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Continuous Hydrologic Simulation of Runoff for the Middle Fork and South Fork of the Beargrass Creek Basin in Jefferson County, Kentucky

Water-Resources Investigations Report 98–4182

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By G. Lynn Jarrett, University of Louisville, Aimee C. Downs, U.S. Geological Survey, and Patricia A. Grace–Jarrett, Louisville and Jefferson County Metropolitan Sewer District

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Louisville, Kentucky
1998

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
	Length	
inch (in.)	2.540	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square foot (ft^2)	0.09290	square meter
square mile (mi^2)	2.590	square kilometer

DEM	Digital elevation model
GIS	Geographic information system
HRU's	Hydrologic response units
HSPEXP	Hydrological Simulation Program—FORTRAN Expert System
HSPF	Hydrological Simulation Program—FORTRAN
IMPLND	Impervious land cover
INFILT	Infiltration capacity
LOJIC	Louisville and Jefferson County Information Consortium
LZETP	Lower-zone evapotranspiration parameter
LZSN	Lower-zone nominal storage capacity
MSD	Louisville and Jefferson County Metropolitan Sewer District
NWS	National Weather Service
PERLND	Pervious land cover
SWM	Stanford Watershed Model
UCI	User-control input
USGS	U.S. Geological Survey

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By G. Lynn Jarrett, Aimee C. Downs, *and* Patricia A. Grace–Jarrett

Abstract

The Hydrological Simulation Program—FORTRAN (HSPF) was applied to an urban drainage basin in Jefferson County, Ky. to integrate the large amounts of information being collected on water quantity and quality into an analytical framework that could be used as a management and planning tool. Hydrologic response units were developed using geographic data and a K-means analysis to characterize important hydrologic and physical factors in the basin. The Hydrological Simulation Program—FORTRAN Expert System (HSPEXP) was used to calibrate the model parameters for the Middle Fork Beargrass Creek Basin for 3 years (June 1, 1991, to May 31, 1994) of 5-minute streamflow and precipitation time series, and 3 years of hourly pan-evaporation time series. The calibrated model parameters were applied to the South Fork Beargrass Creek Basin for confirmation. The model confirmation results indicated that the model simulated the system within acceptable tolerances. The coefficient of determination and coefficient of model-fit efficiency between simulated and observed daily flows were 0.91 and 0.82, respectively, for model calibration and 0.88 and 0.77, respectively, for model confirmation. The model is most sensitive to estimates of the area of effective impervious land in the basin; the spatial distribution of rainfall; and the lower-zone evapotranspiration, lower-zone nominal storage, and infiltration-capacity parameters during recession and low-flow periods. The error contribution from these sources varies with season and antecedent conditions.

INTRODUCTION

Urban streams have often been a neglected ecological and cultural resource in an otherwise densely populated landscape. The quality of urban-stream systems is an integral part of the activities in the surrounding watershed and airshed. Changes in water quantity, quality, and fluvial geomorphology are influenced by the original nature of the watershed and the type and intensity of basin activities. Consequently, management of a stream system such that economic, aesthetic, and ecologic goals are achieved requires that the potential for changes to a stream be considered when changes in land-use activities are being planned (Delleur and others, 1976).

The Louisville and Jefferson County Metropolitan Sewer District (MSD) is responsible for managing the streams and drainage basins in and around Louisville, Ky. The MSD has a long history of collecting water-quantity data associated with flood studies and urban development. In 1988, the MSD, in cooperation with the U.S. Geological Survey (USGS), began systematically collecting water-quality data from Jefferson County streams. Systematic evaluation of this expanding data base has been hampered, however, by the lack of a formal conceptual framework and appropriate computer model.

In 1994, the MSD decided to evaluate the utility of using a comprehensive river-basin model to interpret the data and provide guidance on future data-collection efforts. The model also is expected to provide a means of evaluating the water-quality and -quantity consequences of alternative management decisions. The primary objective of the study reported here was to develop a more refined and accurate representation of basin hydrology and water quality by efficiently integrating the large amounts of available information into a model. The second objective required that the model adequately represent the important hydrologic processes.

This report describes the effectiveness of the Hydrological Simulation Program—FORTRAN (HSPF) model in simulating a 3-year hydrologic record for the period June 1, 1991, to May 31, 1994, in the South Fork and Middle Fork Subbasins of Beargrass Creek in Jefferson County, Ky. Although simulations were made for a model of the Muddy Fork Subbasin, those results are not reported here because of a lack of observed record for both the calibration and confirmation periods.

Background

The HSPF version 10.0 (Bicknell and others, 1993) was selected as the most appropriate basin model. The HSPF is capable of continuous simulation of river-basin hydrology and water quality for conventional and toxic organic pollutants. The model is classified as a physically based conceptual model (Wurbs, 1995) that is capable of simulating important hydrologic and water-quality processes. The HSPF model has extensive input data requirements. It is, however, within the model's capacity to manipulate large amounts of hydrologic data.

The HSPF is a collection of FORTRAN source-coded modules that represent water-quantity and -quality processes dependent on a time-series management system. Model parameters are used to adapt the source codes to a wide range of river-basin conditions. The output parameters in the model correlate to physically based properties or process-oriented conditions (Donigian and others, 1984).

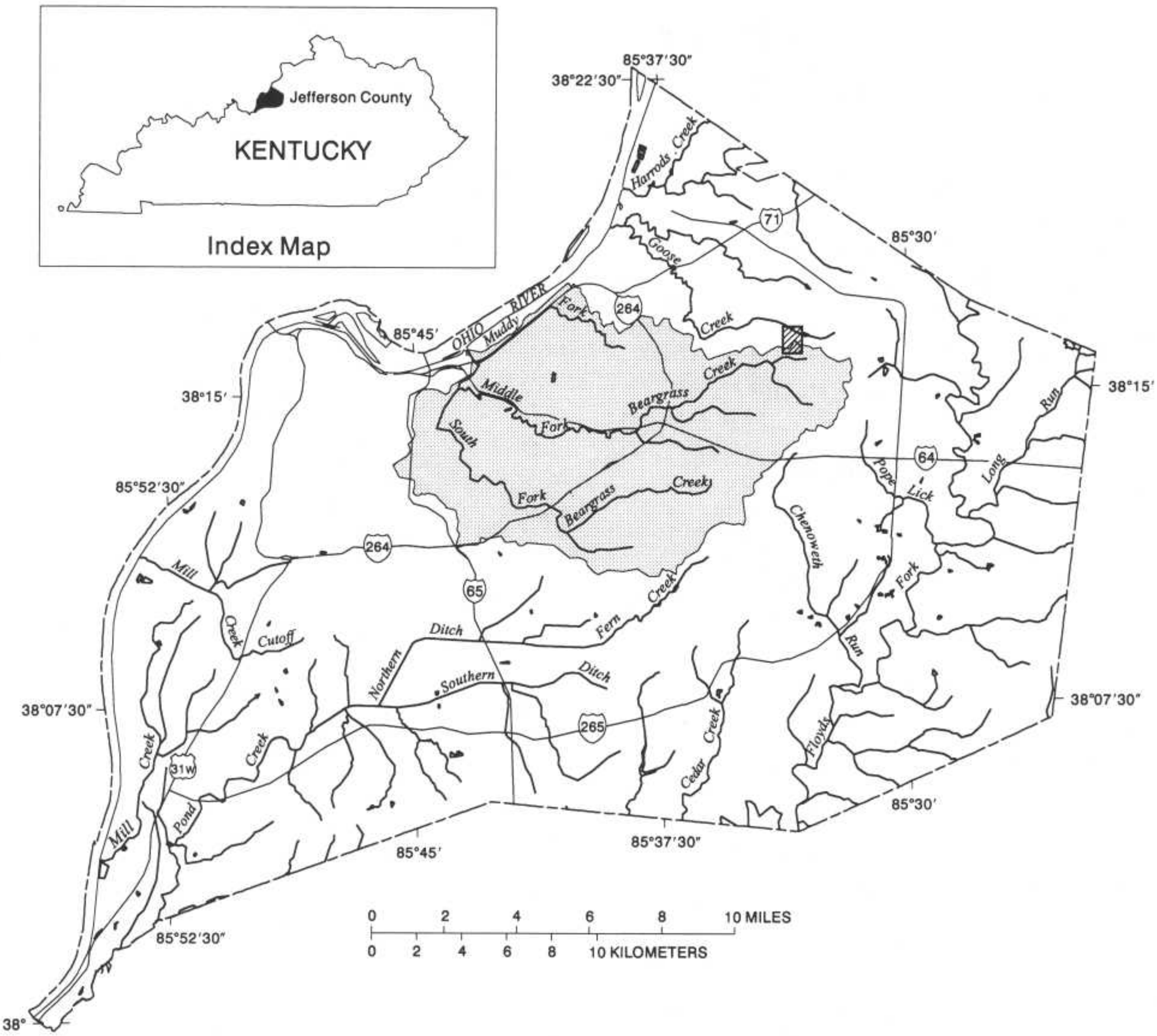
Previous Work

The HSPF model has been widely applied to evaluate agricultural runoff (Moore and others, 1988; Chew and others, 1991; Laroche and others, 1996) and for planning purposes in urban and suburban environments (Ng and Marsalek, 1989; Dinicola, 1989; Duncker and others, 1995). The model also has been used to characterize the effects of changing land uses on channel expansion and channel incision (Booth, 1990). Fontaine (1995) reported that the HSPF model was more accurate than the traditional event-based model (HEC-1) in predicting extreme floods in the upper Midwest. The hydrologic component of the HSPF is based on the Stanford Watershed Model (SWM) (Crawford and Linsley, 1966). One of the early applications of this model (Crawford and Linsley, 1966) was in the Beargrass Creek Basin in Louisville, Ky. Crawford and Linsley's simulations were for the period from 1950 to 1953, prior to extensive urban development in the basin.

Description of Study Area

The Beargrass Creek Basin borders the Ohio River in Jefferson County in north-central Kentucky (fig. 1). The county is the most densely populated area of the State. Streams in the Beargrass Creek Basin drain 61.0 mi^2 of eastern Jefferson County, Ky. The drainage comprises three tributary subbasins: the South Fork, the Middle Fork, and the Muddy Fork. Subbasin sizes for the South Fork, Middle Fork, and Muddy Fork are 27.0 mi^2, 25.1 mi^2, and 8.9 mi^2, respectively (fig. 2). The HSPF model was developed to simulate the entire Middle Fork Basin and 22.04 mi^2 (81.6 percent) of the South Fork Basin to downstream point indicated as number 1 (approximately Logan Street) as shown in figure 2. The HSPF user-control input (UCI) files (included in the appendixes to this report) describe the model for the full part of the simulated basin; however, subareas and reaches downstream from the streamflow gages were deactivated in the model code, and use of these UCI files would yield discharge and average depth at the streamflow-gage locations. Instructions are given in the UCI file for simulation of the full basins. The drainage areas up to the streamflow gages are 18.9 and 17.2 mi^2 for the Middle Fork and South Fork, respectively.

Jefferson County has a moist-continental climate with moderately cold winters and hot, humid summers. Average annual precipitation is approximately 43 in., mostly as rainfall. Average annual snowfall is slightly less than 17 in. and may occur between November and April. Historical rainfall records indicate that March is the wettest month of the year, and October is the driest. Frontal systems moving from the southwest provide the precipitation during most of the year, but, in



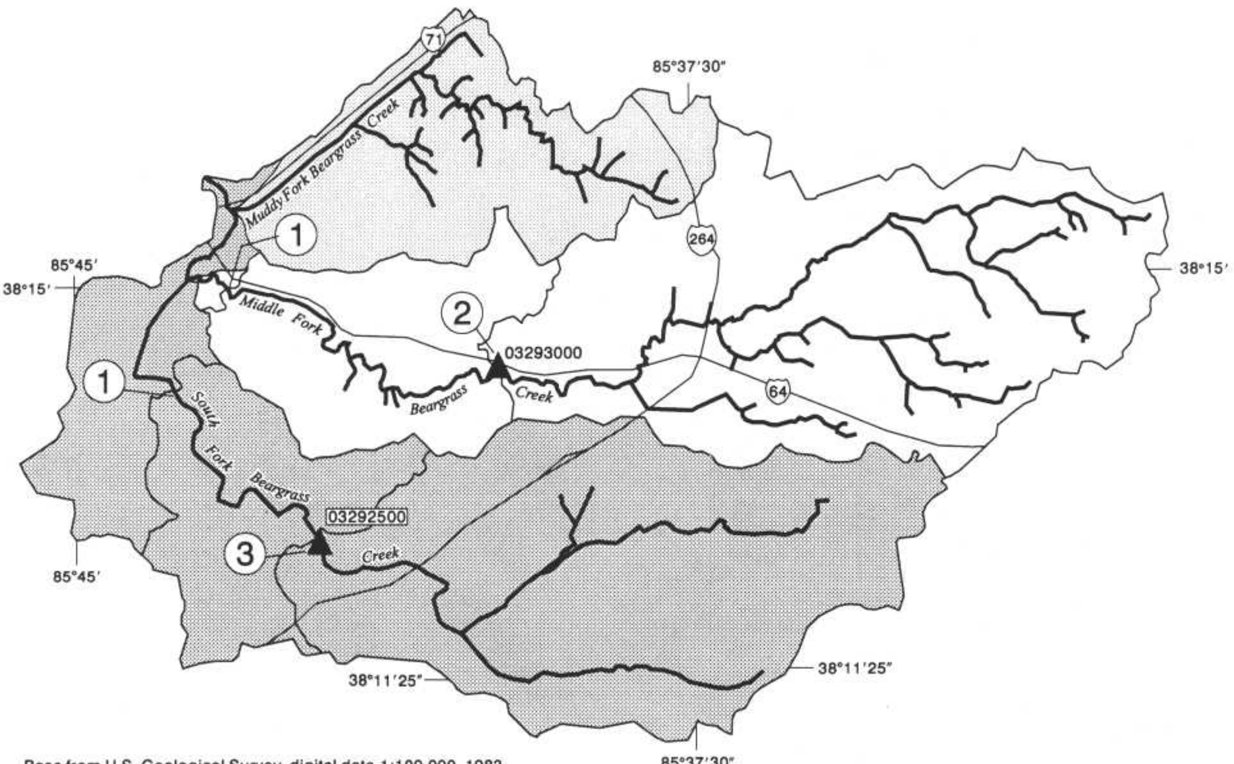
Base from U.S. Geological Survey, digital data, 1:100,000, 1983
Universal Transverse Mercator projection
Zone 16

EXPLANATION

BEARGRASS CREEK BASIN

MIDDLE FORK DIVERSION TO GOOSE CREEK

Figure 1. Location of Beargrass Creek Basin in Jefferson County, Kentucky.



Base from U.S. Geological Survey, digital data, 1:100,000, 1983
Universal Transverse Mercator projection
Zone 16

0 3 6 MILES
0 3 6 KILOMETERS

EXPLANATION

MUDDY FORK BASIN

MIDDLE FORK BASIN

SOUTH FORK BASIN

▲03292500 U.S. GEOLOGICAL SURVEY SURFACE-WATER GAGING STATION

(1) DOWNSTREAM POINT AT WHICH THE MODEL WAS SIMULATED

(2) DOWNSTREAM POINT AT WHICH THE MODEL WAS CALIBRATED

(3) DOWNSTREAM POINT AT WHICH THE MODEL WAS CONFIRMED

Figure 2. Location of Muddy Fork, Middle Fork, and South Fork Subbasins of the Beargrass Creek Basin, Jefferson County, Kentucky; two surface-water gaging stations; and points at which the Hydrological Simulation Program-FORTRAN (HSPF) model was simulated, calibrated, and confirmed.

late summer, convective storms may produce locally heavy rainfall. Evaluation of a local 45-year-long hourly rainfall record indicated that approximately 70 storms occur each year. These storms are defined as 0.1 in. of precipitation with at least 0.01 in. occurring within each hour of the storm's duration.

The headwaters of Beargrass Creek drain Silurian age dolomite, shale, and minor amounts of limestone. The creek cuts into Devonian age limestone and shale before flowing into the Ohio River. A more detailed description of the basins can be found in Evaldi and Moore (1992). Land use in the basins varies from single-family residential to light industrial. The dominant land use in all three subbasins is single-family residential, followed by paved (impervious) surfaces (roads and parking lots), parks, and cemeteries (table 1). The land-use percentages given in table 1 are for the entire basin, which is different from the simulated basin for the South Fork and subbasins used for calibration and confirmation for the Middle Fork and South Fork, respectively. Most of the basin is sewered with separate sanitary and storm sewers. Combined sewers are present in the lower part of each basin. The combined systems periodically overflow to surface waters. Part of the flow in the Middle Fork is diverted to Goose Creek (fig. 1) during high-flow conditions south of Anchorage, Ky., near Whipps Mill Road, east of Hurstbourne Lane.

Table 1. Distribution of land uses in the South and Middle Forks of the Beargrass Creek Basin in Jefferson County, Kentucky

Type of land use	South Fork (percent)	Middle Fork (percent)
Single-family residence	46.7	43.8
Multiple-family residence	4.7	5.8
Commercial	7.6	8.7
Industrial	4.1	1.0
Churches, schools, and other non-commercial facilities	5.8	6.1
Parks, cemeteries, and other public open space	9.8	11.2
Vacant or undeveloped	6.2	9.8
Roads and other paved areas	15.1	13.6

STUDY METHODS

Two long-term stream-discharge-measuring sites are located in the Middle Fork and South Fork Basins of Beargrass Creek (fig. 2). Continuous discharge data collected and computed at these sites were used to calibrate and confirm the HSPF model. In addition, precipitation and pan-evaporation data were compiled. A wide variety of Geographic Information System (GIS) data layers were developed and analyzed to delineate the Hydrologic Response Units (HRU's), which were critical to the basic analysis of the hydrologic system.

Collection of Meteorological Data

Meteorological data were compiled from the USGS/MSD precipitation network and the National Weather Service (NWS). The seven rain gages in the basin that were used to simulate runoff from the Middle Fork and South Fork are described in table 2. Five other rain gages operated by the USGS, in cooperation with the MSD, are outside the basin but within 5 mi of the center of the basin. The locations of the seven rain gages also are shown in figure 3. Precipitation data were available at 5-minute intervals for the calibration period of midnight June 1, 1991, to midnight May 31, 1994. Daily pan-evaporation data were obtained from the NWS for a station located at Nolin River Lake, Ky., approximately 75 mi south of Louisville, Ky. Missing data were filled in with data collected at Patoka Lake, Ind., approximately 80 mi northwest of Louisville.

Development of Geographic Information System (GIS) Data Base

The hydrologic properties of the contributing areas were quantified using ARC/INFO GRID (Environmental Systems Research Institute, Inc., 1992), a raster-based tool for correlating and overlaying multiple GIS data bases. Data layers, obtained from the Louisville and Jefferson County Information Consortium (LOJIC), included land use, hydrography (streams, lakes, and holding ponds), soils (Zimmerman and others, 1966), pavement (roads, sidewalks, and recreational areas), tree cover, catchment basins, buildings, and elevation data. The data were digitized at a resolution of 1:100 from low-altitude aerial photography.

Table 2. Station number, name, and location of the precipitation gages used in the simulation of runoff from the Middle Fork and South Fork Beargrass Creek Basins in Jefferson County, Kentucky

[RG, rain gage; SF, South Fork Beargrass Creek Basin; MF, Middle Fork Beargrass Creek Basin]

Rain gage number	Name	Latitude[1]	Longitude[1]	Basin in which raingage data were used
RG6	Seneca Golf Course along Bon Air Avenue	381353	854018	SF, MF
RG8	McMahan Fire Station at Taylorsville Road	381306	853636	SF, MF
RG11	East County Government Center	381457	853154	MF
RG19	South Fork Beargrass Creek at Trevilian Way	381239	854207	SF, MF
RG22	South Fork Beargrass Creek at Bardstown Road	381200	853946	SF
RG24	South Fork Beargrass Creek Tributary at Bardstown Road	381112	853935	SF
RG27	Middle Fork Beargrass Creek at Shelbyville Road	381456	853616	MF

[1]Degree, minute, and second symbols omitted.

The foundation layer for the analysis was a digital elevation model (DEM) that was generated from the elevation data using the grid-based elevation model, TOPOGRID (Hutchinson and Dowling, 1991). TOPOGRID is unique in that it creates a hydrologically correct elevation surface that takes into consideration known locations of hydrologic features rather than interpolating their location from the contour coverage alone. All data layers, except for catchment basins, swimming pools, parking lots, and tree cover, were converted from vector to raster data. The cell sizes for all the raster data layers were 65.6 by 65.6 ft, an area of 4,305 ft^2.

Raster coverages defining the characteristics of the (1) stream reach, (2) rain gage Thiessen polygon, (3) riparian zone, (4) land use, and (5) land slope were aggregated into one coverage (hereafter referred to as the composite-coverage) that represented the unique combinations of these five characteristics. The composite-coverage yielded 390 unique polygons for the Middle Fork and 318 unique polygons for the South Fork. Some polygons contained identical values known as zones. In GRID calculations, zones do not need to be contiguous. ARC/INFO's statistical capabilities were used to compute area per stream reach; area of each of the composite-coverage zones; and percent of hydrology, soils, pavement, and buildings for each of the composite-coverage zones. Other source data were represented as points instead of polygons, such as stormwater catchment basins and swimming pools, or arcs, such as tree cover and parking lots. Because these point features have no area, frequency was used to estimate density per composite-coverage zone. Arc length was used for arc features to estimate area per composite-cover zone.

Delineation of Hydrologic Response Units (HRU's)

Many factors affect how precipitation is converted into streamflow within a drainage basin. The spatial variability of these factors can be incorporated into the HSPF by subdividing the drainage basin into small subunits, which may then be characterized by a system of Hydrologic Response Units (HRU's). Each of the HRU's are simulated with unique parameter configurations. Initially, four HRU's—three pervious and one impervious—were developed from the GIS data bases for the Middle Fork Basin. These units were hypothesized to convert precipitation to streamflow in different ways and at different rates. Dinicola (1989) attributed physical significance to the parameter sets developed in a regional calibration of the HSPF in the northwestern part of the State of Washington. After developing hypotheses regarding the distinct hydrologic responses occurring in the modeled watersheds, parameter sets were developed to test those hypotheses.

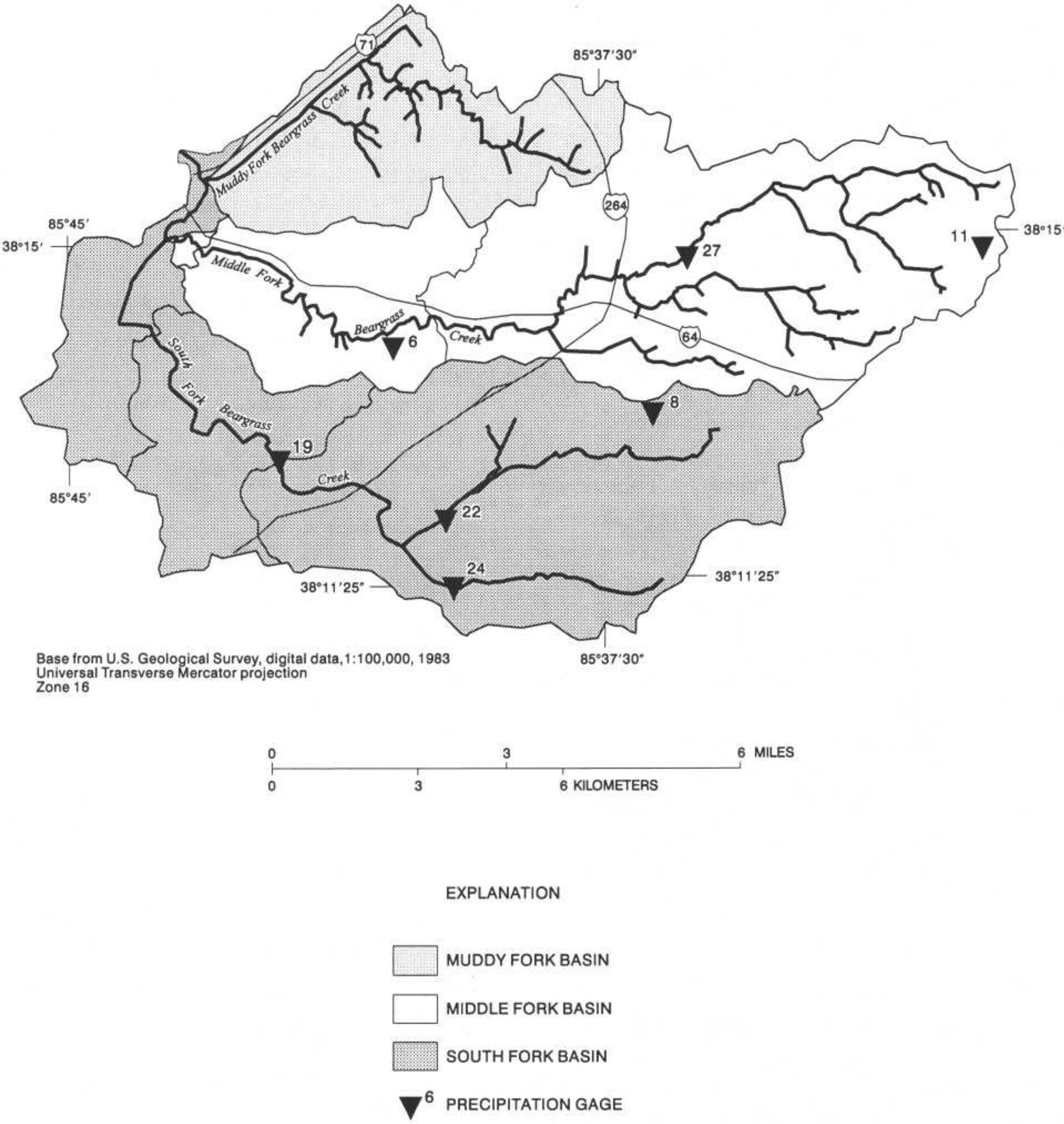


Figure 3. Location of precipitation gages used for runoff simulation in the Middle Fork and South Fork Subbasins of the Beargrass Creek Basin, Jefferson County, Kentucky.

Similar to Dinicola's (1989) method, the HRU's for this study were developed around physically based concepts; however, the parameter sets were developed from empirical and spatial data.

A K-means cluster analysis was used to aggregate four basic groups of data based on the hydrologically relevant information associated with each of the polygons. The K-means technique is a nonhierarchical grouping procedure that is used to associate multidimensional data. Details on and examples of the K-means technique are given in Hartigan (1975); Wilkinson and Hill (1994); Hair and others (1987); and Haag and others (1995). The classification variables used to group the pervious land components of the polygons were as follows: (1) X_{infilt} = soil permeability (inches per hour), (2) X_{lzs} = soil-storage capacity (inches of water per inch of soil times the depth in inches to the seasonally high water table), and (3) X_{tree} = area of tree canopy (square feet). The correlation of these variables produced three distinct clusters for pervious areas that form the basis of the HRU's. The clusters (HRU's) are a lawn cluster, a wooded cluster, and a riparian cluster. The riparian cluster (HRU) was primarily characterized by its close proximity to streams. A fourth cluster was identified as impervious but is not shown in figure 4. The impervious cluster (and IMPLND's in HSPF) are characterized as completely impervious surfaces such as roads and parking lots. Each of the classification variables contributed significantly at the 5-percent level to differentiating the clusters as determined by an analysis of variance applying the F-test. Notched box plots illustrate the separation of the pervious clusters as a function of the classification variables (fig. 4).

The three pervious clusters of polygons became the basis for each of the three pervious (PERLND) HRU's used as input to the Middle Fork model. The three pervious units were further subdivided into one of three slope classes: (1) 0 to 5 percent, (2) greater than 5 percent to 12 percent, and (3) greater than 12 percent.

Impervious (IMPLND) areas were clustered in an attempt to define another group of HRU's, but this attempt was not successful. Information on slope, the density of catch basins leading to storm sewers, and the type of imperviousness did not produce unique clusters; subsequently, only one IMPLND surface unit was identified with input parameters developed for each of the three previously mentioned slope classes.

The HRU's in the South Fork Basin were generated on the basis of a linear discriminant-function equation developed for the Middle Fork Basin. Surrogate information on soil permeability, soil storage capacity, and area of tree canopy were used to identify the HRU's. As previously stated, 318 polygons were delineated in the South Fork Basin after aggregating the multiple GIS data coverages. The classification variables of soil permeability, soil storage capacity, and area of tree canopy were assigned to each polygon in the South Fork Basin. An equation was developed on the basis of the results of cluster analysis for the Middle Fork Basin to predict what HRU a particular polygon would be assigned based on the three previously mentioned variables.

The 318 polygons in the South Fork Basin were assigned to either one of the three PERLND or the one IMPLND HRU on the basis of the following equation:

$$HRU = b_0 + b_1 X_{infilt} + b_2 X_{lzs} + b_3 X_{tree}, \qquad (1)$$

where

HRU	is assigned a value of 1, 2, or 3 for each of the 318 polygons in the basin,
X_{infilt}	is soil permeability (inches per hour),
X_{lzs}	is soil storage capacity (inches),
X_{tree}	is area of tree canopy (square feet), and
b_0, b_1, b_2, and b_3	are weighing coefficients (table 3).

For the three pervious Hydrologic Response Units (HRU's)—Lawn, Riparian, and Wooded—the following equations apply:

$$Lawn = (-4.715) + 1.468 X_{infilt} + 2.083 X_{lzs} + 0.003 X_{tree}, \qquad (2)$$

$$Riparian = (-56.099) + 1.450 X_{infilt} + 8.361 X_{lzs} + (-0.002) X_{tree}, \quad \text{and} \qquad (3)$$

$$Wooded = (-19.004) + 1.296 X_{infilt} + 4.749 X_{lzs} + 0.001 X_{tree}. \qquad (4)$$

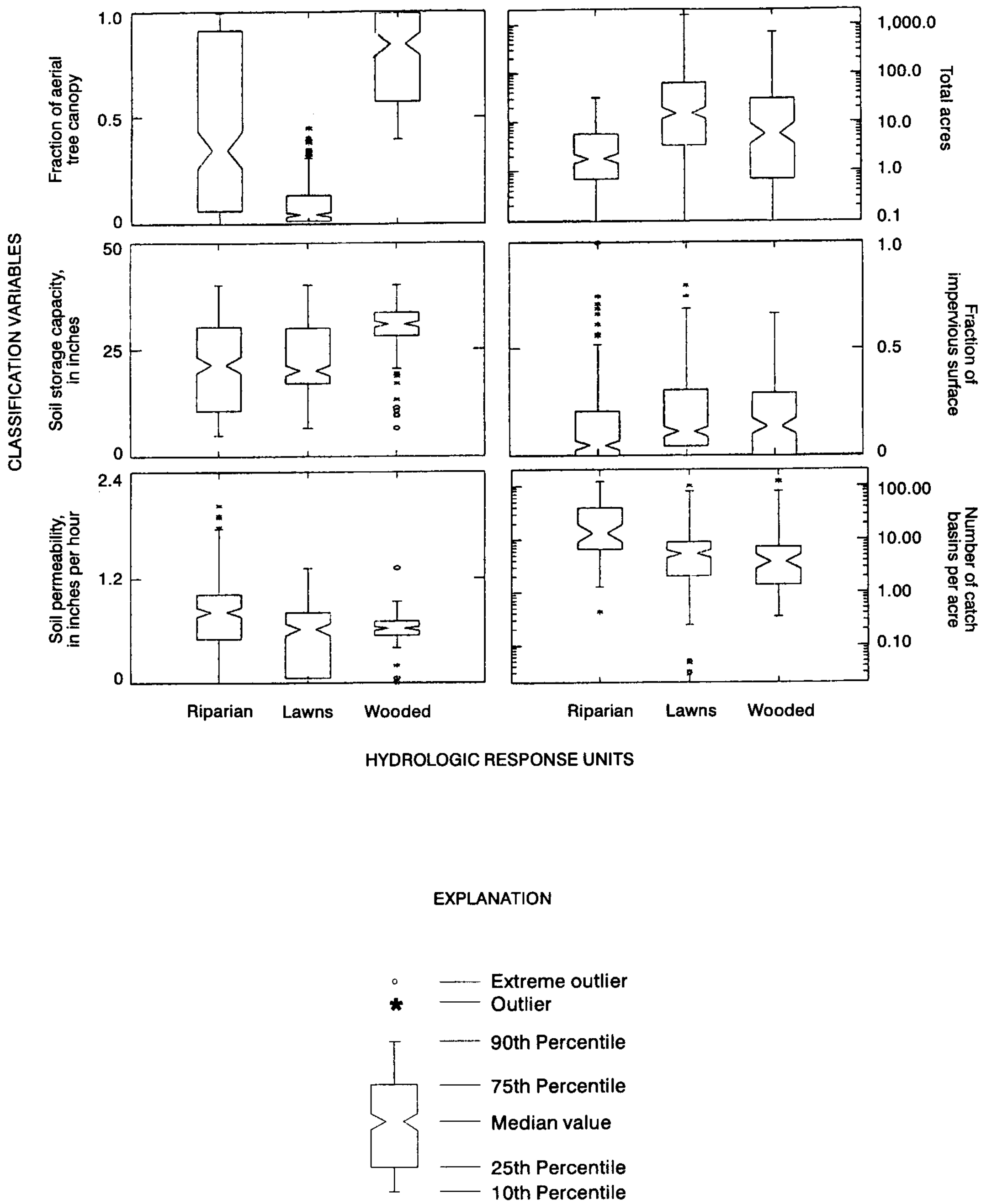


Figure 4. Classification of land-use data into three distinct pervious Hydrolologic Response Units for the Middle Fork Beargrass Creek Basin in Jefferson County, Kentucky. (Impervious Hydrologic Response Unit not shown)

Table 3. Weighing coefficient values for estimating hydrologic response units (HRU's) in the South Fork Beargrass Creek Basin in Jefferson County, Kentucky

[infilt, soil permeability in inches per hour; lzs, soil storage capacity in inches; tree, area of tree canopy in square feet]

Coefficient	Lawn	Riparian	Wooded
b_0	-4.715	-56.099	-19.004
b_1 for infilt	1.468	1.450	1.296
b_2 for lzs	2.083	8.361	4.749
b_3 for tree	.003	-.002	.001

The authors acknowledge that this procedure for establishing the HRU's in the South Fork Basin may be a potential source of error in the confirmation of the model; however, in the event that sufficient GIS coverages are not available, this is considered an acceptable technique. This conclusion is supported by the generally good confirmation results obtained for the South Fork Beargrass Creek that are described later. The distribution of land cover in terms of the various PERLND's and IMPLND's in the Middle Fork and South Fork Basins are listed in tables 4 and 5, respectively.

HYDROLOGIC SIMULATION

The HSPF model was initially setup and calibrated to data for the Middle Fork Basin of Beargrass Creek because of data availability. The model was confirmed by simulating runoff for the South Fork Basin. Although statistical results indicate that the model did not simulate the hydrologic system as well in the South Fork Basin as in the Middle Fork Basin, the confirmation results indicate the calibrated HSPF model is still applicable and transferable to other similar basins.

Table 4. Percentage of pervious (PERLND) and impervious (IMPLND) land cover in the Hydrological Simulation Program—FORTRAN (HSPF) model for the Middle Fork Beargrass Creek Basin in Jefferson County, Kentucky

[HRU, Hydrologic Response Unit; %, percent; ≤, less than or equal to; <, less than; >, greater than]

Land-cover type (HRU)	Low slope (≤5%)	Medium slope (5%<slope≤12%)	High slope (>12%)	Total
		Above streamflow gage		
Pervious				
Lawn	7.55	0.91	0.43	8.89
Riparian	30.73	5.76	.75	37.24
Wooded	31.86	.82	.33	33.01
Impervious	18.26	2.10	.50	20.86
		Total basin modeled		
Pervious				
Lawn	19.32	5.02	3.79	28.13
Riparian	22.64	4.24	.55	27.45
Wooded	23.47	.61	.24	24.32
Impervious	16.48	2.42	1.20	20.10

Table 5. Percentage of pervious (PERLND) and impervious (IMPLND) land cover in the Hydrological Simulation Program—FORTRAN (HSPF) model for the South Fork Beargrass Creek Basin in Jefferson County, Kentucky

[HRU, Hydrologic Response Unit; %, percent; ≤, less than or equal to; <, less than; >, greater than]

Land-cover type (HRU)	Low slope (≤5%)	Medium slope (5%<slope≤12%)	High slope (>12%)	Total
		Above streamflow gage		
Pervious				
Lawn	5.06	0.75	2.48	8.29
Riparian	24.55	.16	.0	24.71
Wooded	34.54	5.53	.06	40.13
Impervious	25.10	1.24	.53	26.87
		Total basin modeled		
Pervious				
Lawn	4.0	.82	4.97	9.79
Riparian	18.70	.12	.0	18.82
Wooded	36.32	7.75	.05	44.12
Impervious	23.95	2.22	1.10	27.27

Model Setup

Seventeen parameters are included in the HSPF source code for simulating the rainfall-runoff process for PERLND surfaces, and four parameters are included for IMPLND surfaces (table 6). The three most sensitive PERLND surface parameters for controlling the annual and monthly water balances in a basin are lower-zone evapotranspiration (LZETP), lower-zone nominal storage capacity (LZSN), and infiltration capacity (INFILT). The effect of INFILT on the annual and monthly water balances is indirect (Lumb and others, 1994). Initial estimates of these parameters were obtained using spatially distributed digital data coverages for trees and soils.

The LZETP parameter, an index value that ranges from 0.01 to 0.99, was calculated as the sum of the fractional area of tree cover within each grid cell for each polygon. This value was then allowed to vary monthly either as a function of the monthly potential evapotranspiration or pan evaporation.

The moisture-holding capacity (LZSN) for the soil was estimated by multiplying the available water capacity by the depth to the seasonally high water table. This produced an estimate of pore volume for each soil. An areal-weighted storage volume was computed for each polygon by the same methods used for infiltration.

The soil information was obtained from the Jefferson County Soil Survey (Zimmerman and others, 1966). INFILT was estimated for each polygon by computing an areally weighted mean permeability value by use of the following equation:

$$I = \frac{\sum_{i=1}^{n} (a_i P_i)}{\sum_{i=1}^{n} a_i} , \qquad (5)$$

where

- I is areal-weighted minimum infiltration value,
- a_i is area in acres for soil i,
- P_i is minimum permeability value for soil i, and
- n is the number of polygons in the basin.

Table 6. Hydrological Simulation Program—FORTRAN (HSPF) parameters used to simulate hydrology

Abbreviation	Explanation
LZETP	Lower-zone evapotranspiration. An index value (ranging from 0 to 0.99) representing the density of deep-rooted vegetation in PERLND's.
INFILT	Infiltration capacity. An index to the infiltration capacity of the soils. This parameter also affects percolation to the ground-water zone.
INFEXP	Exponent for the infiltration equation. Controls rate of infiltration decrease as a function of increasing soil moisture.
INFILD	Ratio of maximum to mean infiltration rate.
INTFW	Interflow index. An index that controls the amount of infiltrated water that flows as shallow subsurface runoff.
IRC	Interflow recession coefficient. An index for the rate of shallow subsurface flow.
CEPSC	Interception storage capacity of PERLND's.
RETSC	Retention storage capacity for IMPLND's.
LZSN	Lower-zone nominal storage. An index to the soil moisture holding capacity.
UZSN	Upper-zone nominal storage. An index to the amount of surface storage in depressions and the upper few inches of soil.
BASETP	Fraction of available potential-evapotranspiration demand that can be met from ground-water outflow. Simulates evapotranspiration from riparian vegetation.
AGWETP	Fraction of available potential-evapotranspiration demand that can be met from stored ground water. Simulates evapotranspiration from phreatophytes, in general.
AGWRC	Ground-water recession parameter. An index of the rate at which ground water drains from the land.
KVARY	Ground-water outflow modifier. An index of how much affect recent recharge has on ground-water outflow.
DEEPFR	Fraction of ground water that does not discharge to the surface within the boundaries of the modeled area.
LSUR	Average length of the overland flow plane (PERLND or IMPLND).
SLSUR	Average slope of the overland flow plane (PERLND or IMPLND).
NSUR	Average roughness of the overland flow plane (PERLND or IMPLND).

Values for parameters without physically measurable surrogates or for parameters that were not measured were initially estimated from literature values. A model-sensitivity analysis was done after the initial calibration. This analysis indicated what aspect of the hydrograph was affected by varying each of these parameters and the magnitude of the effects. On the basis of the results of the sensitivity analysis, the values of most of the parameters obtained from the literature were adjusted only slightly during the calibration process.

Model Calibration

The hydrologic model was calibrated by using the Hydrological Simulation Program—FORTRAN Expert System (HSPEXP) (Lumb and others, 1994), various statistical techniques, and visual techniques to relate simulated discharge to observed discharge (James and Burges, 1982). The model was calibrated using data for a 5-minute time step for a 3-year period.

The HSPEXP provides an alternative to numerical optimization (Liou, 1970; Shanholtz and Carr, 1975; Mein and Brown, 1978; Jacomino and Fields, 1997; Magette and others, 1976; Pierre, 1986) for refining parameter estimates. Numerical optimization tends to remove the modeler from the process of relating the model to the physical environment. In addition, multiple numerical solutions may be found for the same conditions. As a result, it is important that historical information about and the physical constraints of the hydrologic system be considered during model calibration. The HSPEXP source code provides a means to incorporate expert modeling experience with the HSPF system and knowledge of the prototype system into the calibration process.

The convergence criteria used in application of the HSPEXP to minimize error differences of selected runoff characteristics and the respective acceptable differences between simulated and observed characteristic values are presented in table 7. In the calculation of the storm statistics, 10 storms were identified as follows: March 5-9, 1992; March 17-21, 1992; May 2-5, 1992; May 29-June 3, 1992; June 15-20, 1992; July 26-31, 1992; August 5-10, 1992; September 15-20, 1992; August 1-6, 1993; and October 16-21, 1993. The acceptable differences applied in the calibration to runoff for the Middle Fork Beargrass Creek Basin are more stringent than the default values recommended by Lumb and others (1994); thus, the calibration obtained in this model is considered very good. The simulated and observed daily discharges for the Middle Fork Beargrass Creek Basin are shown in figures 5a-c.

Model Confirmation

The calibrated model parameters of the Middle Fork Basin were applied in the South Fork Basin of Beargrass Creek. The time period (June 1, 1991, to May 31, 1994) for calibration and confirmation were the same; however, the two basins had only three precipitation gages in common, and those gages had different areal weightings for each basin (table 2). The geometry and land uses also differed between basins (tables 4 and 5). The simulated and observed daily discharges for the South Fork Beargrass Creek Basin are shown in figures 6a-c. In the calculation of the storm statistics, 10 storms were identified as follows: March 5-14, 1992; March 17-27, 1992; May 2-13, 1992; May 28-June 5, 1992; June 17-25, 1992; July 26-August 5, 1992; August 7-15, 1992; September 17-24, 1992; August 1-7, 1993; and October 16-21, 1993. As indicated in table 8, figures 5a-c, and figures 6a-c, the confirmation simulation for the South Fork Basin cannot be considered as statistically accurate as the calibration simulation in the Middle Fork Basin.

Table 7. Minimized error in the difference of selected runoff characteristics during calibration of the Hydrological Simulation Program—FORTRAN (HSPF) to the Middle Fork Beargrass Creek at Louisville, Kentucky, from June 1, 1991, to May 31, 1994

Minimized error characteristic	Error difference between simulated and observed values (percent)	Target criteria applied in this study (percent)	Suggested default criteria[1]
Error in total volume	3.74	5.0	10.0
Error in low-flow recession	-.02	.030	.030
Error in the 50-percent lowest flows	-.74	5.0	10.0
Error in the 10-percent highest flows	-2.09	5.0	15.0
Error in storm volumes	-7.71	20.0	20.0
Seasonal volume error	7.23	20.0	30.0
Summer-storm volume error	-10.70	50.0	50.0

[1]Lumb and others (1994), p. 56, 58.

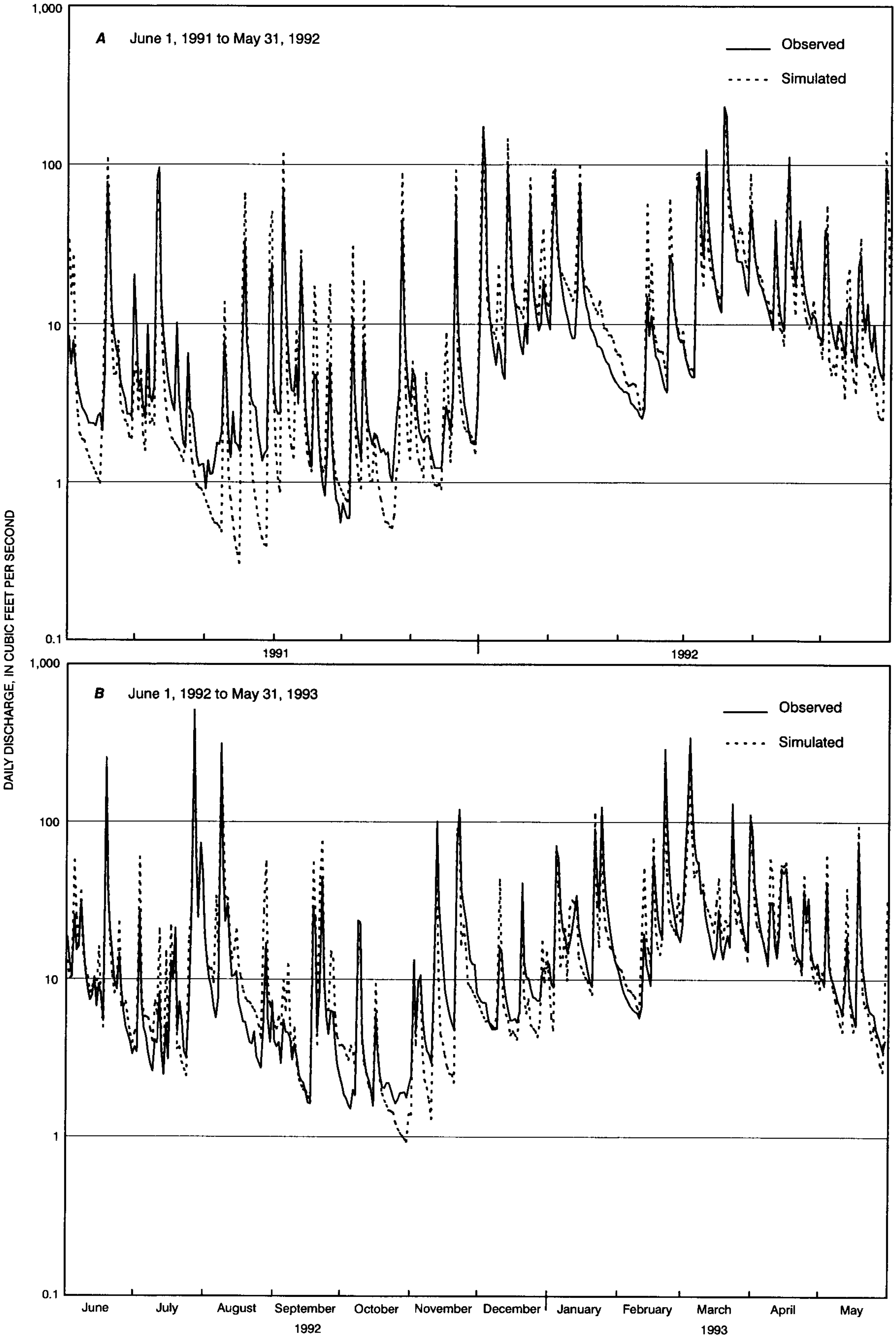


Figure 5. Observed and simulated (from model calibration) daily discharge for the Middle Fork Beargrass Creek at Louisville, Kentucky.

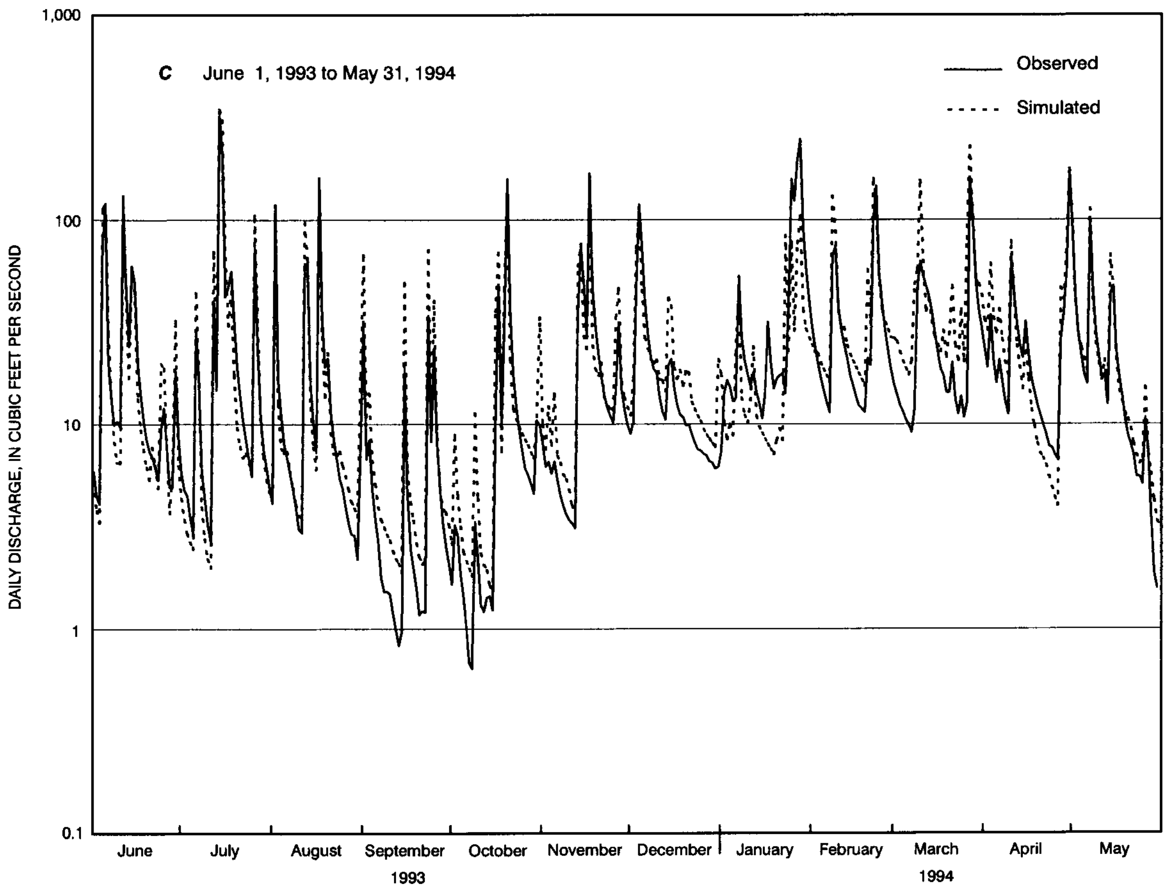


Figure 5. Observed and simulated (from model calibration) daily discharge for the Middle Fork Beargrass Creek at Louisville, Kentucky—Continued.

Simulation Results and Errors

Several model-fit statistics were calculated for the model calibration and confirmation (table 8). The absolute error is defined as the simulated value minus the observed value, and the relative error as the simulated value minus the observed value divided by the observed value (James and Burges, 1982). Two other statistics—the coefficient of model-fit efficiency (Nash and Sutcliffe, 1970) and the coefficient of determination (Mosteller and Tukey, 1977)—are provided principally as a basis to compare the models developed and applied here to other published models. The calibrated model for Middle Fork Basin was made to fit the observed streamflow data. Of the eight characteristics of the hydrograph compared, the differences between the observed and simulated runoff characteristics are all less than about 8 percent (table 9). Differences in the observed and simulated low flows (lowest 50 percent of flows) of the confirmed South Fork model are nearly 10 times greater than these differences for the calibrated Middle Fork model. The differences in the observed and simulated summer storm volume for the confirmed South Fork model are nearly twice as large as those for the calibrated Middle Fork model. Still, errors in the simulated runoff for the South Fork model are not unreasonable considering that no calibration was done and all criteria were within the limits suggested by Lumb and others (1994). The other model fit statistics would generally classify the model results as good relative to the results of other studies summarized by Duncker and others (1995).

Evaluation of the residuals indicates that large errors are predominantly associated with convective storms in summer and late snowfall events in the winter of 1994 (January 16 to February 10, 1994). The convective storms often produce locally heavy rainfall that may not be adequately estimated by the discrete rainfall network used in this study. Snowstorms of the magnitude observed in the winter of 1994 are rare in the Louisville area and do not justify incorporating simulation of snowmelt; their occurrence however, does have

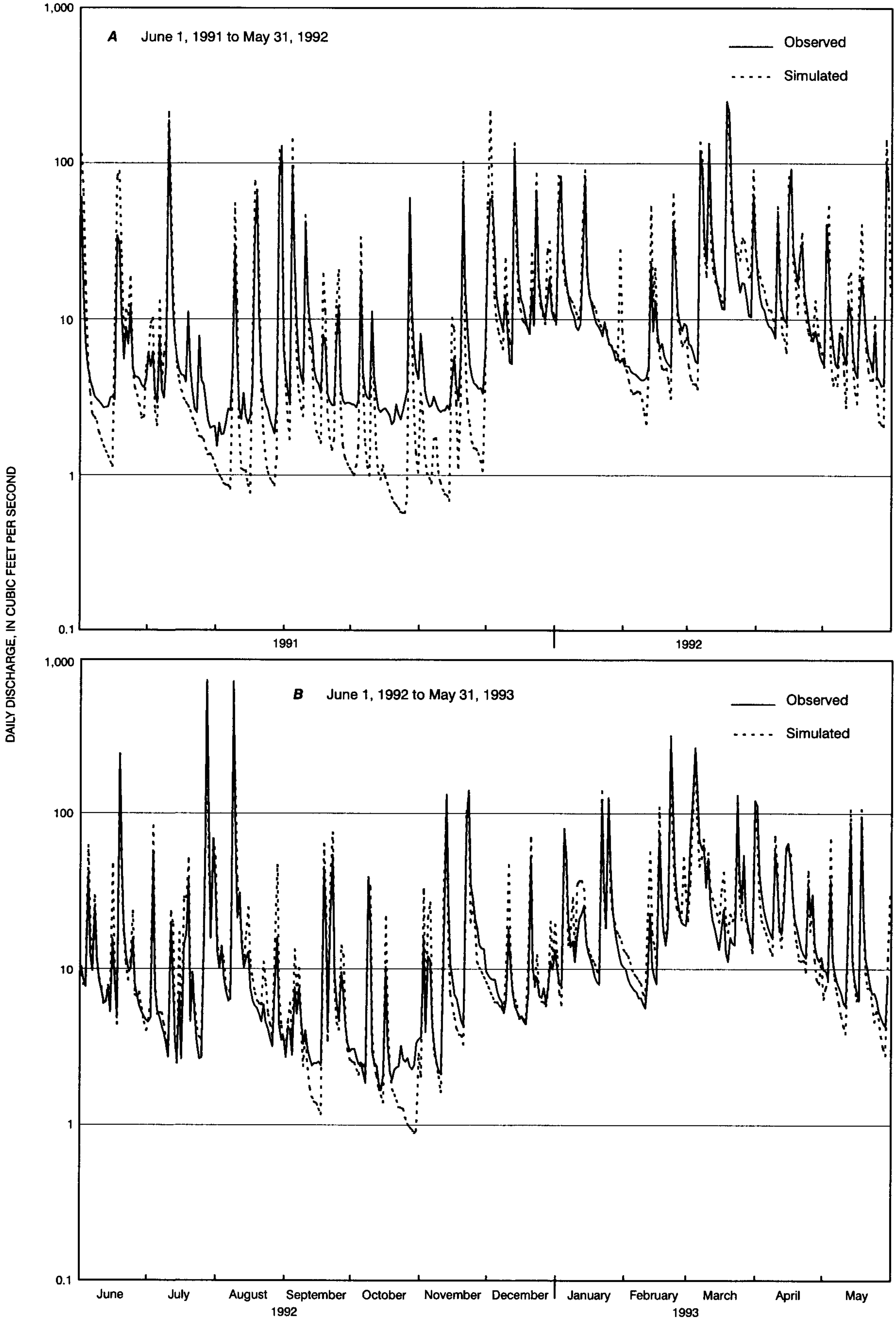


Figure 6. Observed and simulated (from model confirmation) daily discharge for the South Fork Beargrass Creek at Louisville, Kentucky.

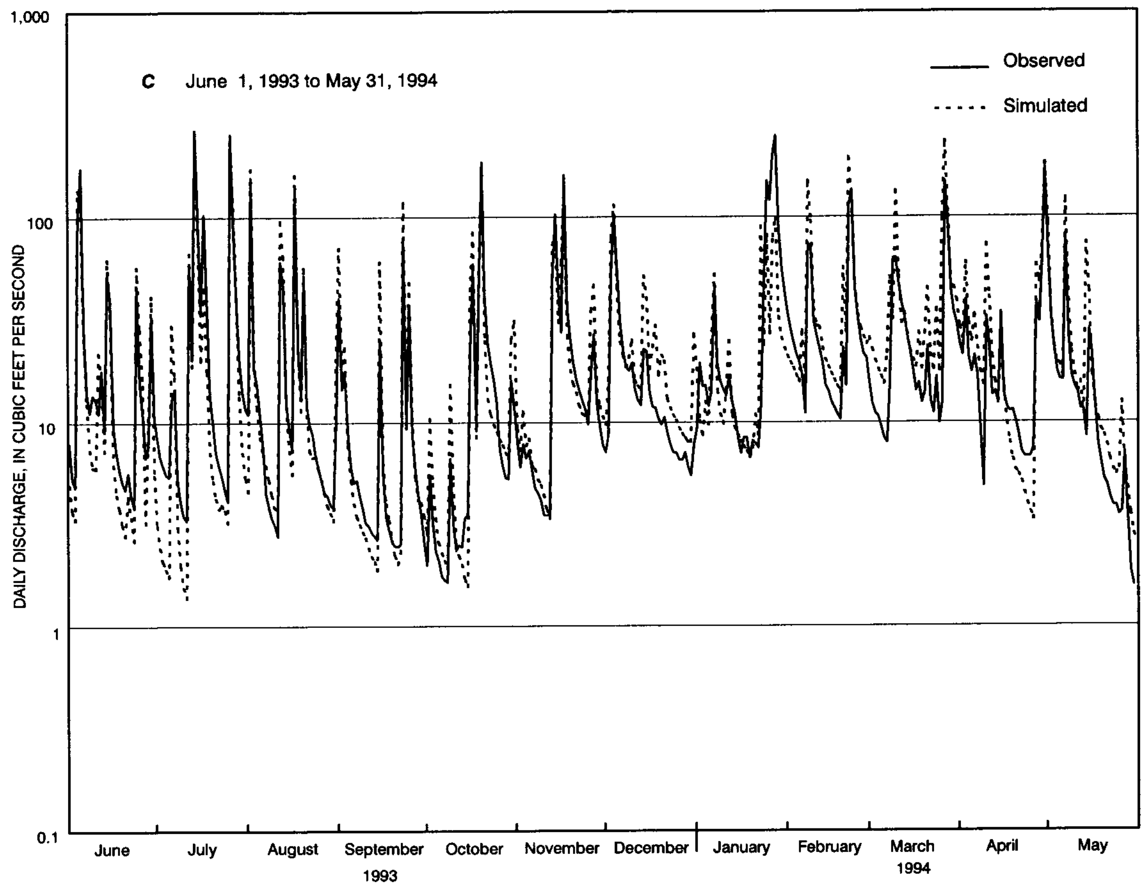


Figure 6. Observed and simulated (from model confirmation) daily discharge for the South Fork Beargrass Creek at Louisville, Kentucky—Continued.

Table 8. Statistical summary for observed and simulated daily streamflow and relative and absolute error series for the Middle Fork and South Fork Basins of Beargrass Creek at Louisville, Kentucky, from June 1, 1991, to May 31, 1994

[---, not applicable]

	Middle Fork		South Fork	
	Mean	Standard deviation	Mean	Standard deviation
Observed streamflow, in cubic feet per second	20.2	37.1	21.2	45.2
Simulated streamflow, in cubic feet per second	20.9	33.5	22.3	37.2
Absolute error (simulated–observed)	.76	15.7	1.09	21.7
Relative error (percent difference) (simulated–observed)/observed, in percent	15.3	64.3	8.3	63.5
Coefficient of model-fit efficiency	.82	---	.77	---
Coefficient of determination	.91	---	.88	---

Table 9. Statistics for the criteria used in the hydrologic calibration and confirmation of the Hydrological Simulation Program—FORTRAN (HSPF) model applied to the Middle Fork and South Fork Basins of Beargrass Creek at Louisville, Kentucky, from June 1, 1991, to May 31, 1994

	Observed	Simulated	Percent error (simulated/ observed -1) (percent)
Middle Fork (calibration)			
Total annual runoff, in inches	45.5	47.2	3.7
Total highest 10 percent flows, in inches	22.8	22.4	-1.8
Total lowest 50 percent flows, in inches	5.10	5.14	-.8
Total storm volume, in inches	6.47	5.97	-7.7
Average storm peaks, in cubic feet per second	653.6	699.6	7.0
Summer flow volume, in inches	10.8	11.4	5.6
Winter flow volume, in inches	13.2	13.0	-1.5
Summer storm volume, in inches	3.48	3.11	-10.6
South Fork (confirmation)			
Total annual runoff, in inches	51.6	56.0	8.5
Total highest 10 percent flows, in inches	27.3	27.9	2.0
Total lowest 50 percent flows, in inches	6.0	5.6	-7.7
Total storm volume, in inches	10.3	9.4	-8.0
Average storm peaks, in cubic feet per second	914.9	910.8	-.5
Summer flow volume, in inches	14.3	14.3	.0
Winter flow volume, in inches	13.7	15.2	10.3
Summer storm volume, in inches	5.7	4.6	-20.5

ramifications for model efficiency that may persist for several weeks as observed in this study.

SUMMARY AND CONCLUSIONS

A Hydrological Simulation Program—FORTRAN (HSPF) river-basin model was developed for the Middle Fork Basin and South Fork Basin in the Beargrass Creek Basin in Jefferson County, Ky. The simulated period was June 1, 1991, to May 31, 1994. The Hydrological Simulation Program—FORTRAN Expert System (HSPEXP) was used to calibrate the model parameters.

Meteorological data including precipitation and pan-evaporation were compiled. A variety of Geographic Information System (GIS) data coverages were developed and analyzed to delineate unique polygons within each model-grid cell. The polygons were aggregated using a K-means cluster analysis technique into four primary clusters (or groups). The clusters were classified according to their pervious (PERLND) or impervious (IMPLND) land uses and were defined as Hydrologic Response Units (HRU's). In the Middle

Fork Basin, 390 polygons were assigned to the 4 HRU's. The HRU's designated as PERLND areas were lawn, wooded, and riparian areas. A fourth HRU, designated as IMPLND, included surfaces such as roads, parking lots, buildings, and similar structures. Each of the HRU's was further divided on the basis of land slope such that 12 land-cover/land-slope combinations were applied in the model.

In the South Fork Basin, a surrogate method was devised to assign an HRU to a polygon based on an equation developed in the Middle Fork Basin that related the HRU to classification variables of soil permeability, soil-moisture storage capacity, and tree-canopy cover. A total of 318 polygons in the South Fork Basin were assigned to the 4 previously defined HRU's.

An HSPF model was developed and calibrated for the Middle Fork Basin. The simulation results indicated that the calibration was adequate—model-simulated runoff characteristics were within acceptable default criteria limits. The model calibrated for Middle Fork Basin was confirmed by applying it to the South Fork Basin. Though the confirmation results were not as good as for the Middle Fork Basin, the model was still adequate to evaluate simulation of daily flows in ungaged basins. This model could be used to calculate daily streamflow in an ungaged basin with similar land use/land cover where water-quality data are available to improve basin-load estimations.

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APPENDIX A

Beargrass Creek—Middle Fork
user control input (UCI)

```
RUN
GLOBAL
BEARGRASS CREEK--Middle Fork
  START       1991  6  1  0  0  END    1994  5 31 24  0
  RUN INTERP OUTPUT LEVEL    5
  RESUME     0 RUN     1 TSSFL     0 WDMSFL    0 UNITS     1
END GLOBAL
FILES
<type>  <fun>***<------------fname---------------------------------------------->
INFO        21   hspinf.da
ERROR       22   hsperr.da
WARN        23   hspwrn.da
MESSU       25   mf5ram.ech
WDM         26   mf5ram.wdm
            90   mf5ram.out
END FILES
OPN SEQUENCE
    INGRP              INDELT  0: 5
      PERLND     416
      IMPLND     616
      RCHRES      20
      PERLND     316
      PERLND     326
      PERLND     426
      PERLND     436
      PERLND     516
      PERLND     526
      IMPLND     626
      IMPLND     636
      RCHRES      30
      PERLND     417
      PERLND     517
      IMPLND     617
      RCHRES      21
      PERLND     317
      PERLND     327
      PERLND     337
      PERLND     427
      PERLND     527
      PERLND     537
      IMPLND     627
      IMPLND     637
      RCHRES      31
      RCHRES      10
      PERLND     412
      IMPLND     612
      RCHRES      22
      PERLND     311
      PERLND     411
      PERLND     422
      PERLND     437
      PERLND     511
      PERLND     512
      IMPLND     611
      IMPLND     622
```

```
      RCHRES       32
      RCHRES       23
      PERLND      312
      PERLND      432
      PERLND      522
      IMPLND      632
      RCHRES       33
      PERLND      321
      PERLND      331
      PERLND      421
      PERLND      521
      IMPLND      621
      IMPLND      631
      RCHRES       34
 ***
 ***  The network of PERLNDs, IMPLNDs, and RCHRESs listed
 ***  above describes the watershed above the Middle Fork
 ***  Beargrass Creek at Louisville, Kentucky, streamflow
 ***  gage (no. 03293000).  The network of PERLNDs, IMPLNDs,
 ***  and RCHRESs listed below describes the Middle Fork
 ***  Beargrass Creek below the streamflow gage to the outlet.
 ***  The UCI currently is configured to simulate the watershed
 ***  up to the streamflow gage.  To simulate the entire
 ***  watershed delete the *** in the lines below and line up
 ***  the unit names and numbers with the previous lines.  The
 ***  External Targets Block also should be modified when
 ***  simulating the entire watershed.
 ***
 ***  PERLND      313
 ***  PERLND      323
 ***  PERLND      333
 ***  IMPLND      613
 ***  IMPLND      623
 ***  IMPLND      633
 ***  RCHRES       35
 ***  RCHRES       26
 ***  RCHRES       36
      COPY        100
    END INGRP
END OPN SEQUENCE
PERLND
  ACTIVITY
    <PLS >              Active Sections                             ***
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
  311  537    0    0    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
  PRINT-INFO
     <PLS> ******************** Print-flags ************************* PIVL  PYR
     x - x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC *********
  311  537            4                                                   1    5
  END PRINT-INFO
  GEN-INFO
    <PLS >      Name          NBLKS   Unit-systems   Printer***
    x -  x                              t-series Engl Metr***
                                         in  out          ***
```

```
  311  337LAWN                        1          1    1   90     0
  411  437RIPARIAN                    1          1    1   90     0
  511  537WOODED                      1          1    1   90     0
  END GEN-INFO
  PWAT-PARM1
*** <PLS >                   Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE
  311  537    0    1    1    1    1    0    0    0    1
  END PWAT-PARM1
  PWAT-PARM2
***  <PLS>   FOREST       LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
***  x - x                (in)   (in/hr)      (ft)               (1/in)   (1/day)
  311  317      0.0        2.6      0.05     100.0      0.04       0.4      0.96
  321  327      0.0        2.5      0.04      75.0      0.08       0.7      0.95
  331  337      0.0        2.6      0.04      50.0      0.15       0.9      0.94
  411  417      0.0       10.5      0.42     100.0      0.04       0.4      0.96
  421  427      0.0       11.9      0.25      75.0      0.08       0.7      0.95
  432  437      0.0       10.6      0.12      50.0      0.15       0.9      0.94
  511  517      0.0        7.9      0.29     100.0      0.04       0.4      0.96
  521  527      0.0        6.9      0.15      75.0      0.08       0.7      0.95
  537           0.0        6.5      0.13      50.0      0.15       0.9      0.94
  END PWAT-PARM2
  PWAT-PARM3
***  <PLS>   PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
***  x - x  (deg F)   (deg F)
  311  317     40.0      35.0       2.5       2.0      0.01      0.05     0.005
  321  327     40.0      35.0       1.0       2.0      0.01      0.05     0.005
  331  337     40.0      35.0       0.5       2.0      0.01      0.05     0.005
  411  417     40.0      35.0       2.5       2.0      0.01      0.05     0.005
  421  427     40.0      35.0       1.0       2.0      0.01      0.05     0.005
  432  437     40.0      35.0       0.5       2.0      0.01      0.05     0.005
  511  517     40.0      35.0       2.5       2.0      0.01      0.05     0.005
  521  527     40.0      35.0       1.0       2.0      0.01      0.05     0.005
  537          40.0      35.0       0.5       2.0      0.01      0.05     0.005
  END PWAT-PARM3
  PWAT-PARM4
*** <PLS >     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x      (in)      (in)                       (1/day)
  311  317       0.2      0.83      0.25      10.0      0.17      0.47
  321  327       0.2      0.65      0.25      10.0      0.27      0.49
  331  337       0.2      0.52      0.25      10.0      0.37      0.49
  411  417       0.2      0.54      0.25      10.0      0.17      0.31
  421  427       0.2       0.5      0.25      10.0      0.27      0.37
  432            0.2      0.39      0.25      10.0      0.27      0.36
  436  437       0.2      0.39      0.25      10.0      0.37      0.36
  511  517       0.2      0.78      0.25      10.0      0.17      0.44
  521  527       0.2      0.44      0.25      10.0      0.27      0.33
  537            0.2      0.38      0.25      10.0      0.37      0.36
  END PWAT-PARM4
  MON-INTERCEP
*** <PLS >  Interception storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  311  317  0.1 0.11 0.12 0.13 0.14 0.16 0.16 0.16 0.15 0.14 0.12  0.1
  321  327 0.09  0.1 0.09 0.11 0.11 0.13 0.14 0.14 0.13 0.11 0.11 0.09
  331  427 0.07 0.09 0.09 0.11 0.11 0.12 0.12 0.12 0.11 0.09 0.08 0.07
```

```
  432  437 0.04 0.05 0.05 0.08 0.09 0.09 0.11 0.11 0.09 0.07 0.05 0.04
  511  517 0.09  0.1 0.13 0.13 0.14 0.16 0.16 0.16 0.15 0.14 0.12 0.08
  521  537 0.04 0.05 0.07 0.08 0.09 0.09 0.11 0.11 0.09 0.07 0.06 0.04
  END MON-INTERCEP
  MON-UZSN
*** <PLS >  Upper zone storage at start of each month  (inches)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  311  317 0.63 0.63 0.63 0.63  0.6 0.55 0.52 0.52 0.63 0.68 0.73 0.66
  321  327  0.5 0.55  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5 0.55
  331  337 0.42 0.42 0.42 0.42 0.42 0.42 0.43 0.43 0.43 0.43 0.43 0.42
  411  417 0.44 0.44 0.44 0.44 0.34 0.34 0.35 0.35 0.35 0.35 0.45 0.44
  421  427  0.4  0.4  0.4  0.4  0.4  0.4 0.42 0.42 0.42 0.42 0.42  0.4
  432  437 0.29 0.29 0.29 0.29 0.29 0.29 0.31 0.31 0.31 0.31 0.31 0.29
  511  517 0.68 0.68 0.68 0.68 0.58  0.6  0.6  0.6  0.6  0.6  0.7 0.68
  521  527 0.34 0.34 0.34 0.34 0.34 0.34 0.35 0.35 0.35 0.35 0.35 0.34
  537      0.28 0.28 0.28 0.28 0.28 0.28  0.3  0.3  0.3  0.3  0.3 0.28
  END MON-UZSN
  MON-LZETPARM
*** <PLS >  Lower zone evapotransp   parm at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  311  317 0.31 0.31 0.37  0.4 0.56 0.65 0.72 0.73 0.64 0.52 0.49 0.33
  321  337 0.32 0.32 0.39 0.42 0.59 0.66 0.75 0.76 0.66 0.54  0.5 0.34
  411  417 0.19 0.19 0.24 0.26 0.33  0.4  0.5 0.51  0.4 0.38 0.35 0.21
  421  427 0.22 0.22 0.28 0.31 0.42  0.5 0.59  0.6  0.5 0.43  0.4 0.24
  432  437 0.21 0.21 0.28 0.31  0.4 0.49 0.58 0.59 0.49 0.42  0.4 0.23
  511  517 0.27 0.27 0.35 0.37 0.52  0.6  0.7 0.71  0.6 0.52 0.46 0.29
  521  527  0.2  0.2 0.26 0.28 0.36 0.44 0.53 0.54 0.44  0.4 0.37 0.22
  537      0.22 0.22 0.28 0.31  0.4 0.47 0.57 0.58 0.47 0.42  0.4 0.24
  END MON-LZETPARM
  PWAT-STATE1
***  <PLS>  PWATER state variables (in)
***   x - x      CEPS       SURS        UZS       IFWS        LZS       AGWS       GWVS
  311  537        0.0        0.0       0.94       0.08        9.9        0.2        0.0
  END PWAT-STATE1
END PERLND
IMPLND
  ACTIVITY
*** <ILS >               Active Sections
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL
  611  637    0    0    1    0    0    0
  END ACTIVITY
  PRINT-INFO
    <ILS > ******** Print-flags ******** PIVL  PYR
    x -  x ATMP SNOW IWAT  SLD  IWG IQAL *********
  611  637              4                   1    5
  END PRINT-INFO
  GEN-INFO
*** <ILS >      Name              Unit-systems   Printer
*** <ILS >                            t-series Engl Metr
*** x -  x                              in  out
  611  637ROADS/URBAN                    1    1   90    0
  END GEN-INFO
  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
```

```
  611  637    0    1    0    0    0
  END IWAT-PARM1
  IWAT-PARM2
*** <ILS >       LSUR      SLSUR      NSUR      RETSC
*** x -  x       (ft)                            (ft)
  611  617      100.0       0.04     0.025       0.07
  621  627      100.0       0.09     0.025       0.05
  631  637      100.0       0.15     0.025       0.03
  END IWAT-PARM2
  IWAT-PARM3
*** <ILS >     PETMAX    PETMIN
*** x -  x    (deg F)   (deg F)
  611  637       40.0      35.0
  END IWAT-PARM3
  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x       RETS      SURS
  611  637      0.001     0.001
  END IWAT-STATE1
END IMPLND
RCHRES
  ACTIVITY
*** RCHRES  Active sections
*** x -  x HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG
   10   36    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
  PRINT-INFO
*** RCHRES  Printout level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
   10   36    5                                                 1    5
  END PRINT-INFO
  GEN-INFO
***              Name          Nexits   Unit Systems   Printer
*** RCHRES                                 t-series  Engl Metr LKFG
*** x -  x                                   in  out
   10     SPILLWAYS                1         1    1   90    0    0
   20   26LAKES & POND             1         1    1   90    0    1
   30     BEARGRASS CK             1         1    1   90    0    0
   31     BEARGRASS CK             2         1    1   90    0    0
   32   36BEARGRASS CK             1         1    1   90    0    0
  END GEN-INFO
  HYDR-PARM1
***            Flags for HYDR section
    RCHRES  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
     x - x  FG FG FG FG  possible   exit *** possible   exit     possible    exit
   10   30   0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
   31        0  1  1  1    4  5  0  0  0       0  0  0  0  0       1  1  1  1  1
   32   36   0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1
  HYDR-PARM2
*** RCHRES FTBW FTBU        LEN     DELTH     STCOR        KS      DB50
*** x -  x              (miles)      (ft)      (ft)                (in)
   10       0.0 10.0        0.5       1.0       0.0       0.5      0.01
   20       0.0 20.0        0.5       1.0       0.0       0.5      0.01
   21       0.0 21.0        0.5       1.0       0.0       0.5      0.01
```

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    22        0.0 22.0        0.5        1.0        0.0        0.5       0.01
    23        0.0 23.0        0.5        1.0        0.0        0.5       0.01
    26        0.0 26.0        0.5        1.0        0.0        0.5       0.01
    30        0.0 30.0        4.2       33.6        0.0        0.5       0.01
    31        0.0 31.0        3.1       20.9        0.0        0.5       0.07
    32        0.0 32.0        3.9       17.3        0.0        0.5       0.05
    33        0.0 33.0        3.1       18.9        0.0        0.5       0.04
    34        0.0 34.0        1.8       10.7        0.0        0.5       0.05
    35        0.0 35.0        3.5       11.9        0.0        0.5       0.04
    36        0.0 36.0        1.3        2.9        0.0        0.5       0.01
  END HYDR-PARM2
  HYDR-INIT
***          Initial conditions for HYDR section
*** RCHRES       VOL  CAT Initial value  of COLIND     initial  value  of OUTDGT
***  x - x     ac-ft      for each possible   exit  for each possible exit,ft3
   10   26      0.88  0.0  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
   30   36      1.09  0.0  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
  END HYDR-INIT
END RCHRES
COPY
  TIMESERIES
  Copy-opn***
*** x -  x  NPT  NMN
  100         0    7
  END TIMESERIES
END COPY

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   x <Name> x tem strg<-factor->strg <Name>   x   x        <Name> x x  ***
WDM   1006 PREC   10 ENGL              SAME PERLND 311     EXTNL  PREC    1 1
WDM   2251 PET    10 ENGL              DIV  PERLND 311     EXTNL  PETINP 1 1
WDM   1006 PREC   10 ENGL              SAME PERLND 321     EXTNL  PREC    1 1
WDM   2251 PET    10 ENGL              DIV  PERLND 321     EXTNL  PETINP 1 1
WDM   1006 PREC   10 ENGL              SAME PERLND 331     EXTNL  PREC    1 1
WDM   2251 PET    10 ENGL              DIV  PERLND 331     EXTNL  PETINP 1 1
WDM   1006 PREC   10 ENGL              SAME PERLND 411     EXTNL  PREC    1 1
WDM   2251 PET    10 ENGL              DIV  PERLND 411     EXTNL  PETINP 1 1
WDM   1006 PREC   10 ENGL              SAME PERLND 421     EXTNL  PREC    1 1
WDM   2251 PET    10 ENGL              DIV  PERLND 421     EXTNL  PETINP 1 1
WDM   1006 PREC   10 ENGL              SAME PERLND 511     EXTNL  PREC    1 1
WDM   2251 PET    10 ENGL              DIV  PERLND 511     EXTNL  PETINP 1 1
WDM   1006 PREC   10 ENGL              SAME PERLND 521     EXTNL  PREC    1 1
WDM   2251 PET    10 ENGL              DIV  PERLND 521     EXTNL  PETINP 1 1
WDM   1006 PREC   10 ENGL              SAME IMPLND 611     EXTNL  PREC    1 1
WDM   2251 PET    10 ENGL              DIV  IMPLND 611     EXTNL  PETINP 1 1
WDM   1006 PREC   10 ENGL              SAME IMPLND 621     EXTNL  PREC    1 1
WDM   2251 PET    10 ENGL              DIV  IMPLND 621     EXTNL  PETINP 1 1
WDM   1006 PREC   10 ENGL              SAME IMPLND 631     EXTNL  PREC    1 1
WDM   2251 PET    10 ENGL              DIV  IMPLND 631     EXTNL  PETINP 1 1
WDM   1008 PREC   10 ENGL              SAME PERLND 312     EXTNL  PREC    1 1
WDM   2251 PET    10 ENGL              DIV  PERLND 312     EXTNL  PETINP 1 1
WDM   1008 PREC   10 ENGL              SAME PERLND 412     EXTNL  PREC    1 1
WDM   2251 PET    10 ENGL              DIV  PERLND 412     EXTNL  PETINP 1 1
WDM   1008 PREC   10 ENGL              SAME PERLND 422     EXTNL  PREC    1 1
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WDM    2251 PET    10 ENGL            DIV   PERLND 422     EXTNL   PETINP 1 1
WDM    1008 PREC   10 ENGL            SAME  PERLND 432     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 432     EXTNL   PETINP 1 1
WDM    1008 PREC   10 ENGL            SAME  PERLND 512     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 512     EXTNL   PETINP 1 1
WDM    1008 PREC   10 ENGL            SAME  PERLND 522     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 522     EXTNL   PETINP 1 1
WDM    1008 PREC   10 ENGL            SAME  IMPLND 612     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   IMPLND 612     EXTNL   PETINP 1 1
WDM    1008 PREC   10 ENGL            SAME  IMPLND 622     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   IMPLND 622     EXTNL   PETINP 1 1
WDM    1008 PREC   10 ENGL            SAME  IMPLND 632     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   IMPLND 632     EXTNL   PETINP 1 1
WDM    1019 PREC   10 ENGL            SAME  PERLND 313     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 313     EXTNL   PETINP 1 1
WDM    1019 PREC   10 ENGL            SAME  PERLND 323     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 323     EXTNL   PETINP 1 1
WDM    1019 PREC   10 ENGL            SAME  PERLND 333     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 333     EXTNL   PETINP 1 1
WDM    1019 PREC   10 ENGL            SAME  IMPLND 613     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   IMPLND 613     EXTNL   PETINP 1 1
WDM    1019 PREC   10 ENGL            SAME  IMPLND 623     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   IMPLND 623     EXTNL   PETINP 1 1
WDM    1019 PREC   10 ENGL            SAME  IMPLND 633     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   IMPLND 633     EXTNL   PETINP 1 1
WDM    1011 PREC   10 ENGL            SAME  PERLND 316     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 316     EXTNL   PETINP 1 1
WDM    1011 PREC   10 ENGL            SAME  PERLND 326     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 326     EXTNL   PETINP 1 1
WDM    1011 PREC   10 ENGL            SAME  PERLND 416     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 416     EXTNL   PETINP 1 1
WDM    1011 PREC   10 ENGL            SAME  PERLND 426     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 426     EXTNL   PETINP 1 1
WDM    1011 PREC   10 ENGL            SAME  PERLND 436     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 436     EXTNL   PETINP 1 1
WDM    1011 PREC   10 ENGL            SAME  PERLND 516     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 516     EXTNL   PETINP 1 1
WDM    1011 PREC   10 ENGL            SAME  PERLND 526     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 526     EXTNL   PETINP 1 1
WDM    1011 PREC   10 ENGL            SAME  IMPLND 616     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   IMPLND 616     EXTNL   PETINP 1 1
WDM    1011 PREC   10 ENGL            SAME  IMPLND 626     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   IMPLND 626     EXTNL   PETINP 1 1
WDM    1011 PREC   10 ENGL            SAME  IMPLND 636     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   IMPLND 636     EXTNL   PETINP 1 1
WDM    1027 PREC   10 ENGL            SAME  PERLND 317     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 317     EXTNL   PETINP 1 1
WDM    1027 PREC   10 ENGL            SAME  PERLND 327     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 327     EXTNL   PETINP 1 1
WDM    1027 PREC   10 ENGL            SAME  PERLND 337     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 337     EXTNL   PETINP 1 1
WDM    1027 PREC   10 ENGL            SAME  PERLND 417     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 417     EXTNL   PETINP 1 1
WDM    1027 PREC   10 ENGL            SAME  PERLND 427     EXTNL   PREC   1 1
WDM    2251 PET    10 ENGL            DIV   PERLND 427     EXTNL   PETINP 1 1
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WDM    1027 PREC   10 ENGL                 SAME PERLND 437      EXTNL   PREC    1 1
WDM    2251 PET    10 ENGL                 DIV  PERLND 437      EXTNL   PETINP 1 1
WDM    1027 PREC   10 ENGL                 SAME PERLND 517      EXTNL   PREC    1 1
WDM    2251 PET    10 ENGL                 DIV  PERLND 517      EXTNL   PETINP 1 1
WDM    1027 PREC   10 ENGL                 SAME PERLND 527      EXTNL   PREC    1 1
WDM    2251 PET    10 ENGL                 DIV  PERLND 527      EXTNL   PETINP 1 1
WDM    1027 PREC   10 ENGL                 SAME PERLND 537      EXTNL   PREC    1 1
WDM    2251 PET    10 ENGL                 DIV  PERLND 537      EXTNL   PETINP 1 1
WDM    1027 PREC   10 ENGL                 SAME IMPLND 617      EXTNL   PREC    1 1
WDM    2251 PET    10 ENGL                 DIV  IMPLND 617      EXTNL   PETINP 1 1
WDM    1027 PREC   10 ENGL                 SAME IMPLND 627      EXTNL   PREC    1 1
WDM    2251 PET    10 ENGL                 DIV  IMPLND 627      EXTNL   PETINP 1 1
WDM    1027 PREC   10 ENGL                 SAME IMPLND 637      EXTNL   PREC    1 1
WDM    2251 PET    10 ENGL                 DIV  IMPLND 637      EXTNL   PETINP 1 1
WDM    1027 PREC   10 ENGL                 SAME RCHRES  10   36 EXTNL   PREC    1 1
WDM    2251 PET    10 ENGL                 DIV  RCHRES  10   36 EXTNL   POTEV   1 1
END EXT SOURCES

EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
 ***
 ***  The first two lines below specify that the discharge and average depth at
 ***  the streamflow gage Middlefork Beargrass Creek at Louisville, Kentucky,
 ***  (no. 03293000) are loaded into WDM files 340 and 341, respectively.  If
 ***  the entire watershed is to be simulated similar lines need to be added for
 ***  RCHRES 36.  New WDM files (numbers different than 340 and 341) should be
 ***  generated in ANNIE and specified as the external targets for simulation
 ***  results for RCHRES 36.
 ***
RCHRES  34 HYDR   RO      1 1                 WDM    340 DISC    1 ENGL AGGR REPL
RCHRES  34 HYDR   AVDEP  1 1                WDM    341 AVDE    1 ENGL AGGR REPL
RCHRES  34 ROFLOW ROVOL  1 1  0.001038     WDM    320 SIMQ    1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   1 1  0.000086     WDM    321 SURO    1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   2 1  0.000086     WDM    322 IFWO    1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   3 1  0.000086     WDM    323 AGWO    1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   4 1  0.000086     WDM    325 PETX    1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   5 1  0.000086     WDM    326 SAET    1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   6 1  0.000086     WDM    327 UZSX    1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   7 1  0.000086     WDM    328 LZSX    1 ENGL AGGR REPL
END EXT TARGETS
SCHEMATIC
<-Volume->                  <--Area-->     <-Volume->  <ML#> ***
<Name>   x                  <-factor->     <Name>   x        ***
PERLND 416                        54.8     RCHRES  20      1
IMPLND 616                        14.4     RCHRES  20      2
PERLND 316                         5.6     RCHRES  30      1
PERLND 326                         6.5     RCHRES  30      1
PERLND 416                       586.0     RCHRES  30      1
PERLND 426                       126.6     RCHRES  30      1
PERLND 436                         9.5     RCHRES  30      1
PERLND 516                        25.3     RCHRES  30      1
PERLND 526                        14.0     RCHRES  30      1
IMPLND 616                       161.6     RCHRES  30      2
IMPLND 626                        43.7     RCHRES  30      2
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IMPLND 636	3.9	RCHRES	30	2
PERLND 416	265.7	RCHRES	21	1
PERLND 417	6.9	RCHRES	21	1
PERLND 426	15.2	RCHRES	21	1
PERLND 517	54.2	RCHRES	21	1
IMPLND 616	70.6	RCHRES	21	2
IMPLND 617	16.4	RCHRES	21	2
IMPLND 626	4.6	RCHRES	21	2
PERLND 317	45.5	RCHRES	31	1
PERLND 327	8.6	RCHRES	31	1
PERLND 337	6.9	RCHRES	31	1
PERLND 416	582.2	RCHRES	31	1
PERLND 417	453.6	RCHRES	31	1
PERLND 426	252.8	RCHRES	31	1
PERLND 427	61.7	RCHRES	31	1
PERLND 436	61.3	RCHRES	31	1
PERLND 517	373.8	RCHRES	31	1
PERLND 527	7.1	RCHRES	31	1
PERLND 537	11.3	RCHRES	31	1
IMPLND 616	154.6	RCHRES	31	2
IMPLND 617	241.8	RCHRES	31	2
IMPLND 626	74.9	RCHRES	31	2
IMPLND 627	27.3	RCHRES	31	2
IMPLND 636	22.0	RCHRES	31	2
IMPLND 637	8.0	RCHRES	31	2
PERLND 412	38.8	RCHRES	22	1
PERLND 416	287.7	RCHRES	22	1
PERLND 417	28.3	RCHRES	22	1
PERLND 517	362.3	RCHRES	22	1
IMPLND 612	9.7	RCHRES	22	2
IMPLND 616	61.3	RCHRES	22	2
IMPLND 617	106.0	RCHRES	22	2
PERLND 311	55.5	RCHRES	32	1
PERLND 411	23.9	RCHRES	32	1
PERLND 412	492.1	RCHRES	32	1
PERLND 416	3.6	RCHRES	32	1
PERLND 417	510.3	RCHRES	32	1
PERLND 422	25.7	RCHRES	32	1
PERLND 427	137.3	RCHRES	32	1
PERLND 437	10.1	RCHRES	32	1
PERLND 511	20.3	RCHRES	32	1
PERLND 512	8.3	RCHRES	32	1
PERLND 517	2120.2	RCHRES	32	1
PERLND 527	39.9	RCHRES	32	1
PERLND 537	26.6	RCHRES	32	1
IMPLND 611	32.0	RCHRES	32	2
IMPLND 612	126.4	RCHRES	32	2
IMPLND 616	0.8	RCHRES	32	2
IMPLND 617	736.8	RCHRES	32	2
IMPLND 622	5.0	RCHRES	32	2
IMPLND 627	49.5	RCHRES	32	2
IMPLND 637	10.5	RCHRES	32	2
PERLND 412	15.8	RCHRES	23	1
PERLND 512	254.6	RCHRES	23	1
IMPLND 612	67.1	RCHRES	23	2

PERLND 312	11.3	RCHRES	33	1
PERLND 412	151.3	RCHRES	33	1
PERLND 422	39.1	RCHRES	33	1
PERLND 432	6.0	RCHRES	33	1
PERLND 512	362.8	RCHRES	33	1
PERLND 522	6.3	RCHRES	33	1
IMPLND 612	142.4	RCHRES	33	2
IMPLND 622	13.0	RCHRES	33	2
IMPLND 632	4.4	RCHRES	33	2
PERLND 311	718.4	RCHRES	34	1
PERLND 317	36.4	RCHRES	34	1
PERLND 321	89.6	RCHRES	34	1
PERLND 331	42.4	RCHRES	34	1
PERLND 411	39.3	RCHRES	34	1
PERLND 412	13.5	RCHRES	34	1
PERLND 421	7.8	RCHRES	34	1
PERLND 511	102.5	RCHRES	34	1
PERLND 521	28.0	RCHRES	34	1
IMPLND 611	160.2	RCHRES	34	2
IMPLND 612	2.1	RCHRES	34	2
IMPLND 617	7.9	RCHRES	34	2
IMPLND 621	24.3	RCHRES	34	2
IMPLND 631	9.5	RCHRES	34	2
PERLND 311	1279.7	RCHRES	35	1
PERLND 313	210.1	RCHRES	35	1
PERLND 321	333.1	RCHRES	35	1
PERLND 323	65.8	RCHRES	35	1
PERLND 331	285.7	RCHRES	35	1
PERLND 333	50.3	RCHRES	35	1
IMPLND 611	289.8	RCHRES	35	2
IMPLND 613	42.5	RCHRES	35	2
IMPLND 621	67.5	RCHRES	35	2
IMPLND 623	13.6	RCHRES	35	2
IMPLND 631	73.1	RCHRES	35	2
IMPLND 633	11.3	RCHRES	35	2
PERLND 311	131.1	RCHRES	26	1
PERLND 313	109.6	RCHRES	26	1
PERLND 321	11.0	RCHRES	26	1
PERLND 323	29.8	RCHRES	26	1
PERLND 331	5.0	RCHRES	26	1
PERLND 333	18.5	RCHRES	26	1
IMPLND 611	29.1	RCHRES	26	2
IMPLND 613	22.9	RCHRES	26	2
IMPLND 621	2.4	RCHRES	26	2
IMPLND 623	5.7	RCHRES	26	2
IMPLND 631	1.2	RCHRES	26	2
IMPLND 633	4.1	RCHRES	26	2
PERLND 311	64.7	RCHRES	36	1
PERLND 313	363.9	RCHRES	36	1
PERLND 321	47.7	RCHRES	36	1
PERLND 323	196.3	RCHRES	36	1
PERLND 331	33.3	RCHRES	36	1
PERLND 333	152.1	RCHRES	36	1
IMPLND 611	14.4	RCHRES	36	2
IMPLND 613	76.0	RCHRES	36	2

IMPLND 621	10.4	RCHRES	36	2
IMPLND 623	37.8	RCHRES	36	2
IMPLND 631	8.4	RCHRES	36	2
IMPLND 633	33.8	RCHRES	36	2
RCHRES 20		RCHRES	30	4
RCHRES 30		RCHRES	31	4
RCHRES 21		RCHRES	31	4
RCHRES 31		RCHRES	33	3
RCHRES 31		RCHRES	10	3
RCHRES 22		RCHRES	32	4
RCHRES 32		RCHRES	33	4
RCHRES 23		RCHRES	33	4
RCHRES 33		RCHRES	34	4
RCHRES 34		RCHRES	35	4
RCHRES 35		RCHRES	36	4
RCHRES 26		RCHRES	36	4
PERLND 311	2249.4	COPY	100	90
PERLND 312	11.3	COPY	100	90
PERLND 313	683.6	COPY	100	90
PERLND 316	5.6	COPY	100	90
PERLND 317	81.9	COPY	100	90
PERLND 321	481.4	COPY	100	90
PERLND 323	291.9	COPY	100	90
PERLND 326	6.5	COPY	100	90
PERLND 327	8.6	COPY	100	90
PERLND 331	366.4	COPY	100	90
PERLND 333	220.9	COPY	100	90
PERLND 337	6.9	COPY	100	90
PERLND 411	63.2	COPY	100	90
PERLND 412	711.5	COPY	100	90
PERLND 416	1780.3	COPY	100	90
PERLND 417	999.1	COPY	100	90
PERLND 421	7.8	COPY	100	90
PERLND 422	64.8	COPY	100	90
PERLND 426	394.6	COPY	100	90
PERLND 427	199.0	COPY	100	90
PERLND 432	6.0	COPY	100	90
PERLND 436	70.8	COPY	100	90
PERLND 437	10.1	COPY	100	90
PERLND 511	122.8	COPY	100	90
PERLND 512	625.7	COPY	100	90
PERLND 516	25.3	COPY	100	90
PERLND 517	2910.5	COPY	100	90
PERLND 521	28.0	COPY	100	90
PERLND 522	6.3	COPY	100	90
PERLND 526	14.0	COPY	100	90
PERLND 527	47.0	COPY	100	90
PERLND 537	37.9	COPY	100	90
IMPLND 611	525.5	COPY	100	91
IMPLND 612	347.7	COPY	100	91
IMPLND 613	141.4	COPY	100	91
IMPLND 616	463.3	COPY	100	91
IMPLND 617	1108.9	COPY	100	91
IMPLND 621	104.6	COPY	100	91
IMPLND 622	18.0	COPY	100	91

```
IMPLND 623                        57.1      COPY    100      91
IMPLND 626                       123.2      COPY    100      91
IMPLND 627                        76.8      COPY    100      91
IMPLND 631                        92.2      COPY    100      91
IMPLND 632                         4.4      COPY    100      91
IMPLND 633                        49.3      COPY    100      91
IMPLND 636                        25.9      COPY    100      91
IMPLND 637                        18.5      COPY    100      91
END SCHEMATIC
MASS-LINK
  MASS-LINK        1
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER PERO        0.0833333    RCHRES         INFLOW IVOL
  END MASS-LINK    1
  MASS-LINK        2
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO        0.0833333    RCHRES         INFLOW IVOL
  END MASS-LINK    2
  MASS-LINK        3
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
RCHRES     ROFLOW ROVOL  1                 RCHRES         INFLOW IVOL
RCHRES     OFLOW  OVOL   2                 RCHRES         INFLOW IVOL
  END MASS-LINK    3
  MASS-LINK        4
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
RCHRES     HYDR   ROVOL  1                 RCHRES         INFLOW IVOL
  END MASS-LINK    4
  MASS-LINK       90
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER SURO                     COPY           INPUT  MEAN   1
PERLND     PWATER IFWO                     COPY           INPUT  MEAN   2
PERLND     PWATER AGWO                     COPY           INPUT  MEAN   3
PERLND     PWATER PET                      COPY           INPUT  MEAN   4
PERLND     PWATER TAET                     COPY           INPUT  MEAN   5
PERLND     PWATER UZS                      COPY           INPUT  MEAN   6
PERLND     PWATER LZS                      COPY           INPUT  MEAN   7
  END MASS-LINK   90
  MASS-LINK       91
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO                     COPY           INPUT  MEAN   1
IMPLND     IWATER PET                      COPY           INPUT  MEAN   4
IMPLND     IWATER IMPEV                    COPY           INPUT  MEAN   5
  END MASS-LINK   91
END MASS-LINK
FTABLES
  FTABLE      10
   18    4
     DEPTH      AREA     VOLUME      DISCH  FLO-THRU ***
      (FT)   (ACRES)    (AC-FT)      (CFS)     (MIN) ***
```

```
      0.0       0.0       0.0       0.0
    0.119  9.429998      1.12       1.0
    0.165  9.660002       1.6       2.0
    0.202      9.87      1.99       3.0
    0.232     10.02      2.32       4.0
    0.285     10.23      2.91       6.0
     0.33     10.37      3.42       8.0
    0.372      10.5       3.9      10.0
    0.445     11.29      5.02      15.0
    0.618     12.54      7.75      30.0
    0.908     13.31     12.08      60.0
    1.311     14.41     18.88     120.0
    1.916     16.04     30.74     250.0
     2.63     19.12     50.28     500.0
    2.785     32.12     89.47    1000.0
    2.899     60.38    175.03    3000.0
    4.016  76.28999    306.35    5000.0
    5.446     78.98    430.08    7000.0
END FTABLE 10
FTABLE     20
 18    5
    DEPTH      AREA    VOLUME     DISCH   BY-PASS ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (CFS) ***
      0.0       0.0       0.0       0.0       0.0
      0.3     0.003     0.001       0.0       0.0
      0.6     0.012.006999999       0.1       0.0
      0.9     0.026     0.024       0.2       0.0
      1.2     0.047     0.056       0.3       0.0
      1.5     0.073      0.11       0.4       0.0
      1.8     0.105     0.189       0.5       0.0
      2.1     0.143     0.301       0.6       0.0
      2.4     0.187     0.449       0.7       0.0
      2.7     0.237     0.639       0.8       0.0
      3.0     0.292     0.876       0.9       0.0
      3.3     0.353     1.166       1.0       0.0
      3.6     0.421     1.514       2.0       1.1
      3.9     0.494     1.925       3.0       2.1
      4.2     0.572     2.404       4.0       3.1
      4.5     0.657     2.957       6.0       4.0
      4.8     0.748     3.589       9.0       5.0
      5.1     0.844     4.304      12.0       6.0
END FTABLE 20
FTABLE     30
 18    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.0       0.0       0.0       0.0
    0.119  9.429999      1.12       1.0
    0.165  9.660001       1.6       2.0
    0.202      9.87      1.99       3.0
    0.232     10.02      2.32       4.0
    0.285     10.23      2.91       6.0
     0.33     10.37      3.42       8.0
    0.372      10.5       3.9      10.0
    0.445     11.29      5.02      15.0
```

```
      0.618      12.54       7.75       30.0
      0.908      13.31      12.08       60.0
      1.311      14.41      18.88      120.0
      1.916      16.04      30.74      250.0
       2.63      19.12      50.28      500.0
      2.785      32.12      89.47     1000.0
      2.899      60.38     175.03     2000.0
      4.016   76.28999     306.35     4000.0
      5.446      78.98     430.08     6000.0
  END FTABLE 30
  FTABLE     21
   14    5
      DEPTH       AREA     VOLUME      DISCH   FLO-THRU ***
       (FT)    (ACRES)    (AC-FT)      (CFS)      (CFS) ***
        0.0        0.0        0.0        0.0        0.0
        1.0      0.611      0.617        0.6        0.6
        2.0      1.223      2.467        5.0        5.0
        3.0      1.834      5.551       17.0       17.0
        4.0      2.445   9.868001       54.0       54.0
        5.0      3.057     15.422       98.2       98.0
        6.0      3.669     22.206      150.0      150.0
        7.0       4.28     30.225      300.0      300.0
        8.0      4.891     39.477      325.0      325.0
        9.0      5.503     49.962      500.0      500.0
       10.0      6.114     61.681      630.0      630.0
       10.6       6.42     68.003      650.0      650.0
       11.1      6.725     74.634      800.0      800.0
       11.6      7.031     81.573     1000.0     1000.0
  END FTABLE 21
  FTABLE     31
   18    5
      DEPTH       AREA     VOLUME      DISCH   FLO-THRU ***
       (FT)    (ACRES)    (AC-FT)      (CFS)      (MIN) ***
        0.0        0.0        0.0        0.0        0.0
      0.333       4.21        1.4        1.0        0.0
       0.37       4.68       1.73        2.0        0.0
      0.405       5.01       2.03        3.0        0.0
      0.432       5.32        2.3        4.0        0.0
      0.488       5.72       2.79        6.0        0.0
      0.542       6.01       3.26        8.0        0.0
      0.593       6.22        3.7       10.0        0.0
      0.698       6.63       4.63       15.0        0.0
      0.945       7.51        7.1       30.0        0.0
      1.263       8.94      11.29       60.0        0.0
      1.293       13.8      17.84      120.0        0.0
      1.355       24.4      33.07      250.0        0.0
      1.586      37.38      59.28      500.0        0.0
      1.895      58.57     110.98     1000.0        0.0
      2.969       76.6     227.45     1800.0      200.0
      4.283      97.24     403.64     3500.0      500.0
      5.164     104.49     539.58     4500.0     1500.0
  END FTABLE 31
  FTABLE     22
   14    5
      DEPTH       AREA     VOLUME      DISCH   FLO-THRU ***
```

```
     (FT)     (ACRES)     (AC-FT)       (CFS)       (CFS) ***
      0.0         0.0         0.0         0.0         0.0
      1.2       0.725       0.867         0.8         0.8
      2.4        1.45       3.467         8.0         8.0
      3.6       2.174       7.801        30.0        30.0
      4.8       2.899      13.869        70.0        70.0
      6.0       3.624      21.674       180.0       180.0
      7.2       4.349       31.21       265.0       265.0
      8.4       5.074       42.48       350.0       350.0
      9.6       5.799      55.483       600.0       600.0
     10.8       6.524    70.21999       700.0       700.0
     12.0       7.248    86.68999       990.0       990.0
     12.6       7.611      95.576      1100.0      1100.0
     13.2       7.973     104.895      1200.0      1200.0
     13.8    8.335999     114.647      1400.0      1400.0
  END FTABLE 22
  FTABLE     32
   18    4
    DEPTH        AREA      VOLUME       DISCH    FLO-THRU ***
     (FT)     (ACRES)     (AC-FT)       (CFS)       (MIN) ***
      0.0         0.0         0.0         0.0
    0.119    9.429999        1.12         1.0
    0.165    9.660001         1.6         2.0
    0.202        9.87        1.99         3.0
    0.232       10.02        2.32         4.0
    0.285       10.23        2.91         6.0
     0.33       10.37        3.42         8.0
    0.372        10.5         3.9        10.0
    0.445       11.29        5.02        15.0
    0.618       12.54        7.75        30.0
    0.908       13.31       12.08        60.0
    1.311       14.41       18.88       120.0
    1.916       16.04       30.74       250.0
     2.63       19.12       50.28       500.0
    2.785       32.12       89.47      1000.0
    2.899       60.38      175.03      2000.0
    4.016    76.28999      306.35      4000.0
    5.446       78.98      430.08      6000.0
  END FTABLE 32
  FTABLE     23
   14    5
    DEPTH        AREA      VOLUME       DISCH    FLO-THRU ***
     (FT)     (ACRES)     (AC-FT)       (CFS)       (CFS) ***
      0.0         0.0         0.0         0.0         0.0
      0.5       0.288       0.137         0.0         0.0
      1.0       0.577       0.549         0.3         0.3
      1.4       0.865       1.236         0.6         0.6
      1.9       1.154       2.197         1.0         1.0
      2.4       1.443       3.433         5.0         5.0
      2.9       1.731       4.944        12.0        12.0
      3.3       2.019       6.729        23.0        23.0
      3.8       2.308       8.788        38.0        38.0
      4.3       2.596      11.123        60.0        60.0
      4.8       2.885      13.732        82.0        82.0
      5.0       3.029      15.139        94.0        94.0
```

```
     5.2      3.173     16.615       102.0       102.0
     5.5      3.317      18.16       120.0       120.0
END FTABLE 23
FTABLE     33
 18    4
   DEPTH       AREA     VOLUME       DISCH   FLO-THRU ***
    (FT)   (ACRES)   (AC-FT)       (CFS)      (MIN) ***
     0.0        0.0        0.0         0.0
   0.366       5.77       2.11         1.0
   0.395        6.3       2.49         2.0
   0.419       6.69        2.8         3.0
   0.444       6.98        3.1         4.0
   0.483       7.45        3.6         6.0
   0.528       7.79       4.11         8.0
   0.568       8.04       4.57        10.0
   0.654       8.55       5.59        15.0
   0.854       9.42       8.04        30.0
   1.139      10.44      11.89        60.0
    1.51      11.98      18.09       120.0
   1.694      17.25      29.23       250.0
    1.97      18.75      36.93       500.0
   2.096      46.64      97.78      1000.0
   2.445      73.22     179.04      2000.0
   3.882      93.62     363.43      4000.0
   5.042     105.39     531.36      6000.0
END FTABLE 33
FTABLE     34
 18    4
   DEPTH       AREA     VOLUME       DISCH   FLO-THRU ***
    (FT)   (ACRES)   (AC-FT)       (CFS)      (MIN) ***
     0.0        0.0        0.0         0.0
   0.211       3.13       0.66         1.0
    0.25       3.64       0.91         2.0
   0.284       4.02       1.14         3.0
    0.31       4.35       1.35         4.0
    0.36       4.86       1.75         6.0
   0.398       5.25       2.09         8.0
   0.433       5.56       2.41        10.0
   0.507       6.14       3.11        15.0
   0.698       7.02       4.84        30.0
   0.963       7.63       7.35        60.0
   1.349        8.4      11.33       120.0
   1.962       9.28      18.21       250.0
   2.764       10.6       29.3       500.0
   3.391      14.17      48.05      1000.0
   3.636      22.42      81.53      2000.0
   4.174      34.02     141.99      4000.0
   5.006      39.56     198.03      6000.0
END FTABLE 34
FTABLE     35
 18    4
   DEPTH       AREA     VOLUME       DISCH   FLO-THRU ***
    (FT)   (ACRES)   (AC-FT)       (CFS)      (MIN) ***
     0.0        0.0        0.0         0.0
   0.578      10.05       5.81         1.0
```

```
    0.602     10.44      6.29       2.0
    0.621      10.8      6.71       3.0
    0.643     11.11      7.14       4.0
    0.683     11.52      7.87       6.0
    0.717     11.89      8.52       8.0
    0.742     12.19      9.05      10.0
    0.803     12.83      10.3      15.0
    0.944      14.2     13.41      30.0
    1.148     16.06     18.44      60.0
    1.466     18.08     26.51     120.0
    1.949     20.86     40.66     250.0
    2.698     24.06     64.92     500.0
    3.399     31.67    107.64    1000.0
    3.582     65.75    235.51    2000.0
    5.284     95.95    507.03    4000.0
    7.896    116.87    922.77    6000.0
END FTABLE 35
FTABLE     26
 14    5
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (CFS) ***
      0.0       0.0       0.0       0.0       0.0
      1.1     0.654     0.707      41.0       0.0
      2.2     1.309     2.827      63.0       0.0
      3.2     1.963     6.362      95.0       0.0
      4.3     2.618    11.309     119.0       0.0
      5.4     3.273    17.674     132.0       0.0
      6.5     3.927     25.45     148.7       0.0
      7.6     4.582    34.639     169.4       0.0
      8.6     5.236    45.242     194.1       0.0
      9.7     5.891    57.259     238.7       0.0
     10.8     6.545     70.69     293.4       0.0
     11.3     6.873    77.935     335.7       0.0
     11.9       7.2    85.534     386.1       0.0
     12.4     7.527    93.486     446.4       0.0
END FTABLE 26
FTABLE     36
 18    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.0       0.0       0.0       0.0
    0.227      4.15      0.94       1.0
    0.286      4.54       1.3       2.0
    0.335      4.86      1.63       3.0
    0.378      5.13      1.94       4.0
    0.455      5.52      2.51       6.0
    0.523      5.79      3.03       8.0
    0.586      5.96      3.49      10.0
    0.722      6.32      4.56      15.0
    1.045      6.84      7.15      30.0
     1.55      7.29      11.3      60.0
    2.291      7.95     18.21     120.0
     3.05     10.08     30.74     250.0
    3.982     13.64     54.31     500.0
    5.186     18.65     96.71    1000.0
```

```
     6.973      24.18     168.61     2000.0
     9.365      32.12     300.81     4000.0
    10.884      45.57     495.99     6000.0
  END FTABLE 36
END FTABLES
END RUN
```

APPENDIX B

Beargrass Creek—South Fork
user control input (UCI)

```
RUN
GLOBAL
BEARGRASS CREEK--South Fork
  START       1991  6  1  0  0  END    1994  5 31 24  0
  RUN INTERP OUTPUT LEVEL    5
  RESUME     0 RUN     1 TSSFL     0 WDMSFL    0 UNITS     1
END GLOBAL
FILES
<type>  <fun>***<------------fname---------------------------------------------->
INFO       21   hspinf.da
ERROR      22   hsperr.da
WARN       23   hspwrn.da
MESSU      25   sf5.ech
WDM        26   sf5.wdm
           90   sf5.out
END FILES
OPN SEQUENCE
    INGRP              INDELT  0: 5
      IMPLND     612
      IMPLND     614
      IMPLND     622
      IMPLND     632
      PERLND     312
      PERLND     322
      PERLND     332
      PERLND     412
      PERLND     422
      PERLND     512
      PERLND     514
      PERLND     522
      RCHRES      21
      PERLND     314
      PERLND     315
      PERLND     324
      PERLND     511
      PERLND     521
      PERLND     524
      IMPLND     611
      IMPLND     615
      IMPLND     624
      RCHRES      31
      IMPLND     625
      IMPLND     635
      PERLND     325
      PERLND     415
      PERLND     515
      PERLND     525
      PERLND     535
      RCHRES      22
      PERLND     425
      RCHRES      32
      IMPLND     613
      IMPLND     621
      IMPLND     623
      IMPLND     633
```

```
      PERLND     333
      PERLND     334
      PERLND     513
      PERLND     523
      RCHRES      23
      PERLND     323
      PERLND     331
      PERLND     335
      IMPLND     634
      RCHRES      33
 ***
 ***  The network of PERLNDs, IMPLNDs, and RCHRESs listed above
 ***  describes the watershed above the South Fork Beargrass
 ***  Creek at Louisville, Kentucky, streamflow gage (no. 03292500).
 ***  The network of PERLNDs, IMPLNDs, and RCHRESs listed below
 ***  describes the South Fork of Beargrass Creek below the streamflow
 ***  gage to approximately Logan Street in Louisville.  The UCI is
 ***  currently configured to simulate the watershed up to the
 ***  streamflow gage.  To simulate the entire watershed delete
 ***  the *** in the lines below and line up the unit names and numbers
 ***  with the previous lines.  The External Targets Block should also
 ***  be modified when simulating the entire watershed.
 ***
 ***  PERLND     313
 ***  IMPLND     631
 ***  RCHRES      34
      COPY       100
    END INGRP
END OPN SEQUENCE
PERLND
  ACTIVITY
    <PLS >               Active Sections                               ***
    x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
  312  535    0    0    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
  PRINT-INFO
    <PLS> ******************** Print-flags ************************ PIVL  PYR
    x - x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC *********
  312  535              4                                             1    5
  END PRINT-INFO
  GEN-INFO
    <PLS >      Name            NBLKS   Unit-systems   Printer***
    x -  x                                t-series Engl Metr***
                                           in  out          ***
  312  335LAWN                      1        1    1   90    0
  412  425RIPARIAN                  1        1    1   90    0
  511  535WOODED                    1        1    1   90    0
  END GEN-INFO
  PWAT-PARM1
*** <PLS >                  Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE
  312  535    0    1    1    1    1    0    0    0    1
  END PWAT-PARM1
  PWAT-PARM2
***  <PLS>    FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
```

```
***  x - x              (in)   (in/hr)     (ft)            (1/in)   (1/day)
  312  315      0.0      2.6      0.05    100.0      0.04      0.4      0.96
  322  325      0.0      2.5      0.04     75.0      0.08      0.7      0.95
  331  335      0.0      2.6      0.04     50.0      0.15      0.9      0.94
  412  415      0.0     10.5      0.42    100.0      0.04      0.4      0.96
  422  425      0.0     11.9      0.25     75.0      0.08      0.7      0.95
  511  515      0.0      7.9      0.29    100.0      0.04      0.4      0.96
  521  525      0.0      6.9      0.15     75.0      0.08      0.7      0.95
  535           0.0      6.5      0.13     50.0      0.15      0.9      0.94
  END PWAT-PARM2
  PWAT-PARM3
***  <PLS>   PETMAX   PETMIN   INFEXP   INFILD   DEEPFR   BASETP   AGWETP
***  x - x  (deg F)  (deg F)
  312  315     40.0     35.0      2.5      2.0     0.01     0.05    0.005
  322  325     40.0     35.0      1.0      2.0     0.01     0.05    0.005
  331  335     40.0     35.0      0.5      2.0     0.01     0.05    0.005
  412  415     40.0     35.0      2.5      2.0     0.01     0.05    0.005
  422  425     40.0     35.0      1.0      2.0     0.01     0.05    0.005
  511  515     40.0     35.0      2.5      2.0     0.01     0.05    0.005
  521  525     40.0     35.0      1.0      2.0     0.01     0.05    0.005
  535          40.0     35.0      0.5      2.0     0.01     0.05    0.005
  END PWAT-PARM3
  PWAT-PARM4
*** <PLS >    CEPSC     UZSN     NSUR    INTFW      IRC    LZETP
*** x -  x     (in)     (in)                   (1/day)
  312  315      0.2     0.83     0.25     10.0     0.17     0.47
  322  325      0.2     0.65     0.25     10.0     0.27     0.49
  331  335      0.2     0.52     0.25     10.0     0.37     0.49
  412  415      0.2     0.54     0.25     10.0     0.17     0.31
  422  425      0.2      0.5     0.25     10.0     0.27     0.37
  511  515      0.2     0.78     0.25     10.0     0.17     0.44
  521  525      0.2     0.44     0.25     10.0     0.27     0.33
  535           0.2     0.38     0.25     10.0     0.37     0.36
  END PWAT-PARM4
  MON-INTERCEP
*** <PLS >  Interception storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  312  315  0.1 0.11 0.12 0.13 0.14 0.16 0.16 0.16 0.15 0.14 0.12  0.1
  322  325 0.09  0.1 0.09 0.11 0.11 0.13 0.14 0.14 0.13 0.11 0.11 0.09
  331  425 0.07 0.09 0.09 0.11 0.11 0.12 0.12 0.12 0.11 0.09 0.08 0.07
  511  515 0.09  0.1 0.13 0.13 0.14 0.16 0.16 0.16 0.15 0.14 0.12 0.08
  521  535 0.04 0.05 0.07 0.08 0.09 0.09 0.11 0.11 0.09 0.07 0.06 0.04
  END MON-INTERCEP
  MON-UZSN
*** <PLS >  Upper zone storage at start of each month  (inches)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  312  315 0.63 0.63 0.63 0.63  0.6 0.55 0.52 0.52 0.63 0.68 0.73 0.66
  322  325  0.5 0.55  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5 0.55
  331  335 0.42 0.42 0.42 0.42 0.42 0.42 0.43 0.43 0.43 0.43 0.43 0.42
  412  415 0.44 0.44 0.44 0.44 0.34 0.34 0.35 0.35 0.35 0.35 0.45 0.44
  422  425  0.4  0.4  0.4  0.4  0.4  0.4 0.42 0.42 0.42 0.42 0.42  0.4
  511  515 0.68 0.68 0.68 0.68 0.58  0.6  0.6  0.6  0.6  0.6  0.7 0.68
  521  525 0.34 0.34 0.34 0.34 0.34 0.34 0.35 0.35 0.35 0.35 0.35 0.34
  535      0.28 0.28 0.28 0.28 0.28 0.28  0.3  0.3  0.3  0.3  0.3 0.28
  END MON-UZSN
```

```
  MON-LZETPARM
*** <PLS >  Lower zone evapotransp   parm at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  312  315 0.31 0.31 0.37  0.4 0.56 0.65 0.72 0.73 0.64 0.52 0.49 0.33
  322  335 0.32 0.32 0.39 0.42 0.59 0.66 0.75 0.76 0.66 0.54  0.5 0.34
  412  415 0.19 0.19 0.24 0.26 0.33  0.4  0.5 0.51  0.4 0.38 0.35 0.21
  422  425 0.22 0.22 0.28 0.31 0.42  0.5 0.59  0.6  0.5 0.43  0.4 0.24
  511  515 0.27 0.27 0.35 0.37 0.52  0.6  0.7 0.71  0.6 0.52 0.46 0.29
  521  525  0.2  0.2 0.26 0.28 0.36 0.44 0.53 0.54 0.44  0.4 0.37 0.22
  535      0.22 0.22 0.28 0.31  0.4 0.47 0.57 0.58 0.47 0.42  0.4 0.24
  END MON-LZETPARM
  PWAT-STATE1
***  <PLS>  PWATER state variables (in)
***  x - x       CEPS       SURS        UZS       IFWS        LZS       AGWS       GWVS
  312  535        0.0        0.0       0.94       0.08        9.9        0.2        0.0
  END PWAT-STATE1
END PERLND
IMPLND
  ACTIVITY
*** <ILS >               Active Sections
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL
  611  635    0    0    1    0    0    0
  END ACTIVITY
  PRINT-INFO
    <ILS > ******** Print-flags ******** PIVL  PYR
    x -  x ATMP SNOW IWAT  SLD  IWG IQAL *********
  611  635              4                   1    5
  END PRINT-INFO
  GEN-INFO
*** <ILS >      Name             Unit-systems   Printer
*** <ILS >                           t-series Engl Metr
*** x -  x                             in  out
  611  635ROADS/URBAN                   1    1   90    0
  END GEN-INFO
  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
  611  635    0    1    0    0    0
  END IWAT-PARM1
  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                          (ft)
  611  615     100.0      0.04     0.025      0.07
  621  625     100.0      0.09     0.025      0.05
  631  635     100.0      0.15     0.025      0.03
  END IWAT-PARM2
  IWAT-PARM3
*** <ILS >    PETMAX    PETMIN
*** x -  x   (deg F)   (deg F)
  611  635      40.0      35.0
  END IWAT-PARM3
  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
  611  635     0.001     0.001
```

```
  END IWAT-STATE1
END IMPLND
RCHRES
  ACTIVITY
*** RCHRES  Active sections
*** x -  x HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG
   21   34    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY
  PRINT-INFO
*** RCHRES  Printout level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
   21   34    5                                                  1    5
  END PRINT-INFO
  GEN-INFO
***              Name          Nexits   Unit Systems   Printer
*** RCHRES                                t-series  Engl Metr LKFG
*** x -  x                                  in  out
   21   23PONDS LAKES BASINS      1          1    1   90    0    0
   31   34BEARGRASS CK            1          1    1   90    0    0
  END GEN-INFO
  HYDR-PARM1
***        Flags for HYDR section
    RCHRES  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
     x - x  FG FG FG FG  possible   exit *** possible   exit     possible   exit
   21   34   0  1  1  1    4  0  0  0  0      0  0  0  0  0        1  1  1  1  1
  END HYDR-PARM1
  HYDR-PARM2
*** RCHRES FTBW FTBU       LEN     DELTH     STCOR        KS      DB50
*** x -  x             (miles)      (ft)      (ft)                (in)
   21       0.0 21.0       0.5      43.6       0.0       0.5      0.01
   22       0.0 22.0       0.5      33.9       0.0       0.5      0.07
   23       0.0 23.0       0.5      20.9       0.0       0.5      0.05
   31       0.0 31.0       4.2      43.6       0.0       0.5      0.01
   32       0.0 32.0       3.1      33.9       0.0       0.5      0.07
   33       0.0 33.0       3.4      20.9       0.0       0.5      0.05
   34       0.0 34.0       3.2      13.3       0.0       0.5      0.04
  END HYDR-PARM2
  HYDR-INIT
***        Initial conditions for HYDR section
*** RCHRES       VOL  CAT Initial value  of COLIND     initial  value  of OUTDGT
***   x - x     ac-ft      for each possible   exit  for each possible exit,ft3
   21   34      1.09  0.0  4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
  END HYDR-INIT
END RCHRES
COPY
  TIMESERIES
  Copy-opn***
*** x -  x  NPT  NMN
  100         0    7
  END TIMESERIES
END COPY
EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   x <Name> x tem strg<-factor->strg <Name>   x   x        <Name> x x  ***
WDM   1006 PREC   10 ENGL              SAME PERLND 331     EXTNL  PREC   1 1
```

```
WDM    2251 PET    10 ENGL              DIV  PERLND 331     EXTNL  PETINP 1 1
WDM    1006 PREC   10 ENGL              SAME PERLND 511     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 511     EXTNL  PETINP 1 1
WDM    1006 PREC   10 ENGL              SAME PERLND 521     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 521     EXTNL  PETINP 1 1
WDM    1006 PREC   10 ENGL              SAME IMPLND 611     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  IMPLND 611     EXTNL  PETINP 1 1
WDM    1006 PREC   10 ENGL              SAME IMPLND 621     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  IMPLND 621     EXTNL  PETINP 1 1
WDM    1006 PREC   10 ENGL              SAME IMPLND 631     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  IMPLND 631     EXTNL  PETINP 1 1
WDM    1008 PREC   10 ENGL              SAME PERLND 312     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 312     EXTNL  PETINP 1 1
WDM    1008 PREC   10 ENGL              SAME PERLND 322     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 322     EXTNL  PETINP 1 1
WDM    1008 PREC   10 ENGL              SAME PERLND 332     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 332     EXTNL  PETINP 1 1
WDM    1008 PREC   10 ENGL              SAME PERLND 412     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 412     EXTNL  PETINP 1 1
WDM    1008 PREC   10 ENGL              SAME PERLND 422     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 422     EXTNL  PETINP 1 1
WDM    1008 PREC   10 ENGL              SAME PERLND 512     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 512     EXTNL  PETINP 1 1
WDM    1008 PREC   10 ENGL              SAME PERLND 522     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 522     EXTNL  PETINP 1 1
WDM    1008 PREC   10 ENGL              SAME IMPLND 612     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  IMPLND 612     EXTNL  PETINP 1 1
WDM    1008 PREC   10 ENGL              SAME IMPLND 622     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  IMPLND 622     EXTNL  PETINP 1 1
WDM    1008 PREC   10 ENGL              SAME IMPLND 632     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  IMPLND 632     EXTNL  PETINP 1 1
WDM    1019 PREC   10 ENGL              SAME PERLND 313     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 313     EXTNL  PETINP 1 1
WDM    1019 PREC   10 ENGL              SAME PERLND 323     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 323     EXTNL  PETINP 1 1
WDM    1019 PREC   10 ENGL              SAME PERLND 333     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 333     EXTNL  PETINP 1 1
WDM    1019 PREC   10 ENGL              SAME PERLND 513     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 513     EXTNL  PETINP 1 1
WDM    1019 PREC   10 ENGL              SAME PERLND 523     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 523     EXTNL  PETINP 1 1
WDM    1019 PREC   10 ENGL              SAME IMPLND 613     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  IMPLND 613     EXTNL  PETINP 1 1
WDM    1019 PREC   10 ENGL              SAME IMPLND 623     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  IMPLND 623     EXTNL  PETINP 1 1
WDM    1019 PREC   10 ENGL              SAME IMPLND 633     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  IMPLND 633     EXTNL  PETINP 1 1
WDM    1022 PREC   10 ENGL              SAME PERLND 314     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 314     EXTNL  PETINP 1 1
WDM    1022 PREC   10 ENGL              SAME PERLND 324     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 324     EXTNL  PETINP 1 1
WDM    1022 PREC   10 ENGL              SAME PERLND 334     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 334     EXTNL  PETINP 1 1
WDM    1022 PREC   10 ENGL              SAME PERLND 514     EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL              DIV  PERLND 514     EXTNL  PETINP 1 1
```

```
WDM    1022 PREC   10 ENGL                  SAME PERLND 524      EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL                  DIV  PERLND 524      EXTNL  PETINP 1 1
WDM    1022 PREC   10 ENGL                  SAME IMPLND 614      EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL                  DIV  IMPLND 614      EXTNL  PETINP 1 1
WDM    1022 PREC   10 ENGL                  SAME IMPLND 624      EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL                  DIV  IMPLND 624      EXTNL  PETINP 1 1
WDM    1022 PREC   10 ENGL                  SAME IMPLND 634      EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL                  DIV  IMPLND 634      EXTNL  PETINP 1 1
WDM    1024 PREC   10 ENGL                  SAME PERLND 315      EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL                  DIV  PERLND 315      EXTNL  PETINP 1 1
WDM    1024 PREC   10 ENGL                  SAME PERLND 325      EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL                  DIV  PERLND 325      EXTNL  PETINP 1 1
WDM    1024 PREC   10 ENGL                  SAME PERLND 335      EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL                  DIV  PERLND 335      EXTNL  PETINP 1 1
WDM    1024 PREC   10 ENGL                  SAME PERLND 415      EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL                  DIV  PERLND 415      EXTNL  PETINP 1 1
WDM    1024 PREC   10 ENGL                  SAME PERLND 425      EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL                  DIV  PERLND 425      EXTNL  PETINP 1 1
WDM    1024 PREC   10 ENGL                  SAME PERLND 515      EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL                  DIV  PERLND 515      EXTNL  PETINP 1 1
WDM    1024 PREC   10 ENGL                  SAME PERLND 525      EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL                  DIV  PERLND 525      EXTNL  PETINP 1 1
WDM    1024 PREC   10 ENGL                  SAME PERLND 535      EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL                  DIV  PERLND 535      EXTNL  PETINP 1 1
WDM    1024 PREC   10 ENGL                  SAME IMPLND 615      EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL                  DIV  IMPLND 615      EXTNL  PETINP 1 1
WDM    1024 PREC   10 ENGL                  SAME IMPLND 625      EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL                  DIV  IMPLND 625      EXTNL  PETINP 1 1
WDM    1024 PREC   10 ENGL                  SAME IMPLND 635      EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL                  DIV  IMPLND 635      EXTNL  PETINP 1 1
WDM    1024 PREC   10 ENGL                  SAME RCHRES  21   34 EXTNL  PREC   1 1
WDM    2251 PET    10 ENGL                  DIV  RCHRES  21   34 EXTNL  POTEV  1 1
END EXT SOURCES
EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
 ***
 ***  The first two lines below specify that the average depth and discharge at
 ***  the streamflow gage South Fork Beargrass Creek at Louisville, Kentucky,
 ***  (no. 03292500) are loaded into WDM files 441 and 442, respectively.  If
 ***  the entire watershed is to be simulated similar lines need to be added for
 ***  RCHRES 34.  New WDM files (numbers different from 441 and 442) should be
 ***  generated in ANNIE and specified as the external targets for simulation
 ***  results for RCHRES 34.
 ***
RCHRES  33 HYDR   AVDEP  1 1                WDM    441 AVDE   1 ENGL AGGR REPL
RCHRES  33 HYDR   RO     1 1                WDM    442 DISC   1 ENGL AGGR REPL
RCHRES  33 ROFLOW ROVOL  1 1  0.001152      WDM    420 SIMQ   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   1 1  0.000096      WDM    421 SURO   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   2 1  0.000096      WDM    422 IFWO   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   3 1  0.000096      WDM    423 AGWO   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   4 1  0.000096      WDM    425 PETX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   5 1  0.000096      WDM    426 SAET   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   6 1  0.000096      WDM    427 UZSX   1 ENGL AGGR REPL
COPY   100 OUTPUT MEAN   7 1  0.000096      WDM    428 LZSX   1 ENGL AGGR REPL
```

```
END EXT TARGETS
SCHEMATIC
<-Volume->                    <--Area-->     <-Volume->  <ML#>  ***
<Name>   x                    <-factor->     <Name>   x         ***
PERLND 312                           2.7     RCHRES   21       1
PERLND 322                           4.6     RCHRES   21       1
PERLND 332                          76.6     RCHRES   21       1
PERLND 412                         499.1     RCHRES   21       1
PERLND 422                           2.6     RCHRES   21       1
PERLND 512                          42.7     RCHRES   21       1
PERLND 514                           0.3     RCHRES   21       1
PERLND 522                          93.9     RCHRES   21       1
IMPLND 612                         158.4     RCHRES   21       2
IMPLND 614                           0.2     RCHRES   21       2
IMPLND 622                           6.6     RCHRES   21       2
IMPLND 632                           3.3     RCHRES   21       2
PERLND 312                          19.6     RCHRES   31       1
PERLND 314                          49.7     RCHRES   31       1
PERLND 315                          23.2     RCHRES   31       1
PERLND 322                           6.1     RCHRES   31       1
PERLND 324                           4.8     RCHRES   31       1
PERLND 332                          80.3     RCHRES   31       1
PERLND 412                        1376.1     RCHRES   31       1
PERLND 422                           1.5     RCHRES   31       1
PERLND 511                         122.5     RCHRES   31       1
PERLND 512                         117.2     RCHRES   31       1
PERLND 514                         689.2     RCHRES   31       1
PERLND 521                           3.1     RCHRES   31       1
PERLND 522                         208.1     RCHRES   31       1
PERLND 524                           6.4     RCHRES   31       1
IMPLND 611                          56.8     RCHRES   31       2
IMPLND 612                         437.3     RCHRES   31       2
IMPLND 614                         563.4     RCHRES   31       2
IMPLND 615                           8.1     RCHRES   31       2
IMPLND 622                          15.5     RCHRES   31       2
IMPLND 624                           5.3     RCHRES   31       2
IMPLND 632                           3.6     RCHRES   31       2
PERLND 315                           6.0     RCHRES   22       1
PERLND 325                           0.1     RCHRES   22       1
PERLND 412                          91.9     RCHRES   22       1
PERLND 415                           2.0     RCHRES   22       1
PERLND 422                           2.6     RCHRES   22       1
PERLND 515                          36.9     RCHRES   22       1
PERLND 525                           9.4     RCHRES   22       1
PERLND 535                           2.7     RCHRES   22       1
IMPLND 612                          15.8     RCHRES   22       2
IMPLND 615                          11.0     RCHRES   22       2
IMPLND 622                           0.2     RCHRES   22       2
IMPLND 625                           2.0     RCHRES   22       2
IMPLND 635                           0.5     RCHRES   22       2
PERLND 314                           3.6     RCHRES   32       1
PERLND 315                         161.1     RCHRES   32       1
PERLND 325                           7.6     RCHRES   32       1
PERLND 412                         551.8     RCHRES   32       1
PERLND 415                         119.4     RCHRES   32       1
```

PERLND 422	2.6	RCHRES	32	1
PERLND 425	7.1	RCHRES	32	1
PERLND 514	44.9	RCHRES	32	1
PERLND 515	847.0	RCHRES	32	1
PERLND 525	42.9	RCHRES	32	1
PERLND 535	3.8	RCHRES	32	1
IMPLND 612	95.1	RCHRES	32	2
IMPLND 614	40.9	RCHRES	32	2
IMPLND 615	277.0	RCHRES	32	2
IMPLND 625	0.8	RCHRES	32	2
IMPLND 635	10.9	RCHRES	32	2
PERLND 333	2.4	RCHRES	23	1
PERLND 334	1.9	RCHRES	23	1
PERLND 511	62.4	RCHRES	23	1
PERLND 513	15.5	RCHRES	23	1
PERLND 514	43.8	RCHRES	23	1
PERLND 521	3.7	RCHRES	23	1
PERLND 523	5.1	RCHRES	23	1
PERLND 524	15.1	RCHRES	23	1
IMPLND 611	51.3	RCHRES	23	2
IMPLND 613	6.5	RCHRES	23	2
IMPLND 614	18.9	RCHRES	23	2
IMPLND 621	1.6	RCHRES	23	2
IMPLND 623	2.3	RCHRES	23	2
IMPLND 624	5.4	RCHRES	23	2
IMPLND 633	1.6	RCHRES	23	2
PERLND 314	39.0	RCHRES	33	1
PERLND 315	239.3	RCHRES	33	1
PERLND 323	3.8	RCHRES	33	1
PERLND 324	40.6	RCHRES	33	1
PERLND 325	13.2	RCHRES	33	1
PERLND 331	5.8	RCHRES	33	1
PERLND 333	22.6	RCHRES	33	1
PERLND 334	71.1	RCHRES	33	1
PERLND 335	5.7	RCHRES	33	1
PERLND 511	427.4	RCHRES	33	1
PERLND 513	37.2	RCHRES	33	1
PERLND 514	1227.3	RCHRES	33	1
PERLND 521	26.9	RCHRES	33	1
PERLND 523	26.4	RCHRES	33	1
PERLND 524	154.0	RCHRES	33	1
IMPLND 611	351.0	RCHRES	33	2
IMPLND 613	15.5	RCHRES	33	2
IMPLND 614	531.2	RCHRES	33	2
IMPLND 615	59.9	RCHRES	33	2
IMPLND 621	11.9	RCHRES	33	2
IMPLND 623	11.9	RCHRES	33	2
IMPLND 624	64.9	RCHRES	33	2
IMPLND 625	5.2	RCHRES	33	2
IMPLND 633	11.1	RCHRES	33	2
IMPLND 634	25.8	RCHRES	33	2
PERLND 313	19.9	RCHRES	34	1
PERLND 323	34.6	RCHRES	34	1
PERLND 331	55.1	RCHRES	34	1
PERLND 333	378.4	RCHRES	34	1

PERLND 511	132.5	RCHRES	34	1
PERLND 513	1253.8	RCHRES	34	1
PERLND 514	22.7	RCHRES	34	1
PERLND 521	64.8	RCHRES	34	1
PERLND 523	430.4	RCHRES	34	1
PERLND 524	2.5	RCHRES	34	1
IMPLND 611	93.1	RCHRES	34	2
IMPLND 613	576.3	RCHRES	34	2
IMPLND 614	10.7	RCHRES	34	2
IMPLND 621	35.4	RCHRES	34	2
IMPLND 623	144.0	RCHRES	34	2
IMPLND 631	25.7	RCHRES	34	2
IMPLND 633	72.9	RCHRES	34	2
RCHRES 21		RCHRES	31	3
RCHRES 31		RCHRES	33	3
RCHRES 22		RCHRES	32	3
RCHRES 32		RCHRES	33	3
RCHRES 23		RCHRES	33	3
RCHRES 33		RCHRES	34	3
PERLND 312	22.3	COPY	100	90
PERLND 313	19.9	COPY	100	90
PERLND 314	92.4	COPY	100	90
PERLND 315	429.5	COPY	100	90
PERLND 322	10.7	COPY	100	90
PERLND 323	38.4	COPY	100	90
PERLND 324	45.4	COPY	100	90
PERLND 325	20.9	COPY	100	90
PERLND 331	60.9	COPY	100	90
PERLND 332	156.9	COPY	100	90
PERLND 333	403.5	COPY	100	90
PERLND 334	73.0	COPY	100	90
PERLND 335	5.7	COPY	100	90
PERLND 412	2518.8	COPY	100	90
PERLND 415	121.4	COPY	100	90
PERLND 422	9.3	COPY	100	90
PERLND 425	7.1	COPY	100	90
PERLND 511	744.8	COPY	100	90
PERLND 512	159.9	COPY	100	90
PERLND 513	1306.3	COPY	100	90
PERLND 514	2028.2	COPY	100	90
PERLND 515	883.9	COPY	100	90
PERLND 521	98.5	COPY	100	90
PERLND 522	302.0	COPY	100	90
PERLND 523	462.0	COPY	100	90
PERLND 524	178.0	COPY	100	90
PERLND 525	52.3	COPY	100	90
PERLND 535	6.5	COPY	100	90
IMPLND 611	552.2	COPY	100	91
IMPLND 612	706.5	COPY	100	91
IMPLND 613	598.3	COPY	100	91
IMPLND 614	1165.2	COPY	100	91
IMPLND 615	356.1	COPY	100	91
IMPLND 621	49.0	COPY	100	91
IMPLND 622	22.3	COPY	100	91
IMPLND 623	158.3	COPY	100	91

```
IMPLND 624                        75.7     COPY   100     91
IMPLND 625                         7.9     COPY   100     91
IMPLND 631                        25.7     COPY   100     91
IMPLND 632                         6.9     COPY   100     91
IMPLND 633                        85.6     COPY   100     91
IMPLND 634                        25.8     COPY   100     91
IMPLND 635                        11.4     COPY   100     91
END SCHEMATIC
MASS-LINK
  MASS-LINK       1
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER PERO       0.0833333     RCHRES         INFLOW IVOL
  END MASS-LINK   1
  MASS-LINK       2
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO       0.0833333     RCHRES         INFLOW IVOL
  END MASS-LINK   2
  MASS-LINK       3
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
RCHRES     HYDR   ROVOL  1                 RCHRES         INFLOW IVOL
  END MASS-LINK   3
  MASS-LINK       90
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER SURO                     COPY           INPUT  MEAN   1
PERLND     PWATER IFWO                     COPY           INPUT  MEAN   2
PERLND     PWATER AGWO                     COPY           INPUT  MEAN   3
PERLND     PWATER PET                      COPY           INPUT  MEAN   4
PERLND     PWATER TAET                     COPY           INPUT  MEAN   5
PERLND     PWATER UZS                      COPY           INPUT  MEAN   6
PERLND     PWATER LZS                      COPY           INPUT  MEAN   7
  END MASS-LINK   90
  MASS-LINK       91
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO                     COPY           INPUT  MEAN   1
IMPLND     IWATER PET                      COPY           INPUT  MEAN   4
IMPLND     IWATER IMPEV                    COPY           INPUT  MEAN   5
  END MASS-LINK   91
END MASS-LINK
FTABLES
  FTABLE     21
   14    5
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (CFS) ***
       0.0       0.0       0.0       0.0       0.0
       1.2     0.725     0.867       0.6       0.0
       2.4      1.45     3.467       8.0       0.0
       3.6     2.174     7.801      22.0       0.0
       4.8     2.899    13.869      74.0       0.0
       6.0     3.624    21.674     136.0       0.0
       7.2     4.349     31.21     315.0       2.1
```

```
      8.4      5.074      42.48      419.7          2.6
      9.6      5.799     55.483      556.5          3.1
     10.8      6.524      70.22      775.2          3.7
     12.0      7.248      86.69     1035.0          4.2
     12.6      7.611     95.576     1035.4          4.4
     13.2      7.973    104.895     1066.7          4.7
     13.8      8.336    114.647     2097.1          5.0
  END FTABLE 21
  FTABLE     31
   18    4
     DEPTH      AREA     VOLUME      DISCH   FLO-THRU ***
      (FT)   (ACRES)    (AC-FT)      (CFS)      (MIN) ***
      0.0        0.0        0.0        0.0
     0.119  9.429999       1.12        1.0
     0.165  9.660001        1.6        2.0
     0.202      9.87       1.99        3.0
     0.232     10.02       2.32        4.0
     0.285     10.23       2.91        6.0
      0.33     10.37       3.42        8.0
     0.372      10.5        3.9       10.0
     0.445     11.29       5.02       15.0
     0.618     12.54       7.75       30.0
     0.908     13.31      12.08       60.0
     1.311     14.41      18.88      120.0
     1.916     16.04      30.74      250.0
      2.63     19.12      50.28      500.0
     2.785     32.12      89.47     1000.0
     2.899     60.38     175.03     2000.0
     4.016  76.28999     306.35     4000.0
     5.446     78.98     430.08     6000.0
  END FTABLE 31
  FTABLE     22
   14    5
     DEPTH      AREA     VOLUME      DISCH   FLO-THRU ***
      (FT)   (ACRES)    (AC-FT)      (CFS)      (CFS) ***
      0.0        0.0        0.0        0.0        0.0
      1.2      0.725      0.867        0.6        0.0
      2.4       1.45      3.467        8.0        0.0
      3.6      2.174      7.801       22.0        0.0
      4.8      2.899     13.869       74.0        0.0
      6.0      3.624     21.674      136.0        0.0
      7.2      4.349      31.21      315.0        2.1
      8.4      5.074      42.48      419.7        2.6
      9.6      5.799     55.483      556.5        3.1
     10.8      6.524      70.22      775.2        3.7
     12.0      7.248      86.69     1035.0        4.2
     12.6      7.611     95.576     1035.4        4.4
     13.2      7.973    104.895     1066.7        4.7
     13.8      8.336    114.647     2097.1        5.0
  END FTABLE 22
  FTABLE     32
   18    4
     DEPTH      AREA     VOLUME      DISCH   FLO-THRU ***
      (FT)   (ACRES)    (AC-FT)      (CFS)      (MIN) ***
      0.0        0.0        0.0        0.0
```

```
   0.139      4.91       0.68        1.0
   0.193      5.02       0.97        2.0
   0.236      5.13       1.21        3.0
   0.271      5.21       1.41        4.0
   0.333      5.32       1.77        6.0
   0.386      5.39       2.08        8.0
   0.434      5.46       2.37       10.0
   0.521      5.87       3.05       15.0
   0.722      6.52       4.71       30.0
   1.061      6.92       7.34       60.0
   1.531      7.49      11.47      120.0
   2.239      8.34      18.67      250.0
   3.072      9.94      30.54      500.0
   3.254     16.71      54.34     1000.0
   3.387     31.39     106.31     2000.0
   4.692     39.66     186.07     4000.0
   6.362     41.06     261.22     6000.0
END FTABLE 32
FTABLE     23
 14    5
   DEPTH      AREA     VOLUME      DISCH   FLO-THRU ***
    (FT)   (ACRES)    (AC-FT)      (CFS)      (CFS) ***
     0.0       0.0        0.0        0.0        0.0
     1.2     0.725      0.867        0.6        0.0
     2.4      1.45      3.467        8.0        0.0
     3.6     2.174      7.801       22.0        0.0
     4.8     2.899     13.869       74.0        0.0
     6.0     3.624     21.674      136.0        0.0
     7.2     4.349      31.21      315.0        2.1
     8.4     5.074      42.48      419.7        2.6
     9.6     5.799     55.483      556.5        3.1
    10.8     6.524      70.22      775.2        3.7
    12.0     7.248      86.69     1035.0        4.2
    12.6     7.611     95.576     1035.4        4.4
    13.2     7.973    104.895     1066.7        4.7
    13.8     8.336    114.647     2097.1        5.0
END FTABLE 23
FTABLE     33
 18    4
   DEPTH      AREA     VOLUME      DISCH   FLO-THRU ***
    (FT)   (ACRES)    (AC-FT)      (CFS)      (MIN) ***
     0.0       0.0        0.0        0.0
   0.462     10.59       4.89        1.0
   0.535     11.03       5.89        2.0
   0.596     11.34       6.76        3.0
   0.648     11.58       7.51        4.0
   0.736     11.92       8.78        6.0
   0.809     12.25       9.91        8.0
   0.876     12.52      10.97       10.0
   1.017     13.14      13.37       15.0
   1.332     14.49      19.29       30.0
   1.789     16.05      28.72       60.0
   2.451     17.86      43.78      120.0
   3.406     20.78   70.78999      250.0
   4.052     22.84      92.53      500.0
```

```
      5.461     28.31    154.63    1000.0
      5.571     58.45    325.61    2000.0
      6.255    127.89    800.22    4000.0
      6.714    148.01    993.67    6000.0
   END FTABLE 33
   FTABLE     24
    14    5
      DEPTH      AREA    VOLUME      DISCH  FLO-THRU ***
       (FT)   (ACRES)   (AC-FT)      (CFS)     (CFS) ***
        0.0       0.0       0.0        0.0       0.0
        1.2     0.725     0.867        0.0       0.0
        2.4      1.45     3.467        0.0       0.0
        3.6     2.174     7.801        0.0       0.0
        4.8     2.899    13.869        0.0       0.0
        6.0     3.624    21.674        6.0       0.0
        7.2     4.349     31.21       15.0       2.1
        8.4     5.074     42.48       19.7       2.6
        9.6     5.799    55.483       26.5       3.1
       10.8     6.524     70.22       35.2       3.7
       12.0     7.248     86.69       35.0       4.2
       12.6     7.611    95.576       35.4       4.4
       13.2     7.973   104.895       66.7       4.7
       13.8     8.336   114.647       97.1       5.0
   END FTABLE 24
   FTABLE     34
    18    4
      DEPTH      AREA    VOLUME      DISCH  FLO-THRU ***
       (FT)   (ACRES)   (AC-FT)      (CFS)     (MIN) ***
        0.0       0.0       0.0        0.0
      0.361     12.81      4.61        1.0
      0.421     15.08      6.35        2.0
      0.483     15.36      7.42        3.0
      0.544     15.56  8.469999        4.0
      0.597     16.95     10.11        6.0
      0.635     18.02     11.44        8.0
      0.695     18.41     12.81       10.0
      0.725     21.91     15.91       15.0
      0.901     25.65     23.09       30.0
      1.204     27.16     32.69       60.0
      1.621     29.06     47.11      120.0
      2.326     31.62     73.55      250.0
      3.279     35.28    115.66      500.0
      4.513     40.55    182.99     1000.0
      5.234     60.19    314.98     2000.0
      5.633    114.15    642.97     4000.0
      6.457    226.15   1460.25     6000.0
   END FTABLE 34
END FTABLES
END RUN
```

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