Use of Digital Land-cover Data from the Landsat Satellite in Estimating Streamflow Characteristics in the Cumberland Plateau of Tennessee

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FACTORS FOR CONVERTING INCH-POUND UNITS
TO INTERNATIONAL SYSTEM OF UNITS (SI)

For the convenience of readers who may want to use the International System of Units (SI), the data may be converted by using the following factors:

Multiply	By	To obtain
inches (in)	25.40	millimeters (mm)
feet (ft)	0.3048	meters (m)
feet per mile (ft/mi)	0.1894	meters per kilometer (m/km)
miles (mi)	1.609	kilometers (km)
acres	0.4047	hectares
square miles (mi^2)	2.590	square kilometers (km^2)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)

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

$$°C = 5/9(°F - 32)$$

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ABSTRACT

Characteristics of streamflow at ungaged sites in coal-mining areas of the Cumberland Plateau may be estimated with regression equations that relate streamflow characteristics to the physiographic and climatic characteristics of the corresponding drainage basins. An experiment was performed to compare the accuracy of equations using basin characteristics derived from maps and climatological records (control group equations) with the accuracy of equations using basin characteristics derived from digital processing of Landsat spectral data as well as maps and climatological records (experimental group equations).

Results of this experiment show that (with the exception of low flows and four of six annual peak logarithms) drainage area can explain more than 90 percent of the variance in all streamflow characteristics in both groups of equations. Seventeen of 39 experimental group equations that have two basin characteristics each are different from the corresponding control group equations. Five of the 17 differing experimental group equations have no counterpart in the control group because of lack of significance in control group basin characteristics, seven are slightly more accurate, and five are not measurably different in accuracy. When the equations in both groups are arranged into six flow categories, there is no substantial difference in accuracy between equations using basin characteristics derived from maps and climatological records (control group) and equations using basin characteristics derived from Landsat tapes as well as maps and climatological records (experimental group) for this particular study area, the Cumberland Plateau of Tennessee.

INTRODUCTION

Nationally, over the past 90 years, the U.S. Geological Survey has been collecting records of streamflow at more than 16,000 sites. These records are used by planners, engineers and water managers for many purposes, such as determining available water supplies, designing bridges and culverts, or delineating flood-prone areas.

The general objective of the streamflow data program is to provide users with water information at any site on any stream. However, it is impossible to gage every site where data might be needed. In order to satisfy the need without gaging every site, it is often possible to transfer streamflow information to other sites in areas of relatively homogeneous climate, physiography, and geology. Thomas and Benson (1970) describe a statistical method for transferring the information. The method involves regressing a single statistical measure of streamflow (such as mean annual flow derived from the record) against an array of physiographic and climatic characteristics for the corresponding gaged basins within a selected region. The dependent variable is referred to as a streamflow characteristic, while the independent variables are known as basin characteristics. Equations obtained from the multiple regression procedure enable users to estimate streamflow characteristics at any sites on unregulated streams simply by determining the basin characteristics for the ungaged site.

In a previous study, May, Wood, and Rima (1970) obtained equations by the multiple regression procedure for a wide range of streamflow characteristics throughout the state. Randolph and Gamble (written commun., 1976) revised the equations for peak flows. Hollyday (1976) concluded that land-cover data from Landsat satellite imagery can substantially improve the accuracy of some equations for sites in Delaware and eastern Maryland. Pluhowski (1977) demonstrated that land-use data from aircraft photography provide an effective means of significantly improving estimates of streamflow in Delaware, eastern Maryland and Virginia.

The objective of the present study is to test the feasibility of improving upon the regression equations for estimating streamflow in areas affected by coal mining in the Cumberland Plateau of Tennessee by using land-cover information derived from digital processing of Landsat spectral data. The purpose of this report is to summarize the procedures and significant results of this study.

The digital image analysis of Landsat spectral data was performed in the Data Analysis Laboratory, EROS Data Center, Sioux Falls, S. Dak. The multiple linear regressions were performed on the U.S. Geological Survey Reston Computer with the assistance of W. O. Thomas and D. A. Less.

CUMBERLAND PLATEAU STUDY AREA

The Cumberland Plateau, the source of bituminous coal in Tennessee, trends diagonally 140 miles across the east-central part of the state (fig. 1). The essentially flat terrain throughout most of this area lies 900 to 1,000 feet above the Valley and Ridge physiographic province on the east and the Highland Rim on the west. The southern half of the plateau is bisected by a large anticlinal valley, the Sequatchie Valley. The northeast quarter of the plateau contains the highly-dissected Cumberland Mountains section, which rises some 1,400 feet above the general level of the plateau to a maximum elevation of 3,534 feet (Miller, 1974).

The plateau is capped by a sequence of sandstone and shale with minor amounts of siltstone, conglomerate, and coal of Pennsylvanian age. This sequence thins to the south, exposing greater thicknesses of the older

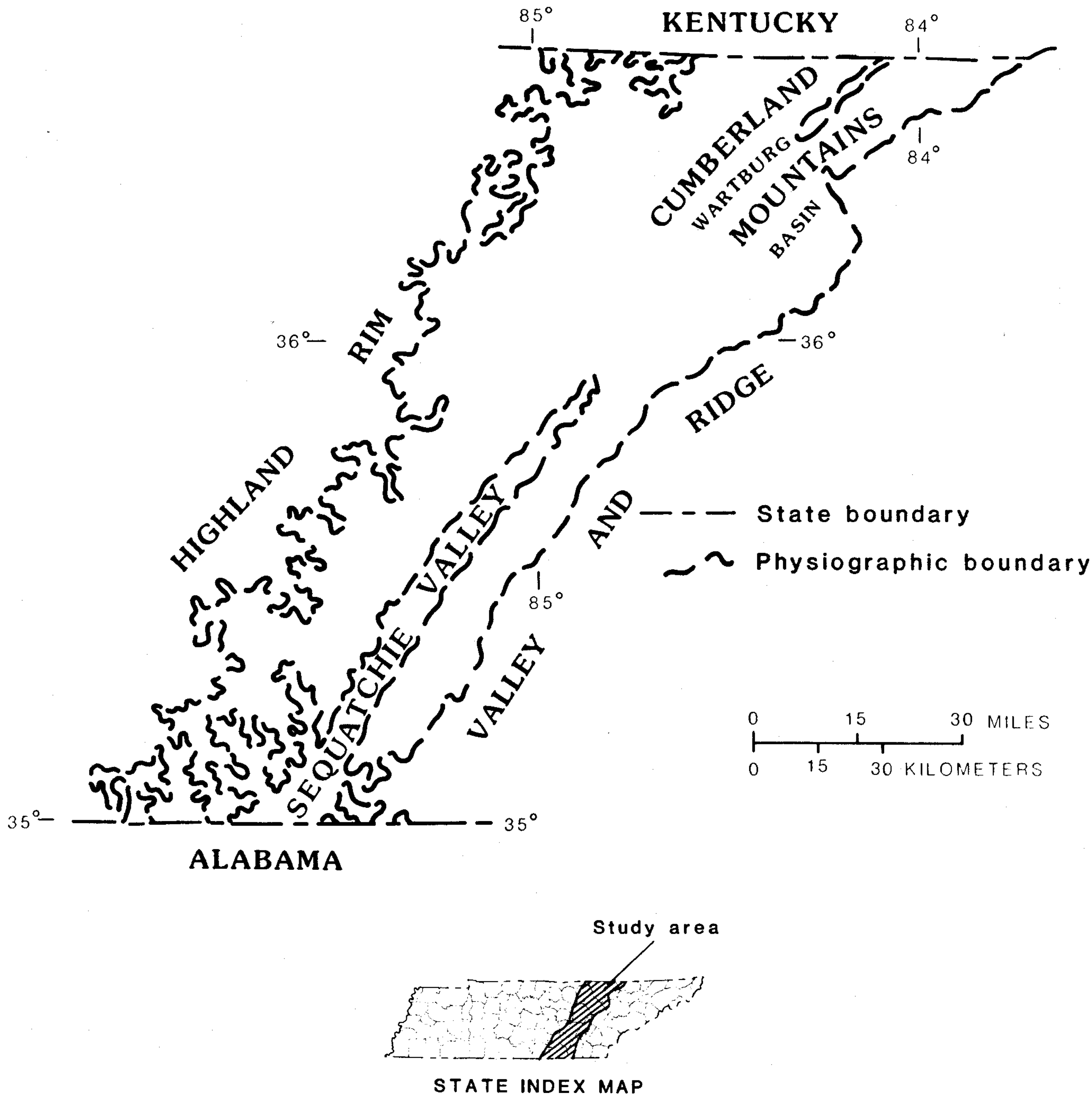

Figure 1.--Cumberland Plateau study area in east-central Tennessee.

underlying carbonate rocks along the escarpments bordering the plateau. The sequence thickens by addition of younger beds to the north, where as much as 3,000 feet of clastic rocks, containing seven commercially important coal seams, occur in the Wartburg basin in the Cumberland Mountains section of the plateau (Luther, 1960). The relatively insoluble sandstone and shale capping the plateau have weathered to a thin stony soil that stores very little water for maintaining streamflow during extended periods without rainfall. The dense bedrock stores relatively small amounts of water almost exclusively in fractures and joints.

Forty-one gaged drainage basins were selected within the study area (table 1). All but four basins lie partly or wholly within the plateau or its escarpments. The study basins cover about 70 percent of the plateau area in Tennessee (fig. 2). Drainage areas for the selected basins range from 0.67 to 954 square miles and have a median of 78.7 square miles. From 7 to 58 years of streamflow record are available for each of these basins. Flood peaks were synthesized for only five gages that have records of less than 10 years.

Mean annual precipitation ranges from 48 to 60 inches, averaging 53 inches; a minor amount occurs as snow. Runoff in the northwestern half of the study area drains to the Ohio River by way of the Cumberland River, while that in the southeastern half drains to the Ohio River by way of the Tennessee River.

EXPERIMENT DESIGN

The approach used in evaluating digital land-cover information from Landsat for improving estimates of streamflow, consists of first deriving and measuring Landsat basin characteristics, and then using these measurements in an analytic experiment. The experiment design was (1) to perform a meaningful multiple-regression analysis by selecting for each of six flow categories as many stream-gaging stations from the basins listed in table 1 as possible, based upon length of streamflow record, (2) to define a (control) set of equations by relating specific streamflow characteristics to basin characteristics derived from maps and climatological records, available in the U.S. Geological Survey Streamflow/Basin Characteristics File, (3) to define a new (experimental) set of equations by adding basin characteristics defined from Landsat tapes, and (4) to compare the accuracy for each streamflow characteristic calculated by the control equation with that calculated by the experimental equation.

BASIN CHARACTERISTICS

CHARACTERISTICS FROM LANDSAT TAPES

The intensity of sunlight reflected from the land surface is recorded digitally in each 1.12-acre pixel (resolution element) in the Landsat tapes. Differences in the reflected light for the most part correspond with different land-cover types or classes such as water or forest.

Table 1.--Drainage basins analyzed for land cover and gaging stations used in multiple regression analysis

[The period of record is given in water years, where a water year begins on October 1 of the preceding year and ends on September 30 of the indicated year]

Map no. (fig. 2)	Station no.	Station name	Location		Drainage area (mi^2)	Period of record (water year)
			Latitude	Longitude		
1	3408500	New River at New River, Tenn.	36°23'	84°33'	382	1934-1976
2	3409000	White Oak Creek at Sunbright, Tenn.	36°15'	84°40'	13.5	1955-1976
3	3409500	Clear Fork near Robbins, Tenn.	36°23'	84°38'	272	1930-1971
4	3410500	South Fork Cumberland River near Stearns, Ky.	36°38'	84°32'	954	1943-1976
5	3414500	East Fork Obey River near Jamestown, Tenn.	36°25'	85°02'	202	1943-1976
6	3415000	West Fork Obey River near Alpine, Tenn.	36°24'	85°10'	115	1943-1971
7	3415500	Obey River near Byrdstown, Tenn.	36°32'	85°10'	445	1919-1943
8	3415700	Big Eagle Creek near Livingston, Tenn.	36°27'	85°16'	7.98	1955-1976
9	3416000	Wolf River near Byrdstown, Tenn.	36°34'	85°04'	106	1943-1976
10	3418000	Roaring River near Hilham, Tenn.	36°20'	85°26'	78.7	1932-1975
11	3418500	Caney Fork at Clifty, Tenn.	35°53'	85°13'	111	1930-1949
12	3418900	Racoon Creek near Old Winesap, Tenn.	35°47'	85°09'	1.52	1972-1976
13	3420000	Calfkiller River below Sparta, Tenn.	35°55'	85°29'	175	1940-1971
14	3420500	Barren Fork near Trousdale, Tenn.	35°40'	85°53'	126	1932-1958
15	3421000	Collins River near McMinnville, Tenn.	35°43'	85°44'	640	1924-1976
16	3423000	Falling Water River near Cookeville, Tenn.	36°05'	85°31'	67	1932-1952
17	3534000	Coal Creek at Lake City, Tenn.	36°13'	84°09'	24.5	1955-1976
18	3538200	Poplar Creek near Oliver Springs, Tenn.	36°01'	84°19'	55.9	1951-1976
19	3538225	Poplar Creek near Oak Ridge, Tenn.	36°00'	84°20'	82.5	1960-1976
20	3538300	Rock Creek near Sunbright, Tenn.	36°12'	84°40'	5.54	1955-1971
21	3538500	Emory River near Wartburg, Tenn.	36°07'	84°37'	83.2	1934-1976
22	3538600	Obed River at Crossville, Tenn.	35°57'	85°03'	12	1955-1976
23	3538800	Obed River Trib. near Crossville, Tenn.	35°59'	85°04'	0.72	1955-1970
24	3538900	Self Creek near Big Lick, Tenn.	35°48'	85°03'	3.8	1967-1974
25	3539100	Byrd Creek near Crossville, Tenn.	35°54'	85°04'	1.1	1967-1975
26	3539500	Daddys Creek near Crab Orchard, Tenn.	35°56'	84°55'	93.5	1930-1958
27	3539600	Daddys Creek near Hebbertsburg, Tenn.	36°00	84°49'	139	1957-1968
28	3539800	Obed River near Lancing, Tenn.	36°05'	84°40'	518	1957-1976
29	3540500	Emory River at Oakdale, Tenn.	35°59'	84°33'	764	1927-1976
30	3541100	Bitter Creek near Camp Austin, Tenn.	36°01'	84°32'	5.53	1967-1976
31	3541200	Forked Creek near Oakdale, Tenn.	36°00'	84°31'	2.44	1967-1975
32	3541500	Whites Creek near Glen Alice, Tenn.	35°48'	84°46'	108	1934-1976
33	3544500	Richland Creek near Dayton, Tenn.	35°30'	85°01'	50.2	1934-1976
34	3570800	Little Brush Creek near Dunlap, Tenn.	35°24'	85°23'	15.4	1959-1976
35	3571000	Sequatchie River near Whitwell, Tenn.	35°12'	85°30'	402	1921-1976
36	3571600	Brown Spring Branch near Sequatchie, Tenn.	35°09'	85°33'	0.67	1955-1976
37	3571800	Battle Creek near Monteagle, Tenn.	35°08'	85°46'	50.4	1955-1976
38	3578000	Elk River near Pelham, Tenn.	35°18'	85°52'	65.6	1951-1976
39	3578500	Bradley Creek near Prairie Plains, Tenn.	35°21'	85°59'	41.3	1951-1976
40	3579900	Boiling Fork Creek at Cowan, Tenn.	35°10'	86°00'	17	1955-1976
41	3596000	Duck River below Manchester, Tenn.	35°28'	86°07'	107	1934-1976

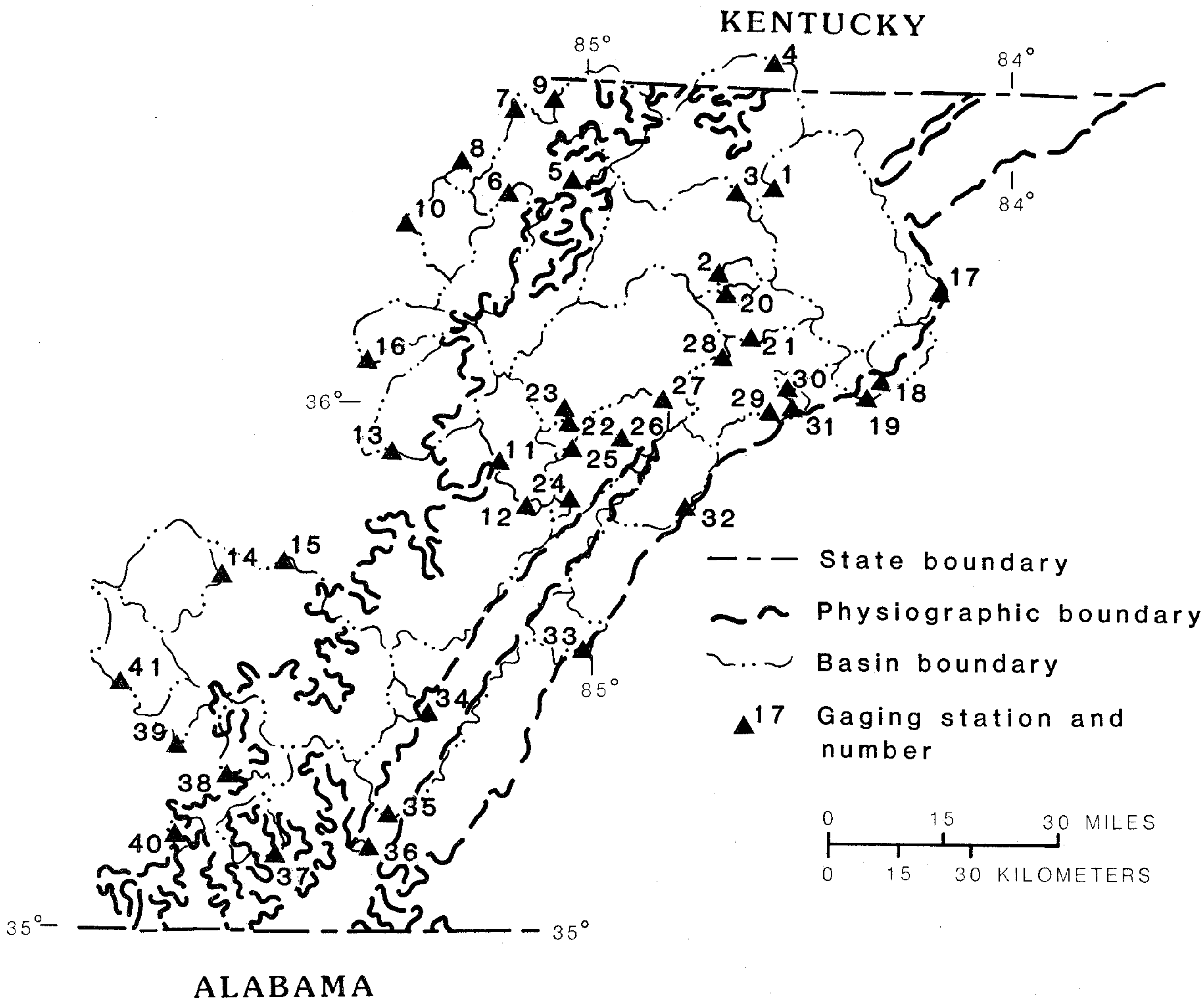

Figure 2.--Drainage basins and gaging stations used in multiple regression analysis.

All of Landsat-1 image 1265-15494 of April 14, 1973, and part of the next adjacent image to the south were selected for automated image analysis on the IDIMS (Interactive Digital Image Manipulation System) at the EROS Data Center. Analysis began in the unsupervised mode. In this mode, the computer puts each pixel of terrain information into one of several classes based only upon the similarity and differences in intensity of reflected sunlight. No training sets are used to train the computer to identify water or forest in the image. Occurrences of each class resulting from this analysis were compared with features seen in 1:120,000-scale infrared aerial photography. This comparison was made to identify those classes comprising conceptually uniform land-cover types such as cropped fields and to identify those classes containing conceptually mixed land-cover types such as water and deep shadow within a single class.

In the second unsupervised classification, the number of required classes was increased from 20 to 42, while processing effort was concentrated upon splitting the classes containing conceptually mixed land-cover types. The resulting classification was not only compared with aerial photography but was also checked in the field using line printer overlays to fourteen 7.5-minute topographic quadrangles in three test sites distributed over the plateau.

Ultimately, 39 spectral classes were combined into the following eight land-cover types to be used as Landsat basin characteristics in regressions with streamflow characteristics:

Basin characteristic	Variable name
Water	WATER
Deciduous forest, well lit (>80 percent deciduous)	DECIDB
Deciduous forest, in shadow (>80 percent deciduous)	DECIDS
Coniferous forest (>80 percent coniferous)	CONIFE
Mixed forest (<80 percent deciduous; <80 percent coniferous)	MIXFOR
Covered ground (crops or pasture)	COVRGD
Bare ground	BAREGD
Dark, coal spoil and asphalt	SPOILTA

Typical examples of these land-cover types are shown in figure 3.

The boundaries of the 41 basins in table 1 were transferred from 1:24,000-scale maps to 1:250,000-scale maps and digitized (fig. 4). The geographic cordinates associated with the digitized boundaries were then matched with Landsat coordinates and a basin-wide count was made of individual pixels in each class. The pixel counts were converted to area measurements in square miles and checked against the drainage areas measured by planimeter from 1:24,000-scale maps. Measurements were then converted to percent of basin covered by each of the eight land-cover types to provide the data set in table 2.

CHARACTERISTICS FROM MAPS AND CLIMATOLOGICAL RECORDS

Initially, most of the following 14 physiographic and climatic characteristics were used as independent variables in developing both the control group and the experimental group of regression equations. Values

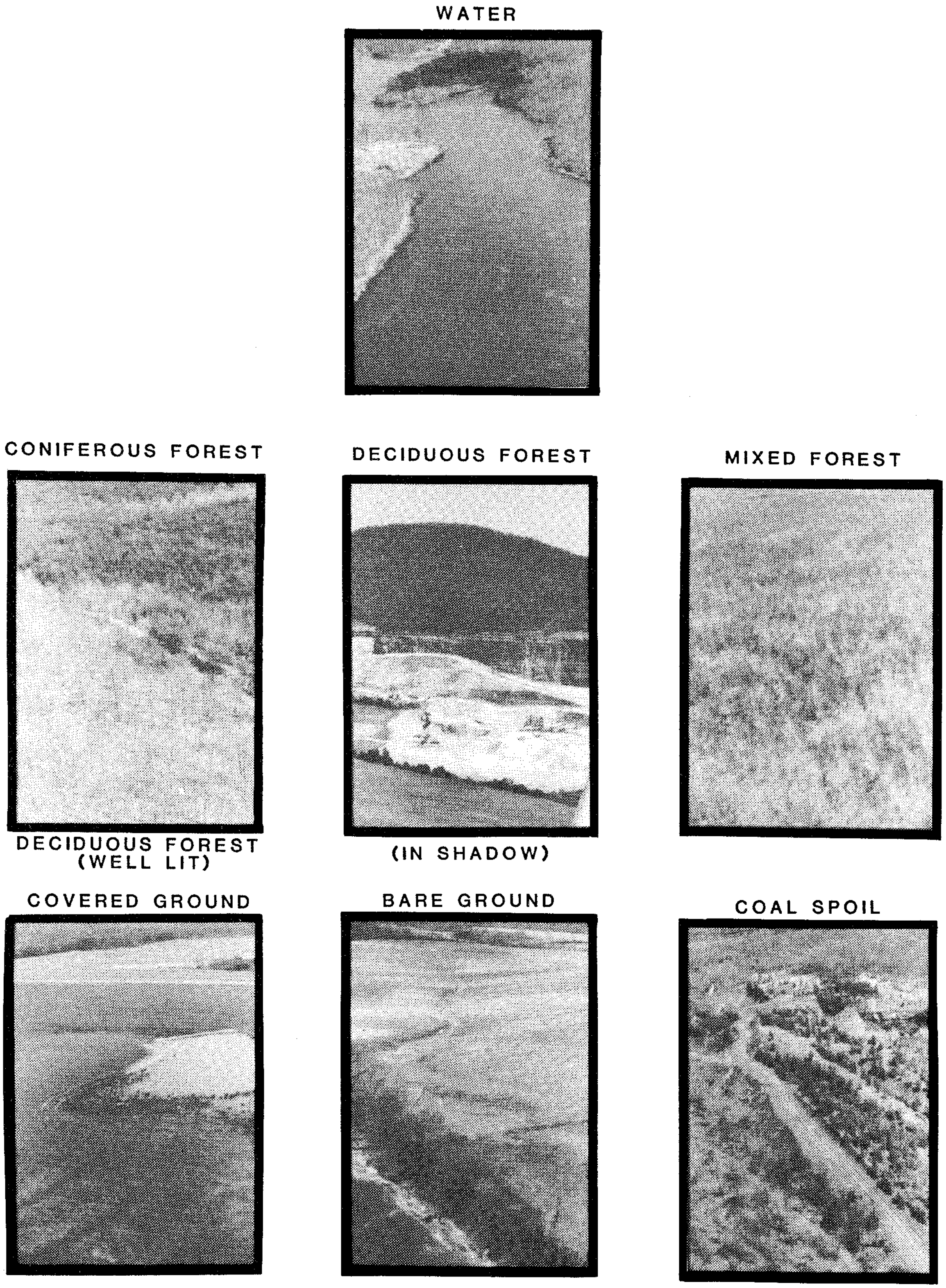

Figure 3.--Typical examples of the eight land-cover types in study area that were used as Landsat basin characteristics.

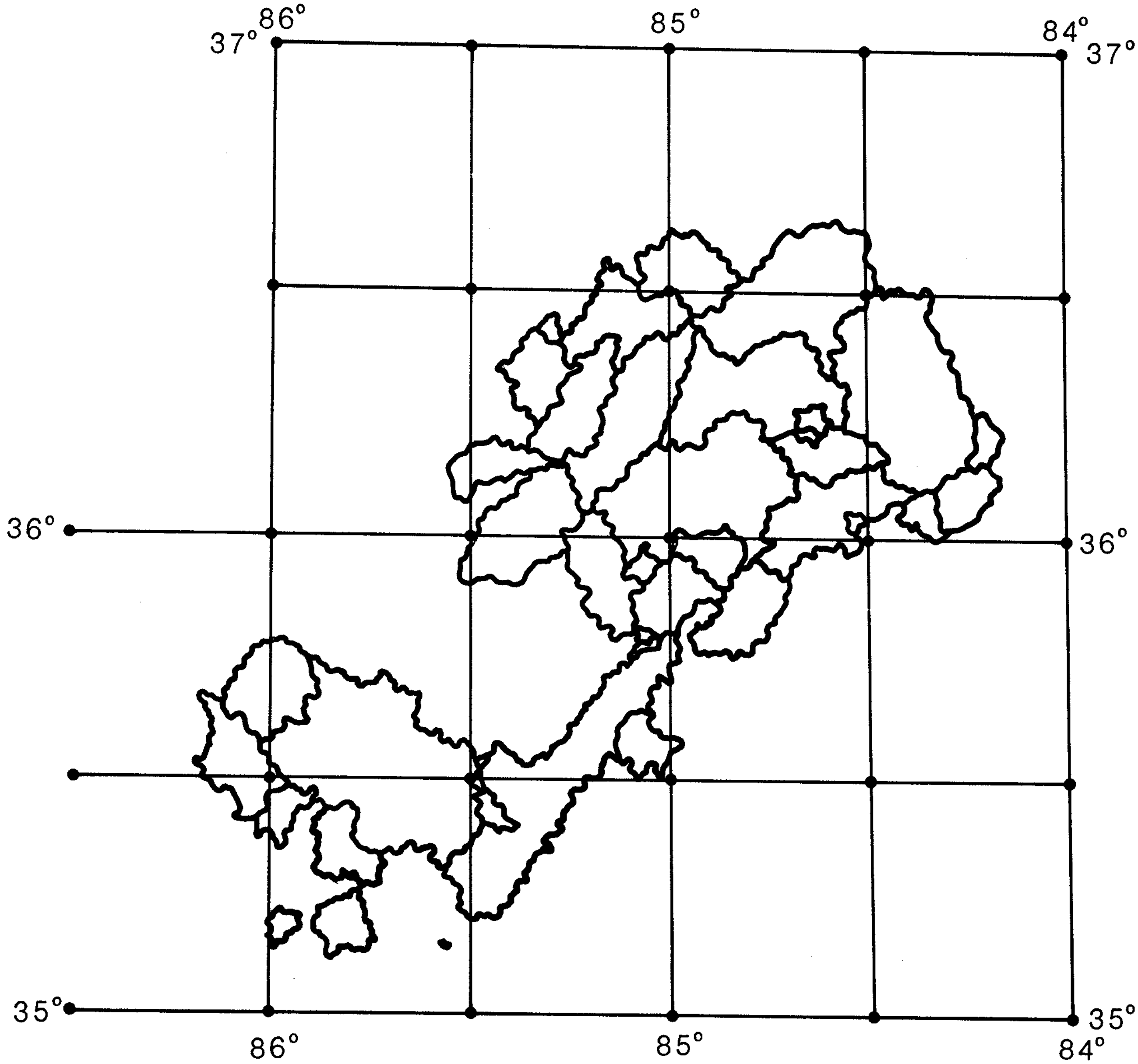

Figure 4.--Geographic coordinate grid and digitized basin boundaries for measuring Landsat basin characteristics within selected basins.

Table 2.--Basin characteristics derived from spectral analysis of Landsat-1 digital tapes

[Table lists the part of the total area of the basin upstream of the given gaging station that is covered by the indicated land-cover type, in percent]

Map no. (fig. 2)	Station no.	Basin characteristics (variable name)							
		Water (WATER)	Deciduous forest, well lit (DECIDB)	Deciduous forest, in shadow (DECIDS)	Coniferous forest (CONIFE)	Mixed forest (MIXFOR)	Covered ground (COVRGD)	Bare ground (BAREGD)	Dark, coal spoil and asphalt (SPOILTA)
1	3408500	0.6	26.5	46.3	1.1	19.1	3.5	0.4	2.6
2	3409000	0.1	32.5	31.6	1.0	27.1	6.3	1.0	0.4
3	3409500	0.1	25.0	15.1	5.2	38.2	14.7	1.5	0.2
4	3410500	0.4	23.2	28.8	5.6	32.2	7.9	0.7	1.2
5	3414500	0.3	38.4	21.4	2.6	27.8	7.7	1.5	0.2
6	3415000	0.1	38.6	29.7	0.7	15.0	15.2	0.7	0.1
7	3415500	0.9	35.8	23.8	1.5	20.5	15.7	1.6	0.2
8	3415700	0.0	31.2	12.0	0.1	10.3	42.6	3.4	0.3
9	3416000	0.1	28.6	27.0	3.2	25.7	14.0	1.2	0.2
10	3418000	0.1	23.4	12.1	0.5	10.5	49.1	4.1	0.2
11	3418500	0.4	48.6	11.2	1.8	18.3	17.2	2.2	0.3
12	3418900	0.0	76.7	12.2	0.0	4.9	4.8	1.4	0.1
13	3420000	0.3	34.4	16.2	0.9	14.9	30.2	2.7	0.3
14	3420500	0.0	23.5	2.2	0.0	2.1	52.8	18.7	0.6
15	3421000	0.2	33.6	11.5	0.9	12.7	33.1	7.5	0.5
16	3423000	0.2	23.0	11.3	0.2	8.0	50.7	6.1	0.6
17	3534000	0.2	26.8	45.6	1.9	20.7	1.6	0.4	2.9
18	3538200	0.2	23.3	25.6	2.3	30.8	16.9	0.3	0.7
19	3538225	0.2	26.0	26.5	1.7	27.3	15.7	0.7	1.7
20	3538300	0.0	34.7	25.6	1.0	36.4	2.3	0.0	0.1
21	3538500	0.2	28.8	35.0	2.6	28.2	4.3	0.1	0.7
22	3538600	2.7	45.8	6.5	0.4	7.3	31.8	4.8	0.8
23	3538800	0.0	31.7	1.8	0.3	3.0	57.9	5.3	0.0
24	3538900	0.0	78.3	3.8	0.1	8.0	8.4	1.3	0.0
25	3539100	0.0	45.6	2.8	0.0	5.5	44.8	1.3	0.0
26	3539500	0.7	39.3	9.4	0.7	14.3	31.6	3.6	0.3
27	3539600	0.6	40.5	12.1	0.8	16.7	25.6	3.2	0.5
28	3539800	0.4	37.8	11.4	2.9	25.8	19.0	2.4	0.3
29	3540500	0.3	35.5	16.9	2.8	26.8	15.6	1.8	0.4
30	3541100	0.0	36.3	19.1	1.2	30.9	10.9	1.1	0.6
31	3541200	0.1	39.1	20.2	2.0	35.5	2.8	0.0	0.3
32	3541500	0.1	42.5	13.1	2.1	31.8	8.5	1.4	0.5
33	3544500	0.1	43.3	8.8	2.7	22.3	15.8	6.4	0.6
34	3570800	0.0	44.4	16.5	2.4	26.3	8.5	1.2	0.6
35	3571000	0.1	33.3	16.3	1.1	17.1	26.9	4.8	0.4
36	3571600	0.0	51.1	10.5	0.0	17.5	20.8	0.0	0.0
37	3571800	0.3	57.5	21.4	0.1	8.9	8.4	2.9	0.5
38	3578000	0.4	54.6	19.2	0.2	7.0	13.7	3.4	1.5
39	3578500	0.1	18.1	9.2	0.4	5.9	43.7	22.1	0.5
40	3579900	0.1	27.7	23.6	0.1	16.1	28.8	3.3	0.3
41	3596000	0.2	34.4	7.5	0.1	3.6	40.1	13.2	1.0

for these variables for all 41 drainage basins are available from the U.S. Geological Survey Streamflow/Basin Characteristics File through program E796 (Slaughter and Saxowsky, 1974) or J763 (Carrigan, 1977) (table 7). Readers may obtain data from WATSTORE or determine the status of these files and programs by contacting any one of the Water Resources Division offices in most States.

AREA: Total drainage area, in square miles, including non-contributing areas.

CONTDA: Drainage area, in square miles, that contributes to surface runoff.

SLOPE: Main channel slope, in feet per mile, computed by the 85- to 10-percent method described by Benson (1962).

LENGTH: Stream length, in miles, measured along channel from gage to divide.

ELEV: Mean basin elevation, in feet above mean sea level, measured from topographic maps by transparent grid sampling method (20 to 80 points in basin were sampled).

STORAGE: Area of lakes, ponds, and swamps in percent of contributing drainage area, measured by the grid sampling method.

FOREST: Forested area, in percent of contributing drainage area, measured by the grid sampling method.

SOIL: Soils index, a relative measure of infiltration, from Soil Conservation Service (written commun., 1969).

LAT GAGE: Latitude of streamgaging station in decimal degrees.

LNG GAGE: Longitude of streamgaging station in decimal degrees.

PRECIP: Mean annual precipitation in inches (Dickson, 1960); grid sampling methods used with isohyetal map.

I24-2: Precipitation intensity; 24-hour rainfall, in inches, that will be equalled or exceeded on the average of once each 2 years (Hershfield, 1961).

JANMIN: Mean minimum January temperature, in degrees Fahrenheit (Dickson, 1960).

JULYMAX: Mean maximum July temperature, in degrees Fahrenheit (Dickson, 1960).

STREAMFLOW CHARACTERISTICS

The following 51 streamflow characteristics were used as dependent variables in developing the regression equations. Values for these variables for most of the drainage basins are available from the U.S. Geological Survey Streamflow/Basin Characteristics File through program E796 or J763 (table 7). Readers may obtain data from WATSTORE or determine the status of these files and programs by contacting any one of the Water Resources Division offices in most States. Flood peaks and peak-flow statistics are available for all 41 basins in the study area. Average discharges and variability in average discharges are available for 17 basins. Low flows and flood volumes are available for 15 basins:

PT: Annual flood peak, in cubic feet per second, of T-year recurrence interval, defined by Log-Pearson Type III fitting, computer program no. J407 (Kirby, 1979); the recurrence intervals of 1.25, 2, 5, 10, 25, 50, 100, 200 and 500 years are denoted in this report as P1.25, P2, P5, etc., respectively.

MEANPK: Mean of logarithms, base 10, of annual peak discharges from computer program no. J407.

SDPK: Standard deviation of logarithms, base 10, of annual peak discharges, from computer program no. J407.

SKEWPK: Skew of logarithms, base 10, of annual peak discharges, from computer program no. J407.

QA: Mean annual discharge, in cubic feet per second, from flow variability computer program no. W4422 (Price and Meeks, 1977).

SDA: Standard deviation of mean annual discharge in cubic feet per second from flow variability computer program no. W4422.

QM: Mean discharge, in cubic feet per second, for "M" calendar month, from flow variability computer program no. W4422; the "M" refers to the numerical order of the month beginning with January as 1.

SDM: Standard deviation, in cubic feet per second, of mean discharge for "M" calendar month, from flow variability computer program no. W4422; the "M" refers to the numerical order of the month beginning with January as 1.

MD,T: Low-flow characteristics: annual minimum "D" day mean discharge, in cubic feet per second, for "T" year recurrence interval, defined by Log-Pearson Type III Fitting, computer program no. A969 (Meeks, 1977); the recurrence intervals of 20 years for the 3-day and 2, 10, and 20 years for the 7-day mean annual minimum discharge are denoted in this report as M3,20; M7,2; M7,10; and M7,20 respectively.

VD,T: Flood volume characteristic: Annual maximum "D"-day mean discharge, in cubic feet per second, for "T"-year recurrence interval, defined by Log-Pearson Type III fitting, computer program no. A969; the recurrence intervals of 2, 10, and 50 years for the 3 and 7-day mean annual maximum discharge are denoted in this report as V3,2; V3,10; V3,50; V7,2; V7,10; and V7,50 respectively.

WRCSKEW: Skew of logarithms, base 10, of annual peak discharges adapted from Water Resources Council (1976) and used for frequency curve computation.

WRCMEAN: Mean of logarithms, base 10, of annual peak discharges adopted from Water Resources Council (1976) and used for frequency curve computation.

WRCSD: Standard deviation of logarithms, base 10, of annual peak discharges adopted from Water Resources Council (1976) and used for frequency curve computations.

REGRESSION ANALYSIS

Multiple linear regression analysis defines the relation between a single streamflow characteristic (dependent variable) and a set of basin characteristics (independent variables) for a selected group of stream-gaging stations. It provides estimates of the coefficients and constant in the regression equation with the general form:

$$y = b(1)X(1) + b(2)X(2) ... + b(n)X(n) + a$$

where y = dependent variable,
X(1) to X(n) = independent variables,
b(1) to b(n) = corresponding coefficients, and
a = constant, or y-intercept.

It is assumed that the model, or form of the equation, is correct in that all significant independent variables are included and that a linear relation is appropriate. In addition, it is assumed that the residuals - that is, the difference between the observed and calculated values of the dependent variable - are normally and independently distributed, with a mean of zero and constant variance. These assumptions were tested in part by information provided by the output from several procedures in the computer program SAS (Barr and others, 1976).

The data were manipulated in the following way prior to developing and testing the regression model with the use of SAS. The data set of 51 streamflow characteristics and 14 basin characteristics was retrieved from the Streamflow/Basin Characteristics File using STATPAC program E796. This data set was then merged with the data set containing eight Landsat basin characteristics. The merged data set was passed from STATPAC to SAS and checked for missing values of streamflow characteristics for some of the 41 basins. The basins that had missing values were automatically eliminated from calculations for the corresponding streamflow characteristics. Before transforming any values to their corrresponding logarithms, a small constant, representative of the limit of measurement, was added to all values of an independent variable, any one of which had an initial value of zero. Thus, the percentage of a basin covered by STORAGE was increased by 0.005 percent, and the percentage of a basin covered by WATER, CONIFE, BAREGD, and SPOILTA was increased by 0.05 percent.

REGRESSION MODEL

All variables were analyzed (by the PROC CORR procedure) to determine the degree of correlation among variables. For those pairs of variables with correlation coefficients greater than 0.8, only one of each pair was used in regression. There was a very high degree of correlation between AREA, which may include parts of the topographic basin that do not contribute to surface runoff, and CONTDA, which included only those parts of the basin which do contribute to surface runoff. For 34 out of 41 basins in this study area, the two values are identical. AREA was chosen in preference to CONTDA for regression analysis because it is more easily determined for any basin. There was also a very high degree of correlation between AREA and LENGTH, which is to be expected provided basin shape does not change significantly from basin to basin. AREA was chosen in preference to LENGTH because it had a higher degree of correlation with the dependent variables. The remaining 12 independent variables were used in the regression analysis even though some correlation coefficients exceeded 0.7.

Two dependent variables from each of 5 flow categories (flood peak, mean flow, standard deviation, low flow, and flood volume) were plotted against the 12 independent variables using the PROC PLOT procedure in SAS. These plots were compared with corresponding plots using data transformed to the logarithmic equivalent. Without exception the plots were more linear, and the deviation from the line of regression was less using logarithmic values for all variables. As a consequence logarithmic values only were used in all subsequent analyses. However, MEANPK, SDPK, SKEWPK, WRCSKEW, WRCMEAN, and WRCSD which were already in file as logarithmic values, were not transformed.

Multiple linear regressions were performed using the STEPWISE procedure in SAS. Two dependent variables from each of the 5 flow categories were selected for regression with the 12 independent variables selected from PROC CORR. The model was:

$$\log y = b(1) \log X(1) + b(2) \log X(2) \ldots + b(n) \log X(n) + a$$

or its equivalent form:

$$y = X(1)^{b(1)} X(2)^{b(2)} \ldots X(n)^{b(n)} 10^{a}.$$

The following options were used: FORWARD, STEPWISE, MAXR, and MINR. For the FORWARD and STEPWISE options a significance level for either entry or retention in the equation was chosen as 0.05, that is no independent variable would either be entered or retained in the calculated equations unless it had at least a 95-percent probability of effectiveness in explaining the variance. The four options differ in the degree to which each searches for a "best" model. FORWARD and STEPWISE settle on a single model within the limits specified for variable significance. MAXR and MINR give the "best" one-variable, two-variable, three-variable model on out to a model containing all independent variables. In addition MAXR and MINR check every variable not included in the model to see if the model could be improved by substituting this variable for any variable already in the model.

The results of the regressions using FORWARD and STEPWISE were identical. Results using MAXR were practically identical with those using STEPWISE within the limits imposed by the significance level. For models with four or less variables, the "best" model for MINR was almost without exception the same as the "best" model for MAXR.

The form of the model was also checked using the GLM (General Linear Model) procedure in SAS. Based upon the results of the STEPWISE procedure, a two- or three-variable model, with fixed independent variables, was stated for each flow category, and equations were computed for all 51 streamflow characteristics. The residuals were plotted against each of the independent variables. Without exception the residuals appeared to be evenly and uniformally distributed about the zero reference.

Residuals were also plotted on maps. The only obvious trend was a tendency for positive residuals for low flows to occur in basins draining large parts of the escarpment along the northwest edge of the Cumberland Plateau. A positive residual is the result of the observed value of low flow exceeding the computed value. There is a tendency for negative residuals for flood peaks in this same area. Both anomalies may be attributed to unusually large basin storage in this area where many streams are diverted for several miles underground in the limestone bedrock cropping out along the escarpment.

An attempt was made to derive meaningful models for low flows and annual peak logarithms. For most low flow equations, less than 50 percent of the variance could be explained. The few low flow equations that could be derived had excessive standard errors and contained illogical regression coefficients and constants. Equations for four of the annual peak logarithms, SDPK, SKEWPK, WRCSKEW, and WRCSD, could explain no more than 20 percent of the variance.

In addition to indicating an appropriate model for the remaining flow categories, the results from STEPWISE and GLM revealed that more than 90 percent of the variance could be explained by a one-variable model using AREA. With so much variance explained by a single independent variable, it was anticipated that there would be little opportunity to improve upon the model by adding an additional variable, whether the additional variable was obtained from maps and climatological records or from analysis of Landsat tapes.

The experiment design envisioned that a control group of equations would be computed with GLM using basin characteristics derived from maps and climatological records. Also, an experimental group of equations would be computed using basin characteristics derived from Landsat tapes as well as from maps and climatological records. The standard error of estimate of the dependent variable for the two groups of equations would then be compared to see if any reduction in standard error could be considered a substantial improvement upon the original (control group) equations. However, because AREA explained more than 90 percent of the variance in so many cases, the experiment design was modified to take this fact into account.

Rather than using GLM, in which the independent variables are fixed in a model statement regardless of their effectiveness in explaining the variance, STEPWISE was used to derive a "best" one-variable model and a "best" two-variable model. This was done first for each of the 51 streamflow characteristics in the control group of equations and then for each of these same streamflow characteristics in the experimental group. A fair test of the effectiveness of the basin characteristics derived from Landsat for improving the equations was made by comparing the degree of improvement in the control group due to adding a second variable to the equation with the degree of improvement in the experimental group due to adding a second variable.

REGRESSION EQUATIONS

Tables 3 and 4 summarize the results of the multiple-regression analyses. The first column contains the streamflow characteristic (Y) coded in accordance with the descriptions given in the section of this report titled "Streamflow Characteristics." The next 10 columns in table 3 (14 columns in table 4) contain the regression coefficients, b(n), for those basin characteristics (out of a total of 12 derived from maps and climatological records and 8 derived from Landsat tapes) which have a 95-percent probability of explaining the variance and that cause the greatest reduction in the standard error. The basin characteristics are explained in the section of this report titled "Basin Characteristics." The next column lists the regression constant exponent (a) corresponding to a particular streamflow characteristic. Because of differences among gaging stations in regard to length of record or purpose of record, not all 41 stations were used in defining each of the regression equations in tables 3 and 4. The column giving the number of stations used in each regression follows the column listing the regression constant exponent.

Table 3.--Control group equations relating streamflow characteristics to physiographic and climatic characteristics of drainage basins as determined from maps and climatological records and statistical parameters and improvement in one-variable equations due to adding a second variable

[Explanation of symbols for flow characteristics are found in the section "Streamflow Characteristics"]
[Explanation of abbreviations for basin characteristics are found in the section "Basin Characteristics"]
[The standard error in percent is an average of the plus and minus percentages because errors expressed in percent are not normally distributed]
[N: No other independent variables met the 0.05 significance level for entry into the equation]
[NM: No meaningful equation was derived]

Model is: $Y = AREA^{b(1)}\ SLOPE^{b(2)}\ ELEV^{b(3)}\ STORAGE^{b(4)}\ FOREST^{b(5)}\ SOIL^{b(6)}\ LATGAGE^{b(7)}\ LNGGAGE^{b(8)}\ PRECIP^{b(9)}\ I24,2^{b(10)}\ JANMIN^{b(11)}\ JULYMAX^{b(12)}\ 10^{a}$

Flow characteristic, Y	Equations: Regression coefficient, b(n), for indicated basin characteristic										Equations: Regression constant exponent, a	Number of basins used	Parameters of best one- and two-variable equation			Change in standard error, in percent
	AREA	SLOPE	ELEV	STORAGE	FOREST	LNGGAGE	PRECIP	I24,2	JANMIN	JULYMAX			R-square	Mean square error	Standard error, in percent	
P1.25	0.8261										1.9795	41	0.9671	0.0171	31	
	0.9061	0.1867									1.5683	41	0.9763	0.0127	26	5
P2	0.8241										2.1641	41	0.9681	0.0165	30	
	0.9020	0.1816									1.7641	41	0.9768	0.0124	26	4
P5	0.8132										2.3691	41	0.9623	0.0191	33	
	0.8875	0.1731									1.9879	41	0.9704	0.0154	29	4
P10	0.8086										2.4742	41	0.9562	0.0221	35	
	0.8810	0.1689									2.1022	41	0.9639	0.0187	32	3
P25	0.8034										2.5867	41	0.9470	0.0267	39	
	0.8742	0.1650									2.2232	41	0.9544	0.0235	36	3
P50	0.7995										2.6611	41	0.9394	0.0304	42	
	0.8691	0.1622									2.3037	41	0.9466	0.0275	40	2
P100	0.7959										2.7278	41	0.9314	0.0344	45	
	0.8646	0.1601									2.3751	41	0.9384	0.0318	43	2
P200	0.7938										2.7865	41	0.9236	0.0385	48	
	N										N		N	N	N	N
P500	0.7897										2.8609	41	0.9125	0.0442	51	
	N										N		N	N	N	N
MEANPK	0.8357										2.1372	41	0.9662	0.0180	32	
	0.9147	0.1844									1.7312	41	0.9749	0.0138	27	5
WRCMEAN	0.9053										1.9766	41	0.7970	0.1541	112	
	0.9599			-0.2363							1.4727	41	0.8393	0.1252	97	15

Table 3.--Control group equations relating streamflow characteristics to physiographic and climatic characteristics of drainage basins as determined from maps and climatological records and statistical parameters and improvement in one-variable equations due to adding a second variable--Continued

Flow characteristic, Y	Equations: Regression coefficient, b(n), for indicated basin characteristic: AREA	SLOPE	ELEV	STORAGE	FOREST	LNGGAGE	PRECIP	I24,2	JANMIN	JULYMAX	Regression constant exponent, a	Number of basins used	Parameters of best one- and two-variable equation: R-square	Mean square error	Standard error, in percent	Change in standard error, in percent
QA	1.0428										0.1444	17	0.9847	0.0025	12	
	1.0051		0.4225								-1.0988	17	0.9897	0.0018	10	2
Q10	1.0301										-0.6319	17	0.8758	0.0227	36	
	N										N		N	N	N	N
Q11	1.0996										-0.2454	17	0.9259	0.0146	28	
	0.9856		1.2782								-4.0068	17	0.9649	0.0074	20	8
Q12	1.1149										0.0624	17	0.9727	0.0053	17	
	1.0400		0.8396								-2.4084	17	0.9899	0.0021	11	6
Q1	1.0257										0.4623	17	0.9816	0.0030	13	
	1.0023							-2.9906			2.1143	17	0.9913	0.0015	9	4
Q2	1.0103										0.5784	17	0.9831	0.0026	12	
	N										N		N	N	N	N
Q3	1.0450										0.4994	17	0.9848	0.0025	12	
	0.9955		0.5559								-1.1365	17	0.9935	0.0012	8	4
Q4	1.0506										0.3089	17	0.9734	0.0045	16	
	0.9931		0.6442								-1.5869	17	0.9849	0.0028	12	4
Q5	1.0555										0.0373	17	0.9673	0.0057	17	
	0.9955		0.6724								-1.9413	17	0.9796	0.0038	14	3
Q6	1.0373										-0.1969	17	0.9722	0.0046	16	
	NM										NM	17	0.9807	0.0035	14	2
Q7	1.0026										-0.1885	17	0.9671	0.0052	17	
	N										N		N	N	N	N
Q8	1.0320										-0.4596	17	0.8885	0.0201	34	
	NM										NM	17	0.9358	0.0124	26	8
Q9	0.9583										-0.3756	17	0.9013	0.0151	29	
	1.0929				-0.7873						0.7754	17	0.9543	0.0075	20	9
SDA	1.0611										-0.4796	17	0.9883	0.0020	10	
	1.0728			0.0362							-0.4483	17	0.9926	0.0014	9	1
SD10	1.2045										-1.0334	17	0.8739	0.0315	43	
	1.0614		1.6046								-5.7553	17	0.9223	0.0208	34	9

Table 3.--Control group equations relating streamflow characteristics to physiographic and climatic characteristics of drainage basins as determined from maps and climatological records and statistical parameters and improvement in one-variable equations due to adding a second variable--Continued

Flow characteristic, Y	Equations: Regression coefficient, b(n), for indicated basin characteristic: AREA	SLOPE	ELEV	STORAGE	FOREST	LNGGAGE	PRECIP	I24,2	JANMIN	JULYMAX	Regression constant exponent, a	Number of basins used	Parameters of best one- and two-variable equation: R-square	Mean square error	Standard error, in percent	Change in standard error, in percent
SD11	1.1533										-0.2912	17	0.8502	0.0353	45	
	0.9692		2.0639								-6.3648	17	0.9352	0.0164	30	15
SD12	1.0765										0.0933	17	0.9807	0.0034	13	
	1.0526							-3.0509			1.7786	17	0.9898	0.0019	11	2
SD1	0.9775										0.4249	17	0.9513	0.0074	20	
	1.0440				-0.3890						0.9936	17	0.9644	0.0058	18	2
SD2	0.9788										0.3907	17	0.9730	0.0040	15	
	0.9984								1.5894		-1.9799	17	0.9802	0.0031	13	2
SD3	1.0667										0.0915	17	0.9799	0.0035	14	
	NM										NM	17	0.9854	0.0027	12	2
SD4	1.0020										0.1146	17	0.9564	0.0069	19	
	0.9290		0.8180								-2.2925	17	0.9763	0.0040	15	4
SD5	1.0145										-0.0284	17	0.9567	0.0070	19	
	0.9368		0.8712								-2.5922	17	0.9787	0.0037	14	5
SD6	1.1953										-0.5899	17	0.9290	0.0165	30	
	N										N		N	N	N	N
SD7	1.1353										-0.4788	17	0.8751	0.0277	40	
	NM										NM	17	0.9520	0.0114	25	15
SD8	1.1822										-0.8206	17	0.9099	0.0209	34	
	N										N		N	N	N	N
SD9	1.0777										-0.5349	17	0.9058	0.0182	32	
	NM										NM	17	0.9325	0.0140	28	4
M3,20	NM										NM	15	0.5125	0.3777	253	
	N										N		N	N	N	N
M7,2	N										N	N	N	N		
	N										N		N	N	N	N
M7,10	NM										NM	15	0.4603	0.2863	189	
	NM										NM	15	0.6143	0.2217	150	39
M7,20	NM										NM	16	0.3175	0.4575	315	
	NM										NM	16	0.5227	0.3446	229	86

Table 3.--Control group equations relating streamflow characteristics to physiographic and climatic characteristics of drainage basins as determined from maps and climatological records and statistical parameters and improvement in one-variable equations due to adding a second variable--Continued

Flow characteristic, Y	Equations: Regression coefficient, b(n), for indicated basin characteristic: AREA	SLOPE	ELEV	STORAGE	FOREST	LNGGAGE	PRECIP	I24,2	JANMIN	JULYMAX	Regression constant exponent, a	Number of basins used	Parameters of best one- and two-variable equation: R-square	Mean square error	Standard error, in percent	Change in standard error, in percent
V3,2	0.9860										1.3828	17	0.9773	0.0034	14	
	0.9686							-2.2270			2.6130	17	0.9831	0.0027	12	2
V3,10	0.9881										1.5997	17	0.9803	0.0030	13	
	N										N		N	N	N	N
V3,50	0.9870										1.7272	15	0.9664	0.0051	17	
	N										N		N	N	N	N
V7,2	1.0143										1.1098	17	0.9814	0.0029	13	
	0.9756		0.4346								-0.1693	17	0.9870	0.0022	11	2
V7,10	0.9877										1.3819	17	0.9858	0.0021	11	
	N										N		N	N	N	N
V7,50	0.9828										1.5027	15	0.9832	0.0025	12	
	N										N		N	N	N	N

Table 4. -- Experimental group equations relating streamflow characteristics to physiographic and climatic characteristics of drainage basins as determined from maps and climatological records, and Landsat tapes and statistical parameters and improvement in one-variable equations due to adding a second variable

[Explanation of symbols for flow characteristics are found in the section "Streamflow Characteristics"]
[Explanation of abbreviations for basin characteristics are found in the section "Basin Characteristics"]
[The standard error in percent is an average of the plus and minus percentages because errors expressed in percent are not normally distributed]
[N: No other independent variables met the 0.05 significance level for entry into the equation]
[NM: No meaningful equation was derived]

Model is: $Y = AREA^{b(1)}\ SLOPE^{b(2)}\ ELEV^{b(3)}\ STORAGE^{b(4)}\ FOREST^{b(5)}\ SOIL^{b(6)}\ LATGAGE^{b(7)}\ LNGGAGE^{b(8)}\ PRECIP^{b(9)}\ I24,2^{b(10)}\ JANMIN^{b(11)}\ JULYMAX^{b(12)}\ BAREGD^{b(13)}\ WATER^{b(14)}\ DECIDB^{b(15)}\ DECIDS^{b(16)}\ COVERGD^{b(17)}\ CONIFE^{b(18)}\ MIXFOR^{b(19)}\ SPOILTA^{b(20)}\ 10^{a}$

Flow characteristic, Y	Equations									Equations--Continued						Parameters of best one- and two-variable equation			
	Regression coefficient, b(n), for indicated basin characteristic													Regression constant exponent, a	Number of basins used	R-square	Mean square error	Standard error, in percent	Change in standard error, in percent
	AREA	SLOPE	ELEV	STORAGE	LNGGAGE	PRECIP	I24,2	JANMIN	BAREGD	WATER	DECIDB	COVRGD	CONIFE	SPOILTA						
P1.25	0.8261														1.9795	41	0.9671	0.0171	31	
	0.8330											-0.1939			2.1967	41	0.9788	0.0113	25	6
P2	0.8241														2.1641	41	0.9681	0.0165	30	
	0.8302											-0.1681			2.3525	41	0.9769	0.0123	26	4
P5	0.8132														2.3691	41	0.9623	0.0191	33	
	0.8875	0.1731													1.9879	41	0.9704	0.0154	29	4
P10	0.8086														2.4742	41	0.9562	0.0221	35	
	0.8810	0.1689													2.1022	41	0.9639	0.0187	32	3
P25	0.8034														2.5867	41	0.9470	0.0267	39	
	0.8742	0.1650													2.2232	41	0.9544	0.0235	36	3
P50	0.7995														2.6611	41	0.9394	0.0304	42	
	0.8691	0.1622													2.3037	41	0.9466	0.0275	40	2
P100	0.7959														2.7278	41	0.9314	0.0344	45	
	0.8519									-0.1809					2.5043	41	0.9388	0.0315	43	2
P200	0.7938														2.7865	41	0.9236	0.0385	48	
	0.8516									-0.1856					2.5558	41	0.9315	0.0354	45	3
P500	0.7897														2.8609	41	0.9125	0.0442	51	
	N														N	N	N	N	N	
MEANPK	0.8357														2.1372	41	0.9662	0.0180	32	
	0.9147	0.1844													1.7312	41	0.9749	0.0138	27	5
WRCMEAN	0.9053														1.9766	41	0.7970	0.1541	112	
	0.9599			-0.2363											1.4727	41	0.8393	0.1252	97	15

Table 4. -- Experimental group equations relating streamflow characteristics to physiographic and climatic characteristics of drainage basins as determined from maps and climatological records, and Landsat tapes and statistical parameters and improvement in one-variable equations due to adding a second variable--Continued

Flow characteristic, Y	Equations: Regression coefficient, b(n), for indicated basin characteristic: AREA	SLOPE	ELEV	STORAGE	LNGGAGE	PRECIP	I24,2	JANMIN	BAREGD	WATER	Equations--Continued: DECIDB	COVRGD	CONIFE	SPOILTA	Regression constant exponent, a	Number of basins used	Parameters of best one- and two-variable equation: R-square	Mean square error	Standard error, in percent	Change in standard error, in percent
QA	1.0428														0.1444	17	0.9847	0.0025	12	
	1.0051		0.4225												-1.0988	17	0.9897	0.0018	10	2
Q10	1.0301														-0.6319	17	0.8758	0.0227	36	
	1.1061								0.1836						-0.8859	17	0.9098	0.0176	31	5
Q11	1.0996														-0.2454	17	0.9259	0.0146	28	
	0.9856		1.2782												-4.0068	17	0.9649	0.0074	20	8
Q12	1.1149														0.0624	17	0.9727	0.0053	17	
	1.0400		0.8396												-2.4084	17	0.9899	0.0021	11	6
Q1	1.0257														0.4623	17	0.9816	0.0030	13	
	1.0023						-2.9906								2.1143	17	0.9913	0.0015	9	4
Q2	1.0103														0.5784	17	0.9831	0.0026	12	
	N														N	N	N	N	N	
Q3	1.0450														0.4994	17	0.9848	0.0025	12	
	0.9955		0.5559												-1.1365	17	0.9935	0.0012	8	4
Q4	1.0506														0.3089	17	0.9734	0.0045	16	
	1.0625										0.4092				-0.3322	17	0.9851	0.0027	12	4
Q5	1.0555														0.0373	17	0.9673	0.0057	17	
	0.9955		0.6724												-1.9413	17	0.9796	0.0038	14	3
Q6	1.0373														-0.1969	17	0.9722	0.0046	16	
	NM														NM	17	0.9807	0.0035	14	2
Q7	1.0026														-0.1885	17	0.9671	0.0052	17	
	N														N	N	N	N	N	
Q8	1.0320														-0.4596	17	0.8885	0.0201	34	
	1.2419												-0.2322		-0.9548	17	0.9500	0.0097	23	11
Q9	0.9583														-0.3756	17	0.9013	0.0151	29	
	1.0474								0.2153						-0.6736	17	0.9571	0.0071	20	9
SDA	1.0611														-0.4796	17	0.9883	0.0020	10	
	1.0728			0.0362											-0.4483	17	0.9926	0.0014	9	1
SD10	1.2045														-1.0334	17	0.8739	0.0315	43	
	1.0614		1.6046												-5.7553	17	0.9223	0.0208	34	9

Table 4. -- Experimental group equations relating streamflow characteristics to physiographic and climatic characteristics of drainage basins as determined from maps and climatological records, and Landsat tapes and statistical parameters and improvement in one-variable equations due to adding a second variable--Continued

Flow characteristic, Y	Equations: Regression coefficient, b(n), for indicated basin characteristic										Equations--Continued				Regression constant exponent, a	Number of basins used	Parameters of best one- and two-variable equation			Change in standard error, in percent
	AREA	SLOPE	ELEV	STORAGE	LNGGAGE	PRECIP	I24,2	JANMIN	BAREGD	WATER	DECIDB	COVRGD	CONIFE	SPOILTA			R-square	Mean square error	Standard error, in percent	
SD11	1.1533														-0.2912	17	0.8502	0.0353	45	
	1.1919										1.3235				-2.3650	17	0.9388	0.0154	29	16
SD12	1.0765														0.0933	17	0.9807	0.0034	13	
	1.0526						-3.0509								1.7786	17	0.9898	0.0019	11	2
SD1	0.9775														0.4249	17	0.9513	0.0074	20	
	0.9640										-0.4619				1.1486	17	0.9681	0.0052	17	3
SD2	0.9788														0.3907	17	0.9730	0.0040	15	
	0.9984							1.5894							-1.9799	17	0.9802	0.0031	13	2
SD3	1.0667														0.0915	17	0.9799	0.0035	14	
	1.0347									0.1169					0.2322	17	0.9873	0.0024	11	3
SD4	1.0020														0.1146	17	0.9564	0.0069	19	
	0.9290		0.8180												-2.2925	17	0.9763	0.0040	15	4
SD5	1.0145														-0.0284	17	0.9567	0.0070	19	
	0.9368		0.8712												-2.5922	17	0.9787	0.0037	14	5
SD6	1.1953														-0.5899	17	0.9290	0.0165	30	
	1.2153										0.6863				-1.6653	17	0.9532	0.0116	25	5
SD7	1.1353														-0.4788	17	0.8751	0.0277	40	
	NM														NM	17	0.9520	0.0114	25	15
SD8	1.1822														-0.8206	17	0.9099	0.0209	34	
	N														N	N	N	N	N	
SD9	1.0778														-0.5349	17	0.9058	0.0182	32	
	NM														NM	17	0.9325	0.0140	28	4
M3,20	NM														NM	15	0.5125	0.3777	253	
	NM														NM	15	0.6757	0.2721	180	73
M7,2	N														N		N	N	N	
	N														N		N	N	N	N
M7,10	NM														NM	15	0.4603	0.2863	189	
	NM														NM	15	0.6190	0.2190	148	41
M7,20	NM														NM	16	0.3175	0.4575	315	
	NM														NM	16	0.5227	0.3446	229	86

Table 4. -- Experimental group equations relating streamflow characteristics to physiographic and climatic characteristics of drainage basins as determined from maps and climatological records, and Landsat tapes and statistical parameters and improvement in one-variable equations due to adding a second variable--Continued

Flow characteristic, Y	Equations										Equations--Continued						Parameters of best one- and two-variable equation			
	Regression coefficient, b(n), for indicated basin										characteristic				Regression constant exponent, a	Number of basins used	R-square	Mean square error	Standard error, in percent	Change in standard error, in percent
	AREA	SLOPE	ELEV	STORAGE	LNGGAGE	PRECIP	I24,2	JANMIN	BAREGD	WATER	DECIDB	COVRGD	CONIFE	SPOILTA						
V3,2	0.9860														1.3828	17	0.9773	0.0034	14	
	0.9758													0.0969	1.4359	17	0.9847	0.0025	11	3
V3,10	0.9881														1.5997	17	0.9803	0.0030	13	
	N														N		N	N	N	N
V3,50	0.9870														1.7272	15	0.9664	0.0051	17	
	N														N		N	N	N	N
V7,2	1.0143														1.1098	17	0.9814	0.0029	13	
	1.0051													0.0879	1.1579	17	0.9872	0.0022	11	2
V7,10	0.9877														1.3819	17	0.9858	0.0021	11	
	0.9803													0.0695	1.4200	17	0.9897	0.0016	9	2
V7,50	0.9828														1.5027	15	0.9832	0.0025	12	
	N														N		N	N	N	N

Each table shows two equations for each flow characteristic. The top line for a characteristic shows the most accurate equation when using only one independent variable. The second line for the same characteristic shows a more accurate equation based upon two independent variables.

The last four columns in tables 3 and 4 give statistical parameters defining the accuracy of the equations and improvements in accuracy due to including an additional independent variable. The R-square parameter measures how much variation in the dependent variable can be accounted for by the model. Specifically, R-square is the ratio of the sum of squares for the dependent variable that can be attributed to the model divided by the total sum of squares for the dependent variable. It can range from 0 to 1, and in general the larger it is, the better the model fit. A value of 0.9671 indicates that we can account for 97 percent of that streamflow characteristic just by knowing the corresponding independent variable(s).

The mean square error, in the next column, is an estimate of σ^2, the variance of the true residuals. It is the ratio of the sum of squares for the dependent variable that can not be attributed to the model divided by the degrees of freedom. Its value is partly dependent upon the magnitude of values in the dependent variable but, in general, the smaller it is, the better the model fit. The standard error of estimate of the dependent variable, or simply standard error in the next column, is another measure of equation accuracy. It is the average difference between input data for the dependent variable and data estimated for the dependent variable by the regression equation. In this sense it is actually the standard error of regression. The errors, in percent, are not normally distributed, and as a consequence, the standard error of estimate, in percent, given in this report is approximately the average of the positive and negative percentages. Standard error, in logarithmic units, was converted to percent by the method described by Hardison (1971).

The last column in tables 3 and 4, change in standard error, lists the improvement in the standard error of estimate of the streamflow characteristic due to including a second independent variable in the equation in those cases where a second independent variable was significant at the 5 percent level for entry into the model.

To illustrate the use of the regression equations, assume that the 1.25-year flood peak (P1.25) is required for New River at New River, Tenn., station 3408500, (table 1). From regression analysis using data from maps and climatological records (table 3) we have

$$P1.25 = AREA^{(0.9061)}\ SLOPE^{(0.1867)}\ 10^{(1.5683)} \pm 26 \text{ percent}$$

and from basin characteristics for New River at New River (table 7) we have

$$P1.25 = 382^{0.9061}\ 7.06^{0.1867}\ 10^{1.5683}$$
$$P1.25 = 218.6(1.440)\ 37.01$$
$$P1.25 = 11{,}600 \text{ ft}^3/\text{s}$$

or from regression analysis using data from maps and climatological records, and Landsat tapes (table 4) we have

$$P1.25 = AREA^{0.8330}\ COVRGD^{-0.1939}\ 10^{2.1967} \pm 25 \text{ percent}$$

and from basin characteristics for New River at New River (table 7 and table 2) we have

$$P1.25 = 382^{0.8330}\ 3.5^{-0.1939}\ 10^{2.1967}$$
$$P1.25 = 141.5(1/1.28)\ 157.3$$
$$P1.25 = 17{,}400\ ft^3/s$$

These regression equations were developed solely for the purpose of testing the usefulness of basin characteristics derived from Landsat for improving regression estimates. These equations are not intended to replace existing operational regressions (W. J. Randolph and C. R. Gamble, written commun., 1976) or regressions developed in the future for operational use.

Table 5 lists the occurrence of significant independent variables in the "best" two-variable equations. A few independent variables occur repeatedly in the equations. With the exception of low flows, AREA occurs in every equation in both the control group and the experimental group wherever a variable was found to be significant within at least a 95 percent confidence limit. In both groups of equations LNGGAGE was found to be the one most effective variable in explaining the variance in low flows. LNGGAGE may be a surrogate for differences in ground-water occurrence affecting streamflow. Stations with a large value of LNGGAGE would tend to lie on the west side of the study area where the corresponding basins are more likely to contain parts of the eastern Highland Rim. The soil and weathered rock capping the Highland Rim is much thicker and more water-bearing than the corresponding material capping the Cumberland Plateau. In addition, large springs occur in the limestone underlying the streambeds in the escarpment along the western edge of the Cumberland Plateau.

Independent variables (basin characteristics) were found to be significant in five more experimental group equations than in control group equations (table 5). In the control group equations, AREA occurs in 33 out of 34 while in the experimental group, AREA occurs in 36 out of 39. In both groups, SLOPE is next to AREA in explaining the variance in flood peaks, and ELEV is next to AREA in explaining variance in mean flows and mean flow variability (standard deviation).

In the experimental group equations, WATER and COVRGD which tend to occur in flatter areas appear to be substituting inversely for SLOPE in equations for flood peaks of either very small or very large recurrence interval. DECIDB which is more common in the Cumberland Plateau than in the adjacent escarpments, Highland Rim, or Sequatchie Valley appears to be substituting for ELEV or FOREST in equations for mean flows and mean flow variability. Although SPOILTA occurs in three of the experimental group equations for flood volumes, the value of the coefficient is so small that the value of SPOILTA approaches 1.0 resulting in only minor adjustments in the calculated value for flood volume.

The following independent variables do not occur in any of the equations because either they were not significant within at least a 95 percent confidence limit or they did not improve the accuracy of the equations as much as other independent variables: SOIL, LATGAGE, DECIDS, and MIXFOR.

ACCURACY COMPARSIONS

As would be expected, where significance was achieved, all two-variable equations are more accurate than the corresponding one-variable equation.

Table 5. -- Basin characteristics found to be signficantly related to streamflow

[The number in the table denotes the number of 2-variable equations in which the indicated basin characteristic was found significant]

Flow characteristic category	Number of 2-variable equations	Basin characteristic																			
		AREA	SLOPE	ELEV	STOR-AGE	FOR-EST	SOIL	LAT-GAGE	LNG-GAGE	PRE-CIP	I24,2	JAN-MIN	JULY-MAX	BARE-GD	WATER	DECIDB	DECIDS	COVR-GD	CONIFE	MIX-FOR	SPOIL-TA
									Control Group Equations												
Flood Peaks	7	7	7	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-
Ann Pk Logs	2	2	1	0	1	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-
Mean Flow	10	10	0	6	0	1	0	0	2	0	1	0	0	-	-	-	-	-	-	-	-
Std. Deviation	11	11	0	4	1	1	0	0	1	0	2	1	1	-	-	-	-	-	-	-	-
Low Flow	2	1	0	0	0	0	0	0	2	1	0	0	0	-	-	-	-	-	-	-	-
Flood Volume	2	2	0	1	0	0	0	0	0	0	1	0	0	-	-	-	-	-	-	-	-
Total	34	33	8	11	2	2	0	0	5	1	4	1	1	-	-	-	-	-	-	-	-
									Experimental Group Equations												
Flood Peaks	8	8	4	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0
Ann Pk Logs	2	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean Flow	11	11	0	5	0	0	0	0	1	0	1	0	0	2	0	1	0	0	1	0	0
Std. Deviation	12	12	0	3	1	0	0	0	1	0	2	1	0	0	1	3	0	0	0	0	0
Low Flow	3	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	2
Flood Volume	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Total	39	36	5	8	2	0	0	0	5	1	3	1	0	2	3	4	0	2	1	0	5

Within the experimental group of equations, 17 two-variable equations are different from the 17 corresponding two- variable equations in the control group. The remaining 22 equations are identical to the corresponding equations in the control group. The 17 differing equations in the experimental group contain basin characteristics derived from Landsat tapes. Five of these 17 are equations for which a second independent variable was found significant within at least a 95 percent confidence limit in the experimental group but not in the control group. Of the remaining 12 equations, 7 equations are more accurate (as measured by standard error) by 3 percent or less than those in the control group, none are less accurate, and 5 are not measurably different.

Table 6 compares the experimental group with the control group as to improvement in accuracy where the 34 control group equations and corresponding 34 experimental equations are grouped according to six flow characteristic categories. When considering the mean error for each flow-category group there is no substantial difference in accuracy between control group and experimental group.

Table 6. -- Comparison of improvement in standard error of control group equations versus experimental group equations as a result of adding a second independent variable

[Only those relationships are considered for which a second variable was found significant within at least a 95 percent confidence limit in both control group and experimental group]

[The standard error in percent is an average of the plus and minus percentages because errors expressed in percent are not normally distributed]

Flow characteristic category	Number of equations	Mean standard error of one-variable equation, in percent	Mean standard error of two-variable equation, in percent		Change in standard error, in percent	
		Control and experimental	Control	Experimental	Control	Experimental
Flood peak	7	36.4	33.1	33.0	3.3	3.4
Ann. pk. log	2	72.0	62.0	62.0	10.0	10.0
Mean flow	10	19.4	14.4	14.1	5.0	5.3
Std. deviation	11	24.5	19.0	18.7	5.5	5.8
Low flow	2	252	190	188	62	64
Flood volume	2	13.5	11.5	11.0	2.0	2.5
Total number of equations	34					

SUMMARY AND CONCLUSIONS

This study tested the feasibility of improving upon the regression equations for estimating streamflow by using land-cover information derived from digital processing of Landsat spectral data. The Cumberland Plateau of Tennessee is a source of bituminous coal where the essentially flat terrain is underlain by coal-bearing sandstone and shale that caps several thousand feet of soluble carbonate rocks. The relatively insoluble sandstone and shale weather to a thin, stony soil. Streamflow records are available for 41 basins having a median drainage area of 78.7 square miles. An experiment was designed to compare the accuracy of equations using basin characteristics derived from maps and climatological records (control group equations) with the accuracy of equations using basin characteristics derived from Landsat tapes as well as maps and climatological records (experimental group equations).

Basin characteristics were derived from Landsat tapes by computer analysis of the sunlight reflected from each 1.12-acre pixel in the study area. The results of two unsupervised classifications were combined to provide information on the percent of each drainage basin covered by water, forest, covered ground, bare ground, and dark, coal spoil and asphalt.

Basin characteristics derived from maps and climatological records cover a wide range of characteristics found to be significant in several previous studies. They include drainage area; main channel slope; stream length; mean basin elevation; lake, pond, and swamp area; forest area; soil infiltration index; latitude and longitude of the gage; mean annual precipitation; precipitation intensity; and mean minimum January and mean maximum July temperature.

Streamflow characteristics derived from the records of the daily discharge of 41 gaged basins are representative of the full range in flow conditions and include all that are commonly used for design or planning. They include annual flood peaks with recurrence intervals of 1.25, 2, 5, 10, 25, 50, 100, 200 and 500 years; mean annual and mean monthly discharges; standard deviation of the mean annual and mean monthly discharges; low-flows; flood volumes; and annual peak discharge logarithms.

These characteristics were checked for the degree of correlation among them. Two independent variables, contributing drainage area and stream length, were eliminated. The logarithms of values for both streamflow characteristics and basin characteristics were used in regressions rather than actual values after comparing plots using actual values with plots using the logarithms of values. Streamflow characteristics were regressed with basin characteristics and plots of the residuals were checked for zero mean and constant variance. Although the regression coefficients in equations for low flows were not meaningful, the mapped distribution of residuals for low flows implied a direct relation between abnormally large low flows and a location of the gage far downstream from a reach of stream that loses part or all of its flow to the underlying rocks. No reasonable models could be developed either for low flows or for most annual peak discharge logarithms. For the remaining flow categories, preliminary results of the regression analysis showed that AREA could explain more than 90 percent of the variance in the streamflow characteristics.

Streamflow characteristics were regressed with basin characteristics to derive a "best" one-variable equation and a "best" two-variable equation. These equations were derived solely for testing Landsat basin characteristics for improving the regression estimates, and they are not intended to replace existing operational regressions (W. J. Randolph and C. R. Gamble, written commun., 1976). The area of the gaged basin occurs in every equation wherever a variable was found to be significant within at least a 95 percent confidence limit. Main channel slope is next to basin area in explaining the variance in flood peaks and flood volumes. In the experimental group equations with two variables, water or covered ground appears to be substituting inversely for main channel slope in equations for flood peaks. Also, well-lit deciduous forest appears to be substituting for mean basin elevation or forest area in equations for mean monthly discharge and standard deviation of mean monthly discharge.

Seventeen experimental group equations with two variables are different from the corresponding control group equations. Of these, five have no counterpart in the control group because of lack of significance in control group variables, seven are more accurate, and five are not measurably different. When the equations are grouped according to flood peak, annual peak discharge logarithms, mean flow, standard deviation of mean flow, low flow and flood volume, there is no substantial difference in accuracy between equations using basin characteristics derived from maps and climatological records (control group) and equations using basin characteristics derived from Landsat tapes as well as maps and climatological records (experimental group) in this particular study area.

In contrast to this study, other studies employing the same methods have shown that land-cover or land-use data from either satellite imagery or aircraft photography can significantly improve estimates of streamflow (Hollyday, 1976, and Pluhowski, 1977). The site of these latter studies was in the Coastal Plain of Maryland, Delaware, and Virginia where the soils are thick and are underlain by water-bearing sediments which store abundant water for maintaining streamflow during extended periods without precipitation. In contrast, this study area has thin soils and has sandstone and shale with little capacity to store significant quantities of water for maintaining streamflow. The differences in the two sites may account for the fact that the techniques described in this report were successful in previous studies but not in this study.

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SUPPLEMENTAL DATA

Table 7.--Basin characteristics and streamflow characteristics for 41 gaging stations in the Cumberland Plateau area of Tennessee

[Explanation of terms and symbols are found in sections "Basin Characteristics" and "Streamflow Characteristics." Gaging station number is listed under "Sample"]

[Undetermined values are shown as: _ _ _ _ 0.0 _ _ _ B]

SAMPLE	AREA	CONTDA	SLOPE	LENGTH	ELEV	STORAGE	FOREST	SOIL INF	LAT GAGE	LNG GAGE
03408500	382.0000	382.0000	7.0600	46.2000	1800.0000	0.0	90.0000	3.5100	36.3855	84.5547
03409000	13.5000	13.5000	54.5200	5.7000	1550.0000	0.0	95.8000	3.5100	36.2439	84.6705
03409500	272.0000	272.0000	12.0000	36.5000	1480.0000	0.0	87.1000	3.5100	36.3883	84.6303
03410500	953.9998	954.0000	9.0000	74.9000	1600.0000	0.0	98.0000	3.1000	36.6269	84.5333
03414500	202.0000	196.0000	37.0000	37.6000	1720.0000	0.1000	92.0000	3.5100	36.4161	85.0264
03415000	115.0000	81.0000	33.6000	20.5000	1310.0000	0.0	86.2000	3.5100	36.3969	85.1744
03415500	445.0000	445.0000	21.2000	62.8000	1420.0000	0.0500	86.1000	3.5100	36.5358	85.1703
03415700	7.9800	4.7700	68.4800	4.4000	1160.0000	0.0300	50.0000	3.5100	36.4491	85.2742
03416000	106.0000	106.0000	12.3000	23.4000	1300.0000	0.0	88.9000	3.5100	36.5603	85.0730
03418000	78.7000	51.6000	14.6000	20.1000	1110.0000	0.0400	51.3000	3.8900	36.3408	85.4264
03418500	111.0000	111.0000	15.2700	19.5000	1840.0000	0.5900	85.7000	3.7000	35.8911	85.2180
03418900	1.5200	1.5200	182.2700	1.8800	1870.0000	0.0	89.5000	3.7000	35.7867	85.1444
03420000	175.0000	111.0000	5.1900	35.4000	1370.0000	0.1400	60.9000	3.7000	35.9086	85.4794
03420500	126.0000	126.0000	11.8000	19.8000	1090.0000	0.0	46.7000	4.0800	35.6653	85.8833
03421000	640.0000	640.0000	25.9000	53.3000	1370.0000	0.0100	65.4000	4.0800	35.7089	85.7294
03423000	67.0000	45.9000	18.2000	24.7000	1160.0000	0.1800	34.4000	3.7000	36.0772	85.5214
03534000	24.5000	24.5000	59.4100	9.1000	1750.0000	0.0	98.1000	3.8900	36.2205	84.1575
03538200	55.9000	55.9000	19.2300	15.7000	1150.0000	0.0	67.9000	3.8900	36.0222	84.3103
03538225	82.5000	82.5000	13.2200	20.2000	1120.0000	0.0	67.5000	3.8900	35.9986	84.3397
03538300	5.5400	5.5400	121.5400	3.5000	1510.0000	0.0	93.8000	3.8900	36.1983	84.6608
03538500	83.2000	83.2000	30.6000	16.5000	1610.0000	0.0	88.6000	3.8900	36.1128	84.6150
03538600	12.0000	12.0000	12.8100	7.7000	1810.0000	0.0	78.3000	3.8900	35.9575	85.0500
03538800	0.7200	0.7200	52.5000	1.6000	1820.0000	0.0	59.1000	3.8900	35.9830	85.0586
03538900	3.8000	3.8000	45.4100	3.6700	1910.0000	1.0500	86.7000	3.8900	35.7983	85.0425
03539100	1.1000	1.1000	40.1300	1.6600	1890.0000	0.0	67.3000	3.8900	35.8944	85.0605
03539500	93.5000	93.5000	9.3000	28.7000	1830.0000	0.7500	79.2000	3.8900	35.9258	84.9130
03539600	139.0000	139.0000	8.6500	39.6000	1810.0000	0.5000	83.2000	3.8900	35.9980	84.8233
03539800	518.0000	518.0000	17.2000	56.3000	1680.0000	0.1600	90.4000	3.8900	36.0814	84.6708
03540500	764.0000	764.0000	18.0000	67.9000	1630.0000	0.1100	87.9000	3.8900	35.9830	84.5580
03541100	5.5300	5.5300	190.0800	4.0500	1490.0000	0.0	81.5000	3.8900	36.0147	84.5258
03541200	2.4400	2.4400	237.6000	3.0300	1230.0000	0.0	96.6000	3.8900	36.0033	84.5125
03541500	108.0000	108.0000	54.0000	19.1000	1580.0000	0.0	96.2000	3.7000	35.7969	84.7603
03544500	50.2000	50.2000	103.0000	12.9000	1790.0000	0.1000	86.2000	3.7000	35.5047	85.0222
03570800	15.4000	15.4000	152.1500	9.0000	1920.0000	0.0	82.4000	3.7000	35.4042	85.3883
03571000	402.0000	384.0000	3.2900	89.2000	1390.0000	0.0	73.8000	3.7000	35.2061	85.4966
03571600	0.6700	0.6700	954.2898	1.4000	1030.0000	0.0	82.9000	3.7000	35.1486	85.5578
03571800	50.4000	50.4000	136.0000	10.9000	1560.0000	0.0	79.2000	3.7000	35.1342	85.7708
03578000	65.6000	65.6000	78.3000	15.5000	1660.0000	0.0	84.6000	3.8900	35.2966	85.8700
03578500	41.3000	41.3000	14.2000	14.7000	1080.0000	0.0	36.8000	3.8900	35.3558	85.9792
03579900	17.0000	17.0000	28.5700	7.5000	1340.0000	0.0200	61.7000	3.8900	35.1625	86.0056
03596000	107.0000	107.0000	13.9000	24.8000	1090.0000	0.1600	55.2000	3.7000	35.4708	86.1216

Table 7.--Basin characteristics and streamflow characteristics for 41 gaging stations in the Cumberland Plateau area of Tennessee--Continued

SAMPLE	PRECIP	I24,2	JANMIN	JULYMAX	P1,25	P2	P5	P10	P25	P50
03408500	54.0000	3.3000	28.0000	88.0000	18000.0000	25100.0000	35200.0000	42300.0000	51500.0000	58600.0000
03409000	51.0000	3.5000	28.0000	87.0000	1340.0000	1940.0000	2810.0000	3420.0000	4220.0000	4850.0000
03409500	51.0000	3.3000	28.0000	86.0000	8920.0000	13500.0000	20500.0000	25600.0000	32400.0000	37700.0000
03410500	48.0000	3.3000	28.0000	88.0000	33200.0000	45400.0000	62200.0000	73300.0000	87400.0000	97900.0000
03414500	53.0000	3.3000	28.0000	86.0000	11400.0000	16900.0000	24800.0000	30400.0000	37700.0000	43400.0000
03415000	55.0000	3.5000	28.0000	87.0000	4840.0000	7000.0000	10100.0000	12100.0000	14800.0000	16800.0000
03415500	54.0000	3.4000	28.0000	87.0000	9890.0000	15900.0000	25700.0000	33000.0000	43100.0000	51200.0000
03415700	52.0000	3.5000	28.0000	89.0000	451.0000	713.0000	1130.0000	1430.0000	1850.0000	[illegible]80.0000
03416000	53.0000	3.4000	28.0000	88.0000	4640.0000	7930.0000	13300.0000	17300.0000	[illegible]00.0000	27200.0000
03418000	54.0000	3.6000	28.0000	89.0000	2010.0000	3320.0000	5400.0000	[illegible]	9020.0000	10700.0000
03418500	54.0000	3.4000	29.0000	85.0000	4230.0000	6210.0000	9120.0000	11200.0000	13800.0000	15900.0000
03418900	51.0000	3.6000	29.0000	85.0000	121.0000	19[illegible]	297.0000	376.0000	482.0000	568.0000
03420000	55.0000	3.3000	30.0000	87.0000	5450.0000	7660.0000	10900.0000	13100.0000	16000.0000	18200.0000
03420500	52.0000	3.5000	31.0000	90.0000	5410.0000	9580.0000	16300.0000	21300.0000	27900.0000	33100.0000
03421000	53.0000	3.5000	31.0000	88.0000	15200.0000	24000.0000	36900.0000	45800.0000	57200.0000	65800.0000
03423000	56.0000	3.3000	30.0000	88.0000	2380.0000	3410.0000	4700.0000	5480.0000	6380.0000	7000.0000
03534000	52.0000	3.5000	29.0000	88.0000	1920.0000	2860.0000	4300.0000	5340.0000	6730.0000	7830.0000
03538200	53.0000	3.5000	29.0000	88.0000	2350.0000	3460.0000	5250.0000	6600.0000	8500.0000	10100.0000
03538225	56.0000	3.5000	29.0000	88.0000	3060.0000	4560.0000	6850.0000	8480.0000	10700.0000	12400.0000
03538300	51.0000	3.5000	28.0000	87.0000	535.0000	746.0000	1040.0000	1250.0000	1510.0000	1710.0000
03538500	53.0000	3.5000	28.0000	87.0000	4720.0000	7080.0000	11100.0000	14200.0000	18800.0000	22700.0000
03538600	52.0000	3.5000	28.0000	85.0000	484.0000	664.0000	916.0000	1090.0000	1300.0000	1470.0000
03538800	52.0000	3.5000	28.0000	85.0000	72.0000	121.0000	209.0000	280.0000	384.0000	471.0000
03538900	52.0000	3.6000	29.0000	85.0000	210.0000	338.0000	578.0000	750.0000	983.0000	1180.0000
03539100	51.0000	3.6000	28.0000	85.0000	62.0000	96.0000	176.0000	236.0000	324.0000	400.0000
03539500	52.0000	3.5000	28.0000	85.0000	2950.0000	4840.0000	8000.0000	10400.0000	13800.0000	16600.0000
03539600	52.0000	3.5000	28.0000	86.0000	6190.0000	7670.0000	9520.0000	10700.0000	12100.0000	13100.0000
03539800	52.0000	3.5000	28.0000	86.0000	23500.0000	34700.0000	51500.0000	63500.0000	79400.0000	91900.0000
03540500	53.0000	3.5000	28.0000	86.0000	29400.0000	46500.0000	73800.0000	94200.0000	122000.0000	145000.0000
03541100	55.0000	3.5000	28.0000	87.0000	596.0000	1010.0000	1840.0000	2480.0000	3400.0000	4210.0000
03541200	55.0000	3.5000	29.0000	87.0000	218.0000	335.0000	576.0000	758.0000	1020.0000	1250.0000
03541500	53.0000	3.5000	28.0000	86.0000	6590.0000	11400.0000	20400.0000	27900.0000	39400.0000	49500.0000
03544500	58.0000	3.5000	30.0000	85.0000	2590.0000	4400.0000	7400.0000	9670.0000	12800.0000	15300.0000
03570800	55.0000	3.5000	30.0000	84.0000	1480.0000	1930.0000	2510.0000	2880.0000	3330.0000	3660.0000
03571000	56.0000	3.5000	30.0000	85.0000	7660.0000	11400.0000	16800.0000	20500.0000	25300.0000	28900.0000
03571600	56.0000	3.5000	30.0000	87.0000	72.0000	102.0000	144.0000	172.0000	209.0000	236.0000
03571800	60.0000	3.5000	30.0000	86.0000	2700.0000	3610.0000	5010.0000	5940.0000	7130.0000	8020.0000
03578000	58.0000	3.5000	30.0000	85.0000	2830.0000	4190.0000	6230.0000	7650.0000	9540.0000	11000.0000
03578500	53.0000	3.5000	31.0000	88.0000	1600.0000	2490.0000	3870.0000	4880.0000	6250.0000	7330.0000
03579900	57.0000	3.5000	30.0000	87.0000	1440.0000	2070.0000	2990.0000	3620.0000	4440.0000	5070.0000
03596000	52.0000	3.5000	32.0000	89.0000	3980.0000	7480.0000	14700.0000	21200.0000	32000.0000	41900.0000

Table 7.--Basin characteristics and streamflow characteristics for 41 gaging stations in the Cumberland Plateau area of Tennessee--Continued

SAMPLE	P100	P200	MEANPK	SDPK	SKEWPK	QA	SDQA	Q10	Q11	Q12
03408500	65900.0000	73500.0000	4.3930	0.1600	0.0900	746.0000	199.0000	128.0000	468.0000	1079.0000
03409000	5490.0000	6150.0000	3.3020	0.1880	0.4910	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03409500	43300.0000	49200.0000	4.1230	0.2080	0.0520	465.0000	123.4000	46.0000	210.0000	592.0000
03410500	108000.0000	119000.0000	4.6580	0.1620	0.1190	1782.0000	456.0000	386.0000	1213.0000	2576.0000
03414500	49200.0000	55100.0000	4.2270	0.2000	-0.0360	386.0000	91.0800	57.4000	217.0000	478.0000
03415000	18800.0000	20800.0000	3.8470	0.1920	-0.2250	159.0000	42.2000	19.3000	80.4000	185.0000
03415500	59700.0000	68800.0000	4.2030	0.2470	-0.6040	752.0000	254.0000	126.0000	433.0000	917.0000
03415700	2530.0000	2900.0000	2.8530	0.2370	-1.3280	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03416000	31800.0000	36600.0000	3.8990	0.2760	-0.3710	177.0000	51.2100	23.1000	95.5000	214.0000
03418000	12400.0000	14200.0000	3.5170	0.2550	-0.3640	106.0000	31.2700	16.9000	46.8000	113.0000
03418500	18000.0000	20200.0000	3.7930	0.1990	-0.3350	207.0000	43.0000	21.1000	87.0000	309.0000
03418900	660.0000	745.0000	2.2800	0.2300	0.0	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03420000	20500.0000	22900.0000	3.8760	0.1640	-0.1230	370.0000	88.1100	69.0000	216.0000	449.0000
03420500	38300.0000	43800.0000	3.9740	0.2910	-0.3330	218.0000	53.1400	60.2000	102.0000	217.0000
03421000	74500.0000	83200.0000	4.3780	0.2360	-0.1410	1140.0000	305.7000	218.0000	664.0000	1360.0000
03423000	7580.0000	8130.0000	3.5260	0.1800	-1.0260	111.0000	33.8700	13.6000	49.3000	130.0000
03534000	8980.0000	10200.0000	3.4490	0.2010	-0.1570	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03538200	11800.0000	13600.0000	3.5400	0.2010	0.1560	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03538225	14200.0000	16100.0000	3.6610	0.2080	0.1830	182.0000	61.0000	55.6000	134.0000	289.0000
03538300	1910.0000	2120.0000	2.8740	0.1730	0.1560	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03538500	27000.0000	31800.0000	3.8580	0.2170	0.2560	148.0000	37.1000	13.3000	65.4000	226.0000
03538600	1630.0000	1800.0000	2.8240	0.1650	-0.1770	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03538800	566.0000	670.0000	2.1250	0.2190	1.2280	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03538900	1390.0000	1585.0000	2.4800	0.2300	-0.2300	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03539100	482.0000	567.0000	1.8800	0.3000	-0.0500	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03539500	19700.0000	22900.0000	3.6640	0.2300	-0.6790	174.0000	44.8000	21.8000	101.0000	276.0000
03539600	14000.0000	15000.0000	3.8850	0.1110	-0.5150	267.0000	66.7000	66.2000	264.0000	366.0000
03539800	105000.0000	118000.0000	4.5420	0.2030	0.6950	1086.0000	265.0000	314.0000	1032.0000	1620.0000
03540500	168000.0000	194000.0000	4.6760	0.2480	0.1390	1410.0000	376.7998	153.0000	844.0000	1940.0000
03541100	5100.0000	6035.0000	2.9400	0.2800	-0.1000	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03541200	1490.0000	1741.0000	2.4000	0.2900	0.0	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03541500	60900.0000	73900.0000	4.0510	0.2730	0.3130	215.0000	53.6000	20.1000	104.0000	319.0000
03544500	18000.0000	20800.0000	3.6260	0.2630	-0.1820	107.0000	32.5000	18.2000	88.1000	148.0000
03570800	3980.0000	4310.0000	3.2850	0.1360	0.4810	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03571000	32500.0000	36200.0000	4.0540	0.2030	-0.2220	728.0000	191.7000	135.0000	422.0000	866.0000
03571600	264.0000	292.0000	2.0090	0.1770	-0.1480	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03571800	8910.0000	9820.0000	3.5920	0.1590	1.1050	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03578000	12500.0000	14000.0000	3.6230	0.2040	0.3100	134.0000	24.4300	21.4000	86.5000	161.0000
03578500	8460.0000	9650.0000	3.3960	0.2290	-0.6920	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03579900	5710.0000	6360.0000	3.3170	0.1890	0.6930	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
03596000	53800.0000	67800.0000	3.8760	0.3280	0.2920	175.0000	50.6500	28.4000	77.8000	185.0000

Table 7.--Basin characteristics and streamflow characteristics for 41 gaging stations in the Cumberland Plateau area of Tennessee--Continued

SAMPLE	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	SDQ10
03408500	1496.0000	1537.0000	1643.0000	1122.0000	656.0000	309.0000	286.0000	159.0000	106.0000	177.0000
03409000	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
03409500	925.0000	1100.0000	1110.0000	731.0000	398.0000	177.0000	159.0000	88.4000	67.2000	54.2400
03410500	3455.0000	3576.0000	3870.0000	2659.0000	1603.0000	809.0000	640.0000	392.0000	290.0000	412.0000
03414500	772.0000	923.0000	889.0000	565.0000	329.0000	166.0000	128.0000	63.6000	66.2000	65.4400
03415000	326.0000	397.0000	386.0000	234.0000	121.0000	67.6000	52.0000	27.0000	25.0000	17.5100
03415500	1300.0000	1490.0000	1740.0000	1270.0000	666.0000	408.0000	265.0000	279.0000	174.0000	201.1000
03415700	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
03416000	355.0000	426.0000	416.0000	256.0000	136.0000	96.5000	66.0000	24.8000	28.9000	18.0100
03418000	204.0000	246.0000	254.0000	161.0000	84.4000	59.0000	50.2000	27.6000	24.4000	13.6600
03418500	451.0000	542.0000	465.0000	338.0000	177.0000	53.0000	31.9000	49.5000	21.6000	47.2000
03418900	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
03420000	683.0000	841.0000	842.0000	562.0000	309.0000	152.0000	156.0000	92.3000	92.0000	67.1700
03420500	434.0000	530.0000	438.0000	292.0000	175.0000	122.0000	100.0000	93.0000	74.5000	26.3200
03421000	2000.0000	2580.0000	2570.0000	1760.0000	968.0000	612.0000	440.0000	325.0000	254.0000	208.0000
03423000	257.0000	267.0000	233.0000	148.0000	90.9000	51.0000	39.4000	33.8000	31.1000	15.1700
03534000	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
03538200	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
03538225	311.0000	283.0000	393.0000	238.0000	156.0000	95.5000	136.0000	61.4000	34.2000	62.7000
03538300	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
03538500	329.0000	352.0000	319.0000	205.0000	113.0000	47.2000	54.9000	30.4000	22.8000	17.4000
03538600	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
03538800	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
03538900	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
03539100	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
03539500	373.0000	433.0000	360.0000	257.0000	143.0000	46.6000	39.4000	33.3000	19.4000	41.3000
03539600	383.0000	498.0000	667.0000	434.0000	229.0000	84.0000	112.0000	61.9000	47.2000	80.4700
03539800	2005.0000	1753.0000	2669.0000	1632.0000	1085.0000	440.0000	466.0000	149.0000	187.0000	391.0000
03540500	2740.0000	3280.0000	3280.0000	2120.0000	1160.0000	539.0000	448.0000	267.0000	210.0000	245.9000
03541100	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
03541200	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
03541500	506.0000	512.0000	475.0000	302.0000	166.0000	48.1000	65.1000	48.7000	35.8000	49.3000
03544500	219.0000	227.0000	232.0000	153.0000	93.3000	43.8000	35.7000	20.6000	14.3000	42.3000
03570800	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
03571000	1280.0000	1590.0000	1660.0000	1180.0000	643.0000	343.0000	283.0000	218.0000	160.0000	153.5000
03571600	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
03571800	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
03578000	223.0000	303.0000	299.0000	239.0000	139.0000	51.2000	48.8000	30.2000	19.0000	28.6100
03578500	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
03579900	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
03596000	357.0000	444.0000	406.0000	270.0000	131.0000	72.1000	62.5000	46.7000	39.4000	13.6100

Table 7.--Basin characteristics and streamflow characteristics for 41 gaging stations in the Cumberland Plateau area of Tennessee--Continued

SAMPLE	SDQ11	SDQ12	SDQ1	SDQ2	SDQ3	SDQ4	SDQ5	SDQ6	SDQ7	SDQ8
03408500	584.0000	785.0000	960.0000	847.0000	729.0000	520.0000	552.0000	249.0000	384.0000	217.0000
03409000	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
03409500	276.2000	543.7000	738.5000	657.5000	515.7998	366.2000	275.3999	140.4000	240.5000	118.4000
03410500	1227.0000	1832.0000	2141.0000	1873.0000	1814.0000	1301.0000	1110.0000	628.0000	769.0000	517.0000
03414500	237.3000	398.3999	529.2998	458.0999	351.0000	288.2000	231.9000	159.1000	209.4000	71.2200
03415000	93.6300	166.0000	239.8000	212.9000	154.5000	121.9000	101.9000	65.1500	77.3800	27.6100
03415500	546.0000	954.2000	908.2000	794.5999	957.0000	536.7998	426.0999	578.5000	314.0000	290.8999
03415700	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
03416000	103.8000	181.9000	260.5999	231.9000	174.8000	153.9000	98.6200	89.1700	62.5300	16.9700
03418000	49.0400	111.5000	184.2000	160.6000	130.2000	93.3300	61.3000	49.7800	58.2000	23.1100
03418500	107.0000	269.0000	303.0000	318.0000	201.0000	123.0000	126.0000	53.8000	28.7000	107.0000
03418900	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
03420000	261.8999	398.2998	466.2998	440.2000	319.3999	278.7998	221.2000	120.5000	172.5000	87.0800
03420500	61.2700	197.0000	345.0000	321.8999	168.2000	110.8000	90.3400	49.7100	38.8900	56.8700
03421000	819.7998	1223.0000	1450.0000	1462.0000	1210.0000	872.0999	612.7998	735.2998	300.2998	251.5000
03423000	45.7500	150.0000	213.3000	175.1000	97.2200	69.8200	80.0500	38.5600	32.2400	39.4000
03534000	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
03538200	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
03538225	152.0000	196.0000	164.0000	127.0000	221.0000	129.0000	143.0000	72.9000	247.0000	79.9000
03538300	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
03538500	77.6000	206.0000	239.0000	226.0000	113.0000	89.4000	83.6000	45.3000	94.9000	42.8000
03538600	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
03538600	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
03538900	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
03539100	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
03539500	173.0000	206.0000	240.0000	257.0000	135.0000	113.0000	93.4000	48.4000	50.2000	62.9000
03539600	383.3999	287.3999	200.5000	222.4000	263.0000	267.8999	158.0000	133.5000	174.2000	40.5600
03539800	1087.0000	971.0000	1228.0000	927.0000	1255.0000	950.0000	838.0000	425.0000	746.0000	130.0000
03540500	1270.0000	1562.0000	1833.0000	1845.0000	1454.0000	999.7998	782.2998	946.2000	714.0000	376.0999
03541100	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
03541200	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
03541500	192.0000	266.0000	321.0000	291.0000	161.0000	133.0000	113.0000	56.8000	94.1000	65.2000
03544500	134.0000	106.0000	141.0000	113.0000	94.5000	68.4000	96.6000	67.8000	56.1000	28.8000
03570800	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
03571000	654.2998	736.0000	823.0999	818.2000	740.7000	513.0000	397.2998	371.7000	217.4000	172.9000
03571600	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
03571800	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
03578000	141.2000	109.7000	122.0000	144.7000	146.4000	110.5000	97.0400	45.4600	35.4900	29.1800
03578500	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
03579900	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
03596000	110.9000	175.4000	323.7998	274.5000	195.5000	149.0000	84.0000	56.9400	42.0100	36.7700

Table 7.--Basin characteristics and streamflow characteristics for 41 gaging stations in the Cumberland Plateau area of Tennessee--Continued

SAMPLE	SDQ9	M3,20	M7,2	M7,10	M7,20	V3,2	V3,10	V3,50	V7,2	V7,10
03408500	185.0000	0.1810	4.9100	0.4660	0.2140	9601.1992	16740.8984	24184.6992	5826.0977	9121.5000
03409000	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
03409500	147.8000	0.7950	4.9600	1.4510	0.9980	6280.3984	10679.2969	14395.0977	3848.5999	6072.1992
03410500	388.0000	15.2310	47.5790	20.9350	16.6210	21925.6992	38245.7969	53200.3984	13390.5977	21212.0000
03414500	102.7000	3.9940	9.9240	5.0430	4.2100	5280.0977	9409.7969	14019.8984	3128.2000	5190.1992
03415000	36.3300	2.7420	4.4780	3.0830	2.8880	2285.7000	3653.5000	4741.7969	1337.2000	2115.2998
03415500	282.8999	10.3000	23.6000	13.7000	11.8000	8215.7969	13523.3984	17273.0000	5216.8984	8376.1992
03415700	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
03416000	30.6700	3.6100	8.8000	5.2390	4.5750	2413.0000	5007.2969	7777.5977	1428.7998	2726.3999
03418000	31.9100	3.3000	6.7000	3.9000	3.4000	1373.0999	2535.2998	3455.0999	840.2000	1479.2998
03418500	49.5000	0.0	0.4300	0.0500	0.0200	2438.0999	4162.1992	5897.0977	1635.0999	2394.0999
03418900	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
03420000	103.6000	14.2000	26.6000	17.2000	15.4000	4181.0000	7064.7969	9616.2969	2677.0999	4341.1992
03420500	54.8700	34.4000	45.7000	37.1000	34.8000	2808.3999	5182.8984	7313.8984	1716.0000	2972.2998
03421000	215.3000	49.9280	92.0550	63.7240	57.5520	13686.5000	25650.7969	37105.0000	8668.5000	14870.2969
03423000	54.8500	2.1000	4.7000	2.6000	2.3000	1639.2000	2501.5999	3022.2998	999.0999	1562.0999
03534000	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
03538200	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
03538225	31.5000	4.8980	8.4650	5.6070	5.2050	2258.8999	4176.8984	6157.0977	1388.7000	2374.2000
03538300	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
03538500	66.4000	0.0	0.2600	0.0	0.0	2163.0000	3746.7998	5082.2969	1331.2000	2117.0000
03538600	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
03538800	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
03538900	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
03539100	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
03539500	46.7000	0.0100	0.3600	0.2900	0.0100	2169.5999	3872.2000	5379.7969	1392.5999	2270.5999
03539600	62.3900	0.3000	1.8000	0.5000	0.3000	3051.7998	4669.0977	6487.5000	2003.2000	3201.5000
03539800	250.0000	0.6500	8.0000	1.3000	0.7500	12325.6992	20905.6992	30271.5977	8012.0000	12190.5000
03540500	389.7998	0.0	7.1000	0.6000	0.2000	18305.0977	34006.1992	49953.2969	11676.1992	18941.2969
03541100	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
03541200	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
03541500	103.0000	0.0700	0.4800	0.1200	0.0800	2999.7000	5002.0977	6628.8984	1817.0000	2784.0000
03544500	39.3000	0.0100	0.1600	0.0300	0.0100	1308.2000	2146.0000	2801.0000	798.7998	1242.2998
03570800	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
03571000	198.4000	26.7390	52.6320	32.1470	28.1870	7699.0977	12859.1992	17124.3984	5162.5000	8260.0000
03571600	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
03571800	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
03578000	18.9700	1.0750	3.3250	1.4370	1.1360	1883.5999	3081.8999	4155.0977	1090.0000	1750.2998
03578500	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
03579900	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
03596000	29.3400	10.6380	19.0560	12.6580	11.2120	2640.0000	4960.0000	7180.0000	1540.0000	2720.0000

Table 7.--Basin characteristics and streamflow characteristics for 41 gaging stations in the Cumberland Plateau area of Tennessee--Continued

SAMPLE	V7,50	P500	WRC SKEW	WRC MEAN	WRC SD
03408500	12019.7969	83900.0000	0.1130	4.4030	0.1730
03409000	0.0 B	7070.0000	0.0500	3.2880	0.1910
03409500	7806.0000	57300.0000	0.0290	4.1320	0.2150
03410500	27588.0000	134000.0000	0.0140	4.6580	0.1620
03414500	7254.5000	63400.0000	-0.0030	4.2270	0.2000
03415000	2748.7998	23600.0000	-0.0590	3.8430	0.1890
03415500	10827.7969	81700.0000	0.0	4.2030	0.2470
03415700	0.0 B	3420.0000	0.0	2.8530	0.2370
03416000	4062.5000	43400.0000	-0.1160	3.8940	0.2720
03418000	2032.7000	16700.0000	-0.0870	3.5170	0.2550
03418500	2945.5000	23100.0000	0.0	3.7930	0.1990
03418900	0.0 B	875.0000	0.0	2.2800	0.2300
03420000	5784.5977	26100.0000	0.0850	3.8870	0.1780
03420500	3939.8999	51200.0000	-0.2400	3.9700	0.2860
03421000	20034.8984	94900.0000	-0.1970	4.3720	0.2290
03423000	1923.5000	8820.0000	-0.3960	3.5210	0.1770
03534000	0.0 B	11900.0000	0.0680	3.4590	0.2080
03538200	0.0 B	16200.0000	0.2530	3.5480	0.2080
03538225	3274.2000	18700.0000	0.0500	3.6610	0.2080
03538300	0.0 B	2400.0000	0.0500	2.8740	0.1730
03538500	2715.3999	38900.0000	0.3380	3.8630	0.2210
03538600	0.0 B	2030.0000	0.0500	2.8240	0.1650
03538800	0.0 B	823.0000	0.0500	2.0840	0.2830
03538900	0.0 B	1887.0000	-0.0400	0.2600	2.5400
03539100	0.0 B	702.0000	0.1500	2.0200	0.2700
03539500	2924.7998	27600.0000	0.0420	3.6870	0.2570
03539600	4515.7969	16300.0000	0.0500	3.8850	0.1110
03539800	15618.8984	137000.0000	0.0500	4.5420	0.2030
03540500	24641.0000	230000.0000	0.0290	4.6690	0.2380
03541100	0.0 B	7452.0000	0.0500	3.0200	0.2900
03541200	0.0 B	2140.0000	0.2000	2.5500	0.2500
03541500	3445.7000	93700.0000	0.1830	4.0670	0.2920
03544500	1574.2000	24800.0000	-0.0810	3.6400	0.2710
03570800	0.0 B	4730.0000	0.0	3.2850	0.1360
03571000	10668.0000	41200.0000	-0.0890	4.0540	0.2030
03571600	0.0 B	331.0000	0.0	2.0090	0.1770
03571800	0.0 B	11000.0000	0.0	3.5580	0.1690
03578000	2345.0999	16200.0000	0.0	3.6230	0.2040
03578500	0.0 B	11300.0000	0.0	3.3960	0.2290
03579900	0.0 B	7250.0000	0.0	3.3170	0.1890
03596000	3790.0000	90300.0000	0.2380	3.8870	0.3370