1 4			7.2
13	Industrial				0.5	0.1							
14	Extractive				0.1	0.3							
15	Transportation		0 7			0.2				0.5			1.8
16	Institutional					2 6		0 2		1.9			5 0
17	Strip or clustered	0.4	2 8		0 6	0.4			0.4	0 3	1 6		
18	Mixed	0 4			0 1								
19	Open or other					2.1				2 1			2.3
////	AGRICULTURE	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
21	Cropland & pasture	79.5	80.1	73.4	70 9	23 7	33.0	39.7	66.3	38.6	57.7	18.9	40.9
22	Orchards												
23	Feeding operations												
24	Other												
////	FORESTLAND	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
41	Heavy crown cover	15.2	12.1	22 7	23.7	33.3	67.0	42.9	31.8	41.4	40.7	80.7	11.8
42	Light crown cover	3.1	3.8	2.0	1 6	6 7			0.4	1 5		0.4	4.8
////	WATER	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
52	Lakes												
53	Reservoirs	0.1			0.1								
54	Bays and estuaries							12.2					
////	WETLANDS	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
61	Vegetated	0.9						1.5					
////	BARREN LAND	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
75	"Other"				0 1	0 9							

Table 4. -- Level II land-use classifications, in percent, for selected basins in Delaware, eastern Maryland and Virginia (Based on high-altitude photography). -- Continued.

Category Number	Level II Category Description	Scott Run nr McLean Va. #6462	Little Falls Br. nr Bethesda Md. #6465.5	Rock Creek at Washington DC #6480	N.E. Br. Anacostia R at Riverdale Md. #6495	N.E. Br. Anacostia R. nr Colesville Md #6505	Holmes Run nr Annandale Va. #6526.1	Henson Cr. at Oxon Hill Md. #6535	Accotink Cr nr. Fairfax Va. #6539	Cedar Run nr Warrenton Va. #6555	Cub Run nr Chantilly Va. #6568	Cub Run nr Chantilly Va. #6569 4	Giles Run nr Woodbridge Va. #6578
////	URBAN	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
11	Residential	24 8	72.9	37 5	24 5	14 9	49.1	39.4	42 7	1 6		5.1	6.4
12	Commercial	14.9	12.0	5.4	4.8	0 9	3 9	5 4	12.3			0.3	
13	Industrial				0.5		1.1		1 8				
14	Extractive			0.1	3 3			6 2			. 0	0 7	0.7
15	Transportation	12 6		0 4	[illegible]		3.5	5.6	5.0		13.4	2.8	1.4
16	Institutional	0.7		4.1	3 9	0 6	6 9	2 2	2 0	0.3		0.2	3.3
17	Strip or clustered				0 4	0.4		0.3			0.6	1.3	
18	Mixed			0.1									
19	Open or other	2.6	9 0	5 7	5.2	9 2	3.4	4.1	7.3		34.9	8.2	
////	AGRICULTURE	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
21	Cropland & pasture	9 6		25 7	15 8	42 4	1 3	4 8	8 6	63 1	28.0	46 9	33 3
22	Orchards			0.4									
23	Feeding operations												
24	Other												
////	FORESTLAND	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
41	Heavy crown cover	28.8	2.4	18.1	36 3	25.6	29.3	28 4	17 3	33.0	15.6	30 8	54.9
42	Light crown cover	6.0	3.7	2 2	2 6	6 0	1.5	3.6	3 0	1.6	6.5	3.7	
////	WATER	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
52	Lakes			0.1	0 1								
53	Reservoirs			0.2	0 1					0.4			
54	Bays and estuaries												
////	WETLANDS	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
61	Vegetated												
////	BARREN LAND	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
75	"Other"												

Table 4. -- Level II land-use classifications, in percent, for selected basins in Delaware, eastern Maryland and Virginia (Based on high-altitude photography). -- Continued.

Category Number	Level II Category Description	Mattawoman Cr. nr Pomonkey, Md. #6580											
////	URBAN	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
11	Residential	2.8											
12	Commercial	0.7											
13	Industrial												
14	Extractive	0.1											
15	Transportation	0.1											
16	Institutional	2.0											
17	Strip or clustered	0.7											
18	Mixed												
19	Open or other	0.8											
////	AGRICULTURE	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
21	Cropland & pasture	24.7											
22	Orchards												
23	Feeding operations												
24	Other												
////	FORESTLAND	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
41	Heavy crown cover	67.0											
42	Light crown cover	1.0											
////	WATER	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
52	Lakes												
53	Reservoirs	0.1											
54	Bays and estuaries												
////	WETLANDS	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
61	Vegetated												
////	BARREN LAND	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
75	"Other"												

For example, at Shellpot Creek (station No. 01477800), 84.9 percent of the basin is characterized by the Level I, URBAN category (table 3). This value was obtained by adding the various Level II categories listed under the generalized URBAN classification in table 4. Thus, the 84.9 percent URBAN Level I classification shown in table 3 for Shellpot Creek is equal to the sum of the following Level II URBAN categories listed in table 4:

Category and number			Percent
Residential	(11)	-------------	69.8
Commercial	(12)	-------------	2.9
Transportation	(15)	-------------	1.5
Institutional	(16)	-------------	5.4
Mixed	(18)	-------------	0.7
Open or other	(19)	-------------	4.6
		TOTAL	84.9

Similarly, the Level I FOREST category for Shellpot Creek (11.0 percent) in table 3 was obtained by adding Level II forest heavy crown cover (10.1 percent) and light crown cover (0.9 percent) in table 4. Because only single Level II categories, cropland and pasture, and reservoirs correspond to the general Level I category of AGRICULTURE and WATER respectively, identical values are shown at corresponding category levels for Shellpot Creek (tables 3 and 4).

Based on high-altitude photographs, the highest measured percentage (93.9) Level I URBAN designation was at Little Falls Branch near Bethesda (table 3). By way of contrast, no urban development was detected in the high-altitude photographs of 11 Delmarva Peninsula basins. Agricultural usage ranged from zero at Little Falls Branch to 96.2 percent at Morgan Creek near Kennedyville. Forest cover ranged from 3.8 percent at Morgan Creek to 81.1 percent at St. Leonard Creek near St. Leonard. With the exception of Rhode River near Galesville, water areas identified in the 1:100,000 scale land-use maps amounted to less than 1 percent of the total drainage area of all basins. The Rhode River watershed is the only basin without a stream-gaging station as its downstream reference point. Land use given in tables 3 and 4 for the Rhode River catchment is for the entire basin above its confluence with West River. The high percentage (12.2) of the basin in the WATER category results from the largely estuarine lower part of the watershed. Wetlands were detected in four of the basins while only two basins had land use corresponding to the Level I BARREN category.

Land Use Based on Landsat-1 Imagery

The significantly lower resolution of Landsat imagery relative to high-altitude photography precludes its use as a data source for all Level II land-use categories. As previously noted, however, satellite imagery was used as the source base for preparing highly generalized Level I land-use maps at a scale of 1:250,000. The basic problem with Landsat imagery as used in this project is that its spectral and tonal signatures cannot always be consistently matched with categories in land-use classification schemes, especially where land parcels are small and categories are intermixed (Alexander, 1975, written communication). CARETS interpreters experienced particular difficulty in accurately mapping urban and built-up land in non-metropolitan areas using Landsat imagery (K. Fitzpatrick, 1976, oral communication).

Level I land use for 46 selected basins using satellite imagery as the primary source of land-cover information is shown in table 5. In general, these data are within 10 to 15 percent (by category) of the more accurate Level I land-use values based on high-altitude photography given in table 3. K. Fitzpatrick (written communication, 1975) reports that Level I land-use maps, when mapped from high-altitude photography were 7 percent more accurate for the entire CARETS area than the much less expensive Level I satellite-based land-use maps. However, accuracy differences greater than 7 percent between high-altitude and satellite sensors occur in table 5 owing partially to the small size of some of the basins selected for land-use analysis. Thus, in addition to errors stemming from lower resolution and problems with spectral-signature discrimination, errors inherent in accurately positioning such small basins on 1:250,000 scale land-use maps introduced additional variance, thereby further amplifying accuracy losses. Despite additional errors due to basin size, category differences in excess of 20 percent between Level I data based on high-altitude photography (table 3), and that based on satellite imagery (table 5) were detected in just eight basins.

As anticipated, the largest discrepancies when comparing high-altitude with satellite sensor derived Level I categories generally occurred in suburban areas. Interpreters encountered difficulty segregating urban areas from surrounding non-urban land use in satellite imagery. For example, extensive urban areas in the N.W. Branch Anacostia River basin near Colesville, just north of Washington, D.C., were incorrectly interpreted as agricultural land in Landsat-1 imagery; accordingly, a high proportion of the basin (71 percent) was placed in the AGRICULTURE

Table 5. --Level I land-use classifications, in percent, for selected basins in Delaware, eastern Maryland and Virginia (Based on Landsat imagery)

Index No. (fig.2)	STATION NAME	LEVEL I Categories				
		URBAN	AGRICUL-TURE	FOREST	WATER	WETLAND
4778	Shellpot Creek at Wilmington, Del.*	86	0	14	0	0
4780	Christiana River at Coochs Bridge, Del.*	12	56	30	2	0
4785	White Clay Creek above Newark, Del.*	0	80	20	0	0
4832	Blackbird Creek at Blackbird, Del.*	0	51	49	0	0
4835	Leipsic River near Cheswold, Del.*	0	91	9	0	0
4843	Sowbridge Branch near Milton, Del.*	0	52	48	0	0
4845	Stockley Branch at Stockley, Del.*	1	61	38	0	0
4850	Pocomoke River near Willards, Md.*	0	43	56	0	1
4855	Nassawango Creek near Snow Hill, Md.*	2	26	72	0	0
4860	Manokin Br. near Princess Ann, Md.*	0	30	70	0	0
4865	Beaverdam Creek near Salisbury, Md.*	4	51	45	0	0
4870	Nanticoke River near Bridgeville Del.*	0	54	45	1	0

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Table 5. -- Level I land-use classifications based on Landsat imagery, in percent -- Continued.

Index No. (fig. 2)	STATION NAME	LEVEL I Categories				
		URBAN	AGRICU-TURE	FOREST	WATER	WETLAND
4875	Trap Pond Outlet near Laurel, Del.*	0	28	72	0	0
4885	Marshy Hope Cr. near Adamsville, Del.*	4	56	40	0	0
4890	Faulkner Branch at Federalsburg, Md.*	0	71	29	0	0
4900	Chicamacomico River near Salem, Md.*	0	47	53	0	0
4910	Choptank River near Greensboro, Md.*	1	55	44	0	0
4920	Beaverdam Branch at Matthews, Md.*	0	93	7	0	0
4925	Sallie Harris Cr. near Carmichael, Md.*	0	69	31	0	0
4930	Unicorn Branch near Millington, Md.*	0	74	26	0	0
4935	Morgan Creek near Kennedyville, Md.*	0	97	3	0	0
4940	Southeast Cr. at Church Hill, Md.*	0	71	29	0	0
4950	Big Elk Creek at Elk Mills, Md.*	0	80	20	0	0
4955	Little Elk Cr. at Childs, Md.*	0	62	38	0	0
4960	Northeast Creek nr. Leslie, Md.*	0	71	29	0	0
5790	Basin Run at Liberty Grove, Md.*	0	100	0	0	0
5860	North Branch Patapsco River at Cedarhurst, Md.*	2	81	17	0	0
5893	Gwynns Falls at Villa Nova, Md.*	45	25	30	0	0

Table 5. -- Level I land-use classifications based on Landsat imagery, in percent -- Continued.

Index No. (fig. 2)	STATION NAME	LEVEL I Categories				
		URBAN	AGRICULTURE	FOREST	WATER	WETLAND
5900	North River near Annapolis, Md.*	5	13	82	0	0
5910	Patuxent River near Unity, Md.*	0	65	35	0	0
5945	Western Branch near Largo, Md.*	19	35	46	0	0
5946	Cocktown Creek near Huntington, Md.*	0	58	42	0	0
5948	St. Leonard Creek near St. Leonard, Md.*	0	6	94	0	0
6452	Watts Branch at Rockville, Md.*	61	24	15	0	0
6462	Scott Run near McLean, Va.	65	0	35	0	0
64655	Little Falls Branch near Bethesda, Md.*	94	0	6	0	0
6480	Rock Creek at Sherrill Drive, Washington, D.C.*	49	34	16	1	0
6495	N. E. Br. Anacostia River at Riverdale, Md	55	13	32	0	0
6505	N.W. Br. Anacostia River near Colesville Md.*	6	71	23	0	0
65261	Holmes Run near Annandale, Va.	90	0	10	0	0
6535	Henson Creek at Oxon Hill, Md.	85	0	15	0	0
6539	Accotink Cr. near Fairfax, Va.	96	0	4	0	0
6555	Cedar Run near Warrenton, Va.*	0	81	19	0	0
6568	Cub Run near Chantilly, Va.	12	50	38	0	0

Table 5. -- Level I land-use classifications based on Landsat imagery, in percent -- Continued.

Index No. (fig. 2)	STATION NAME	LEVEL I Categories: URBAN	AGRICUL-TURE	FOREST	WATER	WETLAND
6578	Giles Run near Woodbridge, Va.	49	0	51	0	0
6580	Mattawoman Cr. near Pomonkey, Md.*	1	29	70	0	0

*Station used in regression analyses

category (table 5). Based on high-altitude photographs only 42 percent of the basin was agricultural and 26 percent was designated urban (table 3). Using land-use maps derived from satellite imagery only 6 percent of the basin was categorized as urban (table 5).

EXPERIMENT DESIGN

The approach used in evaluating remotely sensed land-use data as a means of improving streamflow estimates was based on (1) selecting as many stream-gaging stations from the basins listed in tables 3-5 as possible to perform a meaningful multiple-regression analysis, (2) applying the same basin and climatic characteristics utilized in the streamflow program analysis of the Maryland district of the U.S. Geological Survey (Forrest and Walker, 1970) to the study basins in order to develop regional equations needed to compute specific streamflow characteristics, (3) incorporating selected Level I and Level II land-use categories developed from both high-altitude and satellite sensors to define other sets of streamflow equations, and (4) comparing standard errors of estimate for each streamflow characteristic (control) equation developed using the basin characteristics available to the Maryland district of the U.S. Geological Survey with those generated by incorporation of remotely sensed land-use information.

STUDY BASINS

Records of 10 or more years are generally required to develop meaningful streamflow statistics. Streamflow records spanning at least 10 years were available for 39 of the 49 basins for which land-use information is presented (tables 3-5). These stations (table 2) formed the network of study basins selected for multiple-regression analysis. The study basins drain into the Chesapeake Bay, Delaware Bay and the Atlantic Ocean (fig. 2), and are situated in the Piedmont and Coastal Plain physiographic provinces. The boundary between these provinces trends northeast through the Washington-Baltimore-Wilmington urban corridor. The

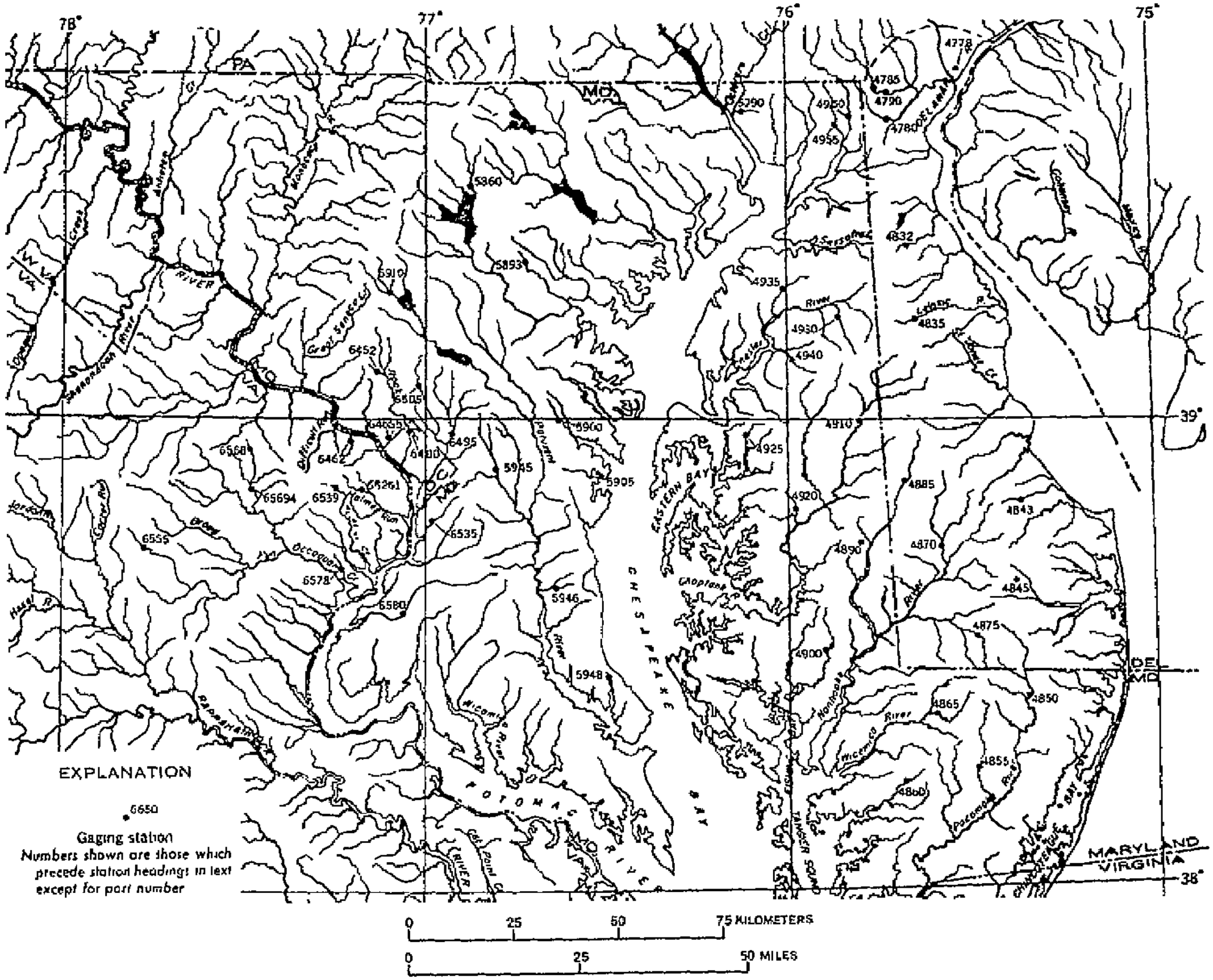

Figure 2. -- Map showing drainage patterns and the location of gaging stations analyzed in this report.

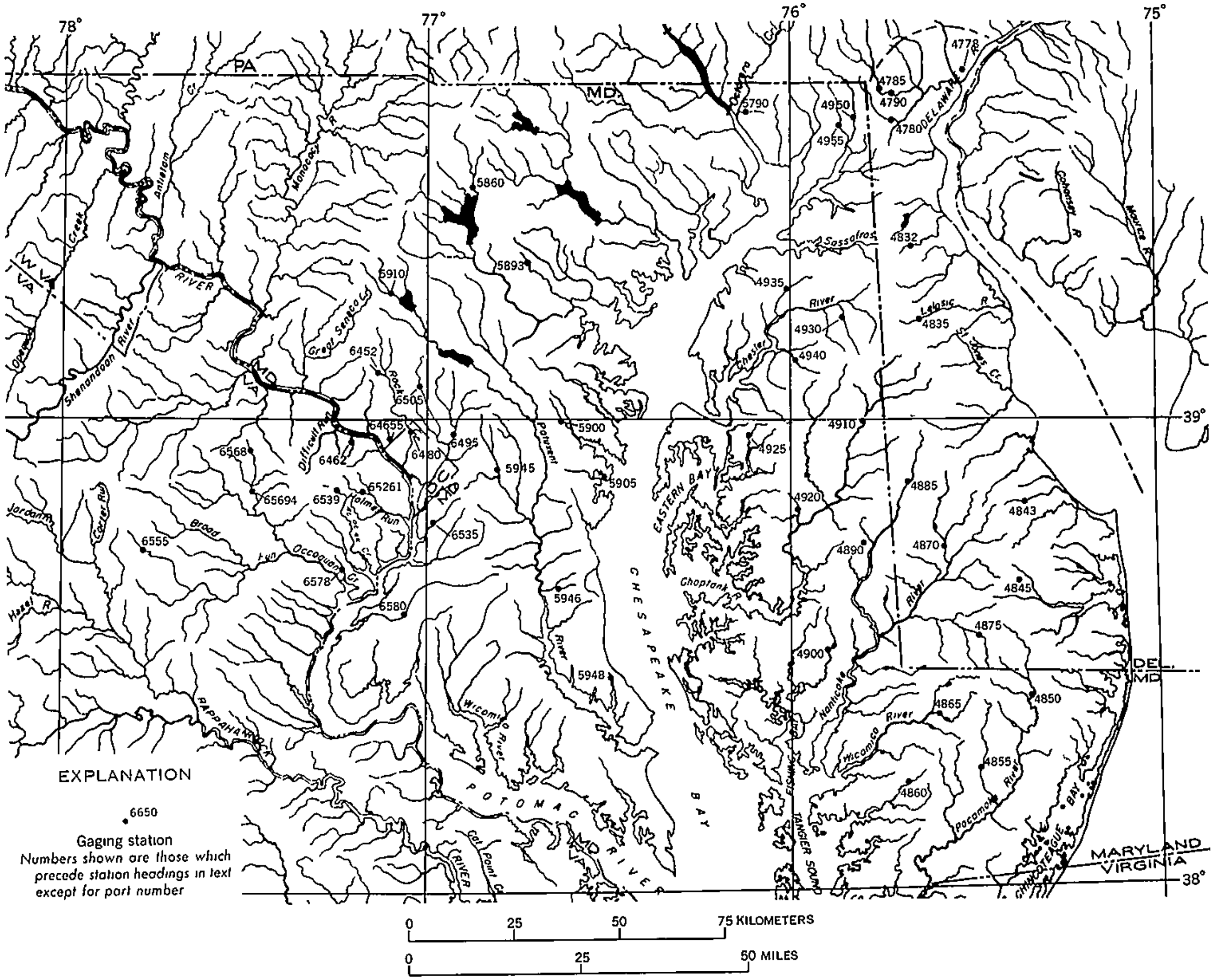

Figure 2. -- Map showing drainage patterns and the location of gaging stations analyzed in this report.

Piedmont is characterized by rolling topography, low hills and ridges, and fairly steep side slopes. The Coastal Plain is low, flat, and poorly drained on the Delmarva Peninsula, but west of the Chesapeake Bay is more rolling with slightly improved drainage.

Average annual basinwide precipitation is quite uniform throughout the area with the lowest amount of 39.9 inches (1010 mm) reported at Cedar Run near Warrenton, Va. and the highest amount of 47.0 inches (1190 mm) at three Delmarva Peninsula basins (table A-1, col. 19). As previously noted, the study basins exhibit a wide variety of land cover ranging from primarily urban in the Washington, Baltimore, and Wilmington metropolitan areas, to extensively forested west of the Chesapeake Bay in the abandoned farm areas just beyond the limits of urban development, and to agricultural in much of the Delmarva Peninsula.

STREAMFLOW CHARACTERISTICS

The streamflow characteristics (dependent variable) used in the streamflow analysis of the Maryland district span the full range of discharge regimen observed at 105 gaging stations. These include measures of high and low flows, discharge variability, and long-term average monthly and annual streamflow. Forty streamflow characteristics, in cubic feet per second, evaluated using all or some of the 39 gaging stations in this report, are as follows:

Q_a, mean annual discharge, defined as the arithmetic average of the annual mean flows.

q_n, mean monthly discharge, where the subscript refers to the numerical order of the month beginning with January as 1,

SD_{a}, standard deviations of the annual means,

SD_{n}, standard deviations of the monthly means, where the subscript n refers to the numerical order of the month beginning with January as 1,

P_{T}, annual flood peak discharge at T-year recurrence interval; recurrence intervals of 2, 5, 10, 25, and 50 years are denoted as P_{2}, P_{5}, P_{10}, P_{25}, and P_{50}, respectively.

$V_{D,T}$, flood volume characteristics are the annual highest average flow for 3-day periods at recurrence intervals of 2 and 25 years ($V_{3,2}$, $V_{3,25}$), and for 7-day periods at recurrence intervals of 2, 10, and 25 years ($V_{7,2}$, $V_{7,10}$, $V_{7,25}$),

$M_{D,T}$, low-flow characteristics are the annual minimum 7-day average flows at recurrence intervals of 2, 10, and 20 years ($M_{7,2}$, $M_{7,10}$, $M_{7,20}$),

D_{50}, discharge equaled or exceeded 50 percent of the time.

BASIN CHARACTERISTICS

Characteristics Based on Maps and Weather Records

Correlation studies performed on the Maryland district streamflow analysis incorporated 12 independent physiographic and climatic parameters into the multiple regression analysis as follows:

A, drainage area, in square miles, as shown in the latest U.S. Geological Survey streamflow reports,

S, main-channel slope, in feet per mile, computed by the 10- to 85-percent method (Benson, 1962),

L, main-channel length, in miles, measured from gaging station to basin divide,

E, mean basin elevation, in feet above mean sea level, measured from topographic maps by the grid method (Benson, 1962).

L, main-channel length, in miles, measured from gaging station to basin divide,

E, mean basin elevation, in feet above mean sea level, measured from topographic maps by the grid method (Martins, 1968),

S_t, area of lakes, ponds, and swamps, in percent of total drainage area, determined by planimetering such areas on topographic maps,

F, forest area, in percent of total drainage area, measured from topographic maps by the grid method,

S_1, soil index, a measure of potential maximum infiltration capacity, in inches, estimated from data provided by the U.S. Soil Conservation Service,

P, mean annual precipitation, in inches, determined from isoheytal maps prepared from National Weather Service records,

$I_{24,2}$, precipitation intensity, expected once every two years over 24-hour periods, in inches, estimated from U.S. Weather Bureau Technical Paper 29,

S_n, mean annual snowfall, in inches, from snowfall maps prepared from National Weather Service records,

T_1, average minimum January temperature, in degrees Fahrenheit, from National Weather Service records,

T_7, average minimum July temperature, in degrees Fahrenheit, from National Weather Service records.

Characteristics Based on High-Altitude Photograph

Land-use classifications based on high-altitude aerial photograph were tested as independent variables in the multiple regression analysis. These classifications, expressed in percent of total drainage area, are as follows:

U_u, Level I urban or built-up land which comprise areas of intensive use with much of the land covered by structures,

U_a, Levels I and II agricultural land consisting predominantly of croplands and pasture,

U_f, Level I forested land,

U_w, Level I and II water areas includes total area covered by lakes, reservoirs, streams, and estuaries,

U_r, Level II, residential, consisting of housing ranging from high density (multiple-family units) to low density (houses on large lots),

U_I, Level II, industrial, consisting of land devoted to light to heavy manufacturing,

U_o, Level II, other urban or built-up land consisting of parks, cemetaries, zoos, waste dumps, golf courses, and undeveloped land within,an urban setting.

U_{fl}, Level II, forest land, light crown cover (10 to 40 percent), and

U_{fh}, Level II, forest land, heavy crown cover (40 percent or greater).

Characteristics Based on Landsat Imagery

Land-use classifications based on Landsat-1 imagery were also tested as independent variables in the multiple regression analysis. These classifications, expressed in percent of total drainage area, are as follows:

Z_u, Level I urban or built-up land which comprise areas of intensive use with much of the land covered by structures,

Z_a, Level I agricultural land consisting predominantly of croplands and pasture, and

Z_f, Level I forested land.

REGRESSION ANALYSIS

The multiple regression technique used defines the relation between a single streamflow characteristic (dependent variable) and an array of climatic, physiographic, and land-use characteristics (independent variables) for a selected network of stream-gaging stations. Only those independent variables that account for significant measures of variance in the streamflow characteristic under analysis are included in the regression equation. Those independent variables that had at least a 95-percent probability of effectiveness were deemed significant to the equation. An indication of accuracy provided by the equation relating a streamflow characteristic to significant basin characteristics is provided by the standard error of estimate. The standard error of estimate is a range of error such that the value estimated by the regression equation is within this range at about two out of three sites, and is within twice this range at about 19 out of 20 sites for the sample population.

Stepforward multiple regression analyses were performed by digital computer using STATPAC program D0094. The program eliminated doubtful dependent variable entries, added a small constant (0.0001) to those dependent variables which go to zero, and transformed all dependent variables and selected independent variables to their logarithms. The independent variable that accounts for most of the variance in the dependent variable was identified and entered into the regression equation. Then the next most effective variable was added to the equation. Because the significance of an independent variable in the equation changes with the addition of each new variable, all previously included variables were retested with the addition of a new variable,and any variable shown to be no longer significant was deleted from the equation. The addition of variables accounting for a progressively smaller part of the variance in the dependent variable continues until the equation is not significantly improved by the inclusion of any additional variables. For each streamflow characteristic equation, the program provided the multiple correlation coefficient, percent of total sums of squares of the dependent variable that are explained by the regression, and the standard error of estimate of the dependent variable. Program D0094 also tabulated observed, computed, and residual values of all streamflow characteristics at each of the 39 gaging stations used in the analysis.

Observed, calculated, and measured values of all dependent and independent variables used in the Maryland district streamflow analysis were obtained from the Streamflow/Basin Characteristics retrieval program E796 and are listed for each station in table A-1 (cols. 1-7, 19-55, 57-66).

MULTIPLE REGRESSION MODEL

The model equation used in the multiple regression analyses is:

$$\log Y = b_1 \log X_1 + b_2 \log X_2 \ \ldots + b_n \log X_n + a + b_{n+1} X_{n+1} + b_{n+2} X_{n+2} \ \ldots + b_m X_m$$

or its equivalent form:

$$Y = X_1^{b_1} X_2^{b_2} \ \ldots \ X_n^{b_n} 10^{[a + b_{n+1} X_{n+1} + b_{n+2} X_{n+2} \ \ldots + b_m X_m]},$$

where

Y = a streamflow characteristic

X_1 to X_m = basin characteristics

a = regression constant, and

b_1 to b_m = regression coefficients.

In this analysis, X_1 through X_n were logarithmically transformed whereas X_{n+1} through X_m were not transformed prior to calculations. Independent variables which tend to vary widely, such as (A) drainage area and (L) main channel length, were log (base 10) transformed, whereas those subject to relatively small variations were used directly. In addition to drainage area and main channel length, (S) main channel slope and (E) mean basin elevation were log transformed. All other basin characteristics were relatively stable and were used directly in the model equation. The model equation was applied uniformly for the development of control and experimental equations without comparing its effectiveness as a predictive tool with models wherein all variables are logarithmically transformed. Rather, simple comparative tests were performed to evaluate the usefulness of remotely sensed land-use data in improving estimates of individual streamflow characteristics.

Specifically, the model was applied to 39 gaged basins in the CARETS region where land-use maps based on high-altitude photography and satellite imagery are available. A control set of equations was developed using the same basin characteristics that Forrest and Walker (1970) incorporated into their evaluation of the Maryland district streamflow program. The regression model was then applied successively to each of three experiments where additional land-use data were incorporated as follows:

(1) four level I land-use categories derived from high-altitude photography,

(2) six individual and combined Level II land-use categories derived from high-altitude photography, and,

(3) three Level I land-use categories derived from Landsat-I imagery.

Comparisons were then made between the control equations for individual streamflow characteristics and those developed for each of the above experiments to determine whether significant improvement in the standard error of estimate had resulted in any of the 40 streamflow-characteristic equations. Changes of 10 or more percent in the standard errors of estimates between the control and experimental equations were arbitrarily deemed significant.

The remotely sensed land-use categories selected for analysis depended on frequency of occurrence and percent basinwide coverage of each category, and category accuracy relative to map derived land-use data. For example, only four of six possible Level I land-use categories based on high-altitude photography were tested in experiment 1. The Level I categories of wetlands and barren land were not used because of the 39 basins in the regression analysis, wetlands were detected in only three basins and barren lands in just two basins (table 3). Moreover, with the exception of the Rhode River basin which was not used in the regression analysis, the portion of either category (wetlands or barren land) relative to total area in any of the basins was less than one percent (table 3). Map derived percentages of areas covered by lakes, ponds, and streams were used in experiment 3 rather than remotely sensed water data based on satellite imagery. Resolution problems as well as spectral and tonal signature degradation precluded accurate detection of the small water bodies found in most of the test basins.

REGRESSION EQUATIONS

Tables 6-9 summarize the results of the multiple regression analyses. The first column of each table indicates streamflow characteristic (Y) coded in accordance with the scheme developed on p. 31. The last column lists the regression constant (a) corresponding to a particular streamflow characteristic. Regression coefficients (b_i) for those independent variables found to be significant at the 95-percent level are listed in the intervening columns. Not all 39 stations in the test network were used in defining each of the regression equations shown in tables 6-9. Owing to varying periods of operation and special purpose gages, sufficient data to define streamflow frequency relationships for all 40 characteristics was not available at all gaging stations. For example, two of the gages were designed to measure floods (crest-gage stations) and were used only in the flood-peak computations. The number of stations used to develop each streamflow characteristic equation is as follows:

Streamflow Characteristic	No. of stations
P_2, P_5, P_{10}, P_{25}	39
Q_A, Q_{1-12}, SDA, SD_{1-12}	37
$M_{7,2}$, $V_{7,2}$, $V_{7,10}$	34
$M_{7,10}$	33
$M_{7,20}$	32
D_{50}	29
$V_{3,2}$	26
$V_{7,25}$	25
$V_{3,25}$	24
P_{50}	15

The regression analysis results incorporating physiographic and climatic basin characteristics identical to those used in the Maryland district analysis are listed in table 6. These are the control equations with which equations using remotely sensed land-use information were compared. Tables 7 and 8 present equations based on the inclusion of four Level I and six Level II land-use categories, respectively. These categories were based on land-use maps using high-altitude photographs as the primary information source. Level I land-use data based on Landsat-1 imagery at three category levels were also analyzed and the results are listed in table 9.

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Table 6. -- Control equations obtained by regressing streamflow characteristics against physiographic and climatic basin parameters obtained from climatologic data and USGS topographic maps.

Model is $Y = A^{b_1} S^{b_2} L^{b_3} E^{b_4} 10^{(a + b_5 S_t + b_6 F + b_7 S_s + b_8 P + b_9 I + b_{10} S_n + b_{11} T_1 + b_{12} T_7)}$

Flow characteristics Y	Exponent or coefficient of basin characteristic: Drainage area A	Main channel slope S	Main channel length L	Mean basin elevation E	Storage S_t	Forest cover F	Soil index S_s	Mean annual precip P	Precip. intensity I(24,2)	Snowfall S_n	January minimum temp T_1	July maximum temp T_7	Regression constant a
Q_a	1.006						0.120		0.108				-.770
q_1	1.027						.140	0.019					-1.228
q_2	1.029						.096	.017					-.918
q_3	1.022					.0017	.159						-.358
q_4	1.006						.112		.161				-.763
q_5	.959								.173	0.013			-.752
q_6	.986												-.115
q_7	.882									.027			-.584
q_8	1.022												-.094
q_9	.887									.021			-.507
q_{10}	.987												-.287
q_{11}	.994												-.084
q_{12}	1.038						.168						-.619

Table 6. — Control equations obtained by regressing streamflow characteristics against physiographic and climatic basin parameters obtained from climatologic data and USGS topographic maps — Continued.

Model is $Y = A^{b_1} S^{b_2} L^{b_3} E^{b_4} 10^{(a + b_5 S_t + b_6 F + b_7 S_i + b_8 P + b_9 I + b_{10} S_n + b_{11} T_1 + b_{12} T_7)}$

Flow characteristics Y	Exponent or coefficient of basin characteristic												Regression constant a
	Drainage area A	Main channel slope S	Main channel length L	Mean basin elevation E	Storage S_t	Forest cover F	Soil index S_i	Mean annual precip. P	Precip. intensity $I(24,2)$	Snowfall S_n	January minimum temp. T_1	July maximum temp. T_7	
SD_a	1.022						.217						-1.226
SD_1	1.074						.194						- .901
SD_2	1.087									-.023			.200
SD_3	1.037							.032		-.015			-1.278
SD_4	1.018							.021					-1.076
SD_5	1.015												- .223
SD_6	1.039												- .400
SD_7	.935					-.0055							- .020
SD_8	1.080												- .093
SD_9	.858											.092	-8.054
SD_{10}	.947				.027	.0043	-.258						.283
SD_{11}	1.031												- .313
SD_{12}	1.087												- .316

Table 6. — Control equations obtained by regressing streamflow characteristics against physiographic and climatic basin parameters obtained from climatologic data and USGS topographic maps — Continued.

Model is $Y = A^{b_1} S^{b_2} L^{b_3} E^{b_4} 10^{(a + b_5 S_t + b_6 F + b_7 S_a + b_8 P + b_9 I + b_{10} S_n + b_{11} T_1 + b_{12} T_7)}$

Flow characteristics Y	Exponent or coefficient of basin characteristic												Regression constant a
	Drainage area A	Main channel slope S	Main channel length L	Mean basin elevation E	Storage S_t	Forest cover F	Soil index S_a	Mean annual precip P	Precip intensity I(24,2)	Snowfall S_n	January minimum temp T_1	July maximum temp T_7	
P_2	1.067	0.770				-.0089				-.023			1.312
P_5	1.017	.783				-.0093				-.029			1.712
P_{10}	.942	.756				-.0094				-.029		0.085	-5.384
P_{25}	.785	.640				-.0069							-5.846
P_{50}	.774							-.213					11.771
$V_{3,2}$	1.067												.831
$V_{3,25}$	1.025												1.270
$V_{7,2}$	1.045												.662
$V_{7,10}$	1.022												.953
$V_{7,25}$	1.025												1.037
$M_{7,2}$	.936												-.937
$M_{7,10}$			3.265										-3.590
$M_{7,20}$	2.530												-4.169
D_{50}	1.014						.276						-1.178

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Table 7. -- Experimental equations obtained by regressing streamflow characteristics against physiographic and climatic basin parameters and four level I land-use categories derived from climatologic data, USGS topographic maps, and high-altitude photographs.

Model is $Y = A^{b_1} S^{b_2} L^{b_3} E^{b_4} 10^{(a + b_5 S_i + b_6 P + b_7 I + b_8 S_n + b_9 T_1 + b_{10} T_7 + b_{11} U_u + b_{12} U_a + b_{13} U_f + b_{14} U_w)}$.

Flow characteristics Y	Exponent or coefficient of basin characteristic*								Level I categories				Regression constant a
	Drainage area A	Main channel slope S	Main channel length L	Mean basin elevation E	Soil index S_i	Mean annual precip. P	Precip. intensity I(24,2)	Snowfall S_n	Urban U_u	Agriculture U_a	Forest U_f	Water U_w	
Q_a	1.014				0.147		0.171				-.0015		-1.035
q_1	1.027				.140	0.019							-1.228
q_2	1.029				.096	.017							-.918
q_3	1.017				.137						.0017		-.272
q_4	1.017				.116		.181					0.133	-.873
q_5	.959						.173	.015					-.752
q_6	1.001						.283				-.0041		-.957
q_7	.987				.199		.426				-.0092		-2.036
q_8	1.022												-.094
q_9	.958						.297				-.0059		-1.019
q_{10}	.987												-.287
q_{11}	1.013				.157		.270				-.0039		-1.444
q_{12}	1.038				.168								-.619

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Table 7. -- Experimental equations obtained by regressing streamlfow characteristics against physiographic and climatic basin parameters, and four level I land-use categories derived from climatologic data, USGS topographic maps, and high-altitude photographs -- Continued.

Model is $Y = A^{b_1} S^{b_2} L^{b_3} E^{b_4} 10^{(a + b_5 S_i + b_6 P + b_7 I + b_8 S_n + b_9 T_1 + b_{10} T_7 + b_{11} U_u + b_{12} U_a + b_{13} U_f + b_{14} U_w)}$.

Flow characteristics Y	Exponent or coefficient of basin characteristic*								Level I categories				Regression constant a
	Drainage area A	Main channel slope S	Main channel length L	Mean basin elevation E	Soil index S_i	Mean annual precip. P	July max temp. T_7	Snowfall S_n	Urban U_u	Agriculture U_a	Forest U_f	Water U_w	
SD_a	1.022				.217								-1.226
SD_1	1.074				.194								- .901
SD_2	1.087							-.023					.200
SD_3	1.037					.032		-.015					-1.278
SD_4	1.044					.018						.156	-1.004
SD_5	1.015												- .223
SD_6	1.039												- .400
SD_7	.914										-.0051		- .020
SD_8	1.080												- .093
SD_9	.858						.092						-8.054
SD_{10}	1.047							-.017		-.0035			- .052
SD_{11}	1.031												- .313
SD_{12}	1.087												- .316

Table 7. -- Experimental equations obtained by regressing streamflow characteristics against physiographic and climatic basin parameters, and four level I land use-categories derived from climatologic data, USGS topographic maps, and high-altitude photographs --Continued.

Model is $Y = A^{b_1} S^{b_2} L^{b_3} E^{b_4} 10^{(a + b_5 S_i + b_6 P + b_7 I + b_8 S_n + b_9 T_1 + b_{10} T_7 + b_{11} U_u + b_{12} U_a + b_{13} U_f + b_{14} U_w)}$

Flow characteristics Y	Exponent or coefficient of basin characteristic*								Level I categories				Regression constant a
	Drainage area A	Main channel slope S	Main channel length L	Mean basin elevation E	Soil index S_i	Mean annual precip. P	Precip. intensity I (2½2)	Snowfall S_n	Urban U_u	Agriculture U_a	Forest U_f	Water U_w	
P_2	0.694			0.462					0.0032		-.0062		1.053
P_5	.996	0.774					-.287	-.029			-.0060	-.380	2.635
P_{10}	.962	.759						-.029			-.0077	-.327	1.907
P_{25}	.838	.634									-.0056		1.711
P_{50}	.774					-.213							1.771
$V_{3,2}$	1.086								.0025				.761
$V_{3,25}$	1.052								.0022				1.195
$V_{7,2}$	1.045												.662
$V_{7,10}$	1.022												.953
$V_{7,25}$	1.025												1.037
$M_{7,2}$	1.081				1.152						-.018		-4.456
$M_{7,10}$			3.625										-3.590
$M_{7,20}$	2.530												-4.169
D_{50}	.989						.284			0.0048		.285	-1.428

*Although T_1 (January mean minimum temperature) was used in the regression analysis it was not significant; accordingly it was not listed in this table

Table 8. -- Experimental equations obtained by regressing streamflow characteristics against physiographic and climatic parameters, and six level II land-use categories derived from climatologic data, USGS topographic maps, and high-altitude photographs

Model is $Y = A^{b_1} S^{b_2} L^{b_3} E^{b_4} 10^{(a + b_5 S_t + b_6 S_s + b_7 P + b_8 I + b_9 S_n + b_{10} T_1 + b_{11} T_7 + b_{12} U_a + b_{13} U_r + b_{14} U_I + b_{15} U_o + b_{16} U_{fh} + b_{17} U_{fl})}$.

Flow characteristic	Exponent or coefficient of basin characteristic*															Regression constant
										Level II categories						
	Drainage area	Main channel slope	Main channel length	Mean basin elev.	Storage	Soil index	Mean annual precip.	Precip. intens.	Snowfall	Pasture & Cropland	Residential	Industrial	Forest heavy	Forest light		
Y	A	S	L	E	S_t	S_s	P	$I(24,2)$	S_n	U_a	U_r	U_I	U_{fh}	U_{fl}		a
Q_a	1.014					0.154		0.180					-.0017			-1.057
q_1	1.027					.140	0.019									-1.228
q_2	1.029					.096	.017									- .918
q_3	1.017					.131							.0018			- .252
q_4	1.006					.161		.112								- .763
q_5	.959							.013	.173							- .752
q_6	.977			-.004		.385		.267					.132			-2.501
q_7	.987					-.010		.475					.236			-2.528
q_8	1.022															- .094
q_9	.963					-.007		.378					.163			-1.846
q_{10}	.987															- .287
q_{11}	.994															- .084
q_{12}	1.038					.168										- .619

Table 8. -- Experimental equations obtained by regressing streamflow characteristics against physiographic and climatic parameters, and six level II land-use categories derived from climatologic data, USGS topographic maps, and high-altitude photographs -- Continued

Model is $Y = A^{b_1} S^{b_2} L^{b_3} E^{b_4} 10^{(a + b_5 S_t + b_6 S_i + b_7 P + b_8 I + b_9 S_n + b_{10} T_1 + b_{11} T_7 + b_{12} U_a + b_{13} U_r + b_{14} U_I + b_{15} U_o + b_{16} U_{fh} + b_{17} U_{fl})}$

Flow characteristic	Exponent or coefficient of basin characteristic*									Level II categories					Regression constant
	Drainage area	Main channel slope	Main channel length	Mean basin elev.	Storage	Soil index	Mean annual precip.	July max. temp.	Snowfall	Pasture & Cropland	Residential	Urban other	Forest heavy	Forest light	
Y	A	S	L	E	S_t	S_i	P	T_7	S_n	U_a	U_r	U_o	U_{fh}	U_{fl}	a
SD_s	1.034					.182								- 014	-1 098
SD_1	1.070					.310					.0024				-1.326
SD_2	1.100								- 023			-.012			.200
SD_3	1 037						.032		-.015						-1 278
SD_4	1 018						.021								-1 076
SD_5	1.015														- 223
SD_6	1.039														- .400
SD_7	909												-.0049		- .028
SD_8	1.080														- .093
SD_9	.858							092							-2 054
SD_{10}	1.068								-.017	-.0047				- 026	.017
SD_{11}	1.031														- .313
SD_{12}	1.108													-.021	- 303

Table 8. -- Experimental equations obtained by regressing streamflow characteristics against physiographic and climatic parameters, and six level II land-use categories derived from climatologic data, USGS topographic maps, and high-altitude photographs -- Continued.

Model is $Y = A^{b_1} S^{b_2} L^{b_3} E^{b_4} 10^{(a + b_5 S_t + b_6 S_i + b_7 P + b_8 I + b_9 S_n + b_{10} T_1 + b_{11} T_7 + b_{12} U_a + b_{13} U_r + b_{14} U_I + b_{15} U_o + b_{16} U_{fh} + b_{17} U_{fl})}$.

Flow characteristic	Exponent or coefficient of basin characteristic*									Level II categories					Regression constant
	Drainage area	Main channel slope	Main channel length	Mean basin elev.	Storage	Soil index	Mean annual precip.	Precip inters	Snowfall	Pasture & Cropland	Residential	Industrial	Forest heavy	Forest light	
Y	A	S	L	E	S_t	S_i	P	$I(24,2)$	S_n	U_a	U_r	U_I	U_{fh}	U_{fl}	a
P_2	0 699			453							.0042		- 0065		1.067
P_5	.999	.694							-.026				-.0069		1 732
P_{10}	967	703							-.026				-.0088		1.694
P_{25}	.835	.631											- 0057		1.714
P_{50}	.774						-.213								11.771
$V_{3,2}$	1.094										.0033				753
$V_{3,25}$	1.060										.0029				1.186
$V_{7,2}$	1.045														662
$V_{7,10}$	1.022														953
$V_{7,25}$	1.025														1.037
$M_{7,2}$	1.076					1.216							-.0198		-4.660
$M_{7,10}$			3.265												-3 590
$M_{7,20}$	2.530														-4.169
D_{50}	.990							.259		0042					-1 280

*Although T_1 (January mean minimum temperature) was used in the regression analysis it was not significant, accordingly, it was not listed in this table.

Table 9. -- Experimental equations obtained by regressing streamflow characteristics against physiographic and climatic basin parameters, and three level I land-use categories derived from climatologic data, USGS topographic maps, and Landsat imagery.

Model is $Y = A^{b_1} S^{b_2} L^{b_3} E^{b_4} 10^{(a + b_5 S_i + b_6 S_t + b_7 P + b_8 I + b_9 S_n + b_{10} T_1 + b_{11} T_7 + b_{12} Z_u + b_{13} Z_a + b_{14} Z_f)}$.

Flow characteristics	Exponent or coefficient of basin characteristic*								Level I Categories			
	Drainage area	Main channel slope	Main channel length	Soil index	Mean annual precip.	Precip intensity	Snowfall	July maximum temperature	Urban	Agriculture	Forest	Regression constant
Y	A	S	L	S_i	P	I (24,2)	S_n	T_7	Z_u	Z_a	Z_f	a
Q_a	1 058			.120		.108						- 770
q_1	1 027			.140	.019							-1 228
q_2	1.029			.096	.017							- .918
q_3	1.044			.138			-.008					- .105
q_4	1 006			112		.161						- .76[illegible]
q_5	.959					.173	.013					- 752
q_6	.986											- 115
q_7	.882						.027					- .584
q_8	1.022											- .094
q_9	.887						021					- .507
q_{10}	.987											- 287
q_{11}	.994											- .084
q_{12}	1.038			.168								- .619

*Although E (mean basin elevation), S_t (storage), and T_1 (January mean minimum temperature) were used in the regression analysis, they were not significant and are not listed in this table.

Table 9. -- Experimental equations obtained by regressing streamflow characteristics against physiographic and climatic basin parameters, and three level I land-use categories derived from climatologic data, USGS topographic maps, and Landsat imagery -- Continued.

Model is $Y = A^{b_1} S^{b_2} L^{b_3} E^{b_4} 10^{(a + b_5 S_t + b_6 S_i + b_7 P + b_8 I + b_9 S_n + b_{10} T_1 + b_{11} T_7 + b_{12} Z_u + b_{13} Z_a + b_{14} Z_f)}$.

Flow characteristics	Exponent or coefficient of basin characteristic*								Level I Categories			
	Drainage area	Main channel slope	Main channel length	Soil index	Mean annual precip.	Precip. intensity	Snowfall	July maximum temperature	Urban	Agriculture	Forest	Regression constant
Y	A	S	L	S_i	P	I(24,2)	S_n	T_7	Z_u	Z_a	Z_f	a
SD_a	1.022			.217								-1.226
SD_1	1 074			.194								- 901
SD_2	1.087						- 023					.200
SD_3	1.037				.032		-.015					-1 278
SD_4	1.018				.021							-1.076
SD_5	1.015											- 223
SD_6	1.039											- .400
SD_7	.922										- 0050	- 040
SD_8	1.080											- 093
SD_9	.858							.092				-8.054
SD_{10}	1.076			-.281			-.029					.994
SD_{11}	1.031											- 313
SD_{12}	1.087											- .316

Table 9. -- Experimental equations obtained by regressing streamflow characteristics against physiographic and climatic basin parameters, and three level I land-use categories derived from climatologic data, USGS topographic maps, and Landsat imagery -- Continued.

Model is $Y = A^{b_1} S^{b_2} L^{b_3} E^{b_4} 10^{(a + b_5 S_x + b_6 S_L + b_7 P + b_8 I + b_9 S_n + b_{10} T_1 + b_{11} T_7 + b_{12} Z_u + b_{13} Z_a + b_{14} Z_f)}$.

Flow characteristics	Exponent or coefficient of basin characteristic*								Level I Categories			
	Drainage area	Main channel slope	Main channel length	Soil index	Mean annual precip.	Precip. intensity	Snowfall	July maximum temperature	Urban	Agriculture	Forest	Regression constant
Y	A	S	L	S_i	P	I (24,2)	S_n	T_7	Z_u	Z_a	Z_f	a
P_2	.991	.746				-.397						2.022
P_5	.918	.735				-.354						2 211
P_{10}	.853	.672									- 0036	1.403
P_{25}	.793	.658									-.0043	1 692
P_{50}	774				-.213							11,771
$V_{3,2}$	1 054								.0021			.809
$V_{3,25}$	1.089								.0024			1.236
$V_{7,2}$	1 038								.0012			654
$V_{7,10}$	1.022											.953
$V_{7,25}$	1.020								.0018			1 014
$M_{7,2}$	.845						.070		-.015			-1.895
$M_{7,10}$			3.265									-3.590
$M_{7,20}$	2.639								-.019			-4.035
D_{50}	.998					.324				.0038		-1.506

To illustrate the use of the regression equations, assume that the 2-year peak flow (P_2) is required for Shellpot Creek at Wilmington (fig. 2, index No. 4778) using (1) map and climate data (table 6), (2) added Level II land use based on high-altitude photography (table 8), or (3) added Level I land use from satellite imagery (table 9). The equations for (1) are:

from table 6:

$$P_2 = A^{1.067} S^{0.770} 10^{(1.312 - 0.0089F - 0.023S_n)}$$

from table A1:

$$P_2 = 7.46^{1.067} 67.1^{0.770} 10^{[1.312 - 0.0089(19) - 0.023 (20)]}$$

$$P_2 = 8.535 (25.50) 10^{0.683}$$

$$P_2 = 1050 \text{ ft}^3/\text{s},$$

(2)

from table 8:

$$P_2 = A^{0.699} E^{0.453} 10^{(1.067 + 0.0042 U_r - 0.0065 \overline{U_{fh}})}$$

from table A1:

$$P_2 = 7.64^{0.699} 271^{0.453} 10^{[1.067 + 0.0042 (69.8) - 0.0065 (10.1)]}$$

$$P_2 = 4.143 (12.65) 10^{1.294}$$

$$P_2 = 1030 \text{ ft}^3/\text{s},$$

and (3)

from table 9:

$$P_2 = A^{0.991} S^{0.745} 10^{(2.022 - 0.397 I_{24,2})}$$

from table A1:

$$P_2 = 7.46^{0.991}\ 67.1^{0.746}\ 10^{[2.022 - 0.397\ (3.3)]}$$

$$P_2 = 7.326\ (23.05)\ 10^{0.712}$$

$$P_2 = 870\ ft^3/s$$

Each of these 2-year peak flow estimates at Shellpot Creek, based on regression analyses, is below the 1,200 ft^3/s computed from actual station records (table A1, col. 24). Part of the variation between predicted and recorded discharge is due to chance. However, Shellpot Creek drains a highly urban area and is subject to flash flooding owing to the impervious nature of its basin. Because the regression analysis is based on rural as well as urban streams, fairly sizeable discrepancies in the 2-year recurrence flood between actual and estimated values were anticipated at the station.

ACCURACY COMPARISONS

Tables 10-12 identify the significant independent variables in both the control and experimental equation arrays as well as the standard error of each equation in logarithmic units and approximate equivalent percentage. The percentages represent arithmetic averages of the plus and minus percent of the mean, calculated using the standard error in log units. Thus, an average standard error of 18.5 percent, corresponding to 0.08 log units, represents a range of 20.2 percent on the plus (high) side and 16.8 on the minus (low) side of the streamflow characteristic mean (Hardison, 1969). The last two columns show the percent change in the standard error resulting from inclusion of land-use information in the analysis. Changes of 10 or more percent in the standard error of estimate are considered to be significant. Plus percent changes are indicative of improved accuracy whereas minus changes represent a loss of accuracy. Percent change values are given for all streamflow characteristics except the three 7-day low-flow categories. Less than 50 percent of the variance in each of these categories was explained by any of the 7-day low-flow regression equations. This strongly suggests that other unidentified independent variables should have been included in the regression analyses. Accordingly, conclusions regarding relative accuracy improvements were not made for any of the low-flow categories.

Experiment 1

In the first experimental array of regression equations, four of six possible Level I land-use classifications derived from high-altitude photographs were tested; namely, FORESTLAND (U_f), AGRICULTURAL (U_a), URBAN AND BUILTUP (U_u), and WATER (U_w). As previously noted, the remaining two Level I categories,

Table 10. -- Comparison of standard error of estimate changes resulting from inclusion in the regression analysis of four level I land-use categories derived from high-altitude photography.

Flow characteristics	Significant predictive variables		Standard error of estimate						Percent change	
			in log units			in percent				
Y	Control equations	Experimental equations	Control	Exper.		Control	Exper.		Plus	Minus
Q_a	A; S_i; $I_{24,2}$	A; S_i; $I_{24,2}$; U_f	0.062	0.058		14.4	13.4		6.9	
q_1	A; S_i; P	A; S_i; P	.061	.061		14.1	14.1		0	0
q_2	A; S_i; P	A; S_i; P	.067	.067		15.5	15.5		0	0
q_3	A; S_i; P	A; S_i; U_f	.073	.073		16.9	16.9		0	0
q_4	A; S_i; $I_{24,2}$	A; S_i; $I_{24,2}$; U_w	.072	.066		16.7	15.3		8.4	
q_5	A; S_n; $I_{24,2}$	A; S_n; $I_{24,2}$	.095	.095		22.0	22.0		0	0
q_6	A	A; $I_{24,2}$; U_f	.133	.114		31.1	26.6		14.5	
q_7	A; S_n	A; S_i; $I_{24,2}$; U_f	.182	.146		43.1	34.2		20.6	
q_8	A	A	.120	.120		28.0	28.0		0	0
q_9	A; S_n	A; $I_{24,2}$; U_f	.143	.127		33.5	29.7		11.3	
q_{10}	A	A	.139	.139		32.6	32.6		0	0
q_{11}	A	A; S_i; $I_{24,2}$; U_f	.117	.097		27.3	22.5		17.6	
q_{12}	A; S_i	A; S_i	.081	.081		18.7	18.7		0	0

Table 10. -- Comparison of standard error of estimate charges resulting from inclusion in the regression analysis of four level I land-use categories derived from high-altitude photography --Continued.

Flow charact-eristics	Significant predictive variables		Standard error of estimate						Percent change	
			in log units			in percent				
Y	Control equations	Experimental equations	Control	Exper.		Control	Exper.		Plus	Minus
SD_a	A, S_i	A, S_i	0.085	0.085		19.7	19.7		0	0
SD_1	A, S_I	A, S_i	.094	.094		21.8	21.8		0	0
SD_2	A, S_n	A, S_n	.107	.107		24.9	24.9		0	0
SD_3	A, S_n, P	A, S_n, P	.095	.095		22.0	22.0		0	0
SD_4	A, P	A, P, U_w	.080	.074		18.5	17.1		7.6	
SD_5	A	A	.116	.116		27.0	27.0		0	0
SD_6	A	A	.149	.149		35.0	35.0		0	0
SD_7	A, F	A, U_f	.195	.197		46.4	46.9			[illegible]
SD_8	A	A	.153	.153		35.9	35.9		0	0
SD_9	A, T_7	A, T_7	.155	.155		36.4	36.4		0	0
SD_{10}	A, S_t, F, S_i	A, S_n, U_a	.152	.155		35.7	36.4			2.0
SD_{11}	A	A	.154	.154		36.2	36.2		0	0
SD_{12}	A	A	.137	.137		32.1	32.1		0	0

Table 10. --Comparison of standard error of estimate changes resulting from inclusion in the regression analysis of four level I land-use categories derived from high-altitude photography -- Continued.

Flow characteristics	Significant predictive variables		Standard error of estimate						Percent change	
			in log units			in percent				
Y	Control equations	Experimental equations	Control	Exper.		Control	Exper.		Plus	Minus
P_2	A, F; S; S_n	A, E; U_f; U_u	0.158	0.177		37.1	41.8			12.7
P_5	A; F; S, S_n	A; S, S_n, $I_{24,2}$; U_f, U_w	.150	.145		35.2	34.0		3.4	
P_{10}	A; F; S, S_n, T_7	A, S; S_n, U_f; U_w	.147	.159		34.5	37.4		-	8.4
P_{25}	A; F; S	A, S; U_f	.158	.186		37.8	44.1			16.7
P_{50}	A; P	A; P	.259	.259		63.2	63.2		0	c
$V_{3,2}$	A	A; U_u	.126	.107		29.4	24.9		15.3	
$V_{3,25}$	A	A, U_u	.146	.135		34.2	31.6		7.6	
$V_{7,2}$	A	A	.089	.089		20.7	20.7		0	0
$V_{7,10}$	A	A	.103	.103		23.9	23.9		0	0
$V_{7,25}$	A	A	.102	.102		23.7	23.7		0	0
$M_{7,2}$	A	A; S_1; U_f	.791	.690		No meaningful equations derived				
$M_{7,10}$	L	L	1.394	1.394		No meaningful equations derived				
$M_{7,25}$	A	A	1.509	1.509		No meaningful equations derived				
D_{50}	A; S_1	A; $I_{24,2}$; U_a; U_w	.143	.106		33.5	24.6		26.6	

Table 11. -- Comparison of standard error estimate changes resulting from inclusion in the regression analysis of six level II land-use categories derived from high-altitude photography.

Flow characteristics Y	Significant predictive variables: Control equations	Significant predictive variables: Experimental equations	Standard error of estimate in log units: Control	Standard error of estimate in log units: Exper.	Standard error of estimate in percent: Control	Standard error of estimate in percent: Exper.	Percent change: Plus	Percent change: Minus
q_a	A, S_i; $I_{24,2}$	A, S_i; $I_{24,2}$; U_{fn}	0.062	0.057	14.4	13.2	8.3	
q_1	A; S_i; P	A; S_i, P	.061	.061	14.1	14.1	0	0
q_2	A; S_i; P	A; S_i; P	.067	.067	15.5	15.5	0	0
q_3	A; S_i, P	A, S_i; U_{fh}	.073	.072	16.9	16.7	1.2	
q_4	A; S_i; $I_{24,2}$	A; S_i; $I_{24,2}$	.072	.072	16.7	16.7	0	0
q_5	A; S_n; $I_{24,2}$	A; S_n; $I_{24,2}$	.095	.095	22.0	22.0	0	0
q_6	A	A; E; S_i; $I_{24,2}$; U_{fh}	.133	.100	31.1	23.2	25.4	
q_7	A; S_n	A; S_i; $I_{24,2}$; U_{fh}	.182	.143	43.1	33.5	22.2	
q_8	A	A	.120	.120	28.0	28.0	0	0
q_9	A; S_n	A; S_i; $I_{24,2}$; U_{fh}	.143	.121	33.5	28.2	15.8	
q_{10}	A	A	.139	.139	32.6	32.6	0	0
q_{11}	A	A	.117	.117	27.3	27.3	0	0
q_{12}	A; S_i	A; S_i	.081	.081	18.7	18.7	0	0

Table 11. -- Comparison of standard error estimate changes resulting from inclusion in the regression analysis of six level II land-use categories derived from high-altitude photography -- Continued.

Flow characteristics	Significant predictive variables		Standard error of estimate				Percent change	
			in log units		in percent			
Y	Control equations	Experimental equations	Control	Exper.	Control	Exper.	Plus	Minus
SD_a	A, S_i	A, S_i, U_{fh}	0.085	0.081	19.7	18.7	5.1	
SD_1	A, S_i	A, S_i, U_r	.094	.089	21.8	20.7	5.5	
SD_2	A, S_n	A, S_n, U_o	.107	.102	24.9	23.7	4.8	
SD_3	A, S_n, P	A, S_n, P	.095	.095	22.0	22.0	0	0
SD_4	A, P	A, P	.080	.080	18.5	18.5	0	0
SD_5	A	A	.116	.116	27.0	27.0	0	0
SD_6	A	A	.149	.149	35.0	35.0	0	0
SD_7	A, F	A, U_{fh}	.195	.199	46.4	47.4		2.2
SD_8	A	A	.153	.153	35.9	35.9	0	0
SD_9	A, T_7	A, T_7	.155	.155	36.4	36.4	0	0
SD_{10}	A, S_t, F, S_i	A, S_n, U_a, $U_{f\ell}$	.152	.148	35.7	34.7	2.8	
SD_{11}	A	A	.154	.154	36.2	36.2	0	0
SD_{12}	A	A, $U_{f\ell}$	.137	.131	32.1	30.6	4.7	

Table 11. -- Comparison of standard error estimate changes resulting from inclusion in the regression analysis of six level II land-use categories derived from high-altitude photography -- Continued.

Flow characteristics	Significant predictive variables		Standard error of estimate						Percent change	
			in log units			in percent				
Y	Control equations	Experimental equations	Control	Exper.		Control	Exper.		Plus	Minus
P_2	A; F; S; S_n	A; E, U_{fh}; U_r	0.158	0.176		37.1	41.6			12.1
P_5	A; F; S; S_n	A; S, S_n, U_{fh}	.150	.165		35.2	38 8			10.2
P_{10}	A, F; S; S_n; T_7	A, S; S_n, U_{fh}	.147	.174		34.5	41.1			19.1
P_{25}	A; F; S	A, S; U_{fh}	.158	.187		37.8	44.4			17.5
P_{50}	A, P	A, P	.259	.259		63.2	63.2		0	0
$V_{3,2}$	A	A; U_r	.126	.106		29.4	24.6		16.3	
$V_{3,25}$	A	A; U_r	.146	.135		34.2	31.6		7.6	
$V_{7,2}$	A	A	.089	.089		20.7	20.7		0	0
$V_{7,10}$	A	A	.103	.103		23.9	23.9		0	0
$V_{7,25}$	A	A	.102	.102		23.7	23.7		0	0
$M_{7,2}$	A	A; S_1; U_{fh}	.791	.685		No meaningful equation derived				
$M_{7,10}$	L	L	1.394	1.394		No meaningful equation derived				
$M_{7,25}$	A	A	1.509	1.509		No meaningful equation derived				
D_{50}	A; S_1	A; $I_{24,2}$; U_a	.143	.120		33.5	28.0		16.4	

Table 12. — Comparison of standard error of estimate changes resulting from inclusion in the regression analysis of three Level I land-use categories derived from Landsat imagery.

Flow characteristics	Significant predictive variables		Standard error of estimate						Percent change	
			in log units			in percent				
Y	Control equations	Experimental equations	Control	Exper.		Control	Exper.		Plus	Minus
Q_a	A, S_i; $I_{24,2}$	A, S_i; $I_{24,2}$	0.062	0.062		14.1	14.1		0	0
q_1	A, S_i, P	A, S_i, P	.061	.061		14.1	14.1		0	0
q_2	A, S_i, P	A, S_i, P	.067	.067		15.5	15.5		0	0
q_3	A, $S_{[illegible]}$ [illegible]	A, S_i, S_n	.073	.074		16.9	17.2			1.8
q_4	A, S_i, $I_{24,2}$	A, S_i, $I_{24,2}$	.072	.072		16.7	16.7		0	0
q_5	A, S_n, $I_{24,2}$	A; S_n, $I_{24,2}$	.095	.095		22.0	22.0		0	0
q_6	A	A	.133	.133		31.1	31.1		0	[illegible]
q_7	A; S_n	A, S_n	.182	.182		43.1	43.1		0	0
q_8	A	A	.120	.120		28.0	28.0		0	0
q_9	A; S_n	A, S_n	.143	.143		33.5	33.5		0	0
q_{10}	A	A	.139	.139		32.6	32.6		0	0
q_{11}	A	A	.117	.117		27.3	27.3		0	0
q_{12}	A, S_i	A, S_i	.081	.081		18.7	18.7		0	0

Table 12.-- Comparison of standard error of estimate changes resulting from inclusion in the regression analysis of three level I land-use categories derived from Landsat imagery. -- Continued.

Flow characteristics	Significant predictive variables		Standard error of estimate				Percent change	
			in log units		in percent			
Y	Control equations	Experimental equations	Control	Exper.	Control	Exper.	Plus	Minus
SD_a	A, S_i	A; S_1	0.085	0.085	19.7	19.7	0	0
SD_1	A, S_i	A, S_i	.094	.094	21.8	21.8	0	0
SD_2	A; S_n	A, S_n	.107	.107	24.9	24.9	0	0
SD_3	A, S_n; P	A, S_n, P	.095	.095	22.0	22.0	0	0
SD_4	A, P	A, P	.080	.080	18.5	18.5	0	0
SD_5	A	A	.116	.116	27.0	27.0	0	0
SD_6	A	A	.149	.149	35.0	35.0	0	0
SD_7	A, F	A, Z_f	.195	.190	46.4	45.1	2.8	
SD_8	A	A	.153	.153	35.9	35.9	0	0
SD_9	A; T_7	A, T_7	.155	.155	36.4	36.4	0	0
SD_{10}	A; S_t, F, S_i	A, S_i, S_n	.152	.157	35.7	36.9		3.4
SD_{11}	A	A	.154	.154	36.2	36.2	0	0
SD_{12}	A	A	.137	.137	32.1	32.1	0	0

Table 12. -- Comparison of standard error of estimate changes resulting from inclusion in the regression analysis of three level I land-use categories derived from Landsat imagery -- Continued

Flow characteristics	Significant predictive variables		Standard error of estimate						Percent change	
			in log units			in percent				
Y	Control equations	Experimental equations	Control	Exper.		Control	Exper.		Plus	Minus
P_2	A, F, S, S_n	A; S, $I_{24,2}$	0.158	0.188		37.1	44.6			20.2
P_5	A, F, S, S_n	A; S, $I_{24,2}$	.150	.190		35.2	45.1			28.1
P_{10}	A; F, S, S_n, T_7	A, S, Z_f	.147	.198		34.5	47.1			36.5
P_{25}	A, F, S	A; S, Z_f	.158	.191		37.8	45.4			20.1
P_{50}	A, P	A, P	.259	.259		63.2	63.2		0	0
$V_{3,2}$	A	A; Z_u	.126	.109		29.4	25.4		13.6	
$V_{3,25}$	A	A; Z_u	.146	.128		34.2	29.9		12.6	
$V_{7,2}$	A	A, Z_u	.089	.084		20.7	19.5		5.8	
$V_{7,10}$	A	A	.103	.103		23.9	23.9		0	0
$V_{7,25}$	A	A, Z_u	.102	.087		23.7	20.2		14.8	
$M_{7,2}$	A	A, S_n, Z_u	.791	.651		No meaningful equation derived				
$M_{7,10}$	L	L	1.394	1.394		No meaningful equation derived				
$M_{7,25}$	A	A, Z_u	1.509	1.435		No meaningful equation derived				
D_{50}	A; S_i	A, $I_{24,2}$, Z_a	.143	.119		33.5	27.8		17.0	

BARREN LAND and WETLAND, were identified in only five of the 39 basins used in the correlation network, and were not included in the regression analysis. Throughout the analyses, U_f was substituted for the USGS topographic map (scale 1:24,000) derived forest (F) category which was used in the control equations, and U_w was used in place of the USGS map derived storage (S_t) category also used in the control equations. No substitutions were required for U_a or U_u because neither category was available for use in the original (control) equations.

Results of the experiment are listed in table 10, which shows that 11 equations were improved (six significantly) and five equations sustained a loss of accuracy (two significantly). By far the most often used independent variable in the regression analysis was FORESTLAND (U_f) as indicated below:

Streamflow Characteristic Type	Number of equations	Number of times that indicated variable occurred			
		U_a	U_f	U_u	U_w
High	10	0	4	3	2
Average	14	1	6	0	2
Low	3	0	1	0	0
Variability	13	1	1	0	1
All characteristics	40	2	12	3	5

Five of the six streamflow characteristic equations significantly improved by inclusion of Level I land-use information involved mean flow characteristics (q_6, q_7, q_9, q_{11} and D_{50}) whereas one flood volume characteristic ($V_{3,2}$) equation was similarly improved. A significant accuracy loss was detected in two flood peak characteristics (P_2, P_{25}). Examination of the four significant variables affecting the P_2 relationships (table 10) in both the control and experimental equation arrays indicates the presence of three dissimilar variables. By way of contrast, the three significant variables governing the P_{25} flood characteristic were identified in both tests; however, F was used in the control set whereas U_f was used in the experimental set. Owing to the loss of accuracy due to the inclusion of U_f in the analysis, F (map derived) is the preferred independent variable for estimating 25-year flood peaks rather than U_f which was obtained from high-altitude aircraft photography.

Experiment 2

In this experiment six Level II categories were included in the regression analysis to evaluate the possible impact of more detailed land-use information on streamflow estimates. As in Experiment 1, Level II data were derived from high-altitude photographs of the CARETS region. Two forest categories were included to depict heavy crown cover (U_{fh}) and light crown cover (U_{fl}). Categories denoting residential (U_r), industrial (U_I) and, open and other (U_o) urban development were also incorporated in the analyses. The urban open and other (U_o) category consists of golf courses, some parks, cemeteries, and undeveloped land within an urban setting (Anderson and others, 1972). The last Level II classification used in the analysis was a combined cropland and pasture category (U_a) which essentially corresponded to the Level I agriculture category used in Experiment 1. Level II U_w was not substituted for S_t (map derived storage) in Experiment 2 because it appears that the S_t category, based on 1:24,000 scale maps, portrays surface-water area with an equivalent accuracy to that derived from high-altitude photographs.

Thirteen equations were improved (five significantly) and five were reduced in accuracy (four significantly) by the inclusion of Level II land-use data derived from high-altitude photography (table 11). The independent variable most often appearing in the test equations was U_{fh} whereas U_I never proved to be significant in any of the 40 equations as shown below:

Streamflow Characteristic type	Number of equations	Number of times that indicated variable occurred					
		U_a	U_{fh}	U_{fl}	U_r	U_o	U_I
High	10	0	4	0	3	0	0
Average	14	1	5	0	0	0	0
Low	3	0	1	0	0	0	0
Variability	13	1	1	3	1	1	0
All characteristics	40	2	11	3	4	1	0

Not surprisingly, the results of this test closely parallel those in Experiment 1 in that the streamflow characteristic equations significantly improved in Experiment 2 were identical to five of the six characteristics similarly improved in Experiment 1. Significant accuracy losses were sustained in four of the five flood peak characteristic equations as evidenced by large minus percent changes (10 to 19 percent) in the standard errors for these experimental equations. As in Experiment 1, more accurate flood estimates were generated in the control equations where F (map derived forest cover) appears as a stronger independent variable than either U_{fh} or U_{fl} (aircraft derived forest categories). The use of Level II aircraft derived land use generated a slight overall loss in accuracy in the equations when compared with the Level I categories used in Experiment 1. Thus, the use of more detailed land-use discrimination provided by Level II was unwarranted in this particular stream-gaging network.

The loss of accuracy in estimating flood peak discharges at all frequency intervals except the 50-year return period, where forest cover is relatively unimportant, is probably a function of how well the land-use information represents the selected streamflow study period. For example, flood flow records used in this analysis included all available gaging-station records through September 30, 1967. The maps available for determining forest cover (F) in the control equations were prepared predominantly during the late 1950's which approximates the median period of actual data collection at the gaging stations (table 2). Land-use maps which were derived from high-altitude photographs obtained in 1970 and 1972 reflect conditions beyond the streamflow analysis cutoff date. Because flood flows are highly dependent on forest cover, the values for this factor (F) used in the control equations were better suited as flood flow predictors than either the Level I (U_f) or Level II (U_{fh} and U_{fl}) aircr aircraft derived forest cover estimates obtained three to five years beyond the flood analysis cutoff date.

Experiment 3

Owing to a significant loss of land-use detail in Landsat imagery, only three of six possible Level I categories were tested in Experiment 3. These include agriculture (Z_a), forestland (Z_f), and urban and built-up (Z_u). As in Experiment 2, S_t (map derived storage) was retained to reflect the percentage of each basin covered by lakes, ponds, and swamps. Level I forestland (Z_f) was substituted for map derived forest (F). Z_a and Z_u

represent land-use characteristics which were not considered in the control equations. Aside from the substitution of Z_f and the addition of Z_a and Z_u to the analysis, all other basin characteristics tested in Experiment 3 were identical with those used in the control equations.

Only six equations were improved (four significantly) and an identical number were reduced in accuracy (table 12). The independent variable appearing most often in the analyses was Z_u which was significant in a total of six low- and high-water equations as indicated below:

Streamflow Characteristic type	Number of equations	Number of times that indicated variable occurred		
		Z_a	Z_f	Z_u
High	10	0	2	4
Average	14	1	0	0
Low	3	0	0	2
Variability	13	0	1	0
All characteristics	40	1	3	6

As in the high-altitude photography experiments, flood peak equations were adversely affected by inclusion of remotely sensed land-use information. Four of the five flood peak equations showed significant accuracy losses. Satellite forest cover, (Z_f) obtained principally in late 1972, was not as effective as map derived values (F) in portraying conditions representative of the flood flow data analyzed in this report. Moreover, additional difficulties in land-use discrimination in satellite imagery that were not encountered in high-altitude photography introduced further errors in evaluating Z_f. The combination of these and other error factors interacted to amplify flood-flow accuracy losses to a range of 20 to 36.5 percent (table 12).

Using a network of gaged basins in the Delmarva Peninsula, Hollyday (1976) found that 12 streamflow characteristics were significantly improved with the inclusion of Landsat derived land-use information. Hollyday extracted the following categories from satellite imagery for use in a multiple regression analysis (1) forest, (2) riparian (streambank) vegetation, (3) water, and (4) combined agricultural and urban land use. Only one accuracy loss (December mean discharge) was detected in his regression analysis of 20 gaging stations, all of which were included in this study.

SUMMARY AND CONCLUSIONS

Maps incorporating the CARETS land-use classification system were utilized to determine land cover in selected basins of Delaware, eastern Maryland and Virginia. Land-use maps based on high-altitude photographs were used to prepare Level I (generalized) and Level II (more detailed) classifications for 49 basins. Only Level I classifications could be defined on the 1:250,000 scale maps derived from Landsat-1 images. Land use varied from highly urbanized in many basins in the Washington-Baltimore-Wilmington corridor to heavily agricultural in the Delmarva Peninsula.

Using a network of gaging stations consisting of 39 of the 49 basins for which land cover was defined, it was demonstrated that land-use data derived from high-altitude aircraft photographs are effective in significantly improving streamflow estimates. Significant improvement in accuracy, defined as a 10 or greater percentage reduction in the standard error of estimate, was detected by comparing streamflow characteristic "control" equations with three experimental equation sets. The control equation set consisted of basin characteristics used in a review of the streamflow program of the Maryland district of the U.S. Geological Survey. Land-use data based on high-altitude photographs and satellite imagery were used in the experimental equation sets. Comparisons of the experimental and control equations utilizing land-use information derived from high-altitude photographs showed significant improvement in six equations incorporating Level I data and in five equations where Level II categories were used. Only four equations showed significant improvement using land-use information derived from Landsat-1 imagery. The lower resolution of imagery relative to high-altitude photographs and difficulties in classifying certain spectral signatures tend to lower the effectiveness of satellite sensors as a means of providing detailed land-use information.

Of the wide range of streamflow characteristics tested, remotely sensed land-use data yielded losses in accuracy only in estimates of flood peaks. These losses in accuracy were probably due to land cover changes stemming from temporal differences among the three primary land-use data sources. For example, high-altitude photographs and satellite imagery were obtained primarily in 1970 and 1972, respectively, and streamflow records analyzed in this study terminated on September 30, 1967. Thus, remotely-sensed land-use data were not synchronous with the period of flood-flow analysis. By way of contrast, map derived land-use data incorporated in the control equations were obtained primarily in the late 1950's, which closely represent the median date associated with the streamflow records in this study.

Because the ability to accurately transfer streamflow data from gaged to ungaged sites is increased by raising network efficiencies, the application of remotely sensed land-use information to improve streamflow network models is a potentially valuable analytical tool. However, the generally favorable improvement in the network model of the Maryland district of the U.S. Geological Survey following inclusion of land-use data based on high-altitude photographs and satellite imagery may or may not be exceeded in other parts of the Nation. Accordingly, it is recommended that experiments, similar to those used in this report be conducted wherever remotely sensed land-use data are currently available. This would permit the making of accurate assessments of the use of remotely sensed land-use information to improve streamflow network models under a wide range of physiographic, climatic, and geologic settings.

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APPENDIX

Table A1. — Streamflow and basin characteristics of stations used in multiple regression analysis (see explanation on p. 84).

STATION No	Col (1) CONTDA	(2) SLOPE	(3) LENGTH	(4) ELEV	(5) STORAGE	(6) FOREST	(7) SOIL	(8) TIMETOPK		(9)		(10)	
01477800	7.4600	67.1000	5.7000	270.9998	0.0190	19.0000	3.0000	0.0	B	0.0	B	0.0	B
1478000	20.5000	22.7000	12.6000	198.9999	0.0700	19.0000	3.7000	0.0	B	0.0	B	0.0	B
1478500	66.7000	18.4000	18.4000	379.9998	0.0730	19.0000	3.7000	0.0	B	0.0	B	0.0	B
1483200	3.8500	15.8000	2.3600	64.0000	0.7000	43.0000	3.7000	0.0	B	0.0	B	0.0	B
1483500	9.3500	10.4000	5.1000	61.0000	0.0100	21.0000	3.7000	0.0	B	0.0	B	0.0	B
1484300	7.0800	7.8900	4.9000	38.0000	3.9530	54.0000	3.7000	0.0	B	0.0	B	0.0	B
1484500	5.2400	4.8700	4.5000	46.0000	0.0400	51.0000	3.7000	0.0	B	0.0	B	0.0	B
1485000	60.5000	1.4900	14.9000	44.0000	15.8900	30.0000	3.7000	0.0	B	0.0	B	0.0	B
1485500	44.9000	3.5600	13.1000	46.0000	6.2000	85.0000	3.7000	0.0	B	0.0	B	0.0	B
1486000	5.8000	5.4700	4.2000	32.0000	0.0	57.0000	3.7000	0.0	B	0.0	B	0.0	B
1486500	19.5000	5.8600	9.5000	50.0000	2.3000	48.0000	3.7000	0.0	B	0.0	B	0.0	B
1487000	75.4000	3.2300	14.3000	50.0000	1.7000	40.0000	3.7000	0.0	B	0.0	B	0.0	B
1487500	16.7000	4.8200	7.5000	50.0000	1.6350	71.0000	[illegible]	0.0	B	0.0	B	[illegible]	[illegible]
1488500	44.8000	2.6500	11.9000	56.0000	0.3000	29.0000	3.7000	0.0	B	0.0	B	0.0	B
1489000	7.1000	7.6500	5.5000	46.0000	0.4740	33.0000	3.7000	0.0	B	0.0	B	0.0	B
1490000	15.0000	4.5300	7.3000	28.0000	0.1000	50.0000	3.7000	0.0	B	0.0	B	0.0	B
1491000	112.9999	3.0100	19.0000	60.0000	1.9090	35.0000	3.7000	0.0	B	0.0	B	0.0	B
1492000	5.8500	14.8000	4.1000	55.0000	0.0	26.0000	3.7000	0.0	B	0.0	B	0.0	B
1492500	8.0900	8.8000	6.1000	59.0000	0.0	32.0000	3.2000	0.0	B	0.0	B	0.0	B
1493000	22.3000	6.0600	9.9000	61.0000	1.5400	43.0000	3.7000	0.0	B	0.0	B	0.0	B
1493500	10.5000	9.1500	6.1000	60.0000	0.2000	8.0000	3.7000	0.0	B	0.0	B	0.0	B
1494000	12.5000	10.6000	5.6000	67.0000	0.0060	24.0000	3.2000	0.0	B	0.0	B	0.0	B
1495000	52.6000	17.9000	23.3000	397.9998	0.0530	14.0000	3.7000	0.0	B	0.0	B	0.0	B
1495500	26.8000	23.7000	16.1000	358.9998	1.0650	23.0000	3.7000	0.0	B	0.0	B	0.0	B
1579000	5.3100	38.0000	3.6000	347.9998	0.0770	19.0000	3.7000	0.0	B	0.0	B	0.0	B
1586000	56.6000	23.9000	14.1000	746.9995	0.0720	38.0000	3.3000	0.0	B	0.0	B	0.0	B
1589300	32.5000	21.0000	13.7000	553.9998	0.0470	33.0000	3.3000	0.0	B	0.0	B	0.0	B
1590000	8.5000	18.1000	4.6000	111.9999	0.3610	70.0000	3.5000	0.0	B	0.0	B	0.0	B
1591000	34.8000	28.2000	12.5000	588.9998	0.0	26.0000	3.5000	0.0	B	0.0	B	0.0	B
1594500	30.2000	7.4400	10.6000	147.0000	0.4800	47.0000	3.1000	0.0	B	0.0	B	0.0	B
1594600	3.8500	22.8000	2.8000	105.9999	0.0	46.0000	3.5000	0.0	B	0.0	B	0.0	B
1655500	13.0000	77.1000	4.8000	639.9995	0.0	33.0000	3.3000	0.0	B	0.0	B	0.0	B
1645200	3.7000	59.5000	2.9000	373.9998	0.1480	26.0000	3.0400	0.0	B	0.0	B	0.0	B
1658000	57.7000	10.5000	17.6000	182.9999	3.2090	59.0000	3.1000	0.0	B	0.0	B	0.0	B
1653500	16.7000	22.9000	8.5000	225.9999	0.1880	45.0000	3.0700	0.0	B	0.0	B	0.0	B
1646550	4.1000	63.2000	2.9000	304.9998	0.0	14.0000	3.0400	0.0	B	0.0	B	0.0	B
1648000	62.2000	12.6000	24.5000	386.9998	0.0520	34.0000	3.0400	0.0	B	0.0	B	0.0	B
1649500	72.8000	27.2000	15.7000	226.9999	1.5300	56.0000	3.0600	0.0	B	0.0	B	0.0	B
01650500	21.1000	19.3000	8.1000	414.9998	0.0400	31.0000	3.0400	0.0	B	0.0	B	0.0	B

Table A1. -- Streamflow and basin characteristics of stations used in multiple regression analysis -- Continued.

STATION No	G1 (11)		(12)		(13)		(14)		(15)		(16)		(17)		(18)		(19) PRECIP	(20) I24,2
1477800	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	45.0000	3.3000
1478000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	45.0000	3.2000
1478500	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	45.0000	3.2000
1483200	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	44.5000	3.2000
1483500	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	45.0000	3.5000
1464300	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	47.0000	3.7000
1484500	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	47.0000	3.6000
1485000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	47.0000	3.4000
1485500	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	47.0000	3.4000
1486000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	46.0000	3.3000
1486500	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	46.0000	3.4000
1487000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	45.5000	3.5000
1487500	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	46.5000	3.4000
1488500	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	46.0000	3.5000
1489000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	45.0000	3.4000
1490000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	45.0000	3.5000
1491000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	45.0000	3.5000
1492000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	44.5000	3.3000
1492500	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	44.5000	3.4000
1493000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	43.5000	3.2000
1493500	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	43.0000	3.2000
1494000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	44.5000	3.2000
1495000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	44.5000	3.3000
1495500	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	44.5000	3.5000
1579000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	43.0000	3.2000
1586000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	45.0000	3.4000
1589300	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	44.5000	3.3000
1590000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	43.5000	4.0000
1591000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	42.5000	3.3000
1594500	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	44.0000	3.8000
1594600	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	44.0000	3.9000
1655500	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	39.5000	3.2500
1645200	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	41.5000	3.2000
1656000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	45.5000	3.7000
1653500	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	43.5000	3.7000
1646550	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	44.0000	3.3000
1648000	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	43.5000	3.2600
1649500	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	43.5000	3.7000
1650500	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	43.5000	3.3000

Table A1. -- Streamflow and basin characteristics of stations used in multiple regression analysis -- Continued.

STATION No	Col. (21) SNOFALL	(22) JANMIN	(23) JULYMAX	(24) P2	(25) P5	(26) P10	(27) P25	(28) P50	(29) QA	(30) SDA
01477800	20.0000	25.5000	85.0000	1199.9993	2099.9990	2999.9968	4699.9961	0.0 B	9.0260	3.0160
1478000	24.0000	25.0000	86.5000	1404.9993	1740.9990	1971.9993	2274.9988	2508.9990	25.3000	7.6930
1478500	25.0000	25.0000	86.0000	2872.9985	3683.9985	4188.9961	0.0 B	0.0 B	71.4100	26.1000
1483200	20.0000	26.0000	86.5000	103.9999	193.9999	274.9998	407.9998	530.9998	4.2020	1.9740
1483500	19.0000	26.5000	86.5000	195.3999	394.3997	617.5996	1059.9493	0.0 B	10.6900	3.5020
1484300	16.0000	27.5000	86.0000	32.6800	56.7000	81.1500	0.0 B	0.0 B	9.8770	3.0630
1484500	15.0000	28.0000	85.5000	55.2200	79.9800	97.8800	122.2000	141.4999	6.9890	2.3680
1485000	13.5000	28.5000	85.5000	642.9998	775.9995	850.9995	932.9995	987.9995	65.6800	20.4500
1485500	12.0000	28.0000	87.0000	485.6997	727.2996	863.1995	1007.9990	0.0 B	50.1300	19.3200
1486000	12.0000	27.0000	85.5000	117.7999	191.4999	239.8999	290.5999	0.0 B	3.9060	1.4410
1486500	13.0000	28.0000	87.0000	243.2999	452.5996	618.6996	853.2996	1045.9995	23.1900	8.1980
1487000	16.5000	26.5000	86.5000	599.9998	999.9995	1399.9990	2039.9985	2649.9985	90.4500	31.5900
1487500	14.0000	28.0000	86.0000	209.0999	333.7998	412.6997	505.7995	0.0 B	16.1100	5.3830
1488500	17.5000	26.5000	87.0000	660.9998	1229.9990	1669.9993	2299.9988	2819.9988	51.4400	22.8600
1489000	16.0000	27.0000	86.0000	177.2999	409.0996	616.4996	935.5996	0.0 B	8.7690	3.2480
1490000	15.0000	28.0000	86.5000	209.9999	335.9998	427.9998	551.9998	648.9995	16.8300	5.0470
1491000	19.0000	26.5000	87.5000	1593.9990	2787.9988	3800.9983	5361.9961	0.0 B	121.2999	57.8000
1492000	17.0000	27.0000	87.0000	271.9998	595.9998	967.9995	1719.9993	2589.9988	6.5830	2.8130
1492500	18.0000	27.0000	87.5000	170.9999	483.1997	844.9995	1608.9993	0.0 B	0.0 B	0.0 B
1493000	20.0000	26.0000	87.0000	282.7998	507.5996	693.8997	973.4995	0.0 B	23.1200	9.3040
1493500	21.0000	26.0000	87.0000	356.9998	672.9995	937.9995	1329.9995	1679.9990	9.1770	3.2900
1494000	20.0000	26.5000	87.5000	464.8997	828.7996	1165.9991	1731.9995	0.0 B	0.0 B	0.0 B
1495000	23.0000	24.5000	86.0000	3108.9985	4871.9961	6292.9961	8404.9961	10229.9922	67.0600	18.4000
1495500	21.0000	24.5000	87.0000	1579.9993	2360.9988	3191.9985	0.0 B	0.0 B	38.2400	12.0400
1579000	20.0000	24.0000	86.5000	571.3997	954.7996	1251.9990	0.0 B	0.0 B	6.7450	2.3380
1586000	29.0000	24.5000	86.5000	2037.9990	2832.9985	3340.9988	3959.9983	0.0 B	59.0700	19.6900
1589300	26.0000	26.5000	86.5000	908.4995	1259.9993	1639.9990	0.0 B	0.0 B	29.2600	8.3670
1590000	20.0000	26.0000	86.5000	144.7999	238.0999	353.9998	604.9998	909.9995	10.1400	2.4300
1591000	22.0000	23.5000	87.5000	1338.9993	2882.9990	4460.9961	7306.9961	0.0 B	34.9400	12.5500
1594500	20.0000	24.0000	88.0000	801.9995	1178.9995	1427.9990	1741.9993	0.0 B	26.1100	8.8690
1594600	15.0000	27.5000	86.5000	137.9999	336.1997	534.9998	0.0 B	0.0 B	4.1310	1.6780
1655500	18.4000	24.3000	87.0000	1079.9990	2119.9988	2899.9988	3959.9983	0.0 B	11.0000	3.9000
1645200	19.0000	26.0000	87.5000	470.7996	847.9995	1135.9990	0.0 B	0.0 B	3.1670	0.7586
1658000	17.0000	26.0000	87.5000	904.3994	1958.9990	3176.9983	5664.9961	0.0 B	52.6900	18.5800
1653500	18.0000	25.5000	87.0000	1047.9990	1734.9993	2303.9990	3165.9963	0.0 B	18.3400	5.7310
1646550	18.0000	26.0000	87.0000	1115.9990	1652.9995	2039.9985	2563.9985	0.0 B	3.1700	0.8512
1648000	19.0000	26.0000	88.0000	1491.9990	2460.9988	3254.9983	4445.9961	5480.9961	55.4800	18.0200
1649500	19.0000	26.0000	87.0000	2295.9988	3564.9983	4607.9961	6163.9961	7565.9961	75.9100	20.4600
01650500	19.0000	25.5000	87.0000	1200.9995	1980.9990	2675.9988	3803.9988	4657.9961	22.3400	7.9580

Table A1. -- Streamflow and basin characteristics of stations used in multiple regression analysis -- Continued.

STATION No	Col (31) Q10	(32) Q11	(33) Q12	(34) Q1	(35) Q2	(36) Q3	(37) Q4	(38) Q5	(39) Q6	(40) Q7
01477800	3.3850	8.1270	9.5860	11.8900	14.3000	16.0400	13.1600	9.3620	4.7730	6.1330
1478000	10.4900	21.1200	26.6800	33.7600	42.7800	44.0500	34.4700	25.6800	15.6900	17.2050
1476500	38.1300	57.6500	68.8400	87.4000	103.8999	123.0999	99.8600	80.0600	53.3700	45.0200
1483200	2.3760	4.1130	4.0980	5.4630	7.3020	9.0740	6.9190	3.8790	1.9710	1.7790
1483500	5.8180	11.2900	11.4300	13.6000	14.9600	16.5600	14.0700	12.4100	7.5620	7.0400
1484300	6.3050	7.2720	8.1010	10.3400	12.1800	15.5400	14.8400	10.6700	8.1930	7.8220
1484500	3.1720	4.8500	6.8670	9.4310	10.4200	13.0700	9.7560	7.3100	5.7490	4.7130
1485000	29.3100	41.2800	70.9000	97.9700	125.7999	148.3999	100.0999	53.0600	36.9600	22.3600
1485500	19.3300	32.8500	51.2300	73.5400	97.0300	117.8999	75.5200	41.6250	27.2200	15.5600
1486000	1.3460	1.8790	4.0750	6.5410	8.7050	9.6560	5.7620	2.6530	1.6840	0.7437
1486500	14.4400	17.6600	22.9800	29.6600	34.1900	40.6200	32.3200	23.0600	17.5000	12.8900
1487000	40.8300	67.6900	91.3000	121.0999	132.6999	164.1999	130.2999	86.0100	69.3900	60.1200
1487500	5.3670	9.7720	15.6000	22.8500	30.4800	37.6500	26.4100	15.5200	9.7350	4.5400
1488500	12.5300	37.2200	58.0400	81.1900	83.6600	106.4999	70.7000	40.6300	28.2000	35.5600
1489000	3.2340	6.1440	8.2740	11.7600	14.1300	16.6000	12.6700	7.3010	5.7320	4.8110
1490000	7.8180	12.5900	15.7800	22.1700	27.4500	33.0700	25.8100	15.9400	10.9300	8.0030
1491000	36.5900	99.7200	138.7999	181.5999	211.9999	254.5999	173.9999	105.5999	59.0000	36.7700
1492000	2.2630	5.8160	6.6340	8.4430	11.4500	13.4700	9.6060	4.8400	2.7010	3.0730
1492500	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
1493000	11.6900	16.4600	20.6600	28.8200	35.8600	43.0300	34.0600	23.7500	16.8400	13.6000
1493500	5.9650	8.1890	9.4250	11.3500	12.1500	13.5100	10.1400	7.8000	6.0730	6.9310
1494000	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
1495000	37.5100	51.9400	58.8800	79.3700	98.3500	101.1999	90.6400	73.3300	54.1400	56.2200
1495500	15.4100	29.9400	44.9600	45.7700	54.5300	63.6700	52.2600	43.4800	30.9100	25.1900
1579000	3.1910	5.3800	7.7550	8.4570	9.0150	10.0600	9.3530	7.9640	5.3590	5.8050
1586000	31.7800	46.4400	53.9100	67.5400	82.8500	94.6500	81.0500	71.7200	55.5000	48.3500
1589300	15.8200	22.4400	26.3500	34.4800	48.0300	54.8800	43.9000	31.3900	19.9900	16.4300
1590000	7.9370	9.7980	9.9450	11.2200	12.0900	13.4800	13.4600	11.1200	8.4590	7.5270
1591000	15.07[illegible]	24.1600	33.5600	41.8300	52.[illegible]500	59.3900	51.2500	42.2800	31.8700	25.9700
1594500	12.4900	20.6400	25.3400	33.4300	43.8000	55.5900	43.9100	28.6400	17.5800	14.4500
1594600	1.8730	2.8740	3.3470	4.2450	5.7790	8.5990	7.9200	5.1490	3.9350	2.3560
1655500	4.2000	6.9000	10.0000	14.0000	20.0000	26.0000	20.0000	13.0000	8.5000	4.8030
1645200	1.4270	1.9810	2.2940	3.5960	4.8230	5.6960	4.3730	3.3610	2.8270	2.7490
1658000	18.7700	32.8500	58.0300	76.6200	106.2999	133.5999	69.7500	37.7400	21.4900	10.9300
1653500	10.5800	15.1800	18.8100	20.3600	27.7100	33.2300	27.6700	20.9300	12.3500	8.5090
1646550	1.5490	2.7220	2.9450	3.2450	3.5560	4.1960	3.6530	3.7770	3.2280	3.1900
1648000	33.2700	44.5100	49.4600	64.7000	79.6700	87.0600	80.6700	64.2300	47.6400	39.9400
1649500	44.5100	63.4400	75.3900	89.6600	110.3999	128.0000	108.2000	78.6100	57.5500	46.1700
01650500	17.6500	21.6800	18.5800	26.7500	37.0900	31.6700	31.7500	22.3700	17.2300	11.5000

Table A1. -- Streamflow and basin characteristics of stations used in multiple regression analysis -- Continued.

STATION No	Col. (41) SD8	(42) SD9	(43) SD10	(44) SD11	(45) SD12	(46) SD1	(47) SD2	(48) SD3	(49) SD4	(50) SD5
01477800	7.4620	4.3810	3.3370	6.9490	6.2290	7.6650	6.0220	6.2480	6.6320	7.7360
1478000	20.0900	12.2800	7.5000	12.5700	17.4500	17.1500	17.9400	17.2600	17.1800	16.9500
1478500	62.3600	39.0700	14.3200	24.8700	35.1100	53.0500	29.6200	49.8600	53.4700	50.3900
1483200	2.0500	2.3160	1.6900	2.6440	2.3970	2.9540	3.5870	4.9430	3.6210	2.4630
1483500	7.9000	5.9020	1.4630	7.9260	6.6500	6.2800	6.3450	5.6640	6.0010	4.7590
1484300	9.8520	7.5470	3.7240	2.9260	2.9700	3.5930	5.3040	5.7550	6.8210	4.2820
1484500	5.4740	3.2670	1.7780	3.6040	5.5100	4.8690	4.9910	5.8580	4.3230	3.7340
1485000	45.3900	17.7000	34.1300	31.6400	35.2000	56.1400	69.8400	75.7100	53.5500	39.3300
1485500	38.8700	13.1600	24.6900	30.1000	27.9800	44.7700	60.7200	63.8500	46.7100	43.1700
1486000	2.5260	1.1490	2.1790	1.9940	2.4260	4.7070	4.8170	5.1560	2.9000	2.7550
1486500	20.8100	12.4600	10.6700	10.9800	16.6500	15.5700	17.0300	18.6900	14.5900	13.2600
1487000	76.8100	49.8500	20.3400	39.0900	69.6700	66.3500	75.3600	77.5600	55.9300	37.6800
1487500	11.6400	5.1700	5.8220	7.9260	8.0380	13.0400	16.6400	17.1000	12.8300	10.5300
1488500	46.7300	17.5200	6.8120	42.4300	57.2600	49.1200	48.7600	55.4000	34.6200	33.1100
1489000	9.9420	4.9800	2.0660	5.5400	5.1260	6.6740	7.6040	7.2420	5.5500	3.4360
1490000	13.5500	9.4120	3.6070	5.5280	7.3800	12.2500	15.4800	12.3500	10.8500	8.3130
1491000	111.6999	47.3400	33.9100	113.4999	124.0999	125.1999	111.1999	93.6900	96.8999	74.3600
1492000	7.5170	3.1740	2.8460	6.3540	4.3770	5.6490	7.0950	5.6940	4.9780	4.2760
1492500	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
1493000	18.1600	15.3200	7.1280	11.4100	12.8100	17.5100	18.0700	19.8600	17.0200	11.0700
1493500	9.0930	7.6260	2.3180	3.2910	4.8990	6.3960	4.3210	5.9080	5.1220	3.5310
1494000	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
1495000	60.7700	44.2300	16.8000	23.1000	27.1800	43.0000	41.9900	37.0600	37.6100	34.6000
1495500	34.0200	20.2000	4.4100	13.2000	22.4000	28.5500	17.3700	24.0400	20.7700	23.8000
1579000	4.9720	3.7090	0.8273	2.2790	3.9970	5.5360	3.0020	2.9570	3.8040	4.0560
1586000	44.3900	32.1500	12.6600	26.9900	30.3000	37.1400	33.6500	28.3800	40.6300	39.8300
1589300	22.5000	16.4300	4.8660	8.8980	15.6900	16.8100	17.0400	21.7900	19.4100	15.0900
1590000	9.3570	7.4560	3.1660	3.6670	3.7640	4.1160	3.5920	3.8130	4.4390	4.2630
1591000	23.6800	20.0500	6.9990	16.4200	24.0300	24.3300	21.0000	19.7600	28.0100	25.9900
1594500	25.8000	16.0100	10.9000	16.2100	15.6100	19.7300	17.5500	24.1000	22.4900	19.1400
1594600	1.9640	1.6400	1.3470	0.9726	1.7450	1.9200	2.7540	3.9950	3.5760	3.1380
1655500	7.0000	4.1000	4.3000	8.3000	8.9000	9.4000	11.0000	10.0000	9.7000	8.3000
1645200	2.8690	2.0970	0.8142	1.3060	1.0020	2.0710	2.2250	2.0820	1.7430	1.3160
1658000	35.7800	13.3800	35.2300	28.6000	49.0100	43.0400	53.2700	65.0300	[illegible]	24.7700
1653500	13.6100	11.4200	9.7060	10.0700	12.7000	11.2900	11.5000	13.7600	[illegible]	16.9900
1646550	3.4990	2.4870	1.1810	2.1130	2.2130	1.6480	1.8230	2.0650	2.3790	2.6470
1648000	43.1400	32.8200	28.5600	33.8000	28.6800	34.2200	37.8600	33.7300	36.2700	29.7500
1649500	66.4600	42.6500	44.0900	38.4500	47.7200	45.7700	47.9000	49.5900	52.1700	42.7000
01650500	17.5300	15.4200	14.3400	15.9200	9.0740	14.8300	22.1900	15.7400	16.9900	12.5600

Table A1. -- Streamflow and basin characteristics of stations used in multiple regression analysis -- Continued.

STATION No	Col. 51 SD6	52 SD7	53 SD8	54 SD9	55 M7,2	56 M7,5	57 M7,10	58 M7,20	59 V3,2	60 V3,25
1477600	2.9450	5.8570	13.6400	4.6430	0.5000	0.0 B	0.2000	0.2000	112.9999	244.9999
1478000	9.2300	16.2400	29.0600	11.4600	3.6000	0.0 B	1.3000	0.9000	273.7998	424.0996
1478500	27.6900	29.0700	66.6300	18.3300	17.0000	0.0 B	7.6000	6.0000	533.0996	869.4995
1483200	1.0110	2.2070	2.0650	3.3720	0.4010	0.0 B	0.0	0.0	0.0 B	0.0 B
1483500	2.6740	5.8640	6.2830	2.9500	3.0000	0.0 B	1.9000	1.7000	66.4400	231.8999
1484300	2.1700	4.5600	7.9870	4.6420	3.8000	0.0 B	1.9000	1.5000	26.0000	59.0000
1484500	4.5780	3.4680	5.2440	1.8390	1.6010	0.0 B	0.6001	0.4000	49.2500	78.5000
1485000	28.4500	17.2200	51.7500	13.0500	5.6000	0.0 B	2.6000	2.0000	0.0 B	0.0 B
1485500	19.5800	19.6000	55.5100	12.3000	2.7000	0.0 B	1.4000	1.2000	421.6997	730.0996
1486000	1.5440	0.6776	4.5260	2.1800	0.1010	0.0 B	0.0001	0.0	44.8200	93.3500
1486500	12.3700	6.4960	22.5200	5.9300	5.4000	0.0 B	0.0 B	0.0 B	137.0999	363.7998
1487000	52.3700	43.2600	94.6700	46.9300	22.0000	0.0 B	14.0000	12.0000	0.0 B	0.0 B
1487500	5.4120	3.5210	17.9400	6.2270	0.3010	0.0	[illegible]	0.1000	109.8999	249.7999
1488500	30.9800	47.0800	79.6400	25.3400	4.6000	0.0 B	2.0000	1.5000	0.0 B	0.0 B
1489000	3.4630	4.0280	13.2400	5.8510	1.0000	0.0 B	0.1000	0.0	65.2800	222.5999
1490000	3.6360	3.1240	15.7900	8.0100	3.3000	0.0 B	1.8000	1.5000	0.0 B	0.0 B
1491000	43.7100	42.4000	218.0999	72.3500	10.0000	0.0 B	4.5000	3.4000	1663.9995	3745.9985
1492000	2.1860	5.2760	11.1500	7.1960	0.1010	0.0 B	0.0	0.0	0.0 B	0.0 B
1492500	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
1493000	10.0400	7.3630	16.8400	19.1700	6.6000	0.0 B	3.9000	0.0 B	133.3999	430.2998
1493500	5.8720	4.9680	7.1290	7.4800	2.9000	0.0 B	1.4000	1.0000	0.0 B	0.0 B
1494000	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
1495000	23.8800	34.0000	58.7300	30.8500	19.0000	0.0 B	6.9000	7.2000	540.3997	1144.9990
1495500	9.9920	13.6000	37.7900	10.7800	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
1579000	1.6660	4.0110	4.0400	1.9550	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
1586000	35.0200	30.1300	38.3700	16.6600	17.0000	0.0 B	7.6000	5.7000	404.8997	819.6597
1589300	8.9610	9.0580	28.8700	11.5400	6.0000	0.0 B	2.9000	2.3000	257.5998	0.0 B
1590000	3.3590	3.7640	7.0040	3.8980	3.7000	0.0 B	2.0000	1.7000	49.1900	160.0999
1591000	21.6900	24.9400	24.1200	15.8800	7.3000	0.0 B	3.0000	2.2000	257.3999	736.1997
1594500	14.8300	13.8900	32.3100	19.9700	1.9000	0.0 B	0.5000	0.3000	296.7998	609.9998
1594600	2.8590	1.9920	2.1060	2.0930	0.2010	0.0 B	0.0001	0.0	21.0000	0.0 B
1655500	9.0000	9.0000	12.0000	4.8000	0.3100	0.0 B	0.1000	0.0700	0.0 B	0.0 B
1645200	1.6730	3.2750	3.1740	2.0540	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
1658000	14.7000	13.0000	99.3000	31.7400	0.0010	0.0 B	0.0001	0.0	553.9996	1569.9990
1653500	8.6100	7.0730	21.4600	13.2700	0.9010	0.0 B	0.0001	0.0	187.7999	515.0996
1646550	2.6770	3.8000	3.9290	2.5350	0.2010	0.0 B	0.1000	0.0	38.5800	104.6999
1648000	27.0900	36.1300	41.0500	30.6700	8.4000	0.0 B	2.2000	1.4000	470.8997	1073.9993
1649500	49.8700	64.6800	65.9900	37.4800	11.0000	0.0 B	4.8000	3.6000	794.8997	1468.9993
1650500	10.3400	5.3110	17.6400	15.6800	3.6000	0.0 B	0.9000	0.6000	184.9999	449.9998

Table A1. -- Streamflow and basin characteristics of stations used in multiple regression analysis -- Continued.

STATION No	Col (61) V3,50	(62) V7,2	(63) V7,10	(64) V7,25	(65) V7,50	(66) D50	(67)
1477800	0.0 B	61.0000	98.0000	119.0000	0.0 B	3.0000	
1478000	457.1997	148.2999	223.9999	263.1997	293.2998	12.6000	
1478500	0.0 B	310.6997	517.9998	639.6997	0.0 B	48.5000	
1483200	0.0 B	18.6600	39.0000	0.0 B	0.0 B	0.0 B	
1483500	0.0 B	40.0700	82.0000	110.7000	0.0 B	7.2500	
1484300	0.0 B	23.5000	42.5000	52.0000	0.0 B	8.6000	
1484500	91.6800	25.2600	46.0000	57.0700	65.2500	4.9500	
1485000	0.0 B	340.0499	515.9998	0.0 B	0.0 B	0.0 B	
1485500	0.0 B	313.1997	488.9998	534.4996	0.0 B	24.0000	
1486000	0.0 B	28.0800	48.0000	57.0700	0.0 B	1.4400	
1486500	420.8997	93.9600	179.9999	222.3999	252.6999	16.7000	
1487000	0.0 B	365.9998	724.9995	0.0 B	1070.9993	0.0 B	
1487500	0.0 B	76.5900	129.9999	154.4999	0.0 B	10.6000	
1488500	0.0 B	316.1997	662.9995	0.0 B	971.3997	0.0 B	
1489000	0.0 B	41.9000	86.0000	107.9999	0.0 B	5.8000	
1490000	0.0 B	74.1400	128.9999	0.0 B	0.0 B	0.0 B	
1491000	0.0 B	713.9995	1579.9993	1975.9993	0.0 B	57.5000	
1492000	0.0 B	43.0000	100.0000	0.0 B	0.0 B	0.0 B	
1492500	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	
1493000	0.0 B	94.0400	193.9999	246.9999	0.0 B	15.0000	
1493500	0.0 B	48.4800	86.0000	0.0 B	0.0 B	0.0 B	
1494000	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	
1495000	1321.9993	302.6997	506.9998	629.6997	779.6997	45.5000	
1495500	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	23.3000	
1579000	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	4.4000	
1586000	0.0 B	252.4999	401.9998	466.0996	0.0 B	41.0000	
1589300	0.0 B	151.9999	246.9999	0.0 B	0.0 B	17.0000	
1590000	210.5999	32.6700	63.0000	85.3400	105.0999	8.1500	
1591000	0.0 B	170.0000	334.9998	476.7998	0.0 B	23.2000	
1594500	0.0 B	170.2999	290.9998	363.1997	0.0 B	14.8000	
1594600	0.0 B	15.0000	27.0000	0.0 B	0.0 B	2.8000	
1655500	0.0 B	83.0000	131.9999	144.9999	151.9999	0.0 B	
1645200	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	1.8200	
1658000	0.0 B	351.9996	786.9995	1119.9993	0.0 B	22.0000	
1653500	0.0 B	102.2999	203.9999	270.3997	0.0 B	10.0000	
1646550	0.0 B	20.8200	41.3100	53.6100	0.0 B	1.0000	
1648000	1222.9990	282.7998	478.9998	562.3997	618.0996	34.6000	
1649500	1601.9993	453.1997	722.9995	847.2996	935.0996	42.0000	
1650500	559.9998	105.9999	199.9999	249.9999	289.9998	12.9000	

Column 67 not used

Table A1. -- Streamflow and basin characteristics of stations used in multiple regression analysis -- Continued.

STATION No	Col (68) URBANBLT	(69) AGRICULT	(70) GAPFORST	(71) WATER	(72) URBAN,R	(73) URBAN,I	(74) URBAN,O	(75) FORST,L	(76) FORST,H	(77) URBN,R+I
1477800	84.9000	3.5000	11.0000	0.6000	69.6000	10.5000	4.6000	0.9000	10.1000	80.3000
1478000	20.9000	59.9000	19.2000	0.0	15.4000	4.3000	0.8000	1.0000	18.1[illegible]	20.7000
1478500	3.0000	78.0000	19.0000	0.0500	1.7000	1.0000	0.3000	0.5000	18.5000	2.7000
1483200	0.0	61.6000	37.6000	0.8000	0.0	0.0	0.0	0.0	37.6000	0.0
1483500	0.0	82.3000	17.7000	0.0	0.0	0.0	0.0	0.2000	17.5000	0.0
1484300	0.0	46.5000	52.5000	0.6000	0.0	0.0	0.0	0.7000	51.8000	0.0
1484500	1.3000	56.5000	42.2000	0.0	0.0	1.3000	0.0	0.0	42.2000	1.3000
1485000	0.2000	49.4000	50.2000	0.0	0.2000	0.0	0.0	0.9000	49.3000	0.2000
1485500	0.2000	19.7000	79.6000	0.0	0.2000	0.0	0.0	5.3000	74.3000	0.2000
1486000	0.0	31.6000	68.4000	0.0	0.0	0.0	0.0	0.5000	67.9000	0.0
1486500	5.1000	44.3000	49.6000	0.4000	1.9000	3.2000	0.0	1.9000	47.9000	5.1000
1487000	1.1000	57.4000	41.3000	0.0	1.0000	0.1000	0.0	0.2000	41.2000	1.1000
1487500	0.0	26.1000	72.8000	0.6000	0.0	0.0	0.0	9 7000	63.[illegible]	0.0
1488500	0.1000	58.0000	41.9000	0.0	0.1000	0.0	0.0	0.2000	41.7000	0.1000
1489000	0.0	72.5000	27.5000	0.0	0.0	0.0	0.0	0.0	27.5000	0.0
1490000	0.0	53.0000	46.8000	0.2000	0.0	0.0	0.0	2.8000	44.0000	0.0
1491000	0.1000	55.8000	43.9000	0.0	0.1000	0.0	0.0	0.9000	43.0000	0.1000
1492000	0.0	71.2000	28.8000	0.0	0.0	0.0	0.0	0.0	28.6000	0.0
1492500	0.0	67.9000	32.1000	0.0	0.0	0.0	0.0	0.0	32.1000	0.0
1493000	0.4000	70.1000	29.2000	0.3000	0.4000	0.0	0.0	1.5000	27.7000	0.4000
1493500	0.0	96.2000	3.8000	0.0	0.0	0.0	0.0	0.0	3.8000	0.0
1494000	0.0	73.5000	26.5000	0.0	0.0	0.0	0.0	0.2000	26.3000	0.0
1495000	1.1000	85.9000	13.0000	0.0	0.9000	0.2000	0.0	0.1000	12.9000	1.1000
1495500	1.2000	79.5000	18.3000	0.1000	0.7000	0.4000	0.0	3.1000	15.2000	1.1000
1579000	1.9000	73.4000	24.7000	0.0	1.9000	0.0	0.0	2.0000	22.7000	1.9000
1586000	3.6000	70.9000	25.3000	0.1000	2.3000	1.2000	0.1000	1.6000	23.7000	3.5000
1589300	35.4000	23.7000	40.0000	0.0	27.3000	5.7000	2.4000	6.7000	33.3000	33.0000
1590000	0.0	33.0000	67.0000	0.0	0.0	0.0	0.0	0.0	67.0000	0.0
1591000	1.5000	66.3000	32.2000	0.0	1.4000	0.1000	0.0	0.4000	31.8000	1.5000
1594500	18.5000	38.6000	42.9000	0.0	12.6000	3.8000	2.1000	1.5000	41.4000	16.4000
1594600	1.6000	57.7000	40.7000	0.0	1.6000	0.0	0.0	0.0	40.7000	1.6000
1655500	1.9000	63.1000	34.6000	0.4000	1.6000	0.3000	0.0	1.6000	33.0000	1.9000
1645200	42.5000	40.9000	16.6000	0.0	26.2000	14.0000	2.3000	4.8000	11.8000	40.2000
1658000	7.2000	24.7000	68.0000	0.1000	3.5000	2.8000	0.9000	1.0000	67.0000	6.3000
1653500	63.2000	4.8000	32.0000	0.0	39.7000	12.2000	10.3000	3.6000	28.4000	51.9000
1646550	93.9000	0.0	6.1000	0.0	73.0000	12.0000	9.0000	3.7000	2.4000	85.0000
1648000	53.3000	25.7000	20.3000	0.3000	37.5000	10.0000	5.8000	2.6000	18.1000	47.5000
1649500	45.1000	15.8000	38.9000	0.2000	24.9000	11.7000	8.5000	2.6000	36.6000	36.6000
1650500	26.0000	42.4000	31.6000	0.0	15.3000	1.5000	9.2000	6.0000	25.6000	16.8000

Table A1. -- Streamflow and basin characteristics of stations used in multiple regression analysis -- Continued.

STATION NO	(78) ERTSCHPN	(79) ERTSAGHI	(80) ERTSFRST	(81) ERTSWATR
01477800	86.0000	0.0	14.0000	0.0
1478000	12.0000	56.0000	30.0000	2.0000
1478500	0.0	80.0000	20.0000	0.0
1482200	0.0	51.0000	49.0000	0.0
1483500	0.0	91.0000	9.0000	0.0
1484300	0.0	52.0000	48.0000	0.0
1484500	1.0000	61.0000	38.0000	0.0
1485000	0.0	43.0000	56.0000	1.0000
1485500	2.0000	26.0000	72.0000	0.0
1486000	0.0	30.0000	70.0000	0.0
1486500	4.0000	51.0000	45.0000	0.0
1487000	0.0	54.0000	45.0000	1.0000
1487500	0.0	28.0000	72.0000	0.0
1488500	4.0000	56.0000	40.0000	0.0
1489000	0.0	71.0000	29.0000	0.0
1490000	0.0	47.0000	53.0000	0.0
1491000	1.0000	55.0000	44.0000	0.0
1492000	0.0	93.0000	7.0000	0.0
1492500	0.0	69.0000	31.0000	0.0
1493000	0.0	74.0000	26.0000	0.0
1493500	0.0	97.0000	3.0000	0.0
1494000	0.0	71.0000	29.0000	0.0
1495000	0.0	60.0000	20.0000	0.0
1495500	0.0	62.0000	38.0000	0.0
1579000	0.0	99.9000	0.1000	0.0
1586000	2.0000	81.0000	17.0000	0.0
1589200	45.0000	25.0000	30.0000	0.0
1590000	5.0000	13.0000	82.0000	0.0
1591000	0.0	65.0000	35.0000	0.0
1594500	19.0000	35.0000	46.0000	0.0
1594600	0.0	58.0000	42.0000	0.0
1655500	0.0	81.0000	19.0000	0.0
1645200	61.0000	24.0000	15.0000	0.0
1646550	94.0000	0.0	6.0000	0.0
1648000	49.0000	34.0000	16.0000	1.0000
1649500	55.0000	13.0000	32.0000	0.0
1650500	6.0000	71.0000	23.0000	0.0
1653500	85.0000	0.0	15.0000	0.0
01658000	1.0000	29.0000	70.0000	0.0

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EXPLANATION

B.	Missing data.
Station No.	These eight digit numbers are permanent nationwide numbers assigned by the U.S. Geological Survey to stations at which streamflow data are collected on a recurrent basis.
Col. 1	Drainage area, in square miles.
Col. 2	Main-channel slope, in feet per mile, determined from elevations at points 10 percent and 85 percent of the distance along the channel from the gaging station to the drainage divide.
Col. 3	Main-channel length, in miles, from the gaging station to the basin divide.
Col. 4	Mean-basin elevation, in feet above mean sea level.
Col. 5	Storage, in percent, of the drainage area covered by lakes, ponds, and swamps.
Col. 6	Forest cover, in percent, of the drainage area covered by forests as shown on USGS 1:24,000 scale topographic maps.
Col. 7	Soil index, a measure of potential maximum infiltration capacity, in inches, estimated from a map or from other data provided by the U.S. Soil Conservation Service.
Cols. 8-18	Not used in the analysis.
Col. 19	Mean annual precipitation, in inches, determined from an isohyetal map prepared from National Weather Service records.
Col. 20	Precipitation intensity, which is the maximum 24-hour rainfall, in inches, having a recurrence interval of 2 years (24-hour 2-year rainfall).
Col. 21	Average annual snowfall, in inches, estimated from maps of average snowfall prepared from National Weather Service records.
Col. 22	Average minimum January temperature, in degrees Fahrenheit.
Col. 23	Average maximum July temperature, in degrees Fahrenheit.

Col. 24-28	Flood-peak characteristics are represented by discharge from the annual flood-frequency curve at recurrence intervals of 2, 5, 10, 25, and 50 years.
Col. 29	Mean annual discharge, in ft^3/s.
Col. 30	Standard deviation of mean annual flows, in ft^3/s.
Col. 31-42	Mean monthly discharge, in ft^3/s beginning with Q_{10} (October).
Col. 43-54	Standard deviation on monthly flows, in ft^3/s.
Col. 55-58	Low-flow characteristics are the annual minimum 7-day mean flows, in ft^3/s at 2-year, 10-year, and 20-year recurrence intervals ($M_{7,2}$, $M_{7,10}$, and $M_{7,20}$); Col. 56 not used.
Col. 59-65	Flood-volume characteristics represent the annual highest average flow, in ft^3/s for 3-day periods at recurrence intervals of 2, 25, and 50 years and for 7-day periods at recurrence intervals of 2, 10, 25, and 50 years.
Col. 66	Fifty percentile discharge on the flow duration curve, in ft^3/s.
Col. 67	Not used in the analysis.
Col. 68-71	Level I land use categories, in percent, determined from high altitude areal photographs.
Col. 72-77	Level II land use categories, in percent, determined from high altitude areal photographs.
Col. 78-81	Level I land use categories, in percent, determined from Landsat (ERTS) imagery.