LINKING THE EFFECTS OF LAND USE CHANGE WITH WATER QUALITY AND DISCHARGE: AN INTEGRATED APPROACH

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(ABSTRACT)

Hydrologic and water-quality equilibria are greatly affected by changing land use. This study presents a methodology that integrates the use of remote sensing, geographical information systems (GIS) and water-quality modeling.

Archived aerial photography proved to be a valuable source of historical land use data. GIS technology was used to compile and analyze spatial data. A comprehensive watershed model was used to link the effects of land use change to water quality.

The Cub Run watershed study area, located in northern Virginia experienced significant land use change between 1979 and 1988. Two aspects of development, impervious surface area and construction activity, that impact discharge and water quality were quantified. Developed land increased 11 percent between 1979 and 1988. Seven percent of the 11 percent increase occurred between 1984 and 1988 with medium-density residential housing and commercial areas

accounting for most of the change. As a result of development, the impervious component of the watershed increased 6 percent. Agricultural areas were affected the most by development, decreasing by 13 percent over the 1979 - 1988 time period.

Watershed discharge did not increase as expected with increasing impermeable watershed surface area, indicating that either stormwater control efforts are working and/or the 6 percent increase in impermeable surface area has not affected discharge.

Soil exposed by construction activity increased 5 percent from approximately 1 percent of total surface area in 1979 to 6 percent total surface area in 1988. Significant increases in suspended sediment loads were recorded between 1982 and 1988 when compared to the 1979-1982 time period. Construction activity is the probable cause of this increase.

A watershed-scale comprehensive water-quality model was successfully calibrated and verified to watershed discharge and, to a lesser degree, suspended solids output. Simulation of suspended solids became less reliable with increased construction activity within the watershed.

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1.0 INTRODUCTION

The effect of human activities on a natural system is dramatic. Modification of the land surface to satisfy resource and development needs impacts a variety of biological, physical and chemical equilibria that constitute a natural system. Hydrology and water quality are two aspects of a natural system that are greatly affected by changing land use.

Impervious surface area, which is a result of intense development, has a great impact on hydrology. Modifying land surface characteristics also affects the quality of water discharged from a watershed. Water quality is degraded by pollutants that accumulate on pervious and impervious surfaces during dry periods. These pollutants are later flushed into streams, rivers, lakes or reservoirs during rain events or thaws.

Water quality is also affected by intermediate periods of construction. In many cases, trees and vegetation are completely stripped from the land surface during the site development and construction phase of urbanization. Soil laid bare and compacted without the protection of vegetation is subjected to the erosive power of rain and runoff, resulting in increased suspended solids concentrations (inorganic and organic) during storm events and high levels of sedimentation in streams and ponds.

Concern over water quality and discharge has prompted the development of watershed monitoring programs and the use of comprehensive, water-quality models. Watershed databases compiled from monitoring programs provide an excellent source of information on watershed response to precipitation events. Comprehensive, water-quality models represent one method by which monitored data can be applied to the study of land use change. These types of models have specific spatial data needs, which may include the amount and location of land use characteristics, slope, length and location of drainage channels and soils. Topographic maps and soil surveys are used to obtain some of these data; however, land use characteristics are dynamic and are seldom recorded or mapped at regular intervals over the history of watershed development. Thus, a method is needed by which a watershed database, modeling techniques and historical land use characteristics can be linked.

1.1 Objectives

This study presents an integrated methodology used to examine the effects of land use change on water quality and discharge within a watershed. The objectives of this study were to:

- Identify a suitable source of historical land use data that represent watershed land use at a specific point in time.

- Examine the suitability of geographic information system (GIS) technology to store, manipulate and present spatial data for watershed model applications.

- Demonstrate model application using GIS derived data by calibrating a comprehensive water-quality model to both discharge and suspended solids output.

- Evaluate the integration of multi disciplinary tools as a methodology to study the effects of land use change on watershed discharge and water quality.

1.2 Study Organization

The study was divided into three phases: Land use analysis, GIS application, and hydrologic model application. Historical land use data were obtained from archived aerial photography. GIS technology was used to compile, analyze and summarize these data for application to a watershed-scale, nonpoint source pollution model that linked the land use changes with the hydrologic impacts. Thus, the dynamic effects of land use change on water quality and discharge could be examined.

2.0 LITERATURE REVIEW

The following review is focused on certain aspects of nonpoint source pollution, historical land use analysis, Geographical Information Systems and water-quality modeling, as they relate to this study.

2.1 Nonpoint Source Pollution

Nonpoint, or distributed-source, pollution was not recognized as a serious problem until the late 1960's. Point-source pollution from industries and municipal sewage treatment facilities was recognized as the primary source of water-quality degradation prior to this time. Nonpoint source pollution originates from man-induced or natural sources that are carried in the air or found on land surfaces and are transported by stormwater, runoff or groundwater. Fifty percent or more of current water-quality problems can be attributed to nonpoint source pollution (Novotny and Chesters, 1981).

Human activity, as characterized by different land uses, creates unique nonpoint source pollution problems. Fertilizers, pesticides and detached sediment caused by tillage practices represent pollutants that originate from agricultural land use. Established and developing urban environments create a variety of nonpoint source pollutants including: animal fecal material, litter and refuse, lawn clippings, abraded road surfaces, winter road surface treatments, oil and gas drippings from vehicles, and detached solids from construction activity. The negative aspects of nonpoint source pollution have been well documented (Athahyde, 1983; Byron and Goldman, 1989; Loher, 1974; Mancini, 1988; Taylor, 1977).

Nonpoint source pollution can have both a short- and long-term effect on water quality. Short-term effects are caused by high concentrations of pollutants moving through a system over a short period of time. Long-term affects can be caused by the deposition of harmful materials within receiving waters especially those with extended retention times (Thomman and Mueller, 1987; Haan, et al., 1982). Pollutant sources may originate from material that has accumulated on the land surface between rain events or the re-suspension of harmful materials trapped within sediments.

Urbanization of watersheds impacts water quality. Three characteristics of urban runoff events which, affect water quality include, intermittent loadings, variability of runoff qualities between precipitation events and relatively high concentrations of suspended solids (Mancini, 1988).

Urbanization, which increases impervious surface area, has a profound effect on watershed hydrology. Increased overland flow and decreased infiltration to shallow and deep groundwater systems are the net effects of urban development. One study reports annual watershed discharge increased 51 percent over a 51 year study period within a developing watershed (Owe, 1985). Another study presents seasonal increases in runoff between rural and urban areas as factors ranging from 1.2 for a summer rainstorm, 2.3 for a fall rainstorm and 7.5 for spring snow melt or winter rain/snow combination events (Taylor, 1977). Others relate significant increases in runoff to paved (impervious) surfaces, reporting a 55 percent increase in runoff correlating with a surface area that is 75 percent-100 percent paved (Athahyde, et al., 1983).

Decreased infiltration is another effect of increased impervious surface area, which results in the reduction of evapotranspiration and groundwater recharge. Negative impacts on groundwater recharge reduce base flow within streams (Walseh, 1989). In terms of surface runoff, increased peak discharge is the result of rapid delivery of surface runoff to the drainage system and the reduction of baseflow.

Urbanization increases sediment loads by disrupting the land surface, altering drainage networks and increasing impervious surface area. Particulate matter from urban environments can be more hazardous to the environment than natural erosion products. Atmospheric deposition from industrial, energy and agricultural production and other materials from vehicles and road surface degradation may contain toxic substances that impact water quality. "Total suspended solids concentration in urban runoff are fairly high in comparison with treatment plant discharges", however, suspended solids from urban sources contain more mineral and man-made particulate matter and less organic particulate (Athayde, et al., 1983). A relationship between watershed development and water-quality degradation was demonstrated in Sierra Nevada watersheds based on NO_3-N, total P, and suspended sediment water-quality parameters (Byron and Goldman, 1989).

In 1978 the Environmental Protection Agency implemented the National Urban Runoff Program to investigate the effects of urban runoff on water quality. The final report which was published in 1983 concluded that heavy metals, coliform bacteria, oxygen demanding substances, and total suspended solids are the most significant contributors to water-quality degradation from urban runoff (Athahyde, et al., 1983).

2.2 Historical Land Use Analysis

Field surveys, county records and remote sensing techniques represent several methods by which land use data are compiled. Field surveys are costly and not practical for large watershed studies. They are best suited for verification of data obtained by other less expensive methods. County records may also provide a source of land use data. However, the data can be difficult to obtain and temporally inconsistent. Remote sensing currently offers one of the best methods of obtaining complete land use coverage at a specific point in time.

Within each watershed basin response to precipitation events is based on the individual physical and cultural characteristics of that basin. These characteristics are greatly altered or influenced by urbanization, where the primary effect is the transformation of watershed surface area from a pervious to an impervious nature. This change is illustrated through historical land use analysis.

Concern over the quality of water entering reservoirs has prompted the establishment of watershed\reservoir monitoring networks. Data compiled by these monitoring programs document changing water quality from the sampling perspective; however, the linkage between water quality and land use is not easily established.

Analysis of aerial photography is one method by which land use data sets are compiled (Loelkes, et al. 1983). Analysis of historical aerial photography documents land use change. Starting in the early 1930's U.S. Government Agencies capitalized on the new aerial photographic technology which provided a unique "bird's eye" perspective of the nation's land surface. The Agricultural Adjustment Administration began a program that photographed farms and ranch lands over vast portions of the country (Reeves, et al., 1975). The Forest Service photographed timber reserves, while many areas of the country were photographed by the Geological Survey in order to produce topographic maps (Reeves, et al., 1975). As a result of these early programs and similar programs to follow, including commercial applications of aerial photography, large portions of the United States have been photographed on a repetitive basis. Historical aerial photography is an invaluable permanent documentation of physical and cultural characteristics of the land surface which can be applied to many areas of watershed and land use research (OWE, 1985; Gluck and McCuen, 1975; Turner, 1990).

The Environmental Protection Agency's Environmental Photographic Interpretation Center (EPIC), a field station of the Environmental Monitoring Systems Laboratory, applies historical and current aerial photography to a variety of environmental concerns, some of which include: wetlands, hydrogeology, abandoned oil, gas and irrigation well identification, land use, hazardous waste site analysis and waste disposal discovery inventories.

Black and white, color, and color infrared photography in 9 x 9 inch format represent the most common aerial photographic products encountered, all of which are applicable to land use analysis. Black and white and color photographic emulsions are sensitive to reflected light within the visible range of the electromagnetic spectrum (EMS). Color infrared images differ from color photography in two ways, blue light is filtered out and the film emulsions are also sensitive to electromagnetic radiation in the infrared portion of the spectrum. The result is a false color image that appears primarily red. Those features such as vegetation that utilize or absorb light in the blue-green range of the EMS, reflect light in the red-infrared range and are represented as red on the image (Smith and Anson, 1968; Reeves, et al., 1975).

Aerial photographic products at appropriate scales ranging in scale from 1:20,000 to 1:80,000 are suitable for the classification used in this study (Modified Anderson level II and III) (Anderson, et al., 1976). The scale 1:60,000 refers to map distance in terms of actual distance represented as a ratio (ie. 1 map inch is equal to 60,000 actual ground inches or 1 map inch is equal to 5000 feet). Large scale aerial photographic products (1:12,000) are also suitable; however the number of frames needed to cover a study area the size of a watershed may be cost prohibitive.

The National Cartographic Information Center (NCIC), U.S. Geological Survey, Reston, Virginia, operates a standard reference database for users of aerial photography called the Aerial Photography Summary Record System or ASPRS. Federal agencies including the U. S. Geological Survey, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the Department of Agriculture, the Department of Defense and the Tennessee Valley Authority, some State and Municipal agencies and a variety of private sources contribute coverage records to ASPRS. Information concerning aerial photographs and/or access to historical aerial photographic products and associated support can be obtained through the National Cartographic Information Center.

Aerial photography obtained from the government ranges in cost from $4 to $18 per frame for black and white, and $5 to $24 per frame for color. The cost of aerial photography from private sources can range from $7 to $85 per frame. The final cost of an aerial photographic analysis will be dependent on study area size, shape, the number of years analyzed and the level of detail needed to meet project objectives. For example, if 1:60,000 scale aerial photography was obtained for a study, one 9x9 inch frame would cover approximately 73 square miles. However, the shape of the study area will also influence the number of frames needed as aerial survey aircraft generally fly straight north-south or east-west lines across surveyed areas.

Comprehensive land use documentation at a specific point in time, availability and cost influenced the selection of historical aerial photography as a data source for this study.

2.3 Geographical Information Systems and Water Resources

Land use, soils, geology, slope, distance to blue line streams, etc., represent a few types of data needed to support various water-quality models. Spatial data exists in a variety of scales and formats from maps to digital tapes. Models may require area (polygon data) or distance (linear data) as part of the data requirements. Manipulation, analysis and representation of spatial data are possible through the use of Geographical Information Systems. Geographical Information Systems (GIS) are computer-based tools by which spatial data can be collected, stored, and analyzed or manipulated (Burrough, 1986). GIS output can be either in report form (tabular), or map form (cartographic).

The concept of GIS is not new to many fields of study. A GIS consists of layers of spatial data and a means to analyze different combinations of these layers. For example, prior to computerization a forester may be interested in insect damage to a certain species of tree at certain elevations. The forester would locate a suitable topographic map (representing elevation) and create overlays representing 1) insect damage and 2) trees mapped by species. A third overlay representing insect damage to certain species of trees, at certain elevations could be compiled by tracing areas that fit the criteria. The forester is working with a simple form of GIS. He has spatial data stored in the form of maps and overlays. The maps were combined and analyzed and a final map based on certain criteria was produced. Computer technology combines the process into one system, GIS.

The use of GIS continues to expand as researchers discover new applications for this technology. The spatial nature of water resource data makes it a prime candidate for GIS application. One such study examined the relationship between watershed disturbance and water-quality degradation from nonpoint source pollution in Sierra Nevada watersheds. A geographic database constructed of computerized overlays of parcel maps, zoning designations and Soil Conservation Service soil surveys was used to provide analysis on the extent of various land capability classes, stream environment zones and high slope areas, development and land type (Byron and Goldman, 1989).

In another study, GIS technology combined with archived imagery was applied to a historical land use analysis. Earth Resources Data Analysis System (ERDAS), historical Landsat images and GIS technology were used to conduct historical land use studies for assessing nonpoint source pollution potentials (DelRegno and Atkinson, 1988). The digital format of satellite imagery is well suited for GIS, however, historical applications are limited due to the availability and costs of historical satellite data. As previously mentioned, aerial photographic archives extend over a longer period of time.

Historical aerial photography, over an approximate 50 year period, was used to conduct a landscape change study. Results from the study confirm that linking of remote sensing and GIS technologies with landscape ecological research can prove to be a useful tool for assessing broad scale changes in rural landscapes (Turner, 1990).

GIS technology has also been applied to water-quality modeling. A demonstration of an integrated approach combining AGNPS and GIS to assess agricultural nonpoint source runoff concluded that computer based studies are cost effective means of conducting AGNPS simulations/analyses (Evans and Miller, 1988).

A GIS has been developed for use with the Universal Soil Loss Equation (USLE) and a delivery ratio to estimate potential sediment loadings to streams from agricultural lands. This program concluded that an integrated approach is cost effective when compared to manual approach and that once the database is established, there is a high potential for reuse and expansion (Hession and Shanholtz, 1988). GIS derived land use data and the USLE were also used to estimate sedimentation and nutrient flux (DelRegno and Atkinson, 1988). GIS technology and U. S. Soil Conservation techniques were used to predict storm water runoff as a demonstration of another integrated use (Berry and Sailor, 1987). It is apparent that research involving the analysis and manipulation of spatial data will benefit from the use of this relatively new computer-based technology.

2.4 Water Quality Model Application:

Water-quality modeling is one method by which the effects of land use change can be studied. Such models are divided into two groups, lumped parameter and distributed parameter models. Distributed parameter models divide the watershed into smaller units. Each unit is modeled separately and is homogeneous, with respect to parameters that describe unit response to precipitation events and input from neighboring units. Total watershed output is obtained from summing the unit outputs.

A watershed is treated as a single unit in lumped parameter models resulting in one output value for the entire watershed area. System parameters such as land use are often characterized through the use of empirical equations. Coefficients and variables used to describe the behavior of system parameters within an equation are determined through calibration studies. Final calibrated and verified lumped parameter models are used to evaluate effects of varied hydrologic and meteorologic conditions on watershed output (Novotny and Chesters, 1981).

The model selected for application in this study was a lumped parameter, comprehensive water-quality model called the Hydrologic Simulation Program-Fortran (HSPF). This program is a modification of the Stanford Watershed Model IV. The model was designed to simulate: temperature, pH, dissolved oxygen, organic matter, pesticides, nutrients, salts, bacteria, sediment and plankton through a reach and reservoir system. It also includes a component to simulate loss and gain from groundwater systems. The overall objective of the HSPF model is to support the evaluation of land use change, point and nonpoint pollution, treatment and best management practices, and fate and transport of pollutants through a reach/reservoir system (Decoursey, 1985, Donigan, 1984).

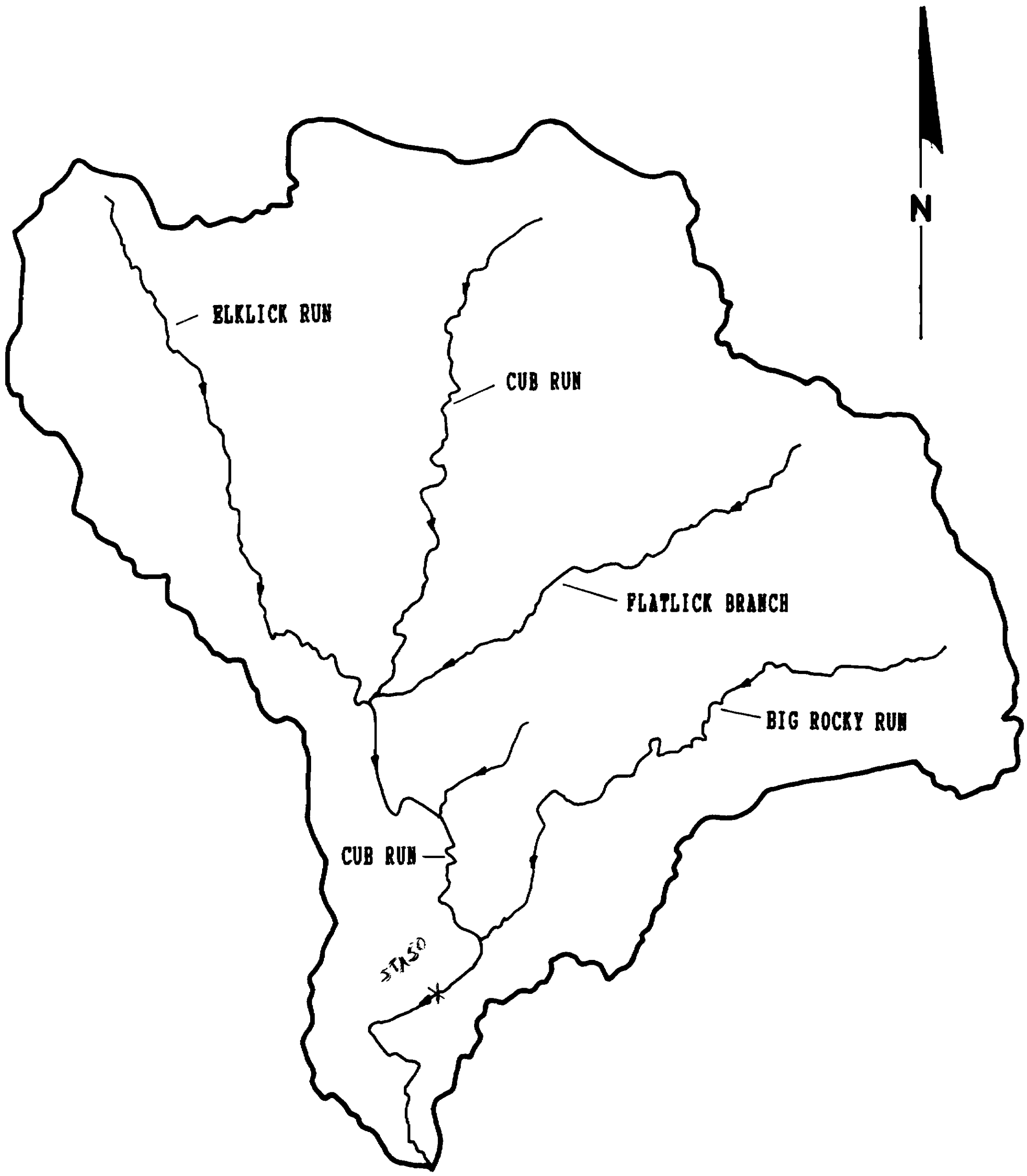
The hydrologic and sediment simulation components of the HSPF model were used to demonstrate model application. One of the major drawbacks of HSPF is the need to estimate many of the hydrologic parameters that are empirically based (Decoursey, 1985). Data used to support parameter value selection may not readily exist, especially in the area of sediment erosion. HSPF simulation of sediment erosion from a watershed is less certain than the hydrologic simulation component because of a smaller knowledge base concerning sediment erosion in different geographic areas of the country (Donigan, et al., 1984). Many of the initial values for these parameters and variables were estimated based on examples presented in the Application Guide for HSPF (Donigian, et al., 1984), basic soil property descriptions obtained from county soil surveys (Porter, et al., 1963; Porter, et al., 1960), and other literature (Donigian, et al., 1977; Donigian, et al., 1976; Novotny and Chesters, 1981; Novotny, 1982; Johanson, et al., 1984; Kibler, 1982).

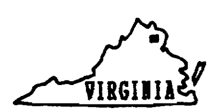
3.0 METHODOLOGY

The discussion of methodology is formatted into four sections pertaining to each phase of this study. The first describes the watershed chosen for the study. Application of aerial photography, land use classification, land use delineation, and land use transfer are discussed under the land use analysis section. Geographical Information Systems procedures and analytical methods are presented in the GIS applications section. Model application is discussed under five sub-sections representing various aspects of the HSPF model.

3.1 Cub Run Watershed

The Cub Run study area is an approximate 33,600 acre (13,594 hectare) sub-watershed of the Occoquan Reservoir drainage basin, located west of Washington, D.C., in the counties of Fairfax and Loudoun, Virginia (see Figure 1). The study area was selected based on availability of water quality and discharge data and the recent development activity. Primary land uses within the study area include agricultural, forested, urban/suburban, and commercial classifications.





Approximate Scale 1:112,000

Study Area location

FIGURE 1: Cub Run Watershed Study Area.

The watershed is characterized by the undulating and rolling topography of the Piedmont Lowlands (Triassic Basin). Sedimentary rocks including sandstones, shales, conglomerate, and igneous rocks consisting of diabase, syenite and metodoirite represent the primary underlying geology. A minor portion of the study area, located along the eastern boundary, is underlain by the crystalline rocks of the Piedmont Upland. Piedmont Lowland soils range from coarse-textured near the Piedmont Upland boundary to fine-textured soils found along the western edge of the study area in Loudoun County. Drainage patterns are dendritic in both the Piedmont Lowlands and Piedmont Uplands; however, the drainage pattern is less developed in the lowland section (Porter, et al., 1960; Porter, et al., 1963).

3.2 Land use analysis

A variety of water-quality and discharge data has been compiled regarding the Occoquan Reservoir and associated watershed since 1973 by the Occoquan Watershed Monitoring Laboratory (OWML) through the Occoquan Watershed Monitoring Program (OWMP). The Occoquan Reservoir database provided an excellent source of information on watershed discharge quantity and quality. However, pertinent information on land use characteristics that influence water quality and discharge were not assembled or even readily available. The land use-analysis phase of this study entailed the compilation of historical land use data from archived aerial photography. Three years of historical aerial photography covering the period of time from 1979 - 1988 were used to obtain historical land use data.

3.3 Application of aerial photography

Historical land use data were obtained through the analysis of aerial photography. Aerial photographic coverage of the study area for the years 1979, 1984 and 1988 was analyzed and compiled onto USGS 7.5 minute quadrangles. Two types of aerial photography were used for land use analyses: 9 X 9 inch color positive imagery (color transparencies) and 4.5 X 37.5 inch optical bar, color infrared imagery (color infrared transparencies). The 1979 coverage was represented by 9 X 9 inch color aerial photography at an approximate 1:27,500 scale consisting of 27 frames over 6 flight lines. The scale and format was excellent for mapping land use at a level of detail suitable for this study. The 1984 and 1988 coverage was represented by color infrared optical bar imagery at a scale of 1:32,500 at nadir (center of the frame). The optical bar imagery provided a good source of information at a suitable scale for land use analysis. However, due to the nature of optical bar imagery, image distortion increases with distance from the center of the frame. Since optical bar imagery is not ideal for mapping purposes, it was used to update a baseline map produced from the 1979 land use analysis. The 1984 optical bar imagery consisted of 10 frames in one flight line. The 1988 optical bar imagery consisted of 11 frames in one flight line. The study area was located near the center of the frames, therefore reducing the amount of optical distortion.

Aerial photography used for this project was selected based on accessibility, suitable resolution and scale. Aerial photography of similar scale and format (9x9 inch) would be ideal for this type of project. Aerial photography ranging in scale from 1:24,000 to 1:60,000 would provide enough detail to accomplish land use analysis for the described classification system.

3.4 Land use classification

A land use classification scheme was adapted for this study from the United States Geological Survey (USGS) Professional Paper 964; A Land Use and Land Cover Classification System for Use with Remote-Sensor Data (Anderson, et al., 1976). The USGS classification scheme is organized as a multilevel outline with a numerical code in which detail or land use resolution increases with each level. For example, Level I agricultural classification is represented by the number 2, encompassing croplands and pasture, orchards, nurseries, horticulture, confined feeding operations/feedlots/holding areas, etc.. Cropland and pasture is a level II classification represented as number 21, where the 2 indicates agriculture and the 1 indicates cropland/pasture. The classification scheme proceeds in a similar manner through Level III in which an idle field is represented as 213 (Anderson, et al., 1976).

The classification scheme used in this study was a modified Anderson Level II, which included some Level III classification. Level I of the adapted scheme included the following categories: Urban or Built-up Land (developed land), Agricultural, Forestland, and Barren Lands. These categories represent primary land use within the study area. The minimum mapping unit applied to the interpretation of land use was approximately 7 acres.

One of the main objectives of this study was to examine a method by which relationships between land use change and water quality in developing areas can be studied. The classification scheme was focused, therefore, on delineation of certain areas heavily influenced by the pervious or impervious nature of the land surface. Land use classification adapted for this study was biased toward land use groups with similar responses to precipitation events.

3.4.1 Land Use Classification Scheme

The following section presents the Anderson classification scheme (Anderson, et al., 1976) as modified to meet study objectives and discusses each classification and its relationship to increasing percentages of impervious surface area.

1 Urban or Built-up Land

11 Residential: Various degrees of impervious area are seen in residential land use. The lowest degree of imperviousness is seen in the low-density residential classification. Higher degrees of impervious area noted in high-density residential classifications. Actual land use delineations were interpreted to include only those areas affected by housing, roads, sidewalks and minor open or forested interstitial areas, such as yards. In the case of a housing subdivision, an effort was made to exclude tracts of open land or forested areas from residential delineation. The analysis was performed to insure consistency in the percentage of impervious area determined for each residential land use. The actual percentage of impervious area per contributing land use classification was determined from the aerial photography: This procedure is discussed in the model application section of the paper.

111 Low-density Residential (LDR): Single family dwellings characterized by large lots and no subdivision (Figure 2). Impervious area as measured from aerial

Figure 2: Low Density Residential Housing (LDR).

photography was 12 percent.

112 Medium-density Residential (MDR): Single family dwellings characterized by subdivisions (Figure 3). Impervious area as measured from aerial photography was 41 percent.

113 High-density Residential (HDR): Multi-family dwellings characterized by duplexes, garden apartments, townhouses, etc. (Figure 4). Impervious area as measured from aerial photography was 82 percent.

114 Mobil Home Community (MHC): Impervious area as measured from aerial photography was 61 percent.

12 Commercial/Institutional/Governmental (COM): This land use classification represents some of the highest degrees of impervious area.

Commercial areas are used mainly for the sale of services and products and include retail sales, wholesale, professional services, vehicle related activities, junk and salvage yards, warehouses, and temporary storage facilities.

Institutional/Governmental includes military facilities, government buildings, correction facilities, medical ,educational, religious, municipal services, road repair and maintenance yards.

Due to the variability in degree of imperviousness from office complex to complex or other facilities, land use delineation was biased to select only those areas dominated by parking areas, sidewalks, building rooftops and other impervious areas. Impervious area as measured from aerial photography was 87 percent.

13 Industrial: Primary processing at extraction sites and extraction equipment. Light industry representing design, assembly, finishing, processing and packaging of products. Heavy industry is characterized by the use of raw materials. Electric generation, tank farms, materials storage and industrial waste treatment are also included under this classification.

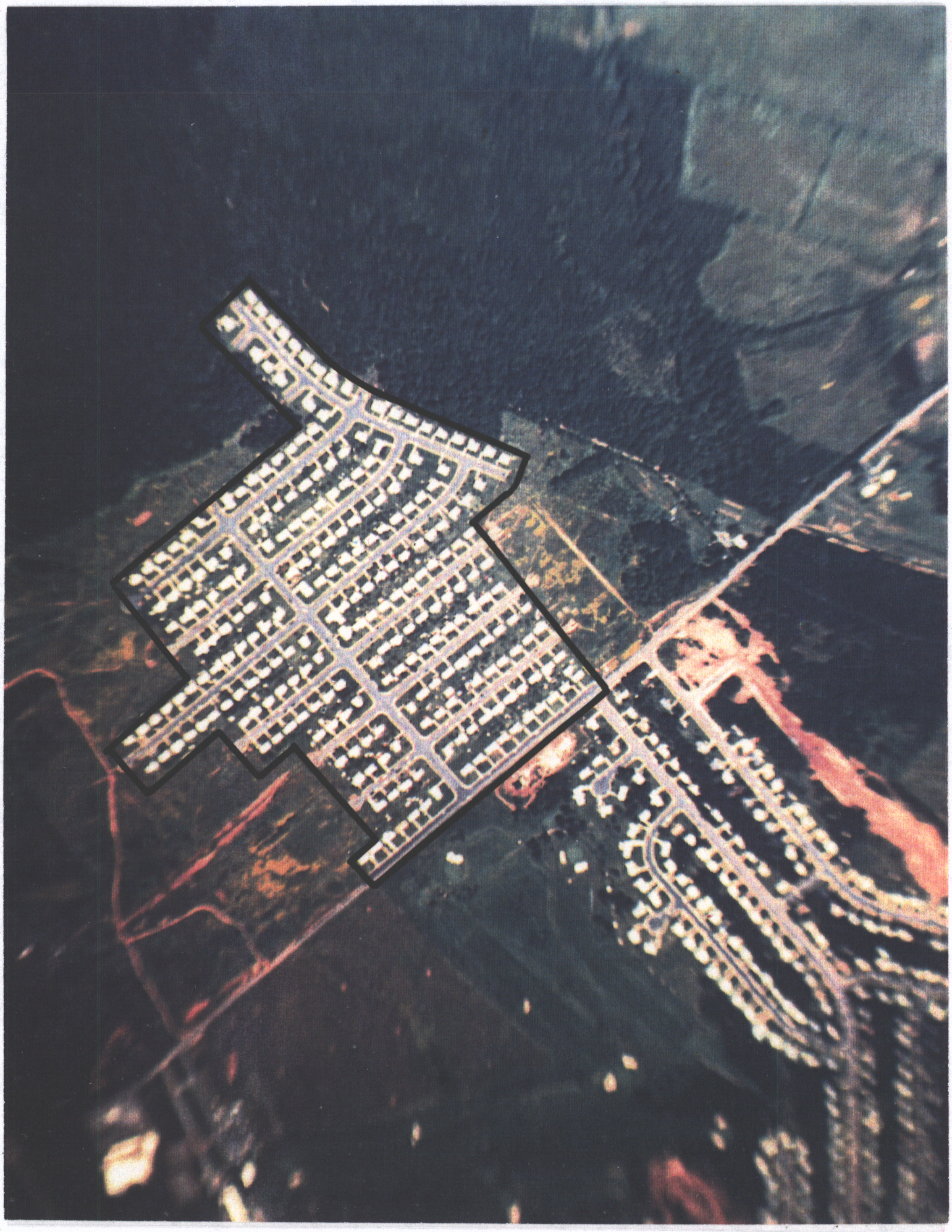


Figure 3: Medium Density Residential Housing (MDR).

Figure 4: High Density Residential Housing (HDR).

Since industrial land cover was minimal, the areas were included with land use classification 12.

14 Transportation: Four lane highways and portions of an airport (runways) were included under this classification. These areas represent a high degree of imperviousness. The attempt was made to account for major road networks; however, an extensive network of minor roads representing 100 percent impervious surface area, exists throughout the study area. Some of this impervious surface area is accounted for under other classification categories such as urban or built-up land; however, minor roads found within the agricultural and forested areas were not represented as impervious surface area.

141 Major highways and interstates (HWY). Impervious area as measured from aerial photography was 66 percent.

144 Runways and intervening open land (AIR). Impervious area as measured from aerial photography was 34 percent.

15 Utilities (UTL): This classification is focused on treatment, transportation and delivery of water, gas, oil and electricity. The utilities classification outlined major power-line and pipeline right-of-ways. This classification was considered 100 percent pervious.

2 Agriculture

21 Cropland, pasture and open fields (AGO): This classification delineates those areas that are pervious, encompassing crop producing areas, pastures, idle fields, plowed fields and farmsteads. Agricultural areas were classified 100 percent pervious.

3 Rangelands: This classification refers to herbaceous and shrub-brush rangelands. The classification was not represented in the study area and is only included to maintain continuity of the modified USGS classification scheme.

4 Forestland

41 Primarily deciduous forest (FOR): However, mixed evergreen forests were combined in this classification. This classification includes both mature and immature stands of trees. Areas intermediate between open fields and immature/mature stands of trees were grouped based on dominate cover type. For example, if tree crown cover exceeded open field cover (approximately greater than 50 percent), the area was designated as 41 forestland. Forestlands were considered 100 percent pervious.

5 Water: The water classification includes waterways, streams, canals, natural and man-made reservoirs and impoundments.

The study area contained several small impoundments/ponds most of which fell below the minimum mapping unit of approximately 7 acres. Small stream size also restricted the inclusion of stream surface area in the land use mapping process. Therefore, this classification was not represented in the study.

6 Wetlands: Forested and Non-Forested Wetlands were not identified for this land use study.

7 Barren Lands

75 One rock quarry was included under this classification (EXT). Rock quarries display a high degree of imperviousness and a high source of sediments transferable through runoff mechanisms. The rock quarry was considered 100 percent impervious.

76 Construction areas were included under this classification (CON). These areas are characterized by exposed and compacted soils. Sediment source and transport is high. Construction areas were treated as 100 percent Impervious land surfaces.

3.4.2 Land use delineation

Aerial photography consists of a series of frames with a certain percentage of overlap between each frame. Overlap allows the image to be viewed in three dimensions with the aid of stereoscopes. Three dimensional viewing adds height and depth to photographic signatures. Aerial photographic signatures are a compilation of a variety of aspects of the viewed image that allow analysts to identify the feature, object, activity, etc. recorded on the imagery. Pattern, texture, tone, height, depth, spatial relationships, color, and intensity represent some of the components used to develop photographic signatures. Examples of photographic signatures have already been illustrated as Figures 2-4 in the previous land use classification discussion.

Land use delineation, based on aerial photographic signatures, was performed in the following manner: Every other frame was selected from each year of coverage to avoid redundancy from overlap. Each selected frame was overlaid with clear drafting film and backlit on a light table. Some overlap remained between each frame and each flight line. Overlap areas were carefully marked on each frame such that boundaries containing the active analysis portion of the frame matched, frame to frame and flight line to flight line. Each identified land use was traced onto the overlay and assigned the appropriate classification number with a fine point technical pen. Land use delineations were then transferred to a map base.

3.4.3 Land use transfer

A Bausch & Lomb (model ZT 4-H) zoom transfer scope (ZTS) was used to transfer historical land use data from the aerial photography to six individual USGS 7.5 minute topographic maps. The ZTS allows analysts to optically adjust scales of photography, maps or overlays to match the scale of a target base map or photograph. The ZTS also allows analysts to optically adjust for image distortion. When scales are matched and distortion adjustments are made, the data are traced onto each map overlay.

The ZTS process for the 1979 imagery was a standard transfer from overlaid 9 X 9 inch color positive imagery to the map base. Due to the configuration of the ZTS equipment and the size and shape of the optical bar imagery (4.5 X 37.5 inch), the ZTS process required an intermediate step. Roads and other features common to both USGS maps and the optical bar imagery were also traced onto overlays. The overlays were then removed and used to complete the ZTS transfer.

Upon completion of the ZTS process, the USGS topographic maps and the associated 1979 map overlays were joined to represent the complete study area. The 1984 and 1988 individual map overlays were then compared to the 1979 base map. Major changes in land use during each year were updated and compiled onto clean study area overlays which represent the 1984 and 1988 land use data. The final overlays representing land uses for 1979, 1984 and 1988 were then ready for the data analysis and manipulation phase of the project.

3.5 GIS application

The Cub Run historical land use data and other associated spatial data were digitized and entered into a Geographical Information System (GIS) for analysis. The GIS used for this study was ARC/INFO versions 4.2 and 5.0 installed on micro VAX computers. The digitizing procedure involved the creation of one template file that contained the study area boundary and tic marks that correspond to latitude and longitude measurements selected from the 1:24,000 scale topographic base maps. The template file was copied to six separate files representing 1979, 1984 and 1988 land use coverage; reach sub-watershed boundaries, perennial blue line streams (as drainage) and topography.

The 1979, 1984 and 1988 land use coverage data layers were used to evaluate historical land use. The topography, reach sub-watershed boundaries and drainage data layers were used to obtain specific watershed data e.g., land use within the lowland headwaters region of the watershed or the length of reach within the lowland headwaters region. The watershed study area was divided into eight areas that relate to stream reach segments. The sub-division was required as part of the watershed modeling effort and is further explained in the model application section of the methodology.

The digitizing process involved taping an overlay/map to the digitizing table and initializing control points or tic marks. Line work was entered in a digitizing mode, and a distinction was made between polygon data layers (ex. land use) and arc data layers (ex. drainage network). The software constructs polygon or arc topologies from the digitized line work. For example, when the program creates an arc topology (ex. drainage), it recognizes the intersections of lines or arcs and creates a node at that point. In the case of a drainage network, a stream channel is represented by an arc and a confluence would be represented by a node. The final drainage network is represented by a series of arcs and nodes each assigned internal identification numbers. These numbers are compiled into a specific table called the arc attribute table or AAT which contains a listing of internal identification numbers and length of each arc in terms of a specified unit of length (meters). It is this process by which the program can distinguish different line segments.

In the case of a land use coverage, the program recognizes enclosed areas as polygons and creates an internal identification number for each polygon. As with the arc topology, a table called the polygon attribute table (PAT) is created. The PAT contains the internal identification number for each polygon and the associated area in terms of a specified unit of area. Historical land use and reach sub-watershed overlays were represented by polygon topology. Drainage and topography were represented by arc topology.

At this point in the GIS process, the spatial data layers that have been compiled represent polygons (land use) or arcs (drainage) that can only be identified by specific internal identification numbers. The next step is to assign attributes (low-density residential or Reach 5) to each polygon or arc. Label points and a second set of identification numbers were assigned to the polygons and arcs within each attribute table. Individual plots representing the polygon data layers and arc data layers at the original base scale or 1:24,000 were generated. These plots also included the new label points and corresponding identification numbers. The plots were overlaid onto the original land use, reach sub-watershed, drainage and topography maps and lists were generated containing attributes for each corresponding identification number. The PAT and AAT files were modified to contain appropriate attribute columns (ex. land use, reach numbers) and the associated data were entered into the tables. A second set of plots showing polygons or arcs and attributes was generated and compared to the original maps for the purpose of editing. A final plot was generated.

One ARC/INFO GIS capability is to combine two layers of information or coverages creating a third data layer that represents both. Each historical land use coverage was combined with the sub-watershed reach coverage. Combining coverages creates a PAT representing land uses and sub-watershed reach areas. This combined coverage can answer questions such as what is the area of each classified land use within Reach 7 sub-watershed in 1979? or How much land in the Reach 5 sub-watershed was under construction in 1984? These questions illustrate the types of spatial data input needed for a variety of surface water models. ARC/INFO output can be generated as data sets or graphic representation, such as maps. Examples of both are seen in the Results section.

An AT personal computer linked to the micro VAX computer, and the screen capture capabilities of PROCOM (Datastorm Technologies, Inc.) were used to complete the final task of exporting the attribute tables from ARC\INFO to a PC-database. The attribute tables were exported as text files. Text files were then imported into the REFLEX database (Borland International, Inc.) where summary tables were generated. Graphs were compiled from summary tables using the Quattro Pro spreadsheet (Borland International, Inc.).

The REFLEX and Quattro Pro database and spreadsheet packages were used for analysis and manipulation of water quality and discharge data. Water quality and discharge dBase formatted files were imported into REFLEX and manipulated to select pertinent discharge and total suspended solids data. The selected data were then exported to Quattro Pro files for the purpose of graphic representation. All field measured and model generated data were eventually compiled into Quattro Pro spreadsheet files.

3.6 Model Application

The application of water-quality models require certain spatial data needs; therefore, data analysis and manipulation were tailored to meet these needs. A watershed-scale model, the Hydrologic Simulation Program - Fortran (HSPF), was selected for model application. This phase of the project was included to demonstrate model application and is not considered an all-inclusive treatment of model capability. Since the movement of nutrients, pesticides, and oxygen demanding substances are closely linked to the movement of water and solids, the discharge and total suspended solids aspects of the HSPF model were calibrated to demonstrate model application.

HSPF is a watershed-scale, lumped-parameter model, designed to allow continuous simulation of a comprehensive range of water-quality and hydrologic processes. The program is modular in structure with a time series manager. The modular concept allows for simulation of processes and the use of utility modules individually or together. The time series manager was designed as one central store of data which can be directly accessed by the individual modules. The time series manager is a critical component of the model due to the amount (spanning years), variety (i.e. precipitation, evaporation, wind) and time step of data (i.e. hourly, daily, monthly measurements) needed to run HSPF simulations.

HSPF consists of three main modules; the first, PERLND simulates the hydrologic and water-quality processes surrounding pervious land surfaces; the second, IMPLND simulates hydrologic and water-quality processes on impervious land surfaces; and the last RCHRES simulates hydraulic processes within river/stream reaches and reservoirs. All HSPF modules were used; however, the demonstration of model application is focused on discharge and suspended solids and therefore, only certain sections within each module were used.

HSPF simulation of hydrologic response is a function of watershed geometry and observed meteorologic data. The model simulates watershed output for surface runoff generated from impervious areas, pervious areas, interflow from pervious areas, and groundwater outflow. Each simulated contribution can be examined individually or combined to represent total simulated discharge. Since the actual watershed discharge is represented by single measurements taken at the outlet, percent contributions from impervious and pervious surface areas, interflow and groundwater outflow could only be inferred or estimated.

A copy of the HSPF model version 9.1, was obtained from the Center for Exposure and Assessment Modeling, U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory in Athens, Georgia. Manuals were obtained from the National Technical Information Service (NTIS) in Springfield, Virginia. The model was run on MS-DOS based personal computers.

3.6.1 HSPF Data Requirements

Data were obtained from a variety of sources. The following section describes the types and sources of HSPF input data. Databases including dBase III Plus and Reflex 2.0, and Quattro Pro spreadsheets were used to examine and manipulate meteorological data, water-quality and discharge data.

3.6.1.1 Precipitation

Daily precipitation data from the Dulles weather monitoring station were obtained from a CD-ROM compiled by Earthinfo Inc., which uses data from the National Climatic Data Center in Ashville, North Carolina. The CD-ROM was maintained at the Virginia Water Resource Research Center (VA-WRRC), Blacksburg VA. A database software package was used to manipulate the acquired data into a HSPF sequential file format for a daily time-step series.

3.6.1.2 Evapotranspiration

Daily evaporation from Beltsville, Maryland were obtained from another CD-ROM compiled by Earthinfo Inc.. A database software package was used to manipulate the acquired data format to match the HSPF sequential file format for a daily time step.

3.6.1.3 Water-quality data

Water quality data were obtained from the Occoquan Watershed Monitoring Laboratory in Manassas, Virginia.

3.6.1.4 Discharge data

Discharge data were obtained from the Occoquan Watershed Monitoring Lab in Manassas, Virginia, and the WASTORE Database compiled by the USGS Water Resource Division.

3.6.1.5 Land use

Delineation of land use was performed as outlined in the data-collection and data-analysis/manipulation portion of this study.

3.6.2 Determination of percent impervious surface area

The last portion of the data collection process involved the determination of percent impervious area for each land use. The percent impervious surface area for each land use was determined in the following manner: Selected areas representing various land uses with impervious components were identified and marked on the 1979 aerial photography. A 35 mm camera with a macrolens was used to isolate each specific area. Two products were produced from 35mm color negatives; 8-inch x 11-inch color photographic enlargements and approximately 7-inch x 10-inch color photocopies. The color photographic enlargements were produced directly from the color negatives. Color 4-inch x 6-inch prints and a Cannon color laser copier were used to produce the color photocopies. Both methods provided an adequate format for determining the percent imperviousness of each land use. Percent impervious and pervious surface area for each land use with an impervious component was accomplished by overlaying each enlargement with mylar drafting film and tracing roads, houses, buildings and other impervious surfaces. The overlays were digitized, impervious vs. pervious surface areas were summed and relative percent imperviousness established.

3.6.3 PERLND Module

The PERLND module simulates hydrologic and water-quality processes within pervious land segments. A land segment is defined as an area containing similar hydrologic characteristics. The primary sections of the PERLND module simulate snow accumulation, water budget, sediment produced from surface erosion and water-quality constituents by various methods for the pervious land segments within the watershed.

Group PWATER of the PERLND module simulates the water budget for the pervious land segments. It is the key component of the PERLND module. The equations used in the PWATER module were derived from the LANDS subprogram of the Stanford Watershed Model IV (Johanson et al., 1983). Since total runoff values are obtained from this section, PWATER is the only PERLND module group applied to the Cub Run watershed. Snow accumulation (under group SNOW) was not simulated for the study area due to the infrequent occurrence of significant snow events that would greatly impact the monthly average of watershed discharge.

There are three groups of PWATER parameters and one group of state variables. The first parameter group includes: fraction of evergreen forest within the pervious land segment, lower zone nominal storage, a value depicting an index to the infiltration capacity of the soil, the length and slope of the assumed overland flow plane, a factor which affects groundwater recession flow and a groundwater recession rate if the proceeding factor is zero.

There are seven parameters in the second set, two of which were not included during simulation because they are associated with snow conditions, which were not included in the simulation. The remaining parameters include: an exponent in the infiltration equation and a ratio between maximum and mean infiltration capacities for the pervious land segment, the fraction of deep water inflow (loss to groundwater storage), the fraction of remaining potential evapotranspiration that can be obtained from baseflow, and the fraction of remaining potential evapotranspiration that can be satisfied from active groundwater storage.

The remaining PWATER parameters represent interception storage capacity, upper zone nominal storage, Manning's "n" for the assumed overland flow plane, interflow inflow, interflow recession and an index to the density of deep-rooted vegetation.

The state variables represent an index to groundwater gradient and several values for storage including: interception storage, surface storage, upper zone storage, interflow storage, lower zone storage and active groundwater storage. Many of the initial values for these parameters and variables were estimated. It should be noted that initial values represent only a starting point in the process. HSPF is a calibration model where most of the parameters and variables were adjusted and no longer resemble the initial values.

Group SEDMNT simulates the production and transport of sediment from a pervious land segment. The composition of the sediment can be considered inorganic, organic or any combination of the two. The characterization of sediment production and removal is based on the ARM and NPS models, and the surface erosion was obtained from Moshe Negev's sediment model and influenced by others (Johanson, et al., 1984). The general principle is based on an equilibrium between sediment that is available for transport and the capacity of surface runoff to transport the sediment.

There are ten parameters in group SEDMNT which include: a factor to characterize supporting management practices, the coefficient in the soil detachment equation, the exponent in the soil detachment equation, the fraction by which detached sediment storage decreases each day, fraction of land surface shielded from the erosive power of rainfall, the rate of accumulation of detached sediment from the atmosphere, the coefficient and exponent in the detached sediment washoff equation and the coefficient and exponent in the soil matrix scour equation.

The supporting management practices factor which is based on the universal soil loss equation represents agricultural conservation practices. Data on conservation practices were not obtained for this study and therefore this factor was not used. The soil detachment equation calculates the amount of soil entering storage as detached sediment. A fraction of detached sediment in storage is decreased each day either by compaction or removal by wind. The fraction of land surface shielded from rainfall is another factor in sediment removal that effects the amount of sediment detached by rainfall, and therefore, entering detached sediment storage. The rate of accumulation of detached sediment from the atmosphere is also considered as a contributor to available detached sediment. Up to this point the model is calculating the availability of detached sediment that can be washed off during a rain event. The sediment washoff equation and the matrix soil scour equation determine the amount or portion of detached material that is carried off by the surface flow.

3.6.4 IMPLND Module

The IMPLND module simulates hydrologic and water-quality processes from impervious land segments. An impervious land segment is defined as an area exhibiting little to no infiltration characteristics. Even though the land segment is impervious, water storage and evaporation processes may be active. Accumulation of water-quality constituents on the land surface are also considered.

IMPLND is used to simulate the movement of water, solids and various pollutants from impervious land surfaces to reaches and/or reservoirs.

Group IWATER of the IMPLND module simulates the hydrologic process for impervious land segments. This includes the retention, routing and evaporation of water from the impervious land surface. It is the key component of the IMPLND module. To determine total discharge for the watershed (PERLND+IMPLND), IWATER was the only group of the IMPLND module applied to the Cub Run watershed.

There are four IWATER parameters including: length of overland flow plane, slope of overland flow plane, Manning's "n" for the overland flow plane and the retention or interception storage capacity of the surface. Length and slope of the overland flow plane was estimated from topographic maps. Initial values for Manning's n was obtained from the literature (Novotny, 1981). Initial values for the retention storage capacity was estimated.

Group SOLIDS simulates the buildup and removal of solids from an impervious land segment. The equations used in this section of the HSPF were based on the NPS model (Johanson, et al., 1984). As with the SEDMNT section in the PERLND module, the focus is on sediment flux in and out of solids storage. There are four parameters in group SOLIDS including: the coefficient and exponent in the solids washoff equation, the rate of solids accumulation on the impervious land surface, and the fraction of solids storage removed each day by agents other than runoff (ie. wind or street sweeping). Initial values for the first three parameters were estimated based on information obtained from the NPS users manual (Donigian and Crawford, 1976). The fraction of solids removed by other processes or actions remained low because of the assumption that suburban and fringe urban areas do not have an extensive need for street sweeping programs.

3.6.5 RCHRES Module

The RCHRES module simulates hydraulic and water-quality processes over a single reach or a completely mixed reservoir or lake. Only the hydraulic component of this module was used to satisfy the model application objectives of this study.

The HYDR section of the RCHRES module is used to simulate hydraulic processes within a reach or a mixed reservoir. Without the RCHRES module, simulated runoff from the pervious and impervious land segments would be "delivered" directly to the watershed outlet. Watershed drainage was divided into eight reach segments based on contributing landform characteristics such as stream gradient and land surface slope. The volume of water entering each reach is determined by surface and subsurface inflow from the contributing watershed area, direct precipitation falling on the surface waters of the reach or reservoir and evaporation from the surface of the reach or reservoir. Precipitation falling directly on the surface of reach waters and surface evaporation from reach waters were not considered in this exercise, due the relatively small size of the stream.

There are six HYDR parameters which include: reach length, width and depth, change in hydraulic head for each reach, surface area of the reach and reach volume. Reach length was obtained from the GIS reach sub-watershed coverage which originated from perennial blue line streams represented on USGS topographic maps. For the purpose of this analysis, perennial blue line stream refers to a single drainage channel represented on USGS topographic maps as a solid blue line (perennial stream symbol), extending from the reach outlet to the furthest extent of the headwater region or the connecting upstream reach. Reach channel depth (stage) was obtained from field measurements and/or from USGS topographic maps. Reach channel width data were obtained from field measurements and or from USGS topographic maps. Change in hydraulic head for each reach was measured from topographic maps as the change in elevation from the furthest upstream extent of the perennial blue line stream to the reach outlet. The surface area of each headwater reach (at selected depths/stages) was calculated as the area of an isosceles triangle where the height is equal to reach length and the base is equal to the reach width at the outlet. The surface area of each intermediate reach (at selected depths/stages) was calculated as the area of a trapezoid where the upstream and downstream widths define the bases of the trapezoid and the height is equal to the reach length.

Two computer programs written in BASIC were used to determine reach volume at selected depths/stages. One program was designed to calculate the cross sectional area as the area of a polygon, and the second program was designed to calculate reach volume. Cross sectional profiles for reaches 1-5 were measured in the field using a transit to establish a level line across the stream channel and recording the depth as a function of distance. Cross sectional profiles for reaches 6-8 were obtained from the USGS topographic maps. Data from the cross sectional profiles were entered into a computer program designed to calculate area. Measured stream width and in some cases base, were used to force fit the cross sectional area into one of two idealized channel shapes that mimic the natural shape. Reaches 1-3 and 6-8 were represented as trapezoidal shapes and reaches 4 and 5 were represented as V-shaped. Reach volume measurements for each selected depth/stage were calculated as a function of cross sectional area and reach length. The cross sectional area for each head water reach was varied from zero to a maximum value at the reach outlet. The cross sectional area for intermediate reaches was varied from minimum to maximum extent for reach inlets and outlets. Increasing cross sectional areas (with distance downstream) were multiplied by increments of distance along the reach length and summed to represent individual reach volumes.

3.6.6 Model Calibration

Model Calibration was conducted according to guidelines given in the Application Guide for Hydrologic Simulation Program - Fortran manual (Donigian, et al., 1984). Initial parameter evaluation was greatly aided by the use of several references including; Users Manual for the Hydrologic Simulation Program - Fortran (HSPF) (Johanson, et al., 1984), Agricultural Runoff Management (ARM) Model Version II: Refinement and Testing (Donigian, et al., 1977), Modeling Nonpoint Pollution from the Land Surface (Donigian, et al., 1976, and the Handbook of Nonpoint Pollution Sources and Management (Novotny and Chesters, 1981). Hydrologic and sediment erosion calibrations were performed to satisfy the objectives of the model application demonstration.

The first step in hydrologic calibration was to obtain a water balance on an annual basis where discharge is equal to precipitation minus actual evapotranspiration, deep percolation and change in soil moisture storage. Initial values for parameters affecting hydrologic simulation in the PERLND and IMPLND modules were obtained from literature sources or estimated based on guidelines or examples represented in the manuals. The first simulation was run and tables representing annual precipitation, evaporation, surface runoff from pervious and impervious surfaces, interflow and groundwater outflow, on a daily time step were generated. Precipitation, evaporation and discharge data were compared to confirm that annual precipitation was greater or equal to the sum of annual evaporation and annual discharge.

Since the Cub Run watershed is governed by continuous or intermittent baseflow conditions, groundwater outflow from the systems is a significant contributor to total outflow. Further hydrologic calibration involved isolating baseflow conditions from the watershed database for each of the simulated years. Values for baseflow discharge were represented by extended dry periods during the summer months. Observed baseflow discharge was compared to corresponding model generated values. Appropriate adjustments were made to those parameters responsible for groundwater movement (primarily DEEPFR: groundwater contributions to inactive groundwater storage) to simulate groundwater discharge during extended dry periods. Minor adjustments to groundwater contributions were made as an interactive process with interflow parameter manipulation during the calibration effort.

The following parameters were manipulated to simulate the pervious surficial and interflow components of the watershed outflow balance. HSPF divides precipitation input into two portions, interception storage and infiltrate. A direct affect on surface runoff volume can be achieved by manipulating the interception storage parameter (CEPSC or INTERCEP), which represents that portion of precipitation returning directly to the atmosphere through the evapotranspiration process.

Infiltrate is the portion of precipitation that reaches the earth's surface. The model routes or proportions infiltrate to surface detention, interflow and the lower soil zone. A direct affect on infiltrate is achieved by manipulating soil infiltration capacity (INFILT).

Surface runoff is calculated in the surface detention portion of the model. Surface detention infiltrate is divided based on a relationship between the percent lost to surface runoff and a ratio between upper zone storage (UZS) and upper zone nominal storage (UZSN). In other words, a determination is made on the amount of surface detention infiltrate entering the ground surface and that which runs off. Direct effects on surface detention through the UZS/UZSN ratio impacts surface runoff values.

Direct effects on lower zone storage can be made by adjusting the lower zone nominal storage parameter (LZSN). Increasing the LZSN will increase actual evapotranspiration and therefore decrease runoff values. The LZSN parameter is the primary parameter manipulated to achieve an annual water balance.

Precipitation that reaches the lower zone is affected by lower zone evapotranspiration (LZETP). Increasing or decreasing LZETP values influence the lower zone storage capacity affecting the amount of infiltrate that can be stored. Less storage impacts the portion of infiltrate routed to interflow or upper zones.

Manipulation of interflow parameters (INTFW) affect the discharge of precipitation contained within the interflow system. Increasing interflow values increases output to runoff.

Annual and monthly hydrologic calibration was achieved primarily by adjusting the following seven key parameters and one state variable in accordance to guidelines provided in the manuals: 1) Interception storage capacity (CEPSC);

2) The fraction of groundwater inflow lost to groundwater storage (DEEPFR); 3) Index to the infiltration capacity of the soil (INFILT); 4) Interflow inflow (INTFW); 5) Lower zone nominal storage (LZSN); 6) Lower zone evapotranspiration (LZETP); 7) Upper zone nominal storage (UZSN); and the upper zone storage state variable (UZS).

3.6.6.1 Hydrologic Calibration

Hydrologic calibration was performed in two steps. The first step involved calibration in which the PERLND and IMPLND modules were used to simulate watershed discharge. This step excludes the routing of runoff through the drainage system network, which is simulated by the RCHRES module. In this procedure, watershed runoff is delivered from the simulated surface area (ex. all forested area) to the watershed outlet. Total discharge is approximately the same as the RCHRES simulated discharge; however, peak discharge would occur instantly.

The model was calibrated for 1979 and was not recalibrated for 1984 and 1988. The calibrated parameter set was applied in combination with the 1979, 1984 and 1988 land use and meteorological data sets to simulate discharge. A three year simulation run was conducted for each data set (1979, 1984 and 1988). For example, a simulation run to obtain 1979 discharge data was started on January 1, 1978 and ended December 31, 1980. Three year simulations which bracket the target year avoid impacts on discharge that were observed when precipitation events occurring over the days or month prior to or after target year, are not accounted for. Parameter values that were calibrated and set for the 1979 meteorological data, land use coverage, associated watershed discharge and water-quality data, were not altered for the 1984 and 1988 simulations. Only the contributing land use areas were changed to match 1984 and 1988 representation. Therefore, 1984 and 1988 represented verification data sets for the integrated historical land use analysis/GIS/modeling procedure.

3.6.6.2 Hydraulic Calibration

The second step in the calibration process involved the addition of the RCHRES module. In this process, runoff is routed from land segments (ex. forested areas, low-density housing, etc.) within each reach sub-watershed to the sub-watershed outlet. Discharge from each sub-watershed reach area was routed to down stream reaches, continuing through the drainage network to the final watershed outlet. The HSPF Application Guide (Donigian 1984) outlines a procedure for calibrating the hydraulic component (RCHRES) for the model; however, simulation results using the RCHRES module were acceptable. Therefore, hydraulic calibration was not performed.

3.6.6.3 Suspended Sediment Calibration

Suspended sediment calibration was achieved by adjusting parameters such that a balance between accumulation of detached sediment and the transport or removal of detached sediment, primarily by surface runoff, was simulated. Parameters that influence sediment accumulation on both pervious and impervious components of the watershed were adjusted until values representing accumulation became relatively stable. Increasing and decreasing trends in detached sediment accumulation are not desirable since they do not represent most natural systems. Once a stable configuration for detached sediment was achieved, the next step in calibration involved adjusting the parameters that control sediment removal by surface runoff. The model is designed to consider two scenarios governing sediment transport or removal from detached sediment storage, conditions where sediment is limiting and conditions where sediment is not limiting. A sediment limiting condition would exist when the amount of sediment available to be washed off the land surface is less than the capacity for runoff to remove it. When the amount of detached sediment on the land surface exceeds the capacity for runoff to remove it, the condition is not limiting.

The Cub Run watershed is represented by four pervious land segments. Two of these land segments which include lawns, open areas (grasses), and forested areas, represent land uses were sediment is limiting. The fourth pervious land segment represents areas laid bare as a result of construction, a condition where sediment is not limiting.

Agricultural land use was included with those land uses represented by sediment limiting conditions even though cultivated lands could be classified under non-sediment limiting conditions. Although not quantified during the land use analysis section of this study, the cultivated component of agricultural land use within the Cub Run study area was considered a minor component of the agricultural land use. The model also contained equations that simulate scour or erosion from confined channels. This portion of the model was only applied to the construction area pervious land segment where erosion rills and channels are a more likely occurrence than within lawns, forested areas, pastures and open, vegetated fields.

Final calibration simulations were conducted over a three year period bracketing the target year. This was the same method applied to the hydrologic calibration effort.

4.0 RESULTS

The following sections present the results of the land use analysis, GIS application and model application portions of this study.

4.1 Land Use Analysis

Three maps representing historical land use data and data pertaining to the relative percent imperviousness for each land use type that contained an impervious component were generated from the analysis of aerial photography. Results from the GIS analysis of land use type, distribution and change are addressed under the GIS application section.

Table 1 is a summary of percent imperviousness for each land use that contained an impervious component. As previously noted, percent imperviousness measurements are based on the interpretation of aerial photographs as illustrated and described in the methodology section (Figures 2-4).

Table 1. Percent imperviousness of land use.

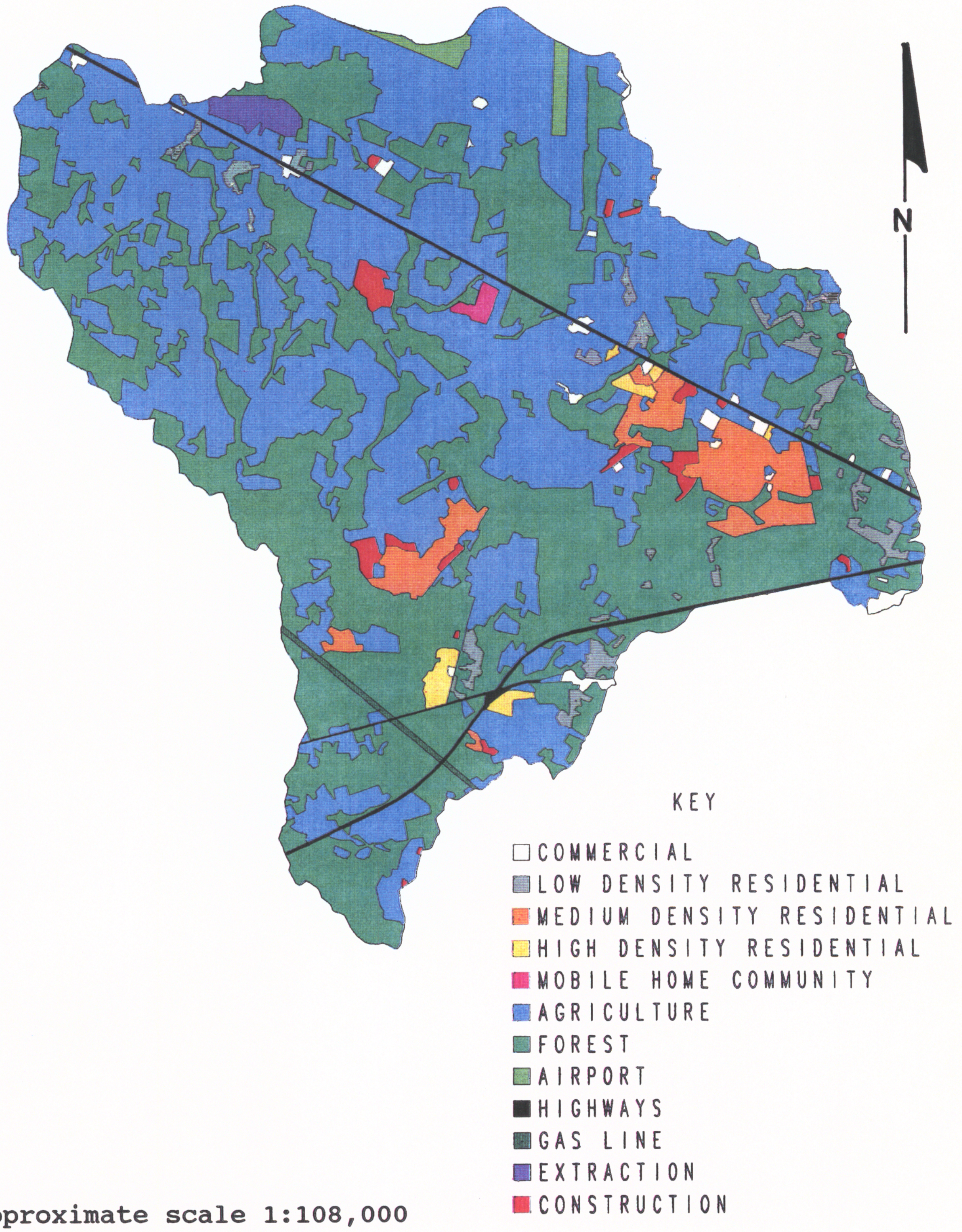
IMPERVIOUS LAND USE	Percent
High-density residential (HDR)	82%
Medium-density residential (MDR)	41%
Low-density residential (LDR)	12%
Mobile Home Community (MHC)	61%
Commercial/Institutional/Governmental (COM)	87%
Extraction (EXT)	100%
Major Highways and Interstates (HWY)	66%
Airport runways (AIR)	34%

4.2 GIS Application

The results compiled under the GIS application include: maps and tables depicting historical land use data at a reach sub-watershed level, and data representing an analysis of land use change. Figures 5 - 7 are GIS map products representing the 1979, 1984 and 1988 Cub Run land use. Note that the majority development has occurred in the southern and eastern portions of the watershed. Figure 8 is also a GIS map product depicting the reach subwatershed division based on perineal blue line stream segments and their contributing areas.

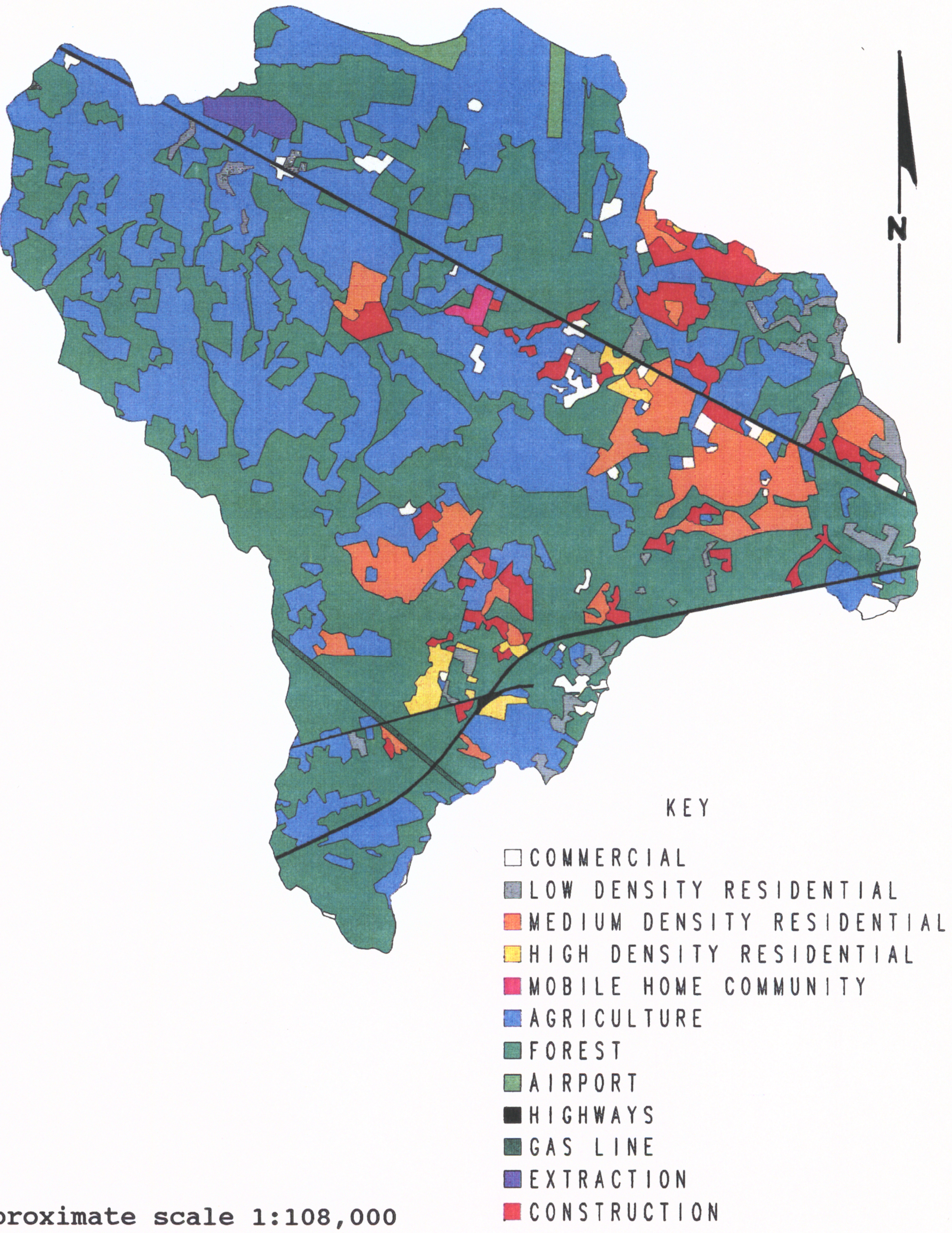
GIS derived land use area measurements are organized into a series of tables (Tables 2 - 4). Land use is represented by subwatershed reach divisions. Area represented by each land use classification is summed and the percentage of total watershed area is given. Land use classification is organized into two groups; the first group represents all classified land use that contain an impervious component (referred to as Impervious Land Use) the second group represents mostly pervious land use. Each land use classification within the pervious and impervious land use categories were summed and total area and percentage of total watershed area are given.

The length of each reach was also obtained from the GIS database. Table 5 presents the perineal blue line reach segments that were graphically represented by Figure 8.



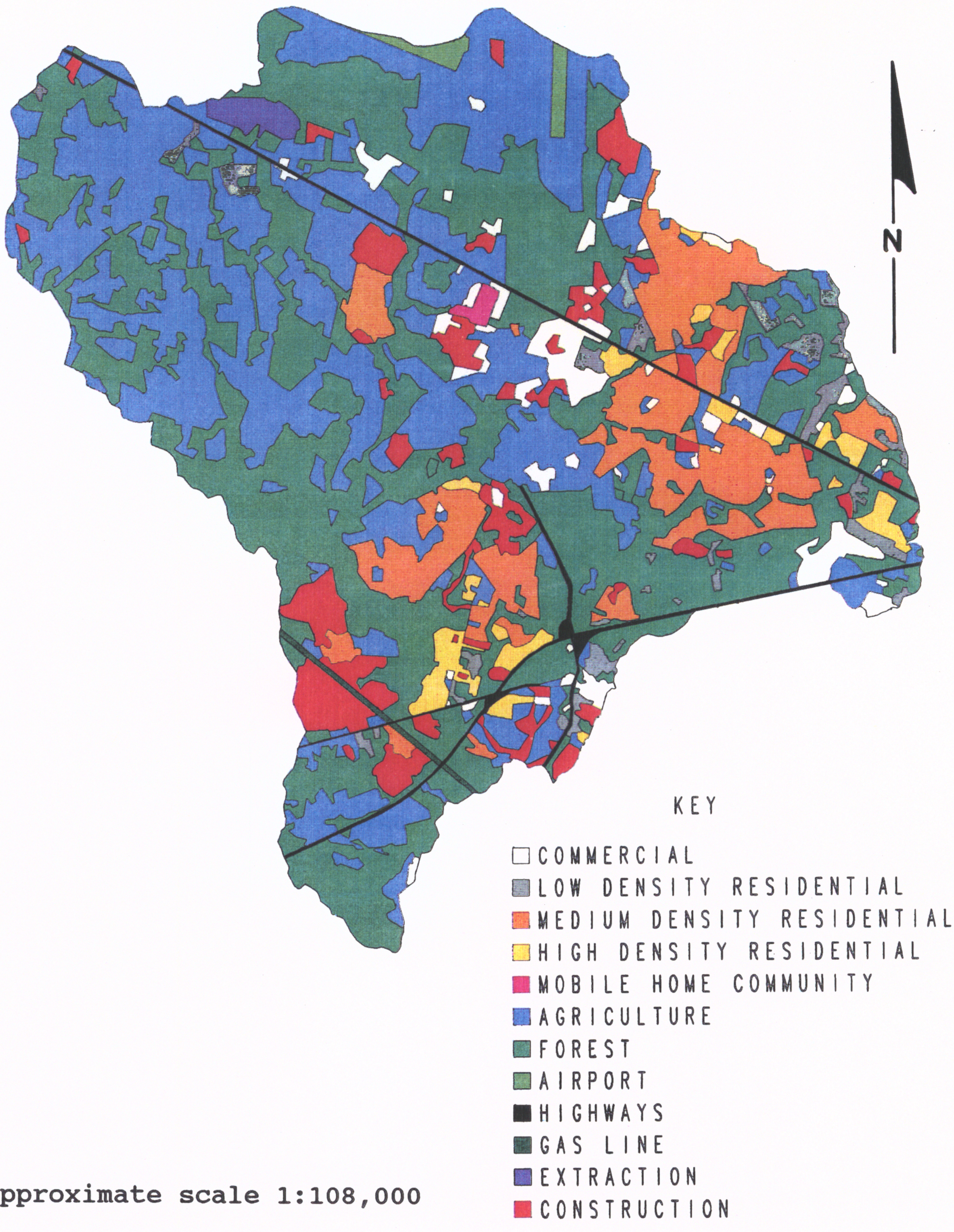
Approximate scale 1:108,000

FIGURE 5: 1979 Cub Run Watershed land use.



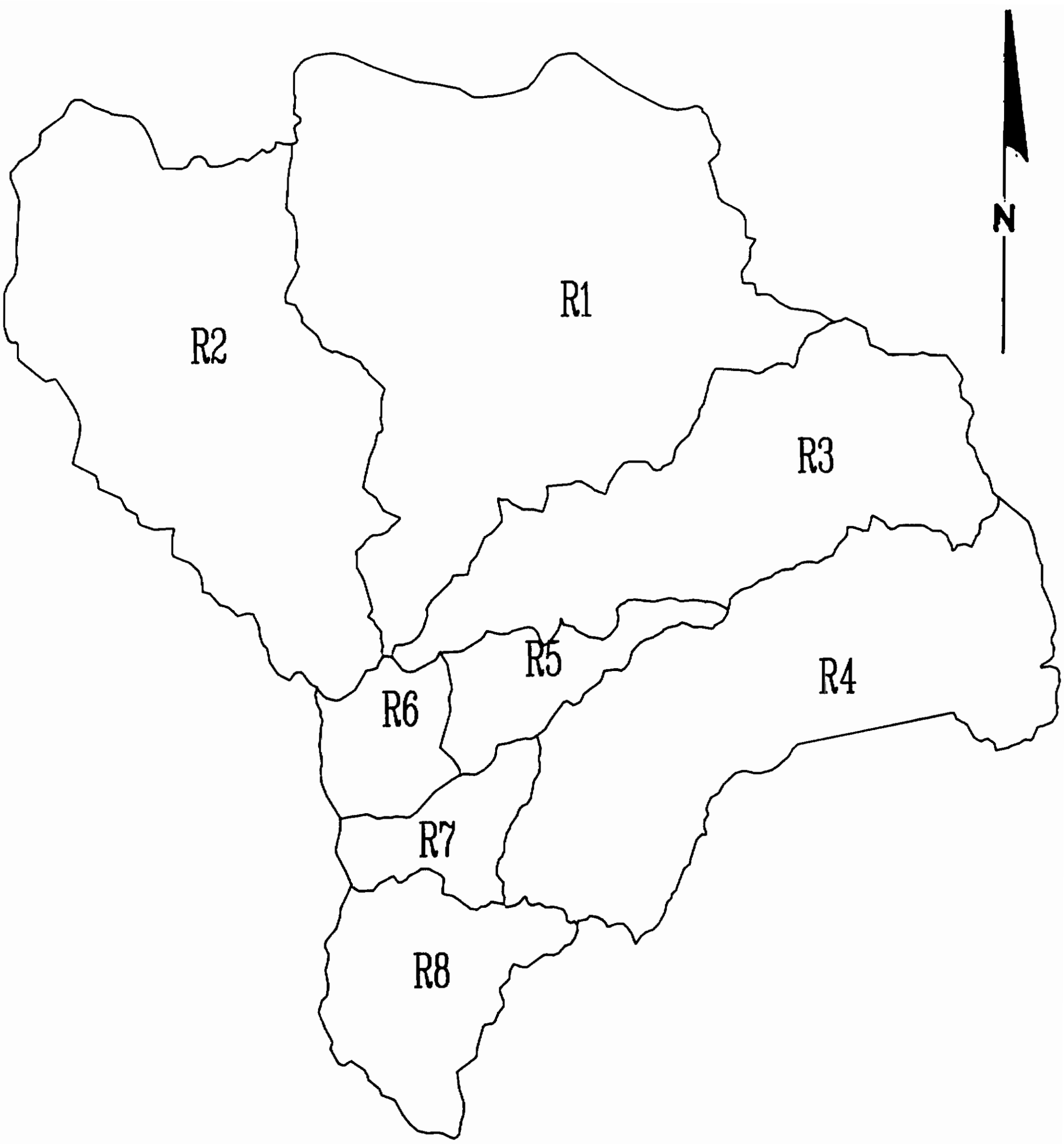
Approximate scale 1:108,000

FIGURE 6: 1984 Cub Run Watershed land use.



Approximate scale 1:108,000

FIGURE 7: 1988 Cub Run Watershed land use.



Approximate Scale 1:112,000

FIGURE 8: Cub Run Watershed reach sub-division.

TABLE 2. Summary of the 1979 Cub Run watershed land use (acres).

	REACH									
	1	2	3	4	5	6	7	8	Total	%
IMPERVIOUS LAND USE										
High-density Residential.. (111)	37	84	214	357			3		696	2
Medium-density Residential (112)	2		278	599	230	93		4	1206	4
Low-density Residential... (113)			59	71			79		209	1
Mobile Home Community..... (114)	67								67	0
Commercial (12)...........	81	16	66	119			1		283	1
Extraction (75)...........	101	93							194	1
Highway (171).............	81	42	37	176			7	55	398	1
Airport (144).............	202								202	1
Sub total.................	571	235	654	1323	230	93	90	59	3255	10
PERVIOUS LAND USE										
Construction (76)........	119		73	74	31	56	3	8	364	1
Agriculture (21).........	5891	4129	2530	1107	333	234	22	636	14882	44
Utilities (15)...........						26	46	22	94	0
Forest (41)..............	3392	3069	1762	3604	477	547	792	1363	15006	45
Sub total................	9403	7198	4365	4785	842	862	862	2029	30346	90
Total of all Land Use....	9974	7433	5019	6108	1072	955	953	2087	33601	100

TABLE 3. Summary of the 1984 Cub Run watershed land use (acres).

	REACH									
	1	2	3	4	5	6	7	8	Total	%
IMPERVIOUS LAND USE										
High-density Residential.. (111)	45	78	279	370			2	20	793	2
Medium-density Residential (112)	190		465	864	280	149	17	10	1975	6
Low-density Residential... (113)	4		86	112			99		301	1
Mobile Home Community..... (114)	68								68	0
Commercial (12)...........	161	12	125	176			1	8	483	1
Extraction (75)...........	105	91							195	1
Highway (171).............	81	41	37	176			7	55	397	1
Airport (144).............	202								202	1
Sub total.................	855	222	992	1698	280	149	125	93	4414	13
PERVIOUS LAND USE										
Construction (76)........	272		423	366	88		16	8	1173	3
Agriculture (21).........	4895	4034	1684	765	232	224	21	542	12397	37
Utilities (15)...........						26	46	22	94	0
Forest (41)..............	3952	3177	1921	3279	472	556	744	1422	15523	46
Sub total................	9119	7211	4027	4410	792	806	827	1994	29187	87
Total of all Land Use....	9974	7433	5019	6108	1072	955	953	2087	33601	100

TABLE 4. Summary of the 1988 Cub Run watershed land use (acres).

	REACH									
	1	2	3	4	5	6	7	8	Total	%
IMPERVIOUS LAND USE										
High-density Residential.. (111)	25	100	299	330			1	22	777	2
Medium-density Residential (112)	437		1236	1190	371	164	26	24	3449	10
Low-density Residential.. (113)	13		221	382	22		144		782	2
Mobile Home Community.... (114)	70								70	0
Commercial (12)..........	525		291	365	3		1	15	1201	4
Extraction (75)..........	102	95							198	1
Highway (171)............	81	42	43	258	7		7	55	493	1
Airport (144)............	202								202	1
Sub total................	1455	237	2090	2526	404	164	179	116	7171	21
PERVIOUS LAND USE										
Construction (76)........	650	31	250	306	119	258	369	141	2123	6
Agriculture (21).........	3993	3895	1196	620	186	110	20	543	10563	31
Utilities (15)...........						26	46	22	94	0
Forest (41)..............	3877	3269	1483	2655	363	398	339	1266	13650	41
Sub total................	8519	7196	2929	3581	668	792	774	1971	26430	79
Total of all Land Use....	9974	7433	5019	6108	1072	955	953	2087	33601	100

TABLE 5. Reach lengths as represented by perineal blue line streams (miles).

REACH	METERS	MILES
R1	9850	6
R2	10800	7
R3	8520	5
R4	11700	7
R5	2310	1
R6	2840	2
R7	2740	2
R8	5410	3

The Cub Run watershed experienced a significant change in land use over a nine year period. One of the most important aspects of this change was an increase in impervious surface area. Impervious surface area can be represented as two different concepts. The first is a comparison of various land use that contain an impervious component. The impervious component can extend from the approximate 98 percent impervious surface area of commercial land uses to an approximate 12 percent impervious surface area observed in low-density housing areas. The comparison of impervious component land use classification indicates the overall trend in development's affect on land use change within the watershed area. Figure 9 represents the change in impervious component land use from 1979 to 1988, where land use containing an impervious component rose from approximately 10 percent of the watershed surface area in 1979 to approximately 21 percent in 1988. Figure 10 presents the fastest growing land uses in terms of surface area.

The second concept deals specifically with the percent impervious surface area of the watershed. These data are needed as model input and are broken down into percent impervious surface area for each land use containing an impervious component. Figure 11 represents the percent of the watershed surface area that is impervious for each year of land use analysis.

Land surface under construction was also examined to better understand sediment loading as a result of construction activity. No attempts were made to identify and include the effects of construction best management practices during simulation. Figure 12 represents the percent of watershed area that was under construction (soils exposed) in 1979, 1984 and 1988. Approximately 1 percent or

336 acres, of the watershed surface area was under construction in 1979. By 1988 approximately 6 percent or 2016 acres, were under construction.

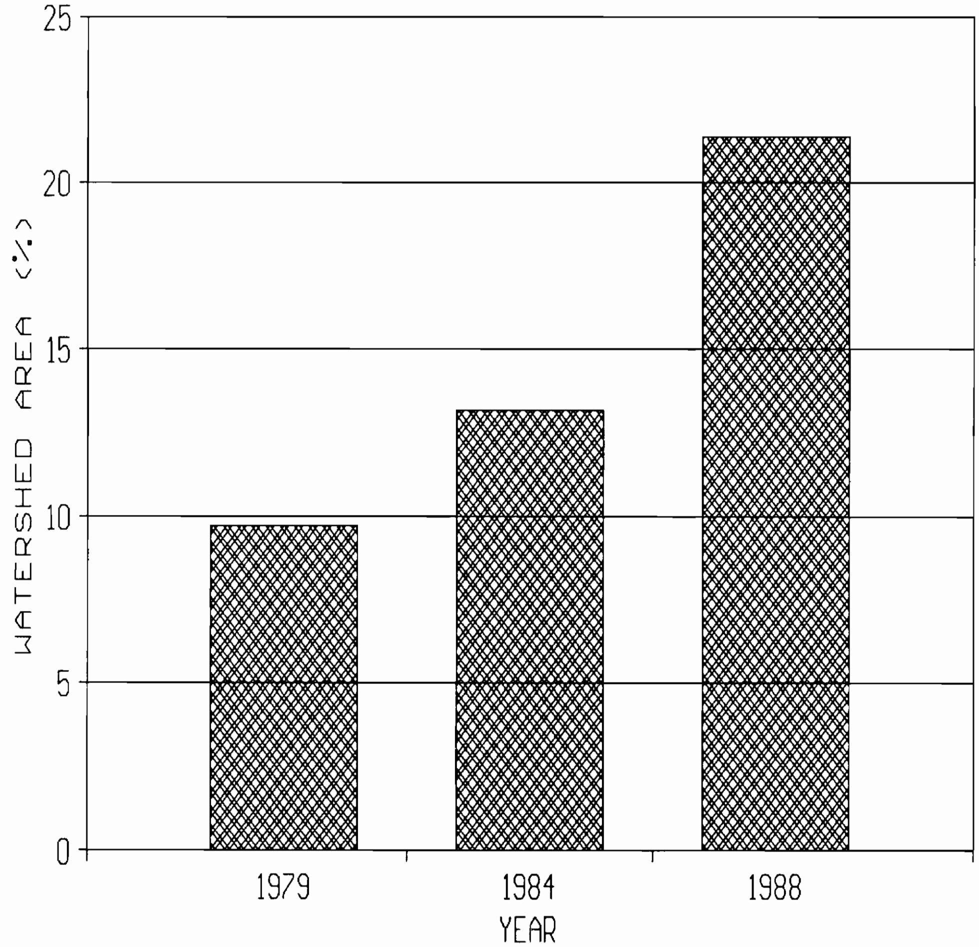
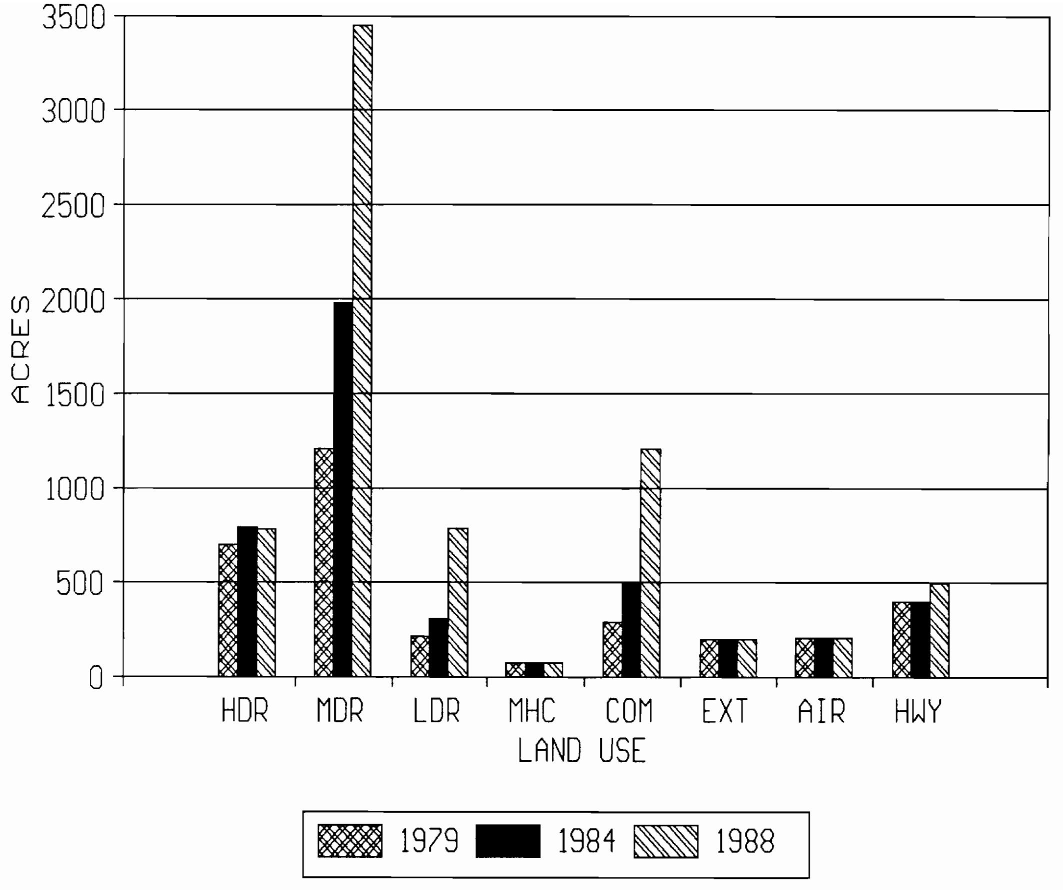


Figure 9: Land use with an impervious component.



HDR - High-density Residential Housing.
MDR - Medium-density Residential Housing.
LDR - Low-density Residential Housing.
MHC - Mobile Home Community.
COM - Commercial.
EXT - Extraction.
AIR - Airport.
HWY - Highway.

Figure 10: Watershed impervious surface area by land use type.

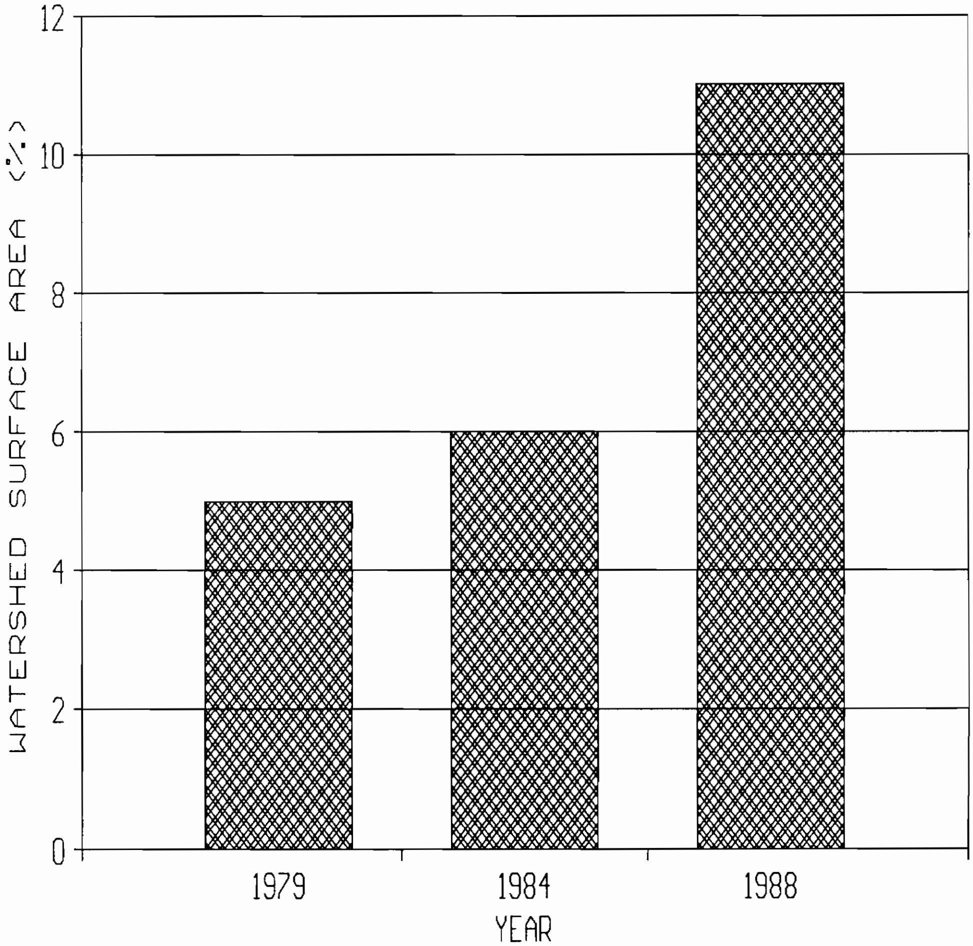


Figure 11: Watershed impervious surface area.

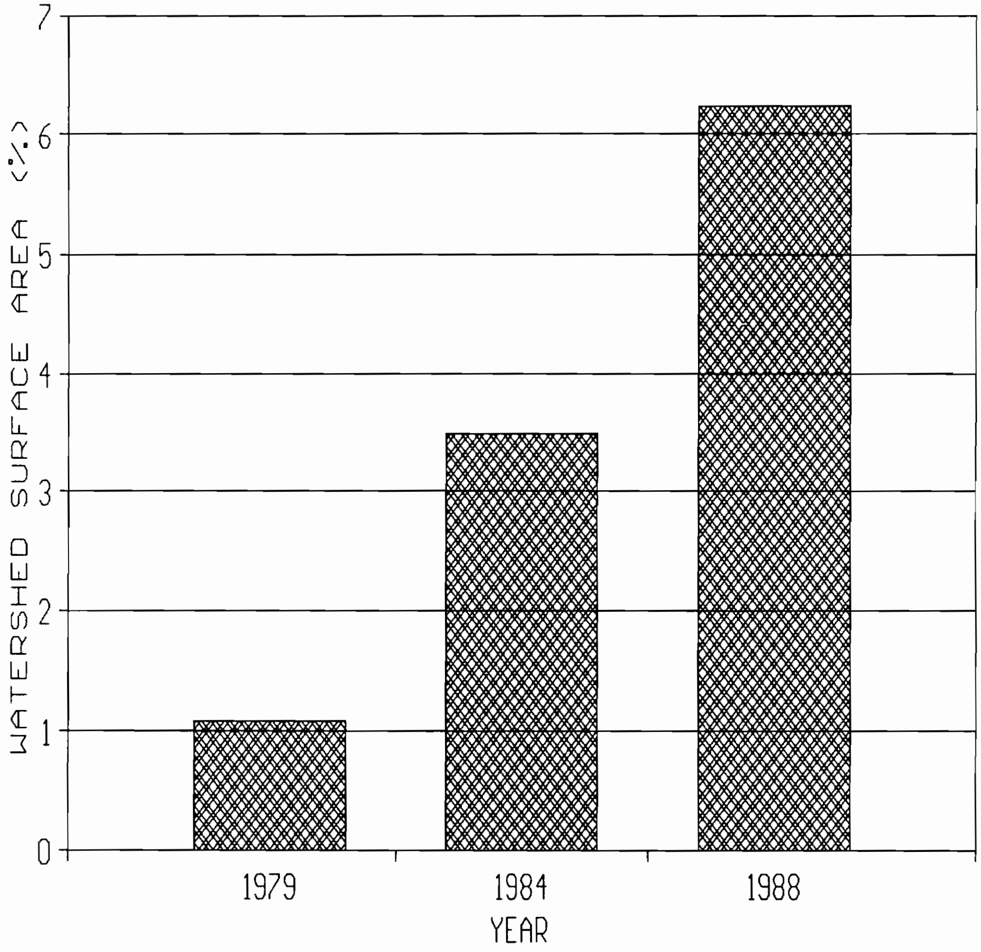


Figure 12: Percent of watershed surface area under construction.

4.3 Model Application

A calibrated watershed-scale hydrologic and water-quality model called HSPF was used to demonstrate model application. Measured discharge and suspended solids data were examined for increasing trends in discharge and sediment concentrations.

Figure 13 represents discharge as the ratio of discharge (inches) to precipitation (inches) over time. It depicts the percent of rainfall that runs off the watershed as a function of precipitation. It is recognized that baseflow from the groundwater system contributes to total runoff sums; however, sources (Owe, 1985; Taylor, 1977; Athahyde, et al., 1983, Thomann and Mueller, 1987) indicate that as watershed surface area becomes more impervious, a greater percentage of overall discharge should increase. As can be seen in Figure 13 this trend did not develop as expected. Throughout this study, discharge is primarily represented and discussed in terms of inches. The unit inch, refers to a volume of discharge distributed across the watershed surface area to a depth of one inch.

Figure 14 represents precipitation data over time. The precipitation data displays seasonal cycles but little overall change in relative magnitude. Figure 15 represents flow-weighted monthly sums of suspended solids as a ratio of tons discharged from the watershed to precipitation over time. There was significantly less material transported out of the watershed in 1979-1981 when compared to the remaining years. The increase in suspended solids discharged from the watershed and the concurrent increase of surface area laid bare by construction leads to the observation that construction activity is the probable cause of increased suspended solids discharge.

Tables 6 and 7 present measured precipitation and potential evaporation data, represented as monthly and annual sums, for 1979, 1984 and 1988. Precipitation and potential evaporation data are presented on a daily time step in Appendix 1. Measured and simulated values for watershed discharge and total suspended solids are presented in the following sections.

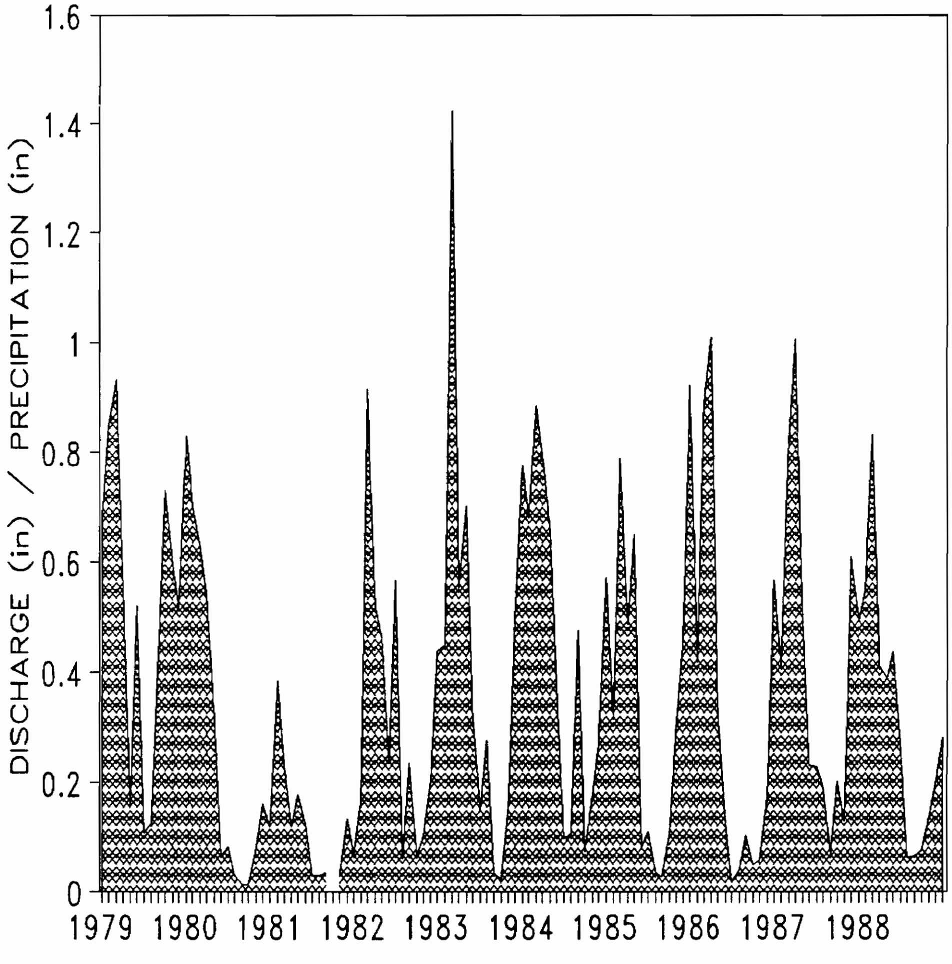


Figure 13: Ratio of discharge to precipitation over time.

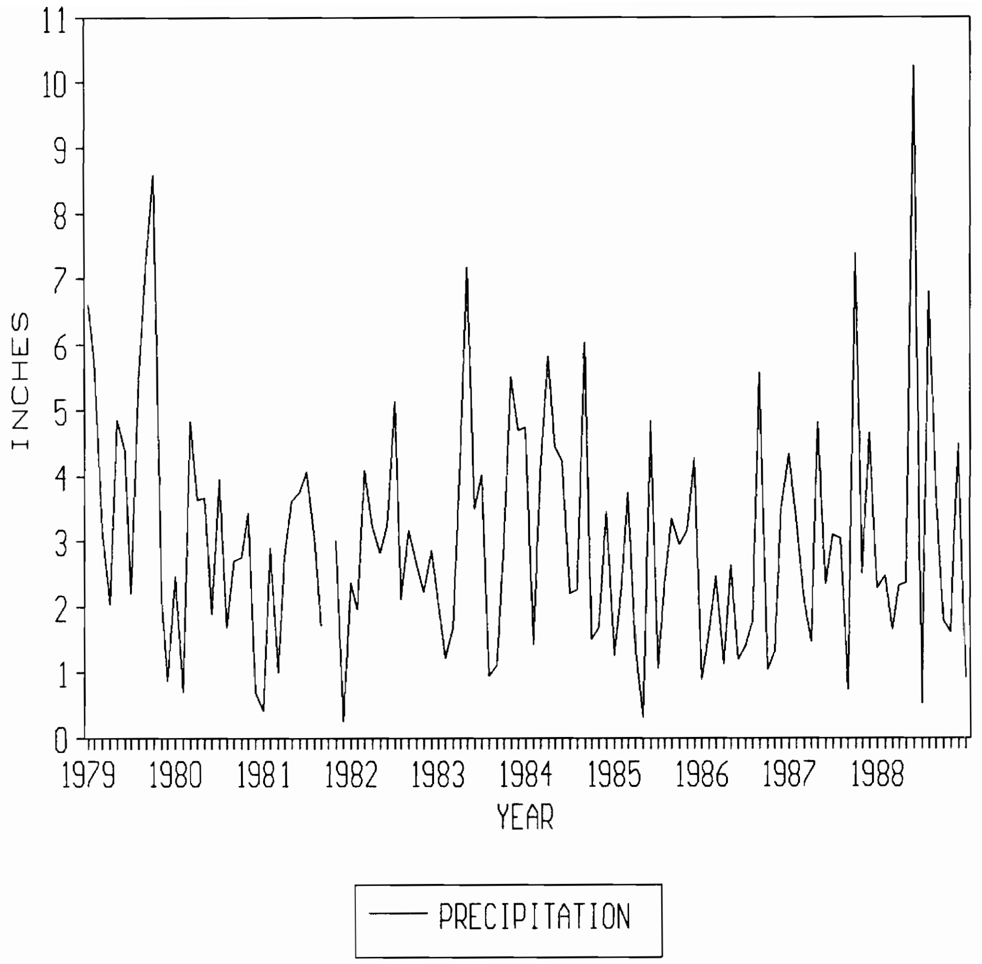


Figure 14: **Precipitation data.**

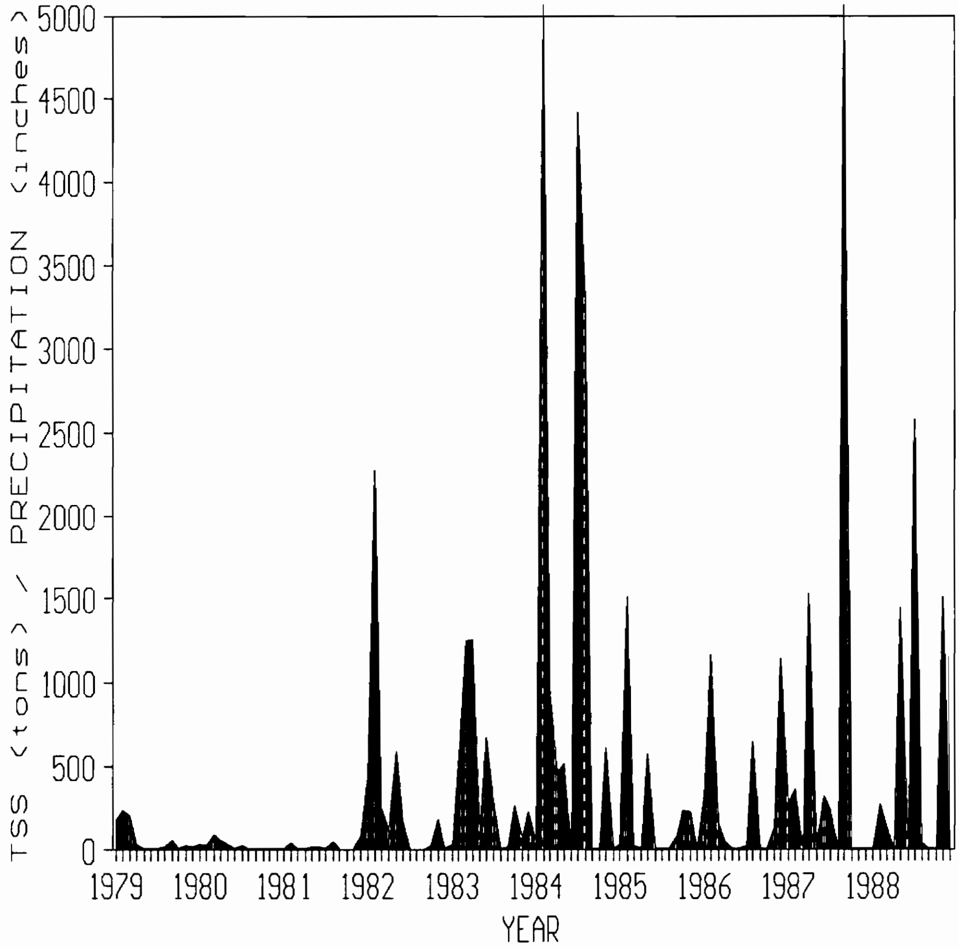


Figure 15: Ratio of suspended solids to precipitation over time.

TABLE 6. Cub Run watershed monthly and annual precipitation data for 1979, 1984 and 1988 (inches).

	Precipitation (inches)												
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Sum
1979	6.6	5.8	3.2	2.1	4.9	4.4	2.2	5.5	7.3	8.6	2.1	0.9	53.4
1984	1.4	4.1	5.8	4.4	4.2	2.2	2.3	6.0	1.5	1.7	3.5	1.3	38.3
1988	2.5	1.6	2.3	2.4	10.2	0.5	6.8	3.9	1.8	1.6	4.5	0.9	39.1

TABLE 7. Cub Run watershed monthly and annual potential evaporation data for 1979, 1984 and 1988 (inches).

	Potential Evaporation (inches)												
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Sum
1979	0.0	0.0	0.0	2.3	2.8	3.3	2.9	2.7	2.5	1.9	0.0	0.0	18.4
1984	0.0	0.0	0.0	2.4	3.5	4.6	4.2	3.7	3.1	1.9	0.0	0.0	23.4
1988	0.0	0.0	0.0	2.9	4.0	5.3	5.3	4.4	2.6	2.4	0.0	0.0	26.8

4.3.1 Hydrologic Simulation

The overall results from the hydrologic simulation were good. Tables 8 and 9 present measured discharge values for 1979, 1984 and 1988 in inches and cubic feet per second (cfs) per month. Tables 10 and 11 presents simulated discharge data for 1979, 1984 and 1988 in inches and cubic feet per second (cfs). Daily measured and simulated discharge data (cfs and inches) during 1979, 1984 and 1988 are presented in Appendix 2. Appendix 3 contains the HSPF input files used to simulate watershed discharge.

Figure 16 represents the precipitation, discharge and simulated discharge for 1979 as a monthly average. Figure 17 represents the residuals as a difference between simulated and actual values.

The 1979 calibrated parameter set was applied to the 1984 and 1988 simulations. No further calibration of the model was performed. Figure 18 represents the precipitation, discharge and simulated discharge for 1984 as a monthly average. Figure 19 represents the residuals as a difference between 1984 simulated and actual data. The simulated February and August data points diverge considerably from the actual data when compared to the remaining data points. The February deviation is probably due to frozen ground conditions corresponding with a storm event. The August deviation can be accounted for in two storm events. The first event occurred on August 9 and 10. A 0.7 inch precipitation event occurred on August 9 followed by a 2.4 inch event on August 10. The watershed responded with a 0.3 inch discharge on August 10 followed by a 0.8 inch discharge on August 11. Model simulation matched the 0.3 inch discharge but did not match the 0.8 inch discharge. A second precipitation event accounting for another 0.8 inches occurred two days later over the 12th and 13th of August. The watershed responded with a 0.8 inch discharge on August 14. Simulation only accounted for 0.1 inch of discharge for this event. A special circumstance of short duration and high intensity storm events over a series of days with saturated ground conditions, may explain the divergence in simulation and actual discharge data. Under these types of conditions, the calibrated parameter set does not mimic the system.

Figure 20 presents precipitation, actual discharge and simulated discharge for 1988 as a monthly average. Figure 21 represents the residuals. The data indicate a good match between actual and simulated discharge values.

Overall, correlation between simulated and actual data was good, with some discrepancy during the months of January and February. Underestimation was probably due to frozen ground ground conditions increasing runoff by reducing infiltration during rain events. Minor adjustments for frozen ground are possible. However, the model was not adjusted for this factor.

TABLE 8. Cub Run watershed measured discharge for 1979, 1984 and 1988 (inches)

Measured Discharge (inches)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Sum
1979	4.5	5.0	3.0	1.1	0.8	1.4	0.2	0.7	3.2	6.3	1.3	0.5	27.7
1984	1.0	3.6	4.6	2.9	1.6	0.2	0.2	2.9	0.1	0.3	0.9	0.7	19.1
1988	1.4	1.4	1.0	0.9	4.5	0.1	0.4	0.3	0.1	0.2	0.9	0.3	11.3

TABLE 9. Cub Run watershed monthly and annual measured discharge data for 1979, 1984 and 1988 (cfs).

Measured Discharge (cfs)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Sum
1979	6410	6909	4169	1585	1074	1996	330	961	4446	8848	1779	641	39150
1984	1365	5090	6504	4141	2254	295	330	4048	151	414	1315	1007	26913
1988	1917	1925	1343	1296	6323	191	588	355	186	298	1251	365	16037

TABLE 10. Cub Run watershed simulated discharge for 1979, 1984 and 1988 (inches).

Simulated Discharge (inches)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Sum
1979	3.6	3.8	2.7	1.0	0.7	1.4	0.3	0.8	3.9	6.0	1.1	0.6	25.8
1984	1.1	2.3	4.4	2.7	1.2	0.2	0.2	1.2	0.2	0.2	0.8	0.7	15.1
1988	1.2	1.0	1.4	0.9	4.3	0.1	1.0	0.5	0.3	0.2	1.1	0.5	12.4

TABLE 11. Cub Run watershed simulated discharge for 1979, 1984 and 1988 (cfs).

Simulated Discharge (cfs)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Sum
1979	5044	5394	3786	1358	922	1985	454	1146	5557	8404	1554	879	36482
1984	1489	3230	6146	3830	1740	282	277	1638	219	240	1121	1035	21248
1988	1656	1358	2029	1210	6078	161	1405	721	363	286	1585	712	17564

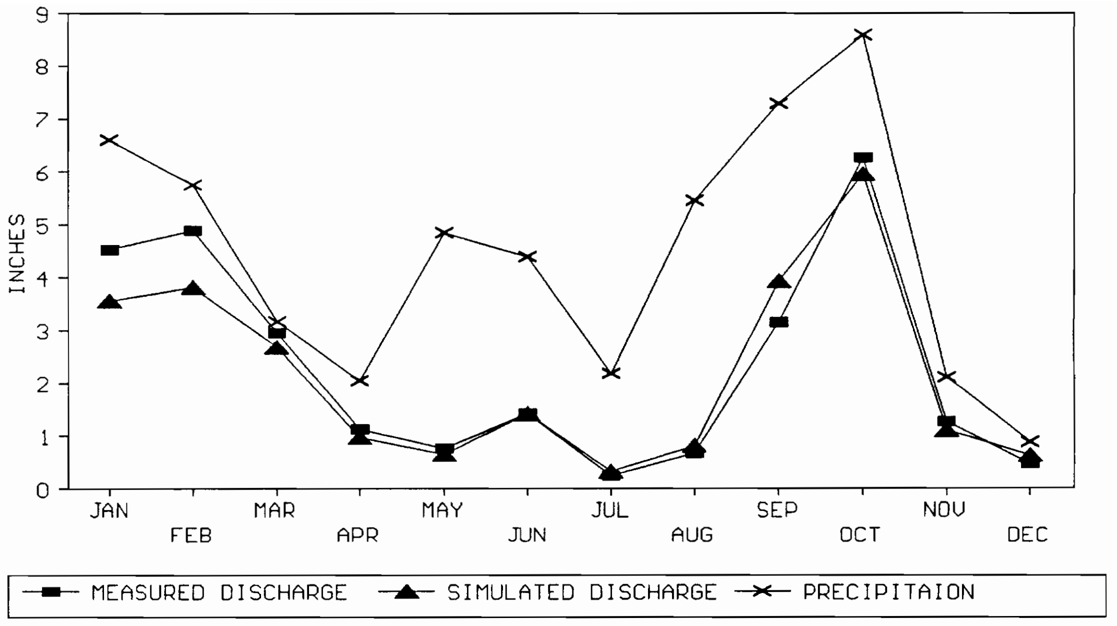


Figure 16: Discharge calibration simulation 1979.

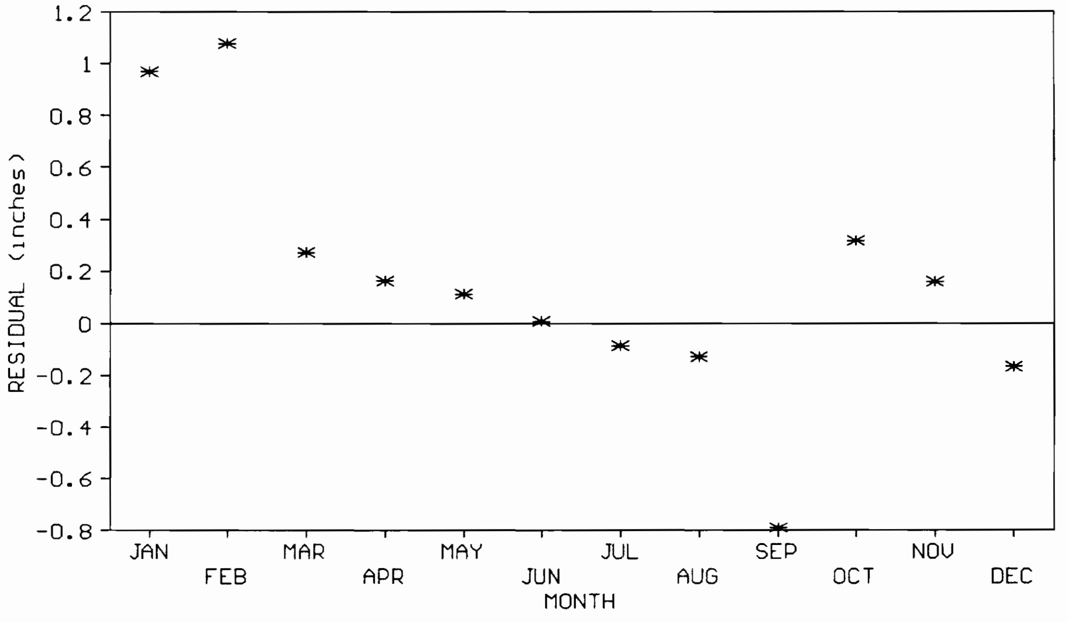


Figure 17: Residual plot for 1979 discharge simulation data.

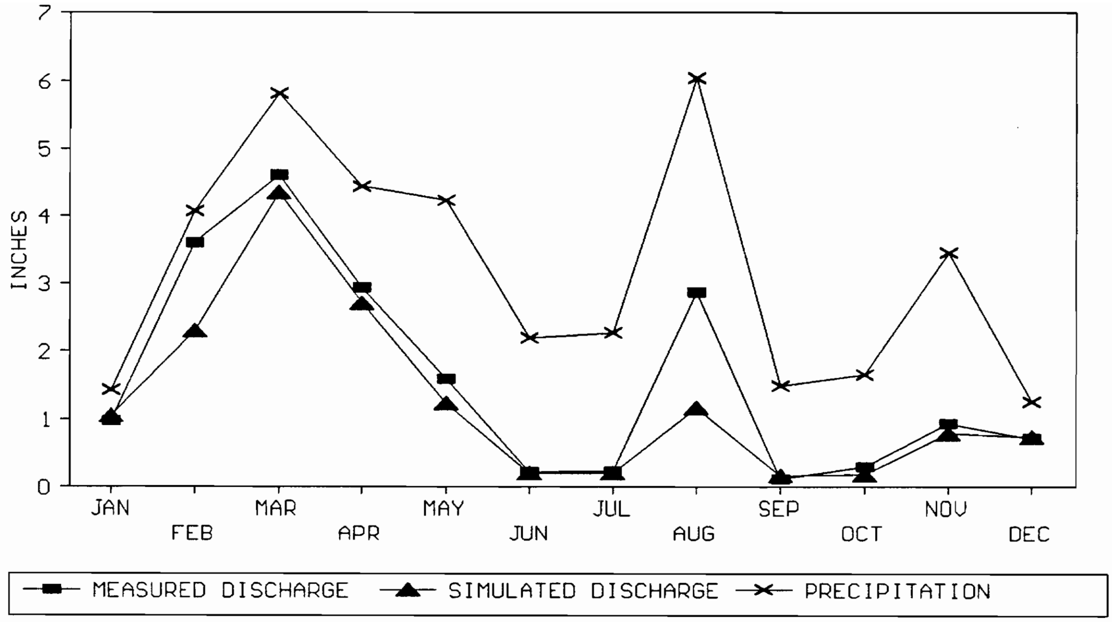


Figure 18: Discharge simulation 1984.

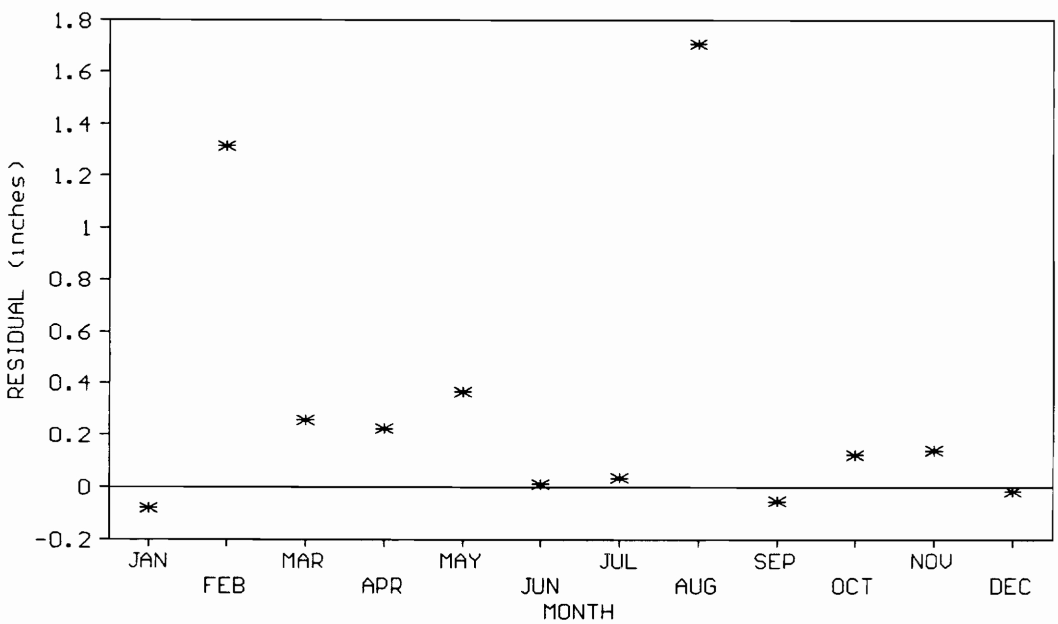


Figure 19: Residual plot for 1984 discharge simulation data.

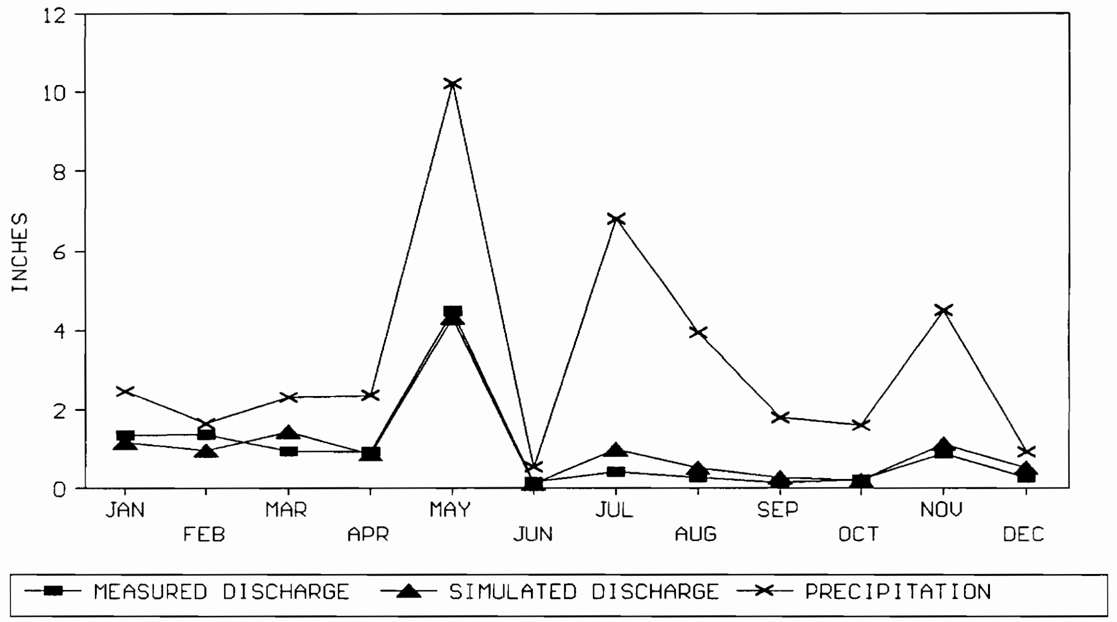


Figure 20: Discharge simulation 1988.

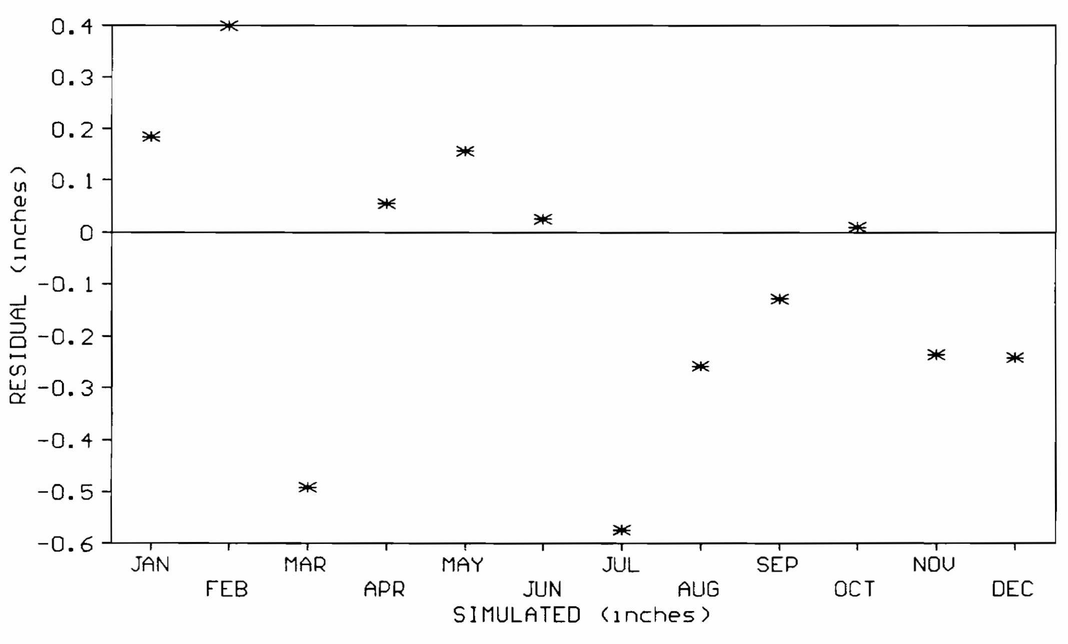


Figure 21: Residual plot for 1988 discharge simulation data.

4.3.2 Suspended Solids Simulation

Results from the suspended sediment calibration were not as good as those obtained from the hydrologic calibration effort. The application guide for Hydrologic Simulation Program - Fortran (Donigian, et al., 1984) warns that sediment calibration is less certain when compared to hydrologic calibration for several reasons: the first is the limited availability and quality of observed monthly values for sediment loss and the second refers to sediment calibration parameters and their inability to simulate the distinct differences between monthly sediment loss and storm event related losses.

There was one obvious problem encountered while working with the total suspended solids (TSS) data contained within the Cub Run database. Values for the 1984 TSS were significantly higher than what could be reasonably expected and therefore the data were not used. Simulation was conducted on the year 1985 assuming that the watershed land use did not change significantly between the 1984 and 1985.

The measured suspended solids data consisted of periodic samples and storm event based samples. A computer program was designed at the Occoquan Watershed Monitoring Laboratory to extract and generate flow-weighted values for total suspended solids based on type of sample obtained.

This approach presents a reasonable characterization of suspended sediment discharge from the watershed. Tables 12 and 13 represent the measured and simulated suspended solids data as monthly and annual sums for 1979, 1985 and 1988. Daily simulated suspended solids data for 1979, 1985 and 1988 are presented in Appendix 4. The HSPF input files used to simulate suspended solids are represented in Appendix 5.

Figures 22, 24 and 26 illustrate a relationship between runoff and measured suspended solids in addition to comparing actual and simulated suspended solids results. Figures 23, 25 and 27 represent corresponding residual plots. In most cases, values for measured suspended solids correlate well with runoff. At the monthly time step, wet months correlate with increased values for suspended solids and lessor values correlate with dry months. In general terms, the measured data indicate an expected trend or relationship between runoff and suspended solids.

Attempts to simulate this process using HSPF produced some interesting results. Several outlier data points were seen in residual plots (Figures 22, 24 and 26). The outlier data points were noted in September and October 1979 (Figure 22), February 1985 (Figure 24), and March, May and November 1988 (Figure 26). Since other data points for 1979 and 1985 correlate well with runoff and simulated values, the 1979 and 1985 deviations may be due to bad data or perhaps an

TABLE 12. Cub Run Watershed measured values for total suspended solids as monthly flow weighted sums (tons); 1979, 1985 and 1988.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Sum
1979	1170	1330	640	60	17	5	2	80	380	8	46	7	3745
1985	35	3480	85	1	170	3	2	10	270	700	710	14	5480
1988	8	670	220	5	3410	1	1340	230	2	2	2420	1	8300

TABLE 13. Cub Run Watershed simulated values for total suspended solids in terms of monthly sums (tons) for 1979, 1985 and 1988.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Sum
1979	1266	1370	665	119	291	585	93	323	1846	1986	278	99	8920
1985	346	1337	216	22	455	11	146	315	376	404	724	134	4490
1988	558	411	1047	571	2682	2	1521	557	304	329	1222	227	9430

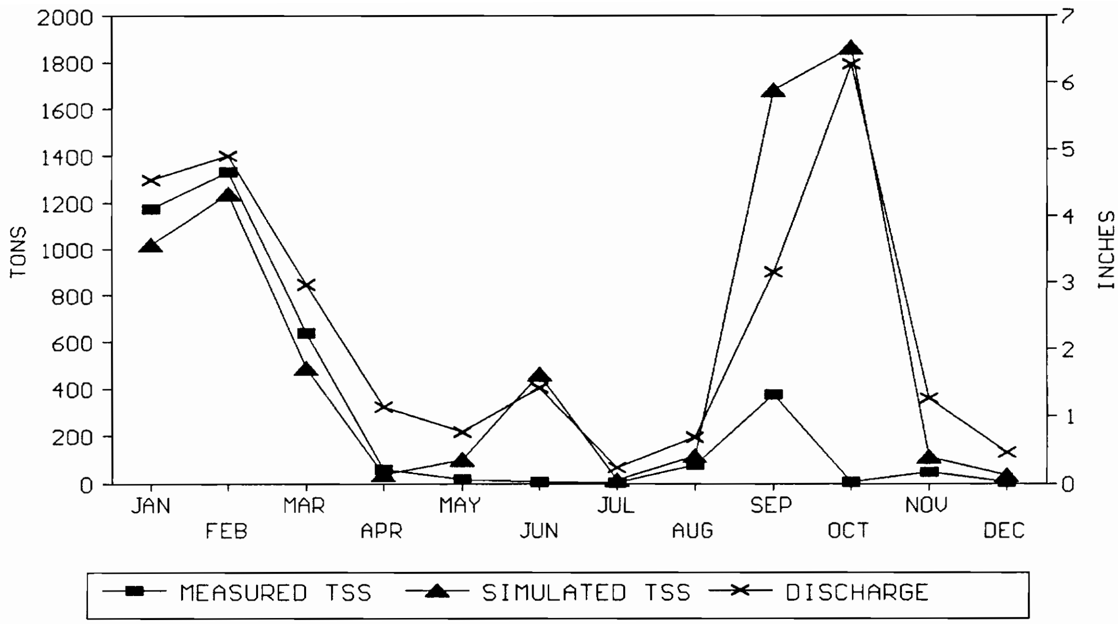


Figure 22: Suspended solids calibration simulation 1979.

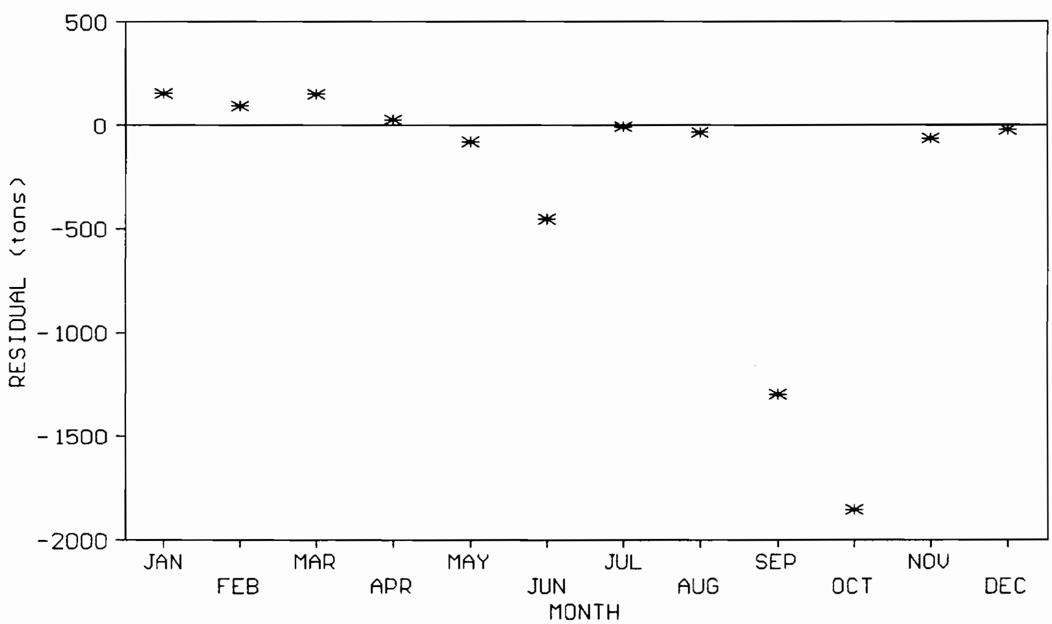


Figure 23: Residual plot for 1979 suspended solids simulation data.

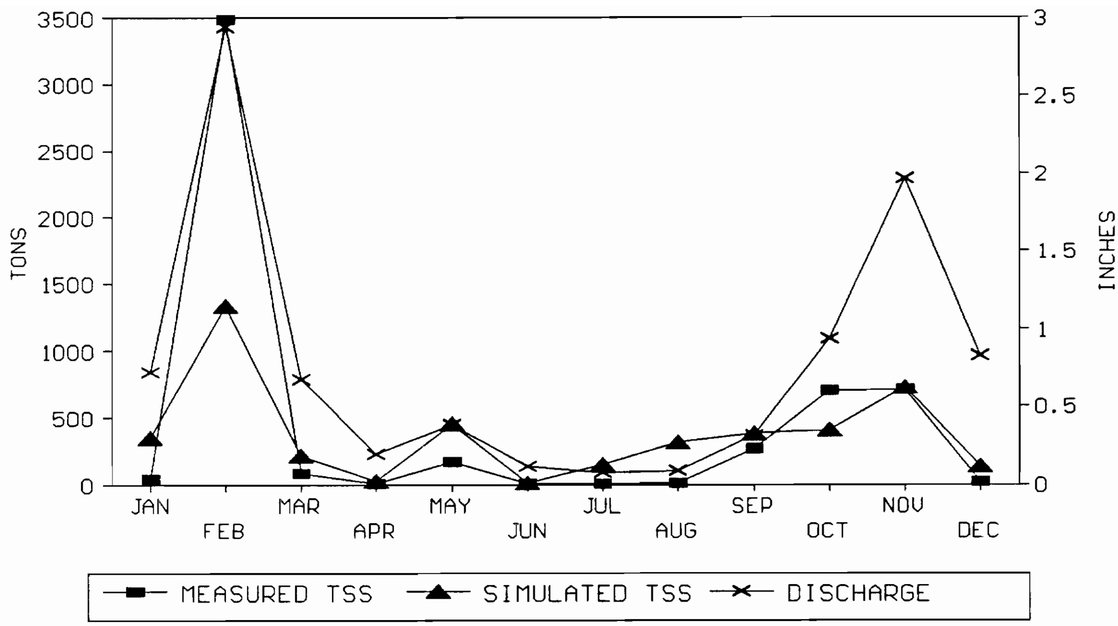


Figure 24: Suspended solids simulation 1985.

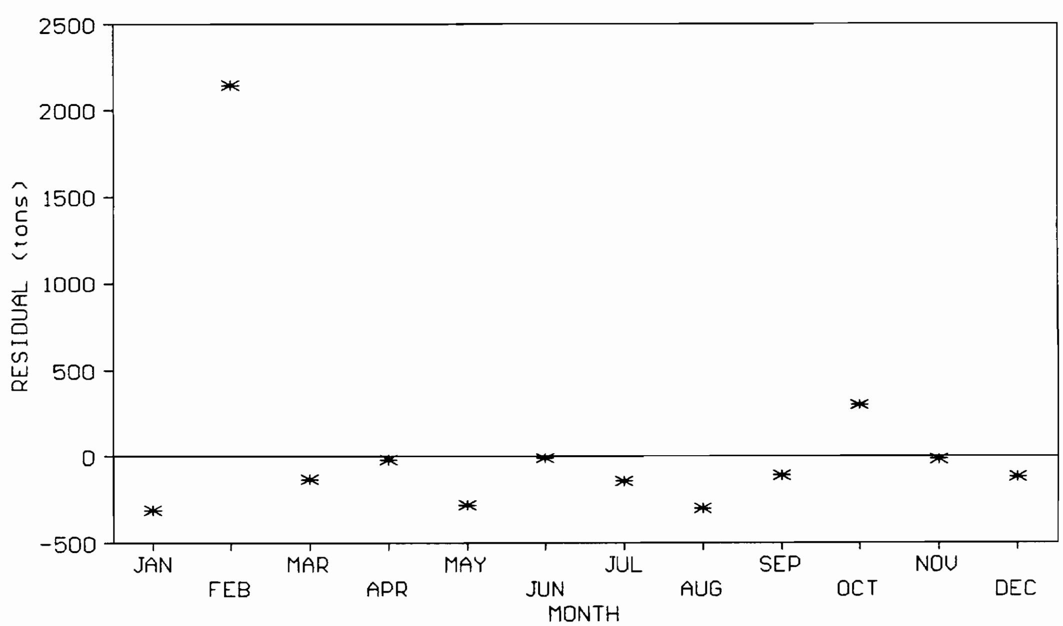


Figure 25: Residual plot for 1985 suspended solids simulation data.

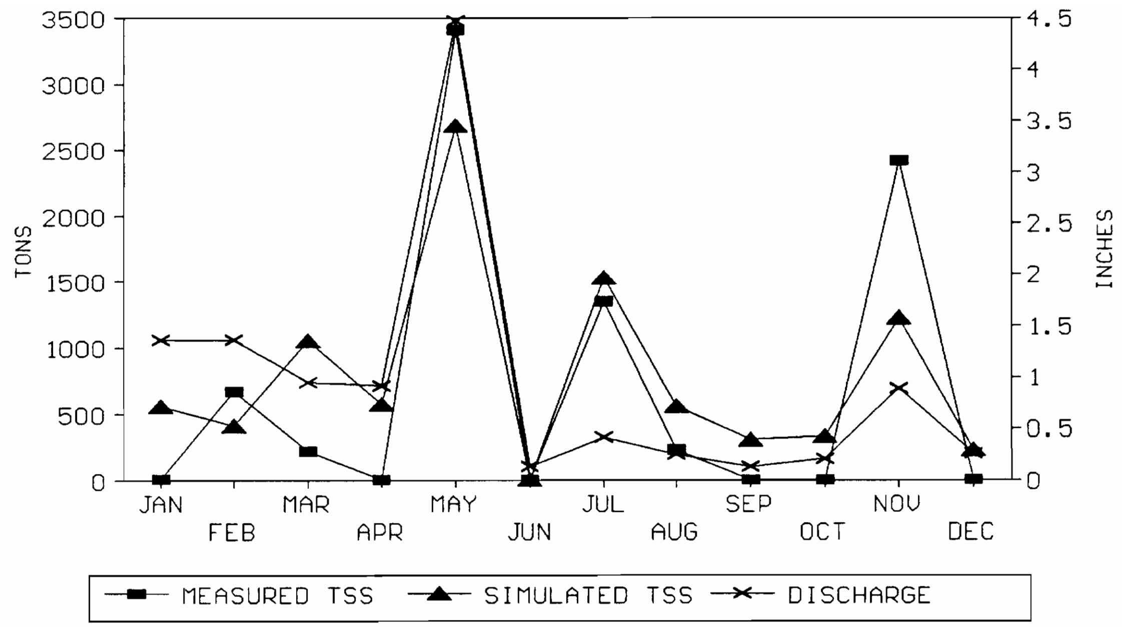


Figure 26: **Suspended solids simulation 1988.**

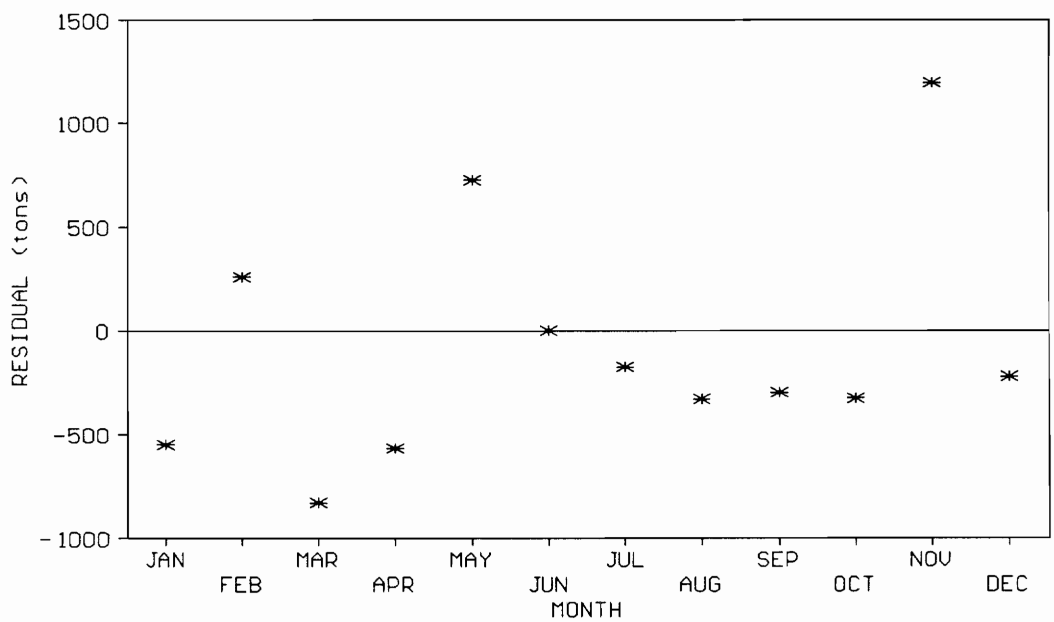


Figure 27: **Residual plot for 1988 suspended solids simulation data.**

unknown factor like a winter storm in February 1985 (increased detached sediment storage due to freeze thaw cycles or road sanding).

The 1988 data presented a different type of problem. Correlation between simulated and measured data for 1988 was not as good as the 1979 and 1985 results. A comparison between actual discharge and actual suspended solids data indicate, that for approximately .75 inches of discharge occurring in November 1988, and about .80 inches of discharge that occurred in October and December 1985, the corresponding November 1988 suspended solids output was approximately 2400 tons while the 1985 amounts were approximately 700 tons for October and less than 100 tons for December. Possible explanations for such varied response are duration and intensity of a single or multiple storm events or site development within a critical area (steep slope, direct connectivity to a stream, failing sediment best management practices, etc.) or critical distance to the mouth of the watershed.

Frequent time steps on the order of minutes or hourly data points are generally used to model duration and intensity of storm events. This HSPF modeling effort was conducted on a daily time step and calibrated to monthly output. Therefore, the effects of duration and intensity of individual storm events was not represented. This type of response to storm events may be evident in the 1988 data especially during "wet months" when storm events dominate the discharge process.

Construction activity has a major impact on watershed suspended solids discharge. Local differences in slope across a construction site create critical areas where step slopes and exposed soils are subjected to the erosive power of rainfall and runoff. The lumped parameter design of

HSPF, where length and slope of the overland flow plane were assigned single values for the entire watershed, is not well suited for characterizing this type of scenario.

Location of construction activity, coincidence of a storm event with maximum area laid bare by construction and/or application of construction best management practice techniques are critical components of the Cub Run watershed suspended solids output. These types of activities, spatial relationships, or events are not conducive to lumped parameter models and/or they require historical data that are not obtainable. The result is further uncertainty in the HSPF simulation of suspended solids output.

5.0 DISCUSSION

The following discussion section addresses the integrated methodology, the Cub Run watershed and future applications.

5.1 Integrated Methodology

The environment represents a complex system of meteorological, physical, biological and cultural characteristics with all aspects existing on an interactive basis. To study a component or several components of the system requires a multidisciplinary integrated approach. Data pertinent to watershed studies have been compiled by different disciplines ie. soil science, climatic, geography, geology, etc. Watershed and water resource analyses must rely on an integrated approach.

The Cub Run integrated approach developed for this research combined the fields of remote sensing, GIS technology, and computer modeling. Remote sensing provided a method of obtaining historical land use data. GIS technology was used to compile and analyze spatial data. A watershed model was used to link the effect of the land use changes with changes in water quantity and quality.

Most watershed modeling studies are used to evaluate changes in pollution control techniques or best management practices. In these types of studies overall land use is not changed, parameters are changed to reflect the best management practice employed. The current research deviates significantly from this approach in that model calibration over time reflects physical changes in land use. The overall goal for such approach is a management tool used to evaluate the potential effects of changing land use on water quality. In the changing land use scenario, one could answer such questions as: what would happen to water quality if 8 percent of the watershed agricultural areas and 3 percent of the forested areas were developed into commercial land use and an additional 12 percent of remaining forested areas and 13 percent of the remaining agricultural areas were converted to high-density residential housing?

Historical land use data sets can be also applied to the calibration and verification processes in modeling. If a calibrated model truly represents a natural system, a change in land use would not effect model output. Verification is commonly conducted without a land use change component. This process involves simulation over a period of time that brackets the date of land use analysis, assuming that the land use component does not change over the period of simulation. In a watershed experiencing a significant change in land use over a period of time, a calibrated and verified model at one year will not be applicable ten years later.

The need to obtain and manipulate data into different formats was evident throughout the Cub Run study. This represents one of the current difficulties of such an integrated approach. Necessary data are collected and maintained by different organizations. The data are generally not designed to be easily consolidated with data from other sources, although the technology now exists to analyze such integrated data.

5.2 Cub Run Watershed

Analysis of land use data for Cub Run illustrates that overall impervious surface area and construction area were increasing significantly during the study period. The impervious component of the watershed increased from 5 percent in 1979 to 11 percent in 1988. This increase was driven primarily by an increase in medium residential housing, whose area almost tripled from 1200 acres in 1979 to 3450 acres in 1988. Commercial land use more than tripled during this period. Although smaller in total watershed surface area, the impervious component of commercial land use was measured at approximately 87 percent impervious. Developed land was taken primarily from agriculture, whose land use dropped from 44 percent to 31 percent during this period. Forested areas also showed a slight drop.

The large increase in impermeable area would normally lead to an increase in the watershed discharge. However, this was not observed in the monitored data. This would indicate that the effort to engineer stormwater runoff controls into watershed development is working.

The area actively under construction also increased substantially over this period, from 360 acres in 1979 to 2120 acres in 1988. Other researchers have found that urbanization increases suspended solid concentrations in runoff. Construction activity is listed as one of the main sources of detached sediment or particulate matter. In comparison to atmospheric deposition of particulate matter and other sources (lawn clippings, etc.) that contribute to suspended solids, the construction areas offer the best explanation of sediment source within the Cub Run watershed. A major increase in the normalized sediment load was seen, particularly between 1979 and 1984. In contrast to stormwater runoff controls, the increasing trend in suspended sediment loads may indicate that attempts to manage detached solids may not be working.

A few drawbacks were encountered while working with HSPF. A major problem with the model is that many of the parameters are derived empirically and studies relating to a specific areas have not been conducted. The results is parameter estimation based on the physical attributes of the watershed. Other problems were encountered during the suspended solids sediment calibration effort. Construction sites or site development introduce a difficult variable to quantify or model. In the case of HSPF the impact of construction sites on suspended solids can be model to some degree. Construction areas are treated as a single pervious land segment and therefore can be adjusted to contribute a greater portion of the suspended solids to the total discharge. The problem is that there are no apparent methods or schemes that could be used to determine the relative contributions of each land segment (ie. agricultural, forested, construction, and urban/suburban) to the total discharge of suspended solids. An estimation of individual contributions must be made for the calibration process. For this reason, calibration of suspended solids become more uncertain.

5.3 Future Applications

The application of GIS and modeling to the Cub Run study provides one example of how such an integrated technique can be used. The Cub Run spatial database contained six layers of information; three years of historical land use data, reach watershed subdivisions, blue line stream segments and topography. The six layers of information represent the minimum data requirements needed to meet project objectives. GIS application was focused on quantifying land use in terms of sub-watershed reaches and reach lengths. However, this role could be further expanded in future applications.

The subdivision of a watershed into reach segments is based on the physical characteristics of the watershed. Each reach is defined by certain uniform physical characteristics that dominate the areal extent of the reach sub-watershed. Soil properties, slope, geology, depth to groundwater, depth to bedrock represent some of these properties of concern. GIS technology would allow for comparison between data layers for the generation of reach sub-watershed divisions. Several reach configurations could be generated and stored as data layers within the database. Once the land use data layers and reach configurations have been added to the database, a number of reach configurations could be tested. Land use tables representing each new reach configuration could be compiled and manipulated for model input.

As previously mentioned, additional layers of information such as geology, general soils, specific soil properties (percent sand or clay, well drained, etc.), complete drainage analysis, wetlands analysis, depth to groundwater, depth to bedrock, and percent slope would greatly increase database versatility to meet the spatial data needs of many complex watershed and water-quality models. In many cases, specific model parameter values are not available and must be estimated based on the physical characteristics of the watershed. This process is referred to as parameter evaluation. A well drained soil, for example, should have a higher rate of infiltration and storage than a poorly drained soil. Such determinations can be made based on the combination and analysis of pertinent data layers. Much of this work would already be completed during the reach sub-watershed analysis. For example distribution of soil properties would provide a bases for the evaluating parameters and defining spatial distribution of parameter values that influence surface runoff and infiltration. Combine soils data with slope data, and areas representing high risk for soil erosion can be identified and considered when selecting parameter values that influence sediment loadings within the reach area. GIS is a significant tool to consider in both quantitative analyses and qualitative analytical support (parameter and reach evaluation, etc).

6.0 CUB RUN WATERSHED SUMMARY

The following section is a summary of the Cub Run watershed data and observations that were based on that data.

Land use containing an impervious component increased from 10 percent (3255 acres) of the watershed surface area in 1979 to 21 percent (7171 acres) in 1988.

Agricultural areas were affected the most by development. Agricultural land use decreased by 13 percent (4319 acres) between 1979 and 1988, while forested areas lost 4 percent (1356 acres) over the same time period.

Developed land increased 11 percent between 1979 and 1988. Seven percent of the 11 percent increase occurred between 1984 and 1988 with medium-density residential housing and commercial areas accounting for most of the change.

The impervious component of the Cub Run watershed increased from approximately 5 to 11 percent of the total surface area between 1979 and 1988.

Watershed surface area laid bare by construction increased from approximately 1 percent of total surface area in 1979 to 6 percent total surface area in 1988.

Watershed discharge did not increase with increasing impermeable watershed surface area. Indicating that either stormwater control efforts are working and/or the 6 percent increase in impermeable surface area has not affected discharge.

Significant increases from sediment loading in terms of total suspended solids, were noted between 1982 and 1988 when compared to the 1979-1982 time period. Construction activity is the probable cause of increased suspended solids sediment loading.

HSPF simulation of suspended solids became less reliable with increased construction activity within the watershed.

7.0 CONCLUSIONS

The main objective of this study was to demonstrate an integrated approach including the collection of historical spatial data, manipulation and analysis of spatial data and model application, all of which focused on the study of land use change and its affects on water quality. This study is important in that it illustrates a method by which historical land use data and other spatial data can be obtained and applied to watershed models. The following conclusions were made:

The use of archived aerial photography was shown to be a suitable source of historical land use data, which allows researchers to characterize the physical and cultural aspects of a watershed at a specific point in time.

GIS technology was proven to be a powerful tool in meeting the special data requirements of a comprehensive watershed model.

The HSPF watershed comprehensive water-quality model was successfully calibrated and verified to watershed discharge and to a lesser degree, suspended-solids output as a demonstration of model application.

Linking land use change to watershed discharge and water quality was successfully presented as an integrated approach.

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APPENDIX 1

Daily Precipitation and Potential Evaporation Data

Cub Run watershed precipitation data for 1979 (inches).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.51	0.00	0.01	0.12	0.00	0.53	0.63	0.02	0.00	4.06	0.00	0.00
2	1.40	0.00	0.00	0.01	0.00	0.08	0.00	0.68	0.03	0.38	0.60	0.00
3	0.00	0.00	0.00	0.39	0.00	1.46	0.00	0.00	0.22	0.16	0.04	0.00
4	0.00	0.00	0.00	0.43	0.31	0.15	0.48	0.00	0.00	0.00	0.00	0.00
5	0.06	0.00	0.68	0.00	0.05	0.00	0.00	0.00	3.78	0.86	0.00	0.00
6	0.10	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00
7	0.74	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.10	0.04	0.00
9	0.00	0.02	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.68	0.03	0.00
10	0.00	0.00	0.24	0.00	0.00	0.34	0.00	0.00	0.00	1.34	0.56	0.00
11	0.13	0.56	0.00	0.00	0.01	0.00	0.00	1.21	0.00	0.12	0.00	0.01
12	0.16	0.00	0.00	0.09	1.21	0.00	0.11	0.00	0.00	0.03	0.12	0.52
13	0.00	0.00	0.00	0.03	0.12	0.00	0.08	0.00	0.32	0.00	0.00	0.00
14	0.00	0.02	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.04	0.00	0.00	0.00	0.00	1.01	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.25	0.00	0.00	0.16	0.00	0.00	0.04	0.00	0.00	0.00	0.00
18	0.00	1.21	0.00	0.00	0.07	0.00	0.00	0.74	0.00	0.00	0.00	0.00
19	1.01	0.00	0.00	0.00	0.05	0.00	0.00	0.03	0.00	0.00	0.00	0.02
20	0.67	0.05	0.00	0.00	0.03	0.22	0.05	0.88	2.59	0.00	0.00	0.00
21	0.00	0.21	0.00	0.02	0.59	0.03	0.13	0.24	0.00	0.80	0.02	0.00
22	1.18	1.52	1.79	0.03	0.12	0.02	0.00	0.35	0.00	0.00	0.00	0.15
23	0.00	1.20	0.02	0.00	0.52	0.00	0.03	0.36	0.00	0.00	0.01	0.18
24	0.00	0.14	0.00	0.20	0.00	0.00	0.01	0.00	0.00	0.00	0.70	0.00
25	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.78	0.00	0.00	0.00	0.00
26	0.44	0.00	0.00	0.02	0.02	0.05	0.46	0.00	0.04	0.06	0.00	0.00
27	0.00	0.00	0.01	0.00	0.10	0.18	0.18	0.00	0.01	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.33	0.02	0.00	0.20	0.00	0.00	0.00
29	0.00		0.15	0.00	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00		0.00		0.00		0.00	0.00		0.00		0.00
SUM	6.61	5.75	3.17	2.05	4.85	4.40	2.18	5.45	7.30	8.59	2.12	0.88

SUM of monthly values 5.33500E+01

Cub Run watershed potential evaporation data for 1979 (inches).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.00	0.00	0.00	0.00	0.14	0.15	0.00	0.11	0.10	0.00	0.00	0.00
2	0.00	0.00	0.00	0.08	0.20	0.04	0.00	0.00	0.11	0.05	0.00	0.00
3	0.00	0.00	0.00	0.04	0.12	0.05	0.17	0.15	0.12	0.08	0.00	0.00
4	0.00	0.00	0.00	0.00	0.03	0.00	0.16	0.06	0.08	0.12	0.00	0.00
5	0.00	0.00	0.00	0.00	0.02	0.00	0.06	0.15	0.11	0.06	0.00	0.00
6	0.00	0.00	0.00	0.16	0.16	0.08	0.14	0.16	0.00	0.05	0.00	0.00
7	0.00	0.00	0.00	0.22	0.10	0.07	0.00	0.13	0.15	0.08	0.00	0.00
8	0.00	0.00	0.00	0.09	0.14	0.11	0.00	0.04	0.11	0.07	0.00	0.00
9	0.00	0.00	0.00	0.10	0.12	0.14	0.18	0.20	0.13	0.11	0.00	0.00
10	0.00	0.00	0.00	0.05	0.17	0.13	0.15	0.00	0.11	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.15	0.11	0.12	0.09	0.11	0.04	0.00	0.00
12	0.00	0.00	0.00	0.15	0.01	0.20	0.15	0.13	0.13	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.14	0.17	0.13	0.00	0.10	0.13	0.00	0.00
14	0.00	0.00	0.00	0.08	0.06	0.19	0.11	0.21	0.11	0.15	0.00	0.00
15	0.00	0.00	0.00	0.13	0.15	0.16	0.11	0.12	0.13	0.05	0.00	0.00
16	0.00	0.00	0.00	0.08	0.17	0.14	0.16	0.13	0.11	0.00	0.00	0.00
17	0.00	0.00	0.00	0.11	0.13	0.08	0.15	0.11	0.11	0.16	0.00	0.00
18	0.00	0.00	0.00	0.18	0.00	0.18	0.12	0.00	0.08	0.07	0.00	0.00
19	0.00	0.00	0.00	0.17	0.02	0.11	0.09	0.00	0.15	0.04	0.00	0.00
20	0.00	0.00	0.00	0.06	0.10	0.15	0.04	0.18	0.09	0.17	0.00	0.00
21	0.00	0.00	0.00	0.09	0.05	0.11	0.12	0.13	0.05	0.08	0.00	0.00
22	0.00	0.00	0.00	0.05	0.00	0.15	0.11	0.08	0.13	0.13	0.00	0.00
23	0.00	0.00	0.00	0.03	0.08	0.09	0.07	0.07	0.07	0.13	0.00	0.00
24	0.00	0.00	0.00	0.13	0.17	0.15	0.08	0.13	0.04	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.05	0.17	0.09	0.11	0.04	0.02	0.00	0.00
26	0.00	0.00	0.00	0.00	0.08	0.16	0.15	0.00	0.00	0.01	0.00	0.00
27	0.00	0.00	0.00	0.00	0.07	0.12	0.09	0.09	0.04	0.02	0.00	0.00
28	0.00	0.00	0.00	0.26	0.07	0.07	0.11	0.06	0.05	0.06	0.00	0.00
29	0.00		0.00	0.00	0.10	0.00	0.06	0.11	0.00	0.04	0.00	0.00
30	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00		0.00		0.00		0.00	0.00		0.00		0.00
SUM	0.00	0.00	0.00	2.25	2.78	3.28	2.91	2.74	2.53	1.91	0.00	0.00

SUM of monthly values 1.84030E+01

Cub Run watershed precipitation data for 1984 (inches).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.00	0.00	0.00	0.00	0.00	0.02	0.76	0.27	0.00	0.51	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.66	0.00	0.00	0.03	0.12
3	0.00	0.30	0.00	0.00	1.03	0.00	0.00	0.53	0.74	0.00	0.00	0.14
4	0.01	0.00	0.00	1.42	0.28	0.00	0.00	0.05	0.06	0.00	0.48	0.00
5	0.00	0.28	0.34	0.32	0.00	0.00	0.10	0.00	0.00	0.00	0.26	0.57
6	0.00	0.00	0.02	0.00	0.21	0.00	0.18	0.00	0.00	0.00	0.00	0.10
7	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.15	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.00	0.02	0.00	0.00
10	0.58	0.04	0.00	0.00	0.00	0.00	0.22	2.38	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.11	0.00	0.01	0.00	0.00	0.00	0.00	0.00
12	0.05	0.04	1.01	0.04	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00
13	0.01	1.27	0.00	0.69	0.00	0.02	0.00	0.61	0.02	0.00	0.00	0.00
14	0.00	0.34	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
15	0.13	0.00	0.00	0.71	0.00	0.02	0.09	0.00	0.00	0.16	0.00	0.00
16	0.00	0.23	0.00	0.11	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.00
17	0.43	0.00	0.02	0.05	0.00	0.44	0.35	0.00	0.00	0.00	0.41	0.00
18	0.03	0.00	0.00	0.00	0.00	0.05	0.00	0.57	0.00	0.00	0.29	0.01
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00
20	0.00	0.00	0.58	0.00	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.20
21	0.00	0.67	0.00	0.19	0.73	0.00	0.00	0.09	0.00	0.33	0.00	0.00
22	0.14	0.19	0.00	0.04	0.00	0.28	0.00	0.00	0.02	0.04	0.00	0.02
23	0.00	0.01	0.96	0.00	0.00	0.13	0.00	0.00	0.01	0.00	0.00	0.00
24	0.00	0.00	0.44	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
25	0.00	0.14	0.00	0.00	0.01	0.00	0.03	0.00	0.11	0.00	0.00	0.00
26	0.00	0.56	1.40	0.24	0.20	0.85	0.00	0.00	0.30	0.37	1.94	0.00
27	0.00	0.00	0.89	0.15	1.00	0.13	0.00	0.00	0.08	0.15	0.04	0.00
28	0.04	0.00	0.00	0.23	0.16	0.24	0.00	0.00	0.15	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
30	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00		0.00		0.00		0.00	0.00		0.00		0.00
SUM	1.42	4.07	5.81	4.44	4.23	2.19	2.26	6.03	1.49	1.66	3.45	1.25

SUM of monthly values 3.83000E+01

Cub Run watershed potential evaporation data for 1984 (inches).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.00	0.00	0.00	0.00	0.11	0.13	0.00	0.13	0.19	0.08	0.00	0.00
2	0.00	0.00	0.00	0.10	0.20	0.15	0.00	0.11	0.19	0.05	0.00	0.00
3	0.00	0.00	0.00	0.12	0.09	0.27	0.16	0.10	0.08	0.09	0.00	0.00
4	0.00	0.00	0.00	0.15	0.04	0.18	0.15	0.11	0.17	0.11	0.00	0.00
5	0.00	0.00	0.00	0.01	0.11	0.19	0.00	0.12	0.04	0.10	0.00	0.00
6	0.00	0.00	0.00	0.06	0.04	0.15	0.42	0.15	0.13	0.16	0.00	0.00
7	0.00	0.00	0.00	0.15	0.10	0.17	0.20	0.15	0.13	0.01	0.00	0.00
8	0.00	0.00	0.00	0.09	0.03	0.18	0.00	0.11	0.13	0.07	0.00	0.00
9	0.00	0.00	0.00	0.11	0.18	0.17	0.34	0.15	0.16	0.04	0.00	0.00
10	0.00	0.00	0.00	0.08	0.13	0.22	0.15	0.11	0.13	0.04	0.00	0.00
11	0.00	0.00	0.00	0.11	0.11	0.20	0.20	0.11	0.08	0.05	0.00	0.00
12	0.00	0.00	0.00	0.12	0.00	0.19	0.19	0.09	0.06	0.10	0.00	0.00
13	0.00	0.00	0.00	0.02	0.20	0.20	0.20	0.06	0.06	0.10	0.00	0.00
14	0.00	0.00	0.00	0.01	0.17	0.22	0.17	0.06	0.06	0.11	0.00	0.00
15	0.00	0.00	0.00	0.04	0.17	0.13	0.16	0.20	0.15	0.06	0.00	0.00
16	0.00	0.00	0.00	0.07	0.14	0.08	0.23	0.15	0.12	0.04	0.00	0.00
17	0.00	0.00	0.00	0.11	0.16	0.04	0.13	0.21	0.13	0.04	0.00	0.00
18	0.00	0.00	0.00	0.08	0.06	0.13	0.09	0.11	0.11	0.06	0.00	0.00
19	0.00	0.00	0.00	0.09	0.21	0.18	0.16	0.10	0.12	0.04	0.00	0.00
20	0.00	0.00	0.00	0.11	0.13	0.15	0.18	0.16	0.15	0.03	0.00	0.00
21	0.00	0.00	0.00	0.04	0.22	0.10	0.13	0.16	0.17	0.06	0.00	0.00
22	0.00	0.00	0.00	0.01	0.09	0.15	0.11	0.08	0.10	0.06	0.00	0.00
23	0.00	0.00	0.00	0.09	0.18	0.01	0.17	0.17	0.14	0.01	0.00	0.00
24	0.00	0.00	0.00	0.16	0.20	0.22	0.17	0.13	0.10	0.02	0.00	0.00
25	0.00	0.00	0.00	0.14	0.08	0.19	0.07	0.15	0.11	0.04	0.00	0.00
26	0.00	0.00	0.00	0.15	0.20	0.24	0.10	0.13	0.05	0.00	0.00	0.00
27	0.00	0.00	0.00	0.08	0.01	0.17	0.09	0.13	0.00	0.15	0.00	0.00
28	0.00	0.00	0.00	0.13	0.05	0.21	0.11	0.09	0.07	0.08	0.00	0.00
29	0.00	0.00	0.00	0.00	0.08	0.00	0.07	0.15	0.00	0.08	0.00	0.00
30	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00		0.00		0.00		0.00	0.00		0.00		0.00
SUM	0.00	0.00	0.00	2.41	3.51	4.63	4.16	3.67	3.13	1.86	0.00	0.00

SUM of monthly values 2.33590E+01

Cub Run watershed precipitation data for 1988 (inches)

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.70	0.00
2	0.00	0.57	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.04	0.00	0.00
3	0.08	0.02	0.00	0.00	0.01	0.00	0.00	0.10	0.00	0.03	0.00	0.00
4	0.04	0.22	0.68	0.01	0.04	0.00	0.00	0.00	0.87	0.00	0.04	0.00
5	0.00	0.00	0.00	0.00	1.61	0.00	0.00	0.00	0.00	0.00	0.74	0.00
6	0.00	0.00	0.00	0.15	0.80	0.00	0.00	1.22	0.00	0.00	0.00	0.00
7	0.16	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.16	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.02	0.05	0.23	1.22	0.00	0.01	0.00	0.00	0.08
10	0.00	0.00	0.01	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.08	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.37	0.02
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.47	0.10	0.00	0.00	0.00	0.00	0.00	0.00
16	0.09	0.00	0.00	0.00	0.23	0.02	0.60	0.00	0.12	0.00	0.62	0.00
17	0.12	0.00	0.00	0.19	3.13	0.00	0.33	0.04	0.00	0.08	0.00	0.00
18	0.37	0.34	0.00	0.00	1.18	0.00	0.24	0.10	0.00	0.00	0.69	0.00
19	0.77	0.00	0.01	0.00	0.34	0.00	1.99	1.06	0.03	0.00	0.22	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.01	0.00	1.36	0.00	0.19
21	0.00	0.07	0.00	0.09	1.28	0.00	1.51	0.13	0.01	0.00	0.00	0.21
22	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.16	0.40	0.08	0.00	0.25
23	0.68	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.35	0.01	0.00	0.00
24	0.00	0.00	1.55	0.00	0.00	0.00	0.49	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.35	0.00	0.00	0.05	0.00	0.00	0.00	0.66	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.44	0.17
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00		0.00		0.00		0.00	0.00		0.00		0.00
SUM	2.47	1.64	2.31	2.35	10.24	0.52	6.80	3.92	1.80	1.60	4.48	0.92

SUM of monthly values 3.90500E+01

Cub Run watershed potential evaporation data for 1988 (inches).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.00	0.00	0.00	0.00	0.13	0.27	0.24	0.15	0.11	0.08	0.00	0.00
2	0.00	0.00	0.00	0.00	0.14	0.29	0.00	0.15	0.13	0.08	0.00	0.00
3	0.00	0.00	0.00	0.00	0.08	0.11	0.39	0.15	0.11	0.07	0.00	0.00
4	0.00	0.00	0.00	0.22	0.07	0.12	0.20	0.18	0.00	0.01	0.00	0.00
5	0.00	0.00	0.00	0.08	0.04	0.08	0.20	0.17	0.00	0.04	0.00	0.00
6	0.00	0.00	0.00	0.14	0.01	0.29	0.18	0.00	0.12	0.11	0.00	0.00
7	0.00	0.00	0.00	0.15	0.01	0.27	0.19	0.44	0.13	0.09	0.00	0.00
8	0.00	0.00	0.00	0.01	0.18	0.25	0.25	0.17	0.11	0.06	0.00	0.00
9	0.00	0.00	0.00	0.04	0.22	0.22	0.22	0.18	0.11	0.08	0.00	0.00
10	0.00	0.00	0.00	0.14	0.11	0.03	0.15	0.15	0.06	0.18	0.00	0.00
11	0.00	0.00	0.00	0.13	0.13	0.18	0.19	0.17	0.12	0.17	0.00	0.00
12	0.00	0.00	0.00	0.04	0.17	0.23	0.08	0.13	0.08	0.12	0.00	0.00
13	0.00	0.00	0.00	0.11	0.16	0.18	0.26	0.16	0.12	0.08	0.00	0.00
14	0.00	0.00	0.00	0.10	0.17	0.20	0.23	0.22	0.14	0.08	0.00	0.00
15	0.00	0.00	0.00	0.16	0.16	0.20	0.41	0.27	0.13	0.08	0.00	0.00
16	0.00	0.00	0.00	0.09	0.13	0.21	0.13	0.17	0.09	0.12	0.00	0.00
17	0.00	0.00	0.00	0.16	0.19	0.11	0.18	0.17	0.01	0.09	0.00	0.00
18	0.00	0.00	0.00	0.02	0.08	0.17	0.22	0.13	0.10	0.01	0.00	0.00
19	0.00	0.00	0.00	0.04	0.11	0.14	0.11	0.11	0.13	0.07	0.00	0.00
20	0.00	0.00	0.00	0.15	0.05	0.20	0.12	0.01	0.08	0.06	0.00	0.00
21	0.00	0.00	0.00	0.17	0.11	0.22	0.09	0.15	0.15	0.07	0.00	0.00
22	0.00	0.00	0.00	0.08	0.46	0.19	0.00	0.04	0.11	0.10	0.00	0.00
23	0.00	0.00	0.00	0.15	0.15	0.17	0.27	0.17	0.06	0.08	0.00	0.00
24	0.00	0.00	0.00	0.16	0.15	0.20	0.20	0.17	0.02	0.11	0.00	0.00
25	0.00	0.00	0.00	0.15	0.14	0.15	0.24	0.17	0.11	0.09	0.00	0.00
26	0.00	0.00	0.00	0.17	0.16	0.20	0.09	0.15	0.10	0.06	0.00	0.00
27	0.00	0.00	0.00	0.15	0.19	0.20	0.09	0.04	0.11	0.12	0.00	0.00
28	0.00	0.00	0.00	0.08	0.14	0.17	0.18	0.08	0.03	0.02	0.00	0.00
29	0.00	0.00	0.00	0.00	0.17	0.00	0.21	0.08	0.00	0.09	0.00	0.00
30	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00		0.00		0.00		0.00	0.00		0.00		0.00
SUM	0.00	0.00	0.00	2.90	4.01	5.26	5.31	4.36	2.56	2.43	0.00	0.00

SUM of monthly values 2.68240E+01

APPENDIX 2

Daily Measured and Simulated Discharge Data

Cub Run watershed measured discharge for 1979 (cfs).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	112.00	46.00	280.00	38.00	13.00	136.00	10.00	7.60	13.00	4080.00	15.00	22.00
2	1010.00	37.00	240.00	49.00	12.00	144.00	23.00	40.00	11.00	504.00	16.00	20.00
3	400.00	29.00	175.00	96.00	12.00	490.00	14.00	72.00	11.00	348.00	115.00	17.00
4	73.00	26.00	130.00	213.00	12.00	649.00	11.00	15.00	11.00	117.00	46.00	16.00
5	45.00	24.00	390.00	240.00	16.00	118.00	13.00	10.00	200.00	567.00	27.00	16.00
6	37.00	21.00	425.00	91.00	17.00	58.00	12.00	8.60	2060.00	223.00	22.00	16.00
7	102.00	19.00	156.00	57.00	14.00	38.00	9.50	8.00	101.00	85.00	20.00	16.00
8	544.00	20.00	95.00	44.00	12.00	28.00	8.60	7.60	48.00	52.00	18.00	15.00
9	146.00	19.00	69.00	71.00	11.00	21.00	8.00	13.00	32.00	249.00	17.00	13.00
10	64.00	16.00	55.00	149.00	10.00	18.00	7.70	8.40	23.00	1400.00	149.00	12.00
11	40.00	15.00	288.00	64.00	9.80	20.00	7.60	7.70	18.00	381.00	214.00	12.00
12	30.00	14.00	126.00	46.00	9.20	25.00	7.50	56.00	16.00	138.00	305.00	12.00
13	29.00	14.00	74.00	38.00	145.00	16.00	16.00	56.00	14.00	110.00	101.00	34.00
14	44.00	14.00	58.00	49.00	174.00	13.00	41.00	17.00	16.00	66.00	90.00	78.00
15	65.00	13.00	46.00	47.00	54.00	11.00	13.00	11.00	19.00	49.00	55.00	30.00
16	35.00	13.00	36.00	35.00	51.00	11.00	9.80	9.00	14.00	39.00	42.00	23.00
17	32.00	13.00	32.00	28.00	25.00	17.00	8.70	8.30	12.00	33.00	33.00	20.00
18	32.00	12.00	29.00	23.00	17.00	32.00	8.00	8.00	11.00	30.00	29.00	16.00
19	24.00	12.00	26.00	20.00	16.00	15.00	7.70	10.00	11.00	26.00	26.00	14.00
20	29.00	17.00	23.00	19.00	17.00	11.00	7.60	42.00	9.80	25.00	23.00	14.00
21	998.00	23.00	21.00	17.00	15.00	10.00	7.60	48.00	62.00	24.00	21.00	14.00
22	379.00	36.00	20.00	16.00	14.00	9.80	7.60	31.00	1250.00	22.00	21.00	13.00
23	120.00	53.00	19.00	15.00	17.00	9.50	7.40	19.00	232.00	22.00	20.00	14.00
24	928.00	463.00	381.00	16.00	52.00	38.00	7.60	14.00	74.00	103.00	19.00	14.00
25	602.00	2470.00	603.00	16.00	104.00	13.00	8.30	14.00	46.00	34.00	19.00	46.00
26	117.00	2580.00	130.00	15.00	101.00	10.00	8.30	24.00	36.00	25.00	96.00	38.00
27	81.00	556.00	74.00	20.00	38.00	9.00	7.60	109.00	29.00	21.00	116.00	23.00
28	75.00	334.00	54.00	21.00	26.00	8.70	8.00	208.00	24.00	20.00	47.00	18.00
29	73.00		44.00	17.00	25.00	8.60	9.50	40.00	22.00	20.00	32.00	16.00
30	80.00		37.00	15.00	17.00	9.20	7.90	23.00	20.00	18.00	25.00	15.00
31	64.00		33.00		18.00		7.40	16.00		17.00		14.00
SUM	6410.00	6909.00	4169.00	1585.00	1074.00	1996.80	330.90	961.20	4445.80	8848.00	1779.00	641.00

SUM of monthly values 39149.7 cfs

Cub Run watershed measured discharge for 1979 (inches).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.079	0.033	0.198	0.027	0.009	0.096	0.007	0.005	0.009	2.890	0.011	0.016
2	0.715	0.026	0.170	0.035	0.009	0.102	0.016	0.028	0.008	0.357	0.011	0.014
3	0.283	0.021	0.124	0.068	0.009	0.347	0.010	0.051	0.008	0.247	0.081	0.012
4	0.052	0.018	0.092	0.151	0.009	0.460	0.008	0.011	0.008	0.083	0.033	0.011
5	0.032	0.017	0.276	0.170	0.011	0.084	0.009	0.007	0.142	0.402	0.019	0.011
6	0.026	0.015	0.301	0.064	0.012	0.041	0.009	0.006	1.459	0.158	0.016	0.011
7	0.072	0.013	0.111	0.040	0.010	0.027	0.007	0.006	0.072	0.060	0.014	0.011
8	0.385	0.014	0.067	0.031	0.009	0.020	0.006	0.005	0.034	0.037	0.013	0.011
9	0.103	0.013	0.049	0.050	0.008	0.015	0.006	0.009	0.023	0.176	0.012	0.009
10	0.045	0.011	0.039	0.106	0.007	0.013	0.005	0.006	0.016	0.992	0.106	0.009
11	0.028	0.011	0.204	0.045	0.007	0.014	0.005	0.005	0.013	0.270	0.152	0.009
12	0.021	0.010	0.089	0.033	0.007	0.018	0.005	0.040	0.011	0.098	0.216	0.009
13	0.021	0.010	0.052	0.027	0.103	0.011	0.011	0.040	0.010	0.078	0.072	0.024
14	0.031	0.010	0.041	0.035	0.123	0.009	0.029	0.012	0.011	0.047	0.064	0.055
15	0.046	0.009	0.033	0.033	0.038	0.008	0.009	0.008	0.013	0.035	0.039	0.021
16	0.025	0.009	0.026	0.025	0.036	0.008	0.007	0.006	0.010	0.028	0.030	0.016
17	0.023	0.009	0.023	0.020	0.018	0.012	0.006	0.006	0.009	0.023	0.023	0.014
18	0.023	0.009	0.021	0.016	0.012	0.023	0.006	0.006	0.008	0.021	0.021	0.011
19	0.017	0.009	0.018	0.014	0.011	0.011	0.005	0.007	0.008	0.018	0.018	0.010
20	0.021	0.012	0.016	0.013	0.012	0.008	0.005	0.030	0.007	0.018	0.016	0.010
21	0.707	0.016	0.015	0.012	0.011	0.007	0.005	0.034	0.044	0.017	0.015	0.010
22	0.268	0.026	0.014	0.011	0.010	0.007	0.005	0.022	0.885	0.016	0.015	0.009
23	0.085	0.038	0.013	0.011	0.012	0.007	0.005	0.013	0.164	0.016	0.014	0.010
24	0.657	0.328	0.270	0.011	0.037	0.027	0.005	0.010	0.052	0.073	0.013	0.010
25	0.426	1.750	0.427	0.011	0.074	0.009	0.006	0.010	0.033	0.024	0.013	0.033
26	0.083	1.828	0.092	0.011	0.072	0.007	0.006	0.017	0.026	0.018	0.068	0.027
27	0.057	0.394	0.052	0.014	0.027	0.006	0.005	0.077	0.021	0.015	0.082	0.016
28	0.053	0.237	0.038	0.015	0.018	0.006	0.006	0.147	0.017	0.014	0.033	0.013
29	0.052		0.031	0.012	0.018	0.006	0.007	0.028	0.016	0.014	0.023	0.011
30	0.057		0.026	0.011	0.012	0.007	0.006	0.016	0.014	0.013	0.018	0.011
31	0.045		0.023		0.013		0.005	0.011		0.012		0.010
SUM	4.541	4.894	2.953	1.123	0.761	1.414	0.234	0.681	3.149	6.268	1.260	0.454

Sum of monthly values 27.732 inches

Cub Run watershed measured discharge for 1984 (cfs).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	28.00	38.00	80.00	115.00	47.00	33.00	77.00	3.50	5.00	62.00	7.40	40.00
2	22.00	29.00	60.00	85.00	31.00	24.00	25.00	6.00	4.40	44.00	7.40	26.00
3	20.00	37.00	49.00	68.00	34.00	17.00	16.00	322.00	7.10	13.00	7.00	31.00
4	19.00	203.00	40.00	519.00	519.00	14.00	9.40	129.00	16.00	9.00	14.00	33.00
5	19.00	175.00	40.00	763.00	177.00	12.00	7.00	28.00	7.80	7.80	73.00	31.00
6	22.00	138.00	66.00	210.00	88.00	11.00	9.80	14.00	5.90	5.90	35.00	358.00
7	23.00	63.00	49.00	112.00	102.00	11.00	7.80	10.00	4.70	4.70	20.00	99.00
8	20.00	42.00	38.00	77.00	139.00	9.40	5.90	8.60	4.70	5.60	15.00	44.00
9	17.00	29.00	39.00	62.00	210.00	7.80	5.60	55.00	4.40	5.60	12.00	32.00
10	29.00	26.00	35.00	54.00	78.00	8.50	5.90	461.00	4.10	6.60	11.00	26.00
11	132.00	36.00	36.00	43.00	50.00	8.20	6.60	1150.00	3.80	6.20	15.00	23.00
12	60.00	58.00	55.00	40.00	36.00	6.20	9.00	195.00	3.50	6.20	14.00	20.00
13	34.00	68.00	75.00	33.00	30.00	5.60	5.30	106.00	3.50	6.20	11.00	17.00
14	27.00	1310.00	244.00	40.00	24.00	5.30	4.40	1070.00	3.80	6.20	10.00	16.00
15	26.00	602.00	201.00	258.00	19.00	4.70	3.80	219.00	4.10	5.90	10.00	14.00
16	22.00	265.00	97.00	555.00	16.00	4.40	3.50	52.00	4.10	7.40	11.00	12.00
17	19.00	139.00	69.00	186.00	15.00	4.40	3.20	30.00	3.50	7.00	11.00	12.00
18	19.00	163.00	52.00	97.00	15.00	10.00	6.80	20.00	3.50	6.20	11.00	13.00
19	19.00	97.00	40.00	73.00	15.00	16.00	12.00	16.00	3.50	6.20	53.00	13.00
20	17.00	75.00	35.00	57.00	14.00	6.60	5.90	48.00	3.50	4.10	37.00	13.00
21	14.00	60.00	116.00	42.00	12.00	5.00	22.00	21.00	3.50	5.60	22.00	12.00
22	14.00	50.00	119.00	40.00	12.00	4.40	19.00	13.00	3.50	4.70	18.00	18.00
23	14.00	101.00	60.00	220.00	25.00	4.40	12.00	11.00	3.20	4.70	15.00	20.00
24	15.00	552.00	40.00	109.00	33.00	4.70	7.40	10.00	3.50	51.00	13.00	13.00
25	29.00	147.00	157.00	69.00	15.00	5.90	5.60	9.00	3.80	21.00	12.00	12.00
26	114.00	79.00	966.00	47.00	16.00	5.30	4.70	7.80	4.10	12.00	11.00	12.00
27	216.00	58.00	210.00	36.00	42.00	4.40	11.00	7.40	4.10	11.00	10.00	9.80
28	160.00	259.00	643.00	31.00	16.00	7.00	5.90	6.60	8.80	14.00	112.00	9.40
29	77.00	191.00	2120.00	55.00	126.00	23.00	4.40	7.40	9.00	38.00	640.00	9.80
30	64.00		479.00	45.00	230.00	12.00	4.10	6.20	6.20	17.00	77.00	9.40
31	54.00		194.00		68.00		3.50	5.60		9.40		9.00
SUM	1365.00	5090.00	6504.00	4141.00	2254.00	295.20	329.50	4048.10	150.60	414.20	1314.80	1007.40

SUM of monthly values 26913.8 cfs

Cub Run watershed measured discharge for 1984 (inches).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.020	0.027	0.057	0.081	0.033	0.023	0.055	0.002	0.004	0.044	0.005	0.028
2	0.016	0.021	0.043	0.060	0.022	0.017	0.018	0.004	0.003	0.031	0.005	0.018
3	0.014	0.026	0.035	0.048	0.024	0.012	0.011	0.228	0.005	0.009	0.005	0.022
4	0.013	0.144	0.028	0.368	0.368	0.010	0.007	0.091	0.011	0.006	0.010	0.023
5	0.013	0.124	0.028	0.540	0.125	0.009	0.005	0.020	0.006	0.006	0.052	0.022
6	0.016	0.098	0.047	0.149	0.062	0.008	0.007	0.010	0.004	0.004	0.025	0.254
7	0.016	0.045	0.035	0.079	0.072	0.008	0.006	0.007	0.003	0.003	0.014	0.070
8	0.014	0.030	0.027	0.055	0.098	0.007	0.004	0.006	0.003	0.004	0.011	0.031
9	0.012	0.021	0.028	0.044	0.149	0.006	0.004	0.039	0.003	0.004	0.009	0.023
10	0.021	0.018	0.025	0.038	0.055	0.006	0.004	0.327	0.003	0.005	0.008	0.018
11	0.094	0.026	0.026	0.030	0.035	0.006	0.005	0.815	0.003	0.004	0.011	0.016
12	0.043	0.041	0.039	0.028	0.026	0.004	0.006	0.138	0.002	0.004	0.010	0.014
13	0.024	0.048	0.053	0.023	0.021	0.004	0.004	0.075	0.002	0.004	0.008	0.012
14	0.019	0.928	0.173	0.028	0.017	0.004	0.003	0.758	0.003	0.004	0.007	0.011
15	0.018	0.426	0.142	0.183	0.013	0.003	0.003	0.155	0.003	0.004	0.007	0.010
16	0.016	0.188	0.069	0.393	0.011	0.003	0.002	0.037	0.003	0.005	0.008	0.009
17	0.013	0.098	0.049	0.132	0.011	0.003	0.002	0.021	0.002	0.005	0.008	0.009
18	0.013	0.115	0.037	0.069	0.011	0.007	0.005	0.014	0.002	0.004	0.008	0.009
19	0.013	0.069	0.028	0.052	0.011	0.011	0.009	0.011	0.002	0.004	0.038	0.009
20	0.012	0.053	0.025	0.040	0.010	0.005	0.004	0.034	0.002	0.003	0.026	0.009
21	0.010	0.043	0.082	0.030	0.009	0.004	0.016	0.015	0.002	0.004	0.016	0.009
22	0.010	0.035	0.084	0.028	0.009	0.003	0.013	0.009	0.002	0.003	0.013	0.013
23	0.010	0.072	0.043	0.156	0.018	0.003	0.009	0.008	0.002	0.003	0.011	0.014
24	0.011	0.391	0.028	0.077	0.023	0.003	0.005	0.007	0.002	0.036	0.009	0.009
25	0.021	0.104	0.111	0.049	0.011	0.004	0.004	0.006	0.003	0.015	0.009	0.009
26	0.081	0.056	0.684	0.033	0.011	0.004	0.003	0.006	0.003	0.009	0.008	0.009
27	0.153	0.041	0.149	0.026	0.030	0.003	0.008	0.005	0.003	0.008	0.007	0.007
28	0.113	0.183	0.455	0.022	0.011	0.005	0.004	0.005	0.006	0.010	0.079	0.007
29	0.055	0.135	1.502	0.039	0.089	0.016	0.003	0.005	0.006	0.027	0.453	0.007
30	0.045		0.339	0.032	0.163	0.009	0.003	0.004	0.004	0.012	0.055	0.007
31	0.038		0.137		0.048		0.002	0.004		0.007		0.006
SUM	0.967	3.606	4.607	2.933	1.597	0.209	0.233	2.868	0.107	0.293	0.931	0.714

Sum of monthly values 19.052 inches

Cub Run watershed measured discharge for 1988 (cfs).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	31.47	82.98	16.41	19.34	9.34	12.94	1.79	3.70	4.55	2.83	38.84	0.94
2	27.61	112.10	14.95	17.29	7.98	10.25	1.20	3.20	4.40	3.07	24.42	16.20
3	21.40	259.07	13.74	15.54	6.94	11.74	1.91	2.93	3.40	3.12	7.88	12.39
4	9.70	165.25	57.86	14.32	7.24	14.31	1.97	2.66	14.01	3.06	5.63	10.15
5	9.79	103.37	168.49	13.29	73.36	9.35	2.02	2.63	31.28	3.51	52.89	9.30
6	6.22	52.35	46.71	12.55	848.66	8.33	1.70	26.52	11.01	3.77	81.54	9.40
7	2.61	35.11	32.80	429.03	210.24	7.80	0.81	63.84	7.40	4.04	18.67	8.30
8	2.92	30.77	25.39	325.96	62.60	8.03	2.10	13.07	4.85	3.49	11.22	8.10
9	2.59	23.93	17.75	101.48	35.87	12.50	8.47	6.59	3.65	3.42	8.64	8.36
10	11.63	23.39	16.64	44.14	51.43	15.93	17.35	5.81	3.35	3.05	7.53	10.71
11	11.65	24.40	14.62	30.37	122.50	9.59	6.17	3.60	3.02	2.65	6.95	10.66
12	10.99	195.22	13.40	24.38	42.49	6.77	5.94	2.36	2.33	2.41	5.67	8.51
13		76.85	14.20	20.35	26.42	5.60	5.73	2.02	3.38	3.20	14.30	7.89
14		37.61	13.14	15.80	20.08	5.15	4.03	2.00	2.80	4.83	17.83	6.85
15	10.65	31.10	11.52	13.42	15.31	4.84	3.18	7.27	2.37	4.25	9.74	7.20
16	9.97	98.91	12.32	12.24	13.68	4.55	2.58	12.56	2.25	4.55	7.47	6.90
17	9.74	53.89	11.35	12.70	25.07	4.40	2.14	5.01	2.06	4.25	89.60	5.90
18	60.31	41.11	10.45	14.48	191.19	4.23	1.96	3.64	2.07	4.56	36.47	6.12
19	95.07	43.74	10.01	17.89	1063.07	4.01	41.33	7.98	2.06	5.20	18.25	5.00
20	783.48	165.68	9.73	14.54	851.53	3.70	14.88	18.93	2.18	7.70	170.45	5.33
21	196.05	61.92	9.07	11.90	493.00	3.38	47.52	23.27	3.55	63.13	50.08	6.40
22	92.04	37.28	8.60	10.40	493.00	3.29	21.78	8.59	3.01	88.67	23.74	8.28
23	58.52	32.79	8.38	9.20	493.00	2.93	81.20	4.95	2.81	22.60	16.53	8.19
24	42.08	29.57	8.37	10.08	496.07	2.82	162.88	4.46	4.14	6.11	13.22	22.42
25	54.07	25.97	8.60	8.79	437.91	2.75	24.06	7.20	23.63	5.15	10.44	45.76
26	105.42	22.66	318.04	8.16	102.67	2.92	20.06	5.45	16.28	5.80	9.45	20.04
27	48.10	20.74	296.30	10.25	38.13	2.57	64.74	3.41	7.70	5.90	16.95	13.09
28	32.07	20.10	71.96	30.24	30.35	2.21	18.78	2.21	5.06	5.63	333.57	12.87
29	26.63	17.29	37.48	16.31	21.15	2.00	9.68	66.72	3.92	6.20	102.59	19.24
30	25.45		22.62	11.34	17.31	1.81	6.04	26.07	2.93	5.60	39.92	13.87
31	59.21		21.70		15.60		4.34	6.75		5.90		11.03
SUM	1917.44	1925.15	1342.60	1295.78	6323.19	190.70	588.34	355.40	185.45	297.65	1250.48	364.80

SUM of monthly values 16036.98 cfs

Cub Run watershed measured discharge for 1988 (inches).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.022	0.059	0.012	0.014	0.007	0.009	0.001	0.003	0.003	0.002	0.027	0.015
2	0.020	0.079	0.011	0.012	0.006	0.007	0.001	0.002	0.003	0.002	0.017	0.011
3	0.015	0.183	0.010	0.011	0.005	0.008	0.001	0.002	0.002	0.002	0.006	0.009
4	0.014	0.117	0.041	0.010	0.005	0.010	0.001	0.002	0.010	0.002	0.004	0.007
5	0.014	0.073	0.119	0.009	0.052	0.007	0.001	0.002	0.022	0.002	0.037	0.007
6	0.011	0.037	0.033	0.009	0.599	0.006	0.001	0.019	0.008	0.003	0.058	0.007
7	0.009	0.025	0.023	0.303	0.149	0.006	0.001	0.045	0.005	0.003	0.013	0.006
8	0.009	0.022	0.018	0.230	0.044	0.006	0.001	0.009	0.003	0.002	0.008	0.066
9	0.009	0.017	0.013	0.072	0.025	0.009	0.006	0.005	0.003	0.002	0.006	0.006
10	0.008	0.017	0.012	0.031	0.036	0.011	0.012	0.004	0.002	0.002	0.005	0.008
11	0.008	0.017	0.010	0.021	0.087	0.007	0.004	0.003	0.002	0.002	0.005	0.007
12	0.008	0.138	0.009	0.017	0.030	0.005	0.004	0.002	0.002	0.002	0.004	0.006
13	0.000	0.054	0.010	0.014	0.019	0.004	0.004	0.001	0.002	0.002	0.010	0.006
14	0.000	0.027	0.009	0.011	0.014	0.004	0.003	0.001	0.002	0.003	0.013	0.005
15	0.008	0.022	0.008	0.009	0.011	0.003	0.002	0.005	0.002	0.003	0.007	0.005
16	0.007	0.070	0.009	0.009	0.010	0.003	0.002	0.009	0.002	0.003	0.005	0.005
17	0.007	0.038	0.008	0.009	0.018	0.003	0.002	0.004	0.001	0.003	0.063	0.004
18	0.043	0.029	0.007	0.010	0.135	0.003	0.001	0.003	0.001	0.003	0.026	0.004
19	0.067	0.031	0.007	0.013	0.751	0.003	0.029	0.006	0.001	0.004	0.013	0.004
20	0.553	0.117	0.007	0.010	0.602	0.003	0.011	0.013	0.002	0.005	0.120	0.004
21	0.138	0.044	0.006	0.008	0.348	0.002	0.034	0.016	0.003	0.045	0.035	0.005
22	0.065	0.026	0.006	0.007	0.348	0.002	0.015	0.006	0.002	0.063	0.017	0.006
23	0.041	0.023	0.006	0.006	0.348	0.002	0.057	0.003	0.002	0.016	0.012	0.006
24	0.030	0.021	0.006	0.007	0.350	0.002	0.115	0.003	0.003	0.004	0.009	0.016
25	0.038	0.018	0.006	0.006	0.309	0.002	0.017	0.005	0.017	0.004	0.007	0.032
26	0.074	0.016	0.225	0.006	0.073	0.002	0.014	0.004	0.011	0.004	0.007	0.014
27	0.034	0.015	0.209	0.007	0.027	0.002	0.046	0.002	0.005	0.004	0.012	0.009
28	0.023	0.014	0.051	0.021	0.021	0.002	0.013	0.002	0.004	0.004	0.236	0.009
29	0.019	0.012	0.026	0.012	0.015	0.001	0.007	0.047	0.003	0.004	0.072	0.014
30	0.018	0.000	0.016	0.008	0.012	0.001	0.004	0.018	0.002	0.004	0.028	0.010
31	0.042	0.000	0.015	0.000	0.011	0.000	0.003	0.005	0.000	0.004	0.000	0.008
SUM	1.354	1.360	0.948	0.915	4.467	0.135	0.416	0.251	0.131	0.210	0.883	0.258

SUM of monthly values 11.328 inches

Cub Run watershed simulated discharge for 1979 (inches).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.06	0.05	0.08	0.04	0.01	0.05	0.05	0.00	0.02	2.46	0.02	0.02
2	0.35	0.04	0.07	0.03	0.00	0.05	0.04	0.04	0.01	0.59	0.06	0.02
3	0.16	0.04	0.06	0.05	0.01	0.41	0.02	0.01	0.01	0.13	0.06	0.02
4	0.09	0.03	0.05	0.10	0.02	0.18	0.03	0.01	0.01	0.09	0.04	0.02
5	0.08	0.03	0.15	0.09	0.01	0.09	0.02	0.00	1.67	0.21	0.03	0.01
6	0.07	0.03	0.15	0.06	0.00	0.07	0.02	0.00	0.40	0.15	0.03	0.01
7	0.15	0.08	0.11	0.05	0.01	0.06	0.02	0.00	0.08	0.10	0.03	0.01
8	0.13	0.08	0.09	0.04	0.00	0.04	0.02	0.01	0.06	0.08	0.02	0.01
9	0.09	0.06	0.07	0.06	0.00	0.03	0.01	0.00	0.05	0.13	0.02	0.01
10	0.07	0.05	0.08	0.06	0.00	0.04	0.01	0.01	0.04	0.63	0.07	0.01
11	0.07	0.10	0.07	0.05	0.00	0.03	0.01	0.06	0.03	0.26	0.07	0.01
12	0.07	0.09	0.06	0.03	0.07	0.02	0.00	0.02	0.02	0.15	0.06	0.06
13	0.05	0.07	0.05	0.04	0.02	0.01	0.00	0.02	0.03	0.11	0.05	0.05
14	0.04	0.06	0.04	0.03	0.03	0.01	0.01	0.01	0.02	0.09	0.04	0.04
15	0.04	0.05	0.04	0.02	0.02	0.01	0.00	0.01	0.02	0.07	0.03	0.03
16	0.04	0.04	0.04	0.02	0.01	0.06	0.00	0.00	0.01	0.06	0.03	0.03
17	0.03	0.05	0.03	0.02	0.01	0.05	0.00	0.00	0.01	0.05	0.02	0.02
18	0.03	0.37	0.03	0.01	0.02	0.03	0.00	0.04	0.01	0.04	0.02	0.02
19	0.19	0.16	0.03	0.01	0.01	0.02	0.00	0.03	0.01	0.04	0.02	0.02
20	0.21	0.10	0.03	0.02	0.01	0.02	0.01	0.06	0.82	0.03	0.02	0.01
21	0.15	0.10	0.03	0.01	0.04	0.02	0.00	0.05	0.26	0.08	0.02	0.01
22	0.42	0.65	0.68	0.01	0.03	0.01	0.00	0.05	0.07	0.07	0.02	0.02
23	0.21	0.69	0.21	0.01	0.05	0.01	0.00	0.05	0.05	0.05	0.02	0.03
24	0.14	0.28	0.09	0.01	0.03	0.01	0.00	0.03	0.05	0.05	0.08	0.02
25	0.11	0.17	0.07	0.02	0.02	0.01	0.00	0.08	0.04	0.04	0.07	0.02
26	0.13	0.14	0.06	0.02	0.02	0.01	0.01	0.07	0.03	0.04	0.05	0.02
27	0.11	0.11	0.05	0.01	0.02	0.01	0.01	0.05	0.03	0.03	0.04	0.01
28	0.09	0.09	0.04	0.00	0.01	0.02	0.00	0.04	0.03	0.03	0.03	0.01
29	0.07		0.05	0.01	0.08	0.01	0.00	0.03	0.02	0.02	0.03	0.01
30	0.06		0.04	0.01	0.06	0.01	0.01	0.03	0.02	0.02	0.02	0.01
31	0.05		0.04		0.04		0.01	0.02		0.02		0.01
SUM	3.57	3.82	2.68	0.96	0.65	1.41	0.32	0.81	3.94	5.95	1.10	0.62

SUM of monthly values 2.58415E+01

Cub Run watershed simulated discharge for 1979 (cfs).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	87.14	65.34	109.01	57.20	8.66	76.38	70.21	2.85	22.16	3479.10	27.41	29.47
2	495.31	57.83	92.88	43.13	3.76	72.52	51.07	52.05	17.47	831.76	78.40	26.15
3	226.15	51.97	80.60	75.23	7.44	574.83	27.25	14.42	20.00	182.62	78.85	23.57
4	129.04	47.33	71.11	136.69	29.15	254.57	42.50	11.27	15.80	133.03	58.24	21.54
5	107.30	43.61	212.03	124.08	18.57	133.03	34.41	5.02	2364.65	301.16	48.05	19.91
6	95.19	40.59	205.90	86.97	6.19	98.52	22.21	3.27	569.36	212.51	40.87	18.59
7	204.82	115.52	158.72	65.31	8.28	77.67	25.99	2.99	109.81	146.60	35.51	17.51
8	181.52	110.18	126.66	59.89	5.50	59.88	23.62	11.21	85.10	117.13	34.52	16.60
9	133.06	86.98	104.61	86.76	5.90	46.58	10.10	2.56	65.90	185.10	31.72	15.82
10	105.53	71.66	112.57	82.09	2.47	50.21	9.18	8.52	53.59	894.92	98.31	15.16
11	98.78	144.86	96.57	67.90	2.87	35.80	9.51	82.80	44.03	372.23	93.93	15.20
12	92.24	132.37	80.75	48.37	92.67	23.67	6.72	28.35	35.11	210.18	82.68	80.22
13	74.10	101.95	70.18	50.13	30.87	20.72	6.81	22.05	43.56	156.16	64.05	77.52
14	62.37	84.80	62.13	39.26	42.45	16.35	7.33	10.70	29.71	121.37	51.92	56.84
15	54.63	72.76	55.87	31.36	23.21	15.26	6.68	8.34	22.69	103.46	43.84	45.24
16	51.88	61.10	50.92	30.52	15.17	90.21	2.59	5.97	20.19	88.83	37.82	36.89
17	45.38	77.57	46.93	26.20	15.92	64.14	2.04	5.12	18.14	65.40	33.26	30.79
18	41.25	515.52	43.68	18.96	23.80	39.18	3.61	61.70	17.39	59.21	29.74	26.29
19	265.43	231.86	40.96	17.29	19.64	34.83	5.01	36.30	11.58	53.49	27.00	24.34
20	291.37	144.17	38.67	22.01	11.34	30.45	7.71	81.76	1152.99	38.56	24.82	20.94
21	210.15	134.82	36.70	19.43	52.00	24.24	3.79	64.41	366.80	119.03	24.44	18.73
22	599.01	920.30	956.48	20.54	45.79	17.67	3.17	65.34	94.53	105.55	22.18	31.63
23	299.90	967.14	302.95	20.96	63.92	18.37	4.89	72.88	76.61	76.12	21.38	40.34
24	195.13	390.57	128.17	17.24	37.78	13.07	3.92	48.27	63.55	69.05	116.84	32.19
25	155.11	244.02	103.75	29.36	33.13	9.17	3.08	113.55	51.78	57.49	99.58	26.23
26	185.41	193.22	85.88	22.99	26.29	8.30	18.89	97.80	47.28	51.47	71.21	22.94
27	161.58	156.50	73.08	20.11	23.53	12.83	11.52	65.33	37.63	43.08	57.20	20.55
28	127.37	129.10	62.60	3.41	19.45	28.20	4.43	51.89	39.61	35.52	46.98	18.77
29	104.67		67.62	16.91	115.72	20.75	6.18	38.99	32.09	32.25	39.42	17.40
30	87.78		58.06	17.82	77.85	17.91	9.52	37.46	28.14	31.78	33.77	16.32
31	75.05		50.34		52.68		9.53	32.40		29.49		15.45
SUM	5043.66	5393.67	3786.39	1358.15	921.99	1985.30	453.46	1145.57	5557.24	8403.66	1553.92	879.14

SUM of monthly values 3.64821E+04

Cub Run watershed simulated discharge for 1984 (inches).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.04	0.02	0.06	0.09	0.02	0.01	0.07	0.01	0.00	0.04	0.00	0.02
2	0.03	0.02	0.05	0.07	0.01	0.01	0.03	0.04	0.00	0.01	0.01	0.03
3	0.03	0.05	0.04	0.06	0.14	0.00	0.01	0.05	0.05	0.00	0.00	0.03
4	0.03	0.03	0.04	0.50	0.12	0.01	0.00	0.01	0.01	0.00	0.04	0.02
5	0.03	0.05	0.08	0.25	0.07	0.00	0.02	0.00	0.01	0.00	0.03	0.09
6	0.02	0.03	0.06	0.13	0.07	0.01	0.00	0.00	0.01	0.00	0.01	0.07
7	0.02	0.03	0.05	0.10	0.05	0.00	0.00	0.00	0.00	0.00	0.01	0.05
8	0.02	0.02	0.05	0.08	0.09	0.00	0.01	0.00	0.00	0.00	0.01	0.04
9	0.02	0.02	0.04	0.07	0.07	0.00	0.00	0.04	0.00	0.00	0.01	0.03
10	0.09	0.02	0.04	0.06	0.05	0.00	0.01	0.34	0.00	0.00	0.01	0.02
11	0.06	0.02	0.03	0.05	0.04	0.00	0.00	0.12	0.00	0.00	0.01	0.02
12	0.05	0.02	0.29	0.04	0.04	0.00	0.00	0.04	0.00	0.00	0.01	0.02
13	0.04	0.35	0.14	0.11	0.03	0.00	0.00	0.11	0.00	0.00	0.01	0.02
14	0.03	0.19	0.08	0.11	0.02	0.00	0.00	0.08	0.00	0.00	0.01	0.02
15	0.04	0.11	0.07	0.21	0.02	0.00	0.00	0.05	0.00	0.01	0.01	0.01
16	0.03	0.10	0.06	0.15	0.02	0.00	0.00	0.04	0.00	0.00	0.01	0.01
17	0.07	0.08	0.05	0.10	0.01	0.03	0.01	0.03	0.00	0.00	0.04	0.01
18	0.06	0.06	0.04	0.08	0.02	0.01	0.00	0.06	0.00	0.00	0.04	0.01
19	0.04	0.05	0.04	0.07	0.01	0.00	0.00	0.04	0.00	0.00	0.02	0.01
20	0.03	0.04	0.13	0.05	0.01	0.00	0.02	0.02	0.00	0.00	0.01	0.03
21	0.03	0.16	0.10	0.06	0.04	0.00	0.00	0.02	0.00	0.02	0.01	0.02
22	0.04	0.13	0.07	0.05	0.02	0.01	0.00	0.02	0.00	0.00	0.01	0.02
23	0.03	0.09	0.33	0.04	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.01
24	0.03	0.07	0.24	0.03	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01
25	0.02	0.07	0.16	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01
26	0.02	0.15	0.74	0.03	0.01	0.04	0.00	0.01	0.02	0.03	0.27	0.01
27	0.02	0.12	0.59	0.03	0.10	0.01	0.00	0.01	0.01	0.01	0.11	0.01
28	0.02	0.09	0.26	0.03	0.05	0.00	0.00	0.01	0.01	0.00	0.04	0.01
29	0.02	0.07	0.17	0.03	0.03	0.01	0.00	0.00	0.01	0.00	0.03	0.02
30	0.02		0.14	0.02	0.02	0.01	0.00	0.01	0.00	0.00	0.02	0.01
31	0.02		0.11		0.02		0.00	0.01		0.00		0.01
SUM	1.05	2.29	4.35	2.71	1.23	0.20	0.20	1.16	0.16	0.17	0.79	0.73

SUM of monthly values 1.50503E+01

Cub Run watershed simulated discharge for 1984 (cfs).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	51.26	23.91	82.55	127.98	25.13	19.12	105.30	12.82	2.03	50.77	6.56	27.71
2	45.64	23.09	69.93	100.74	17.03	14.97	37.09	56.37	0.81	15.15	8.01	38.90
3	41.28	63.94	60.45	82.55	193.25	6.04	10.28	67.32	66.72	5.15	6.67	47.32
4	38.77	41.56	53.21	704.48	163.15	8.35	6.40	14.07	18.68	3.05	61.47	31.40
5	35.45	70.70	106.36	346.33	97.90	6.93	21.40	4.62	15.42	2.69	49.25	131.63
6	32.98	47.41	88.70	190.46	96.04	7.67	5.60	2.14	8.66	0.62	18.03	103.97
7	31.08	37.25	68.53	141.57	70.68	5.98	1.85	1.33	6.06	6.45	11.98	67.90
8	29.48	33.01	77.14	115.86	130.05	4.12	10.59	1.88	4.70	3.49	10.59	51.82
9	28.11	30.09	62.64	94.37	100.12	3.98	1.86	54.00	2.29	4.91	9.82	42.00
10	125.68	32.38	52.21	79.67	75.21	1.06	7.18	478.43	3.05	4.87	9.33	35.18
11	86.76	28.09	46.16	66.44	61.51	0.74	1.53	170.65	4.94	3.81	8.96	30.29
12	68.52	30.29	416.11	56.06	57.01	0.74	0.44	53.89	5.82	0.64	8.66	26.72
13	55.39	499.92	198.76	155.56	37.81	0.41	0.34	148.82	5.86	0.19	8.39	24.05
14	45.95	273.39	119.48	162.16	31.99	0.32	0.26	109.60	5.07	0.05	8.16	22.02
15	58.36	150.96	96.62	295.53	27.20	1.85	0.20	67.13	0.81	9.73	7.94	20.44
16	43.44	147.89	79.97	210.14	24.91	4.42	0.16	51.37	0.62	4.09	7.73	19.19
17	104.98	113.01	69.59	146.44	20.69	43.32	19.61	35.41	0.28	3.27	61.77	18.18
18	78.80	88.17	59.09	117.00	23.69	8.45	3.66	80.22	0.41	1.95	57.03	18.28
19	57.95	72.69	51.46	94.27	13.58	0.91	0.24	51.55	0.17	2.92	21.65	17.03
20	48.43	61.47	177.78	77.01	15.36	0.80	26.64	32.00	0.12	3.36	14.48	41.43
21	42.15	226.79	138.46	81.79	57.48	3.29	3.90	24.35	0.10	25.58	12.85	27.56
22	57.60	190.56	101.30	66.86	30.75	12.88	0.61	23.93	0.12	5.62	11.93	23.72
23	42.68	134.06	467.11	50.29	17.39	20.09	0.25	14.76	0.06	4.73	11.33	20.46
24	35.89	104.36	335.85	39.07	12.87	2.67	0.16	14.00	0.05	4.33	10.88	18.65
25	32.71	102.77	222.90	35.06	17.44	0.26	1.51	10.69	0.21	2.88	10.50	17.60
26	30.44	212.20	1043.51	39.64	10.62	61.17	0.21	9.49	24.29	41.38	386.16	16.81
27	28.69	166.63	837.78	40.00	136.19	11.88	0.06	8.44	15.40	9.37	154.07	16.16
28	31.87	123.35	365.39	41.97	71.60	6.71	0.04	9.25	11.63	3.07	52.62	15.61
29	28.01	99.66	246.33	37.21	38.50	11.83	0.53	4.75	7.99	2.25	40.80	26.77
30	25.96		194.52	33.51	34.54	11.01	4.47	12.45	7.04	6.64	33.12	19.63
31	24.84		156.42		30.25		4.76	12.64		6.80		16.68
SUM	1489.15	3229.59	6146.33	3830.00	1739.90	281.96	277.14	1638.35	219.43	239.82	1120.74	1035.13

SUM of monthly values 2.12475E+04

Cub Run watershed simulated discharge for 1988 (inches).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.02	0.02	0.01	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.08	0.02
2	0.02	0.11	0.01	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.02
3	0.02	0.06	0.01	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01
4	0.02	0.07	0.14	0.01	0.00	0.01	0.00	0.00	0.11	0.00	0.01	0.01
5	0.02	0.04	0.07	0.01	0.21	0.01	0.00	0.00	0.03	0.00	0.11	0.01
6	0.02	0.03	0.04	0.01	0.21	0.00	0.00	0.15	0.01	0.00	0.03	0.01
7	0.03	0.03	0.03	0.27	0.08	0.00	0.00	0.03	0.00	0.00	0.01	0.01
8	0.04	0.02	0.03	0.14	0.04	0.00	0.00	0.01	0.00	0.00	0.01	0.01
9	0.02	0.02	0.02	0.07	0.03	0.00	0.11	0.01	0.00	0.00	0.01	0.02
10	0.02	0.02	0.02	0.04	0.06	0.01	0.02	0.00	0.00	0.00	0.01	0.01
11	0.02	0.03	0.02	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.01
12	0.02	0.02	0.02	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.06	0.01
13	0.01	0.02	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.01
14	0.01	0.07	0.02	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01
15	0.01	0.04	0.01	0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.01	0.01
16	0.02	0.03	0.01	0.01	0.02	0.00	0.05	0.00	0.00	0.00	0.10	0.01
17	0.03	0.02	0.01	0.01	1.20	0.00	0.02	0.00	0.00	0.00	0.03	0.01
18	0.07	0.07	0.01	0.01	0.76	0.00	0.00	0.00	0.00	0.00	0.12	0.01
19	0.16	0.04	0.01	0.01	0.22	0.00	0.28	0.10	0.00	0.00	0.07	0.01
20	0.07	0.03	0.01	0.01	0.12	0.00	0.05	0.02	0.00	0.15	0.03	0.03
21	0.04	0.03	0.01	0.01	0.51	0.00	0.25	0.00	0.00	0.03	0.02	0.04
22	0.03	0.02	0.01	0.01	0.21	0.00	0.07	0.02	0.03	0.00	0.02	0.05
23	0.15	0.02	0.01	0.00	0.12	0.00	0.02	0.00	0.03	0.00	0.01	0.02
24	0.08	0.02	0.47	0.00	0.09	0.00	0.05	0.00	0.01	0.00	0.01	0.02
25	0.05	0.02	0.15	0.02	0.07	0.00	0.02	0.00	0.00	0.00	0.11	0.01
26	0.04	0.02	0.06	0.00	0.05	0.00	0.01	0.00	0.00	0.00	0.11	0.03
27	0.03	0.02	0.05	0.00	0.04	0.00	0.01	0.08	0.00	0.00	0.04	0.02
28	0.03	0.02	0.04	0.01	0.04	0.00	0.01	0.02	0.00	0.00	0.03	0.01
29	0.03	0.02	0.03	0.01	0.03	0.00	0.00	0.01	0.00	0.00	0.02	0.01
30	0.02		0.03	0.01	0.03	0.00	0.01	0.01	0.00	0.00	0.02	0.01
31	0.02		0.02		0.03		0.01	0.01		0.00		0.01
SUM	1.17	0.96	1.44	0.86	4.31	0.11	0.99	0.51	0.26	0.20	1.12	0.50

SUM of monthly values 1.24408E+01

Cub Run watershed simulated discharge for 1988 (cfs).

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	24.11	26.67	20.56	29.14	3.92	20.25	0.49	2.98	2.90	1.19	112.85	23.98
2	22.91	156.68	19.95	26.10	2.39	13.77	4.36	1.68	0.75	0.91	24.11	21.53
3	34.87	84.01	19.40	23.74	4.91	20.36	0.43	1.28	0.90	1.15	7.22	19.71
4	30.88	95.10	190.70	10.11	5.60	18.54	0.01	0.99	154.01	4.37	11.91	18.32
5	23.30	60.55	94.68	14.44	301.26	18.35	0.01	0.76	38.92	2.71	158.38	17.23
6	21.29	45.39	59.58	11.58	290.29	6.20	0.00	216.16	9.17	0.23	36.30	16.34
7	49.38	38.45	47.42	385.37	113.56	4.55	0.00	48.74	5.15	0.01	13.97	15.61
8	58.08	33.79	39.18	191.34	58.49	3.96	0.00	13.96	4.47	1.01	11.09	14.99
9	32.18	30.49	33.42	93.97	39.70	6.26	154.48	9.72	3.76	0.10	9.44	27.45
10	24.93	28.04	30.59	62.73	91.63	14.39	25.95	6.98	5.17	0.00	8.41	17.68
11	22.73	39.41	26.55	48.58	43.35	6.02	2.78	5.09	1.80	0.00	7.72	14.89
12	21.37	28.58	33.52	43.26	25.23	2.04	1.68	3.84	3.15	0.00	78.50	17.04
13	20.40	24.99	24.91	32.59	19.24	3.27	1.09	2.83	0.92	0.00	23.86	14.40
14	19.62	94.24	21.84	27.53	14.51	1.72	0.75	15.29	0.48	0.00	12.00	13.44
15	18.96	52.25	20.52	20.12	55.23	1.19	0.54	3.50	0.36	0.00	10.07	13.04
16	33.04	36.96	19.49	20.26	34.71	0.65	67.71	1.26	3.83	0.00	139.82	12.68
17	42.60	31.89	18.65	17.73	1691.29	4.85	31.12	0.96	5.52	0.00	40.22	12.35
18	99.14	100.92	17.93	20.26	1068.66	1.33	7.04	0.74	0.74	1.53	169.96	12.05
19	224.99	56.90	18.62	17.50	314.49	2.03	393.06	147.37	0.13	0.15	98.65	11.75
20	93.46	40.42	17.07	10.34	175.85	0.31	66.45	32.94	0.81	217.46	43.05	46.57
21	57.94	46.34	16.28	7.49	721.60	0.13	350.40	4.58	0.14	35.50	29.15	61.39
22	46.86	34.19	15.82	10.83	302.24	0.10	100.13	23.60	41.09	3.80	23.56	75.97
23	210.80	29.35	15.40	6.68	165.51	0.08	33.92	6.40	48.80	2.30	20.07	32.86
24	109.30	27.03	666.05	5.12	124.28	0.07	67.13	2.00	11.47	1.50	17.73	21.78
25	71.50	25.31	213.58	31.76	97.68	0.05	26.12	1.19	1.55	1.04	161.96	18.71
26	57.18	23.98	87.43	6.86	76.92	0.04	18.10	0.77	1.07	1.16	153.24	47.38
27	47.38	22.90	68.36	4.10	60.44	0.03	14.19	114.80	0.26	0.58	61.99	25.68
28	40.46	22.00	55.00	7.38	51.49	0.03	7.45	24.52	4.15	2.40	39.99	18.92
29	35.43	21.23	45.39	11.51	41.04	5.04	5.18	7.19	5.89	0.50	32.34	17.03
30	31.70		38.35	11.52	43.45	5.41	12.13	9.75	5.87	3.13	27.38	15.88
31	28.87		33.11		38.95		11.80	9.18		3.30		15.09
SUM	1655.65	1358.07	2029.39	1209.93	6077.92	161.02	1404.49	721.05	363.21	286.06	1584.94	711.76

SUM of monthly values 1.75635E+04

APPENDIX 3

Daily Simulated Suspended Solids Data for 1979, 1985 and 1988

PERLND & IMPLND TSS (tons)

Annual data display: Summary for period ending 1979/12

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	51.64	0.00	0.75	14.97	0.00	25.27	41.11	0.00	0.00	1308.74	0.00	0.02
2	534.42	0.00	0.07	0.38	0.00	1.62	0.44	55.77	0.00	88.48	60.84	0.00
3	8.74	0.00	0.00	31.65	0.00	413.48	0.00	1.11	7.27	8.67	6.06	0.00
4	0.00	0.00	0.00	13.75	21.66	10.74	17.82	0.00	0.30	0.00	0.21	0.00
5	7.84	0.00	112.35	0.20	2.84	0.01	0.04	0.00	1128.54	105.49	0.02	0.00
6	16.66	0.00	7.24	0.00	0.14	0.00	0.00	0.00	44.68	2.21	0.02	0.00
7	70.64	64.66	0.10	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.02	0.00
8	1.92	1.15	0.00	0.00	0.00	0.00	0.00	5.20	0.00	1.69	4.12	0.00
9	0.01	1.85	0.00	37.71	0.00	0.00	0.00	0.25	0.00	57.38	3.07	0.00
10	0.00	0.11	20.93	0.17	0.00	15.42	0.00	0.00	0.00	294.55	69.45	0.00
11	15.53	70.57	0.55	0.00	0.00	0.47	0.00	106.15	0.00	18.57	1.14	0.78
12	8.02	1.23	0.00	0.00	109.64	0.00	0.00	1.86	0.00	1.22	14.65	62.83
13	0.00	0.00	0.00	1.43	2.29	0.00	0.00	0.00	16.54	0.02	0.38	1.24
14	0.00	1.82	0.00	0.14	23.94	0.00	0.00	0.00	0.49	0.00	0.03	0.00
15	0.00	3.28	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.02	0.00
16	4.31	0.14	0.00	0.00	0.00	87.40	0.00	0.00	0.00	0.00	0.02	0.00
17	0.17	21.54	0.00	0.00	2.14	0.57	0.00	0.00	0.00	0.00	0.02	0.00
18	0.00	327.27	0.00	0.00	5.04	0.00	0.00	63.61	0.00	0.00	0.02	0.00
19	174.00	6.44	0.00	0.00	2.45	0.00	0.00	0.84	0.00	0.00	0.02	1.87
20	64.58	6.45	0.00	0.00	0.17	5.19	0.00	22.29	608.41	0.00	0.02	0.11
21	0.51	5.88	0.00	0.00	24.91	0.24	1.01	8.44	26.09	93.94	1.79	0.00
22	264.94	563.56	492.77	0.00	5.27	0.00	0.08	3.40	0.00	1.66	0.13	16.65
23	5.60	283.08	16.85	0.00	7.89	0.00	0.00	4.64	0.00	0.00	0.82	15.01
24	0.00	10.86	0.00	4.66	0.19	0.00	0.00	0.07	0.00	0.00	112.92	0.43
25	0.00	0.01	0.00	11.72	0.00	0.00	0.00	48.45	0.00	0.00	1.76	0.00
26	36.40	0.00	0.00	1.93	0.00	0.00	24.64	0.54	2.19	2.69	0.04	0.00
27	0.19	0.00	0.76	0.11	1.66	4.16	7.96	0.00	0.20	0.19	0.04	0.00
28	0.00	0.00	0.07	0.00	0.14	20.21	0.28	0.00	10.99	0.00	0.03	0.00
29	0.00		11.90	0.00	78.21	0.53	0.00	0.00	0.38	0.00	0.03	0.00
30	0.00		0.39	0.00	1.81	0.00	0.00	0.00	0.06	0.00	0.03	0.00
31	0.00		0.00		0.00		0.00	0.00		0.00		0.00
0 SUM	1266.12	1369.91	664.74	118.83	290.98	585.31	93.38	322.61	1846.24	1985.50	277.73	98.95

SUM of monthly values 8.92029E+03

PERLND & IMPLND TSS (tons)

Annual data display: Summary for period ending 1985/12

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	2.09	343.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.21	23.68
2	30.08	89.39	0.00	0.00	26.96	0.00	73.48	0.00	0.00	50.96	4.57	0.52
3	84.68	1.48	0.00	0.00	40.57	0.00	1.26	0.00	0.00	29.06	36.80	0.00
4	23.27	0.00	13.77	0.00	0.85	0.00	0.00	0.00	0.00	1.97	260.09	0.00
5	12.44	19.69	0.37	0.00	0.00	4.51	0.00	0.00	0.00	0.12	74.27	12.87
6	0.37	0.52	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	1.34	0.39
7	1.00	0.00	0.00	0.00	0.00	1.48	0.00	0.00	0.00	0.00	0.00	0.00
8	0.10	0.00	3.44	0.00	0.00	0.14	0.00	52.06	0.00	0.00	0.00	0.00
9	0.00	0.00	0.19	0.00	0.00	0.00	0.00	1.02	91.80	0.00	0.00	0.00
10	4.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.64	0.00	0.00	0.00
11	0.23	833.76	0.99	0.00	28.49	0.00	0.00	0.00	0.35	0.00	0.00	0.00
12	0.00	17.63	0.10	0.00	0.72	0.00	0.00	0.00	0.00	0.00	0.00	58.38
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	55.76	0.00	1.15
14	0.00	0.00	0.00	0.00	0.00	4.47	10.61	0.00	0.00	18.87	0.00	0.00
15	0.00	0.00	0.00	0.00	24.02	0.25	0.41	0.00	0.00	0.54	50.40	0.00
16	63.55	0.00	0.00	0.00	55.56	0.00	0.00	0.00	0.00	0.00	1.09	0.00
17	3.59	0.00	0.00	0.00	17.39	0.00	0.00	83.36	0.00	0.00	0.00	0.00
18	0.15	0.00	0.00	0.00	0.51	0.00	0.00	1.69	0.00	0.00	0.00	0.00
19	3.44	0.00	0.00	0.00	0.00	0.00	0.00	19.66	0.00	26.70	0.00	2.09
20	0.19	0.00	0.00	0.00	33.12	0.00	0.00	0.60	0.00	213.25	0.00	0.15
21	0.00	0.00	104.40	0.00	95.03	0.00	0.00	0.00	0.00	5.84	0.00	0.00
22	0.00	0.00	41.95	0.00	1.67	0.00	0.00	0.00	0.00	1.04	0.00	27.69
23	4.68	12.33	0.95	21.12	0.00	0.00	22.40	47.49	0.00	0.09	0.00	6.42
24	2.35	17.90	0.00	0.62	0.00	0.00	0.63	106.91	21.48	0.00	0.98	0.26
25	0.15	0.39	0.00	0.00	0.00	0.00	36.39	2.06	246.85	0.00	10.34	0.00
26	0.00	0.00	0.00	0.00	55.20	0.00	0.83	0.00	5.20	0.00	132.49	0.00
27	0.00	0.00	0.97	0.00	1.17	0.00	0.00	0.00	0.00	0.00	12.42	0.00
28	0.00	0.00	21.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	121.54	0.00
29	106.42		26.53	0.00	72.10	0.00	0.00	0.00	0.00	0.00	2.45	0.00
30	2.23		0.50	0.00	1.45	0.00	0.00	0.00	0.00	0.00	0.01	0.00
31	0.00		0.00		0.00		0.00	0.00		0.00		0.00
0 SUM	345.68	1337.01	216.12	21.74	454.80	11.11	146.01	314.87	376.33	404.21	724.06	133.61

SUM of monthly values 4.48555E+03

PERLND & IMPLND TSS (tons)

Annual data display: Summary for period ending 1988/12

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	155.21	0.01
2	0.00	155.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.56	0.00
3	16.59	7.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	8.73	48.11	207.14	0.08	0.00	0.00	0.00	0.00	185.67	0.00	7.68	0.00
5	0.41	1.22	3.88	0.00	451.46	0.00	0.00	0.00	2.04	0.00	230.59	0.00
6	0.00	0.00	0.00	0.91	317.69	0.00	0.00	265.97	0.01	0.00	4.57	0.00
7	36.79	0.00	0.00	470.60	5.38	0.00	0.00	3.34	0.00	0.00	0.00	0.00
8	37.87	0.00	0.00	56.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.97	0.00	0.00	1.27	0.00	2.04	217.96	0.00	0.00	0.00	0.00	16.58
10	0.00	0.00	1.73	0.00	45.23	0.21	5.11	0.00	0.00	0.00	0.00	0.62
11	0.00	17.17	0.18	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.62	12.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	101.25	3.75
13	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.10	0.27
14	0.00	81.27	0.00	0.00	0.00	0.00	0.00	17.20	0.00	0.00	0.00	0.00
15	0.00	1.91	0.00	0.00	56.67	0.00	0.00	0.69	0.00	0.00	0.00	0.00
16	18.58	0.00	0.00	0.00	22.38	0.00	89.35	0.00	3.93	0.00	192.84	0.00
17	26.55	0.00	0.00	4.47	1126.07	0.00	29.79	0.00	0.34	0.00	3.82	0.00
18	97.16	80.75	0.00	0.34	314.59	0.00	4.06	0.00	0.00	0.00	221.03	0.00
19	174.96	1.91	1.72	0.00	25.88	0.00	642.08	181.53	0.00	0.00	59.06	0.00
20	2.03	0.00	0.18	0.00	0.13	0.00	24.15	2.15	0.00	322.13	1.23	45.74
21	0.00	15.55	0.00	0.00	304.66	0.00	458.46	0.00	0.00	6.66	0.01	53.47
22	0.00	0.57	0.00	0.00	11.11	0.00	7.24	1.25	54.28	0.00	0.01	66.14
23	135.49	0.00	0.00	0.00	0.67	0.00	0.00	0.01	55.97	0.00	0.01	1.35
24	1.62	0.00	802.20	0.00	0.00	0.00	42.27	0.00	1.33	0.00	0.01	0.00
25	0.00	0.00	17.20	35.50	0.00	0.00	0.06	0.00	0.00	0.00	186.83	0.00
26	0.00	0.00	0.00	1.06	0.00	0.00	0.00	0.00	0.00	0.00	51.82	37.98
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	83.13	0.00	0.00	0.72	0.98
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	0.00	0.00	0.01	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
30	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
31	0.00		0.00		0.00		0.00	0.00		0.00		0.00
0 SUM	557.74	411.23	1047.13	570.80	2682.11	2.25	1520.54	556.47	303.57	328.79	1222.38	226.87

SUM of monthly values 9.42988E+03

APPENDIX 4

HSPF Discharge Simulation Input Files.

```
RUN

GLOBAL
  Version 8.0 test run:  CR79FT.INP:  PERLND w/ PWATER; IMPLND w/ IWATER; RCHRES
  START       1978              END    1980
  RUN INTERP OUTPUT LEVEL    1
  RESUME     0 RUN     1 TSSFL    15 WDMSFL   16
END GLOBAL

OPN SEQUENCE
    INGRP              INDELT  1:00
      PERLND       1
      PERLND       2
      PERLND       3
      PERLND       4
      IMPLND       1
      RCHRES       1
      RCHRES       2
      RCHRES       3
      RCHRES       4
      RCHRES       5
      RCHRES       6
      RCHRES       7
      RCHRES       8
***   COPY         1
***   COPY         2
***   COPY         3
***   COPY         4
***   COPY         5
      DISPLY       1
      DISPLY       2
***   DISPLY       3
***   DISPLY       4
***   DISPLY       5
***   DISPLY       6
***   DISPLY       7
***   DISPLY       8
***   DISPLY       9
***   DISPLY      10
***   DISPLY      11
***   PLTGEN       1
    END INGRP
END OPN SEQUENCE

PERLND
  ACTIVITY
    <PLS >          Active Sections (1=Active; 0=Inactive)           ***
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
    1    4              1
  END ACTIVITY

  PRINT-INFO
    <PLS >          Print-flags                                  *** PIVL  PYR
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC       ***
    1    4              5                                                   12
  END PRINT-INFO
```

```
GEN-INFO
  <PLS ><-------Name------->NBLKS   Unit-systems   Printer ***
  # -  #                            User  t-series Engl Metr ***
                                          in  out            ***
  1      RESIDENTIAL             1    1    1    1    1    0
  2      FOREST                  1    1    1    1    1    0
  3      AGRICULTURAL            1    1    1    1    1    0
  4      CONSTRUCTION            1    1    1    1    1    0
END GEN-INFO

*** Section PWATER ***

PWAT-PARM1
  <PLS >  PWATER variable monthly parameter value flags ***
  # -  # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE    ***
  1    4    0    0    0    1    1    1    1    0    1
END PWAT-PARM1

PWAT-PARM2
  <PLS > ***  PWATER input info: Part 2
  # -  # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
  1          0.000       9.0     0.015      350.     0.010       0.5      0.98
  2          0.010       8.0     0.020      350.     0.010       0.5      0.98
  3          0.000       8.0     0.017      350.     0.010       0.5      0.98
  4          0.000       2.0     0.006      350.     0.010       0.5      0.98
END PWAT-PARM2

PWAT-PARM3
  <PLS > ***  PWATER input i1Qo: Part 3
  # -  # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
  1    4       40.       35.       2.0       2.0      0.56       .05      0.08
END PWAT-PARM3

PWAT-PARM4
  <PLS >      PWATER input info: Part 4                                  ***
  # -  #      CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
  1            0.15      1.40       0.4       1.0      0.60      0.35
  2            0.25      2.00       0.6       1.2      0.80      0.42
  3            0.21      1.40       0.4       1.0      0.70      0.35
  4            0.01      0.30       0.1       1.0      0.40      0.01
END PWAT-PARM4

MON-INTERCEP
  <PLS>   Only required if VCSFG=1 in PWAT-PARM1                        ***
  # -  #  Interception storage capacity at start of each month          ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1      0.10 0.10 0.12 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.13 0.10
  2      0.18 0.18 0.21 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.23 0.18
  3      0.10 0.10 0.15 0.21 0.21 0.21 0.21 0.21 0.21 0.15 0.12 0.10
  4      0.01 0.01 0.01 0.02 0.02 0.02 0.02 0.02 0.02 0.01 0.01 0.01
END MON-INTERCEP

MON-UZSN
  <PLS>   Only required if VUZFG=1 in PWAT-PARM1                        ***
  # -  #  Upper zone storage at start of each month                     ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       1.6  1.6  1.4  1.4  1.4  1.6  1.6  1.6  1.6  1.4  1.4  1.6
  2       2.2  2.2  2.0  2.0  2.0  2.2  2.2  2.2  2.2  2.0  2.0  2.2
  3       1.6  1.6  1.4  1.4  1.4  1.6  1.6  1.6  1.6  1.4  1.4  1.6
  4       0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3
END MON-UZSN

MON-MANNING
  <PLS >  Only required if VNNFG=1 in PWAT-PARM1                        ***
  # -  #  Manning's n for overland flow at start of each month          ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1      0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40
  2      0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60
  3      0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40
```

```
  4      0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10
 END MON-MANNING

 MON-INTERFLW
   <PLS >  Only required if VIFW=1 in PWAT-PARM1                      ***
   # -  #  Interflow inflow parameter for the start of each month     ***
            JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
   1       1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
   2       1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20
   3       1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
   4       1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
 END MON-INTERFLW

 MON-LZETPARM
   <PLS >  Only required if VLEFG=1 in PWAT-PARM1                     ***
   # -  #  Lower zone ET parameter at start of each month             ***
            JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
   1       0.01 0.01 0.10 0.18 0.35 0.37 0.37 0.37 0.37 0.31 0.20 0.10
   2       0.08 0.08 0.15 0.30 0.42 0.45 0.45 0.45 0.45 0.37 0.22 0.16
   3       0.01 0.01 0.10 0.18 0.35 0.37 0.37 0.37 0.37 0.30 0.20 0.10
   4       0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
 END MON-LZETPARM

 PWAT-STATE1
   <PLS > *** Initial conditions at start of simulation
   # -  # ***  CEPS      SURS      UZS       IFWS      LZS       AGWS      GWVS
   1           0.03      0.1       1.20      2.0       6.5       2.00      0.05
   2           0.05      0.1       1.60      2.0       4.0       2.00      0.10
   3           0.03      0.1       1.20      2.0       4.0       2.00      0.10
   4           0.00      0.1       0.30      2.0       1.8       2.00      0.05
 END PWAT-STATE1
END PERLND

IMPLND
 ACTIVITY
   <ILS >              Active Sections   ***
   # -  # ATMP SNOW IWAT  SLD  IWG IQAL  ***
   1                1
 END ACTIVITY

 PRINT-INFO
   <PLS >          Print-flags ******** PIVL  PYR
   # -  # ATMP SNOW IWAT  SLD  IWG IQAL *********
   1                5                         12
 END PRINT-INFO

 GEN-INFO
   <ILS ><-------Name------->        Unit-systems   Printer ***
   # -  #                          User  t-series Engl Metr ***
                                          in  out           ***
   1     RESIDENTIAL             1    1    1    1    1    0
 END GEN-INFO
```

```
*** Section IWATER ***

  IWAT-PARM1
    <ILS >          Flags          ***
    # -  # CSNO RTOP  VRS  VNN RTLI    ***
    1                  1    1
  END IWAT-PARM1

  IWAT-PARM2
    <ILS >                                            ***
    # -  #      LSUR     SLSUR      NSUR     RETSC    ***
    1           350.      .010      .014      0.01
  END IWAT-PARM2

  IWAT-PARM3
    <ILS >   Only required if CSNO=1  ***
    # -  #*** PETMAX    PETMIN
    1             40.       35.
  END IWAT-PARM3

  MON-RETN
    <ILS >  Only required if VRSFG=1 in IWAT-PARM1 is 1            ***
            Retention storage capacity at the start of each month     ***
    # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1       .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01
  END MON-RETN

  MON-MANNING
    <ILS >  Only required if VNNFG=1 in IWAT-PARM1 is 1            ***
            Manning's n for overland flow at start of each month      ***
    # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1      .014 .014 .014 .014 .014 .014 .014 .014 .014 .014 .014 .014
  END MON-MANNING

  IWAT-STATE1
    <ILS >  IWATER State variables; cond's at the start of simulation ***
    # -  #***   RETS      SURS
    1           .001      0.01
  END IWAT-STATE1
END IMPLND

RCHRES
  ACTIVITY
    RCHRES   Active sections***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG***
    1    8    1
  END ACTIVITY

  PRINT-INFO
    RCHRES          Print-flags ******** PIVL  PYR
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR***
    1    8    4                                                10   12
  END PRINT-INFO
```

```
  GEN-INFO
    RCHRES         Name        Nexits   Unit-systems   Printer     ***
    # -  #                           User  t-series Engl Metr LKFG***
                                           in  out                ***
    1     REACH 1                  1     1    1        0         0
    2     REACH 2                  1     1    1        0         0
    3     REACH 3                  1     1    1        0         0
    4     REACH 4                  1     1    1        0         0
    5     REACH 5                  1     1    1        0         0
    6     REACH 6                  1     1    1        0         0
    7     REACH 7                  1     1    1        0         0
    8     REACH 8                  1     1    1        0         0
  END GEN-INFO

*** Section HYDR ***

  HYDR-PARM1
    RCHRES  Flags for HYDR section***
    # -  #  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT for  each
            FG FG FG FG  possible   exit *** possible   exit     possible   exit
    1    8   0  0  0  0   4  0  0  0  0       0  0  0  0  0
  END HYDR-PARM1

  HYDR-PARM2
    RCHRES  ***
    # -  #     FTABNO        LEN     DELTH      STCOR        KS***   DB50
    1               1        6.0       50.        0.0         .2      0.1
    2               2        6.7      112.        0.0         .2      0.1
    3               3        5.3      107.        0.0         .2      0.1
    4               4        7.3      217.        0.0         .2      0.1
    5               5        1.4       41.        0.0         .2      0.1
    6               6        1.8       11.        0.0         .2      0.1
    7               7        1.7       39.        0.0         .2      0.1
    8               8        3.4       25.        0.0         .2      0.1
  END HYDR-PARM2

  MON-CONVF
    RCHRES  Monthly F(VOL) adjustment factors ***
    # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1       .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00
  END MON-CONVF

  HYDR-INIT
    RCHRES   Initial conditions for HYDR section***
    # -  #***     VOL      Initial  value  of COLIND      initial  value of OUTDGT
         ***    ac-ft      for each  possible   exit      for each  possible  exit
    1             11.        0.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    2             11.        0.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    3             10.        0.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    4             10.        0.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    5              2.        0.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    6             14.        0.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    7             11.        0.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    8             25.        0.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
  END HYDR-INIT
END RCHRES
```

```
FTABLES
  FTABLE       1
 ROWS COLS   (R1)            ***
   2    4
     DEPTH       AREA     VOLUME    FLOW     ***
      (FT)    (ACRES)  (ACRE-FT)  (ft^3/sec)***
       0.0        0.0        0.0       0.0
       7.3       21.8       74.4    1157.5
  END FTABLE  1

  FTABLE       2
 ROWS COLS   (R2)            ***
   2    4
     DEPTH       AREA     VOLUME    FLOW      ***
      (FT)    (ACRES)  (ACRE-FT)  (ft^3/sec) ***
       0.0        0.0        0.0       0.0
       9.4       28.4      147.7    5106.1
  END FTABLE  2

  FTABLE       3
 ROWS COLS    (R3)           ***
   2    4
     DEPTH       AREA     VOLUME      FLOW    ***
      (FT)    (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0        0.0        0.0       0.0
       7.9       10.1       36.9    1318.2
  END FTABLE  3

  FTABLE       4
 ROWS COLS    (R4)           ***
   2    4
     DEPTH       AREA     VOLUME      FLOW    ***
      (FT)    (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0        0.0        0.0       0.0
      21.9      137.5     1011.3   41968.0
  END FTABLE  4

  FTABLE       5
 ROWS COLS   (R5)            ***
   2    4
     DEPTH       AREA     VOLUME      FLOW    ***
      (FT)    (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0        0.0        0.0       0.0
       4.3        2.3        3.2     300.1
  END FTABLE  5

  FTABLE       6
 ROWS COLS   (R6)            ***
   2    4
     DEPTH       AREA     VOLUME      FLOW    ***
      (FT)    (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0        0.0        0.0       0.0
       6.2       23.2       95.8    2063.3
  END FTABLE  6
```

```
  FTABLE      7
 ROWS COLS    (R7)             ***
    2    4
     DEPTH      AREA     VOLUME      FLOW    ***
      (FT)   (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0       0.0       0.0        0.0
       7.6      15.4     100.2     3909.7
  END FTABLE  7

  FTABLE      8
 ROWS COLS    (R8)             ***
    2    4
     DEPTH      AREA     VOLUME      FLOW    ***
      (FT)   (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0       0.0       0.0        0.0
       7.6      30.0     200.4     2227.1
  END FTABLE  8
END FTABLES

DISPLY
  DISPLY-INFO1
*** # -  #<----------Title----------->***TRAN PIVL DIG1 FIL1  PYR DIG2 FIL2 YRND
    1     RUNOFF (IN), CUB RUN w/RCHS    SUM                     1    2   62   12
    2     RUNOFF (cfs),CUB RUN w/RCHS    SUM                     1    2   62   12
    3     PERO   (cfs)                   SUM                     1    2   62   12
    4     PERO   (in)                    SUM                     1    2   62   12
    5     SURO   (cfs)                   SUM                     1    2   62   12
    6     SURO   (in)                    SUM                     1    2   62   12
    7     AGWO   (cfs)                   SUM                     1    2   62   12
    8     AGWO   (in)                    SUM                     1    2   62   12
    9     IFWO   (cfs)                   SUM                     1    2   62   12
   10     IFWO   (in)                    SUM                     1    2   62   12
   11     TAET   (in)                    SUM                     1    2   62   12
  END DISPLY-INFO1
END DISPLY

PLTGEN
  PLOTINFO
    #thru# FILE  NPT  NMN Labl  PYR PIVL  ***
    1        63         1         1   12
  END PLOTINFO

  GEN-LABELS
    #THRU#<----    TITLE                   --------->   ***    <----YLABL------- >
    1       DISCHARGE  (IN)
  END GEN-LABELS

  SCALING
    #THRU#<--YMIN--><--YMAX--><-IVLIN-->***
    1                  2.0        .01
  END SCALING

  CURV-DATA
  PLOT-OPN     ***
    #THRU#   <---CURVE LABEL-> LINE INTG  COL TRAN ***
    1           DISCHARGE
  END CURV-DATA
END PLTGEN
```

```
COPY
  TIMESERIES
    # -  #  NPT  NMN***
    1             1
    2             1
    3             1
    4             1
    5             1
  END TIMESERIES
END COPY

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
TSS      2 PRECIP   ENGLZERO               PERLND   1   4 EXTNL  PREC
TSS      8 EVAPOR   ENGL         .7        PERLND   1   4 EXTNL  PETINP
TSS      2 PRECIP   ENGLZERO               IMPLND   1     EXTNL  PREC
TSS      8 EVAPOR   ENGL         .7        IMPLND   1     EXTNL  PETINP
END EXT SOURCES

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
PERLND   1 PWATER PERO           19.26     RCHRES   1     INFLOW IVOL
PERLND   2 PWATER PERO          282.55     RCHRES   1     INFLOW IVOL
PERLND   3 PWATER PERO          490.73     RCHRES   1     INFLOW IVOL
PERLND   4 PWATER PERO            9.95     RCHRES   1     INFLOW IVOL
IMPLND   1 IWATER SURO           28.31     RCHRES   1     INFLOW IVOL
RCHRES   1 ROFLOW                 1.00     RCHRES   6     INFLOW
PERLND   1 PWATER PERO            7.54     RCHRES   2     INFLOW IVOL
PERLND   2 PWATER PERO          255.66     RCHRES   2     INFLOW IVOL
PERLND   3 PWATER PERO          343.96     RCHRES   2     INFLOW IVOL
IMPLND   1 IWATER SURO           12.03     RCHRES   2     INFLOW IVOL
RCHRES   2 ROFLOW                 1.00     RCHRES   6     INFLOW
PERLND   1 PWATER PERO           31.99     RCHRES   3     INFLOW IVOL
PERLND   2 PWATER PERO          146.74     RCHRES   3     INFLOW IVOL
PERLND   3 PWATER PERO          210.76     RCHRES   3     INFLOW IVOL
PERLND   4 PWATER PERO            6.10     RCHRES   3     INFLOW IVOL
IMPLND   1 IWATER SURO           22.50     RCHRES   3     INFLOW IVOL
RCHRES   3 ROFLOW                 1.00     RCHRES   6     INFLOW
PERLND   1 PWATER PERO            4.56     RCHRES   6     INFLOW IVOL
PERLND   2 PWATER PERO           45.56     RCHRES   6     INFLOW IVOL
PERLND   3 PWATER PERO           21.64     RCHRES   6     INFLOW IVOL
PERLND   4 PWATER PERO            4.63     RCHRES   6     INFLOW IVOL
IMPLND   1 IWATER SURO            3.17     RCHRES   6     INFLOW IVOL
RCHRES   6 ROFLOW                 1.00     RCHRES   7     INFLOW
PERLND   1 PWATER PERO           11.32     RCHRES   5     INFLOW IVOL
PERLND   2 PWATER PERO           39.76     RCHRES   5     INFLOW IVOL
PERLND   3 PWATER PERO           27.78     RCHRES   5     INFLOW IVOL
PERLND   4 PWATER PERO            2.59     RCHRES   5     INFLOW IVOL
IMPLND   1 IWATER SURO            7.87     RCHRES   5     INFLOW IVOL
RCHRES   5 ROFLOW                 1.00     RCHRES   7     INFLOW
PERLND   1 PWATER PERO            1.63     RCHRES   7     INFLOW IVOL
PERLND   2 PWATER PERO           65.98     RCHRES   7     INFLOW IVOL
PERLND   3 PWATER PERO            5.65     RCHRES   7     INFLOW IVOL
PERLND   4 PWATER PERO            0.21     RCHRES   7     INFLOW IVOL
IMPLND   1 IWATER SURO            5.88     RCHRES   7     INFLOW IVOL
RCHRES   7 ROFLOW                 1.00     RCHRES   8     INFLOW
PERLND   1 PWATER PERO           62.96     RCHRES   4     INFLOW IVOL
PERLND   2 PWATER PERO          300.20     RCHRES   4     INFLOW IVOL
PERLND   3 PWATER PERO           92.18     RCHRES   4     INFLOW IVOL
PERLND   4 PWATER PERO            6.20     RCHRES   4     INFLOW IVOL
IMPLND   1 IWATER SURO           47.23     RCHRES   4     INFLOW IVOL
RCHRES   4 ROFLOW                 1.00     RCHRES   8     INFLOW
PERLND   1 PWATER PERO            1.74     RCHRES   8     INFLOW IVOL
PERLND   2 PWATER PERO          113.54     RCHRES   8     INFLOW IVOL
PERLND   3 PWATER PERO           54.79     RCHRES   8     INFLOW IVOL
PERLND   4 PWATER PERO             .66     RCHRES   8     INFLOW IVOL
IMPLND   1 IWATER SURO            3.14     RCHRES   8     INFLOW IVOL
```

```
RCHRES   8 HYDR   ROVOL        .000357    DISPLY   1     INPUT  TIMSER
*** ROVOL units are acre-ft/day;.504 converts acre-ft/day to cubic feet/sec
RCHRES   8 HYDR   ROVOL           .504    DISPLY   2     INPUT  TIMSER
***
*** The following conversions represent each land segment contribution
*** to watershed output in terms of cfs without reaches.
***
PERLND   1 PWATER PERO          141.00    COPY     1     INPUT  MEAN   1
PERLND   2 PWATER PERO         1249.98    COPY     1     INPUT  MEAN   1
PERLND   3 PWATER PERO         1247.49    COPY     1     INPUT  MEAN   1
PERLND   4 PWATER PERO           30.33    COPY     1     INPUT  MEAN   1
IMPLND   1 IWATER SURO          131.13    COPY     1     INPUT  MEAN   1
COPY     1 OUTPUT MEAN    1       .504    DISPLY   3     INPUT  TIMSER
COPY     1 OUTPUT MEAN    1    .000357    DISPLY   4     INPUT  TIMSER
***
*** The following conversions represent each land segment contribution
*** to watershed output in terms of SURFACE FLOW without reahces.
***
PERLND   1 PWATER SURO          141.00    COPY     2     INPUT  MEAN   1
PERLND   2 PWATER SURO         1249.98    COPY     2     INPUT  MEAN   1
PERLND   3 PWATER SURO         1247.49    COPY     2     INPUT  MEAN   1
PERLND   4 PWATER SURO           30.33    COPY     2     INPUT  MEAN   1
IMPLND   1 IWATER SURO          131.13    COPY     2     INPUT  MEAN   1
COPY     2 OUTPUT MEAN    1       .504    DISPLY   5     INPUT  TIMSER
COPY     2 OUTPUT MEAN    1    .000357    DISPLY   6     INPUT  TIMSER
***
*** The following conversions represent each land segment contribution
*** to watershed output in terms of GROUND WATER without reaches.
***
PERLND   1 PWATER AGWO          141.00    COPY     3     INPUT  MEAN   1
PERLND   2 PWATER AGWO         1249.98    COPY     3     INPUT  MEAN   1
PERLND   3 PWATER AGWO         1247.49    COPY     3     INPUT  MEAN   1
PERLND   4 PWATER AGWO           30.33    COPY     3     INPUT  MEAN   1
COPY     3 OUTPUT MEAN    1       .504    DISPLY   7     INPUT  TIMSER
COPY     3 OUTPUT MEAN    1    .000357    DISPLY   8     INPUT  TIMSER
***
*** The following conversions represent each land segment contribution
*** to watershed output in terms of INTERFLOW without reaches.
***
PERLND   1 PWATER IFWO          141.00    COPY     4     INPUT  MEAN   1
PERLND   2 PWATER IFWO         1249.98    COPY     4     INPUT  MEAN   1
PERLND   3 PWATER IFWO         1247.49    COPY     4     INPUT  MEAN   1
PERLND   4 PWATER IFWO           30.33    COPY     4     INPUT  MEAN   1
COPY     4 OUTPUT MEAN    1       .504    DISPLY   9     INPUT  TIMSER
COPY     4 OUTPUT MEAN    1    .000357    DISPLY  10     INPUT  TIMSER
***
```

```
*** The following conversions represent each land segment contribution
*** to watershed output in terms of TOTAL EVPOTRANS w/o reaches
***
PERLND    1 PWATER TAET          141.00     COPY      5      INPUT  MEAN    1
PERLND    2 PWATER TAET         1249.98     COPY      5      INPUT  MEAN    1
PERLND    3 PWATER TAET         1247.49     COPY      5      INPUT  MEAN    1
PERLND    4 PWATER TAET           30.33     COPY      5      INPUT  MEAN    1
COPY      5 OUTPUT MEAN   1     .000357     DISPLY   11      INPUT  TIMSER
*** ROVOL units are acre-ft/day; .50 converts acre-ft/day to cfs
RCHRES    8 HYDR   ROVOL   ***      .50     PLTGEN    1      INPUT  MEAN    1
END NETWORK

END RUN
```

```
RUN

GLOBAL
  Version 8.0 test run:  CR84FT.INP:  PERLND w/ PWATER; IMPLND w/ IWATER; RCHRES
  START       1983                END    1985
  RUN INTERP OUTPUT LEVEL    1
  RESUME     0 RUN     1 TSSFL    15 WDMSFL   16
END GLOBAL

OPN SEQUENCE
    INGRP              INDELT  1:00
      PERLND       1
      PERLND       2
      PERLND       3
      PERLND       4
      IMPLND       1
      RCHRES       1
      RCHRES       2
      RCHRES       3
      RCHRES       4
      RCHRES       5
      RCHRES       6
      RCHRES       7
      RCHRES       8
***   COPY         1
***   COPY         2
***   COPY         3
***   COPY         4
***   COPY         5
      DISPLY       1
      DISPLY       2
***   DISPLY       3
***   DISPLY       4
***   DISPLY       5
***   DISPLY       6
***   DISPLY       7
***   DISPLY       8
***   DISPLY       9
***   DISPLY      10
***   DISPLY      11
***   PLTGEN       1
    END INGRP
END OPN SEQUENCE

PERLND
  ACTIVITY
    <PLS >          Active Sections (1=Active; 0=Inactive)            ***
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
    1    4              1
  END ACTIVITY

  PRINT-INFO
    <PLS >          Print-flags                                  *** PIVL  PYR
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC       ***
    1    4              5                                                   12
  END PRINT-INFO
```

```
GEN-INFO
  <PLS ><-------Name------->NBLKS   Unit-systems   Printer ***
  # -  #                           User  t-series Engl Metr ***
                                          in  out           ***
  1     RESIDENTIAL              1    1    1    1    1    0
  2     FOREST                   1    1    1    1    1    0
  3     AGRICULTURAL             1    1    1    1    1    0
  4     CONSTRUCTION             1    1    1    1    1    0
END GEN-INFO

*** Section PWATER ***

PWAT-PARM1
  <PLS >  PWATER variable monthly parameter value flags ***
  # -  # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE   ***
  1    4    0    0    0    1    1    1    1    0    1
END PWAT-PARM1

PWAT-PARM2
  <PLS > ***  PWATER input info: Part 2
  # -  # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
  1          0.000       9.0     0.015      350.     0.010       0.5      0.98
  2          0.010       8.0     0.020      350.     0.010       0.5      0.98
  3          0.000       8.0     0.017      350.     0.010       0.5      0.98
  4          0.000       2.0     0.006      350.     0.010       0.5      0.98
END PWAT-PARM2

PWAT-PARM3
  <PLS > ***  PWATER input info: Part 3
  # -  # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
  1    4       40.       35.       2.0       2.0      0.56       .05      0.08
END PWAT-PARM3

PWAT-PARM4
  <PLS >     PWATER input info: Part 4                                ***
  # -  #     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
  1           0.15      1.40       0.4       1.0      0.60      0.35
  2           0.25      2.00       0.6       1.2      0.80      0.42
  3           0.21      1.40       0.4       1.0      0.70      0.35
  4           0.01      0.30       0.1       1.0      0.40      0.01
END PWAT-PARM4

MON-INTERCEP
  <PLS>   Only required if VCSFG=1 in PWAT-PARM1                      ***
  # -  #  Interception storage capacity at start of each month        ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1      0.10 0.10 0.12 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.13 0.10
  2      0.18 0.18 0.21 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.23 0.18
  3      0.10 0.10 0.15 0.21 0.21 0.21 0.21 0.21 0.21 0.15 0.12 0.10
  4      0.01 0.01 0.01 0.02 0.02 0.02 0.02 0.02 0.02 0.01 0.01 0.01
END MON-INTERCEP

MON-UZSN
  <PLS>   Only required if VUZFG=1 in PWAT-PARM1                      ***
  # -  #  Upper zone storage at start of each month                   ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       1.6  1.6  1.4  1.4  1.4  1.6  1.6  1.6  1.6  1.4  1.4  1.6
  2       2.2  2.2  2.0  2.0  2.0  2.2  2.2  2.2  2.2  2.0  2.0  2.2
  3       1.6  1.6  1.4  1.4  1.4  1.6  1.6  1.6  1.6  1.4  1.4  1.6
  4       0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3
END MON-UZSN

MON-MANNING
  <PLS >  Only required if VNNFG=1 in PWAT-PARM1                      ***
  # -  #  Manning's n for overland flow at start of each month        ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1      0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40
  2      0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60
  3      0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40
```

```
    4      0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10
  END MON-MANNING

  MON-INTERFLW
    <PLS >  Only required if VIFW=1 in PWAT-PARM1                        ***
    # -  #  Interflow inflow parameter for the strat of each month      ***
             JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1      1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
    2      1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20
    3      1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
    4      1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
  END MON-INTERFLW

  MON-LZETPARM
    <PLS >  Only required if VLEFG=1 in PWAT-PARM1                       ***
    # -  #  Lower zone ET parameter at start of each month              ***
             JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1      0.01 0.01 0.10 0.18 0.35 0.37 0.37 0.37 0.37 0.31 0.20 0.10
    2      0.08 0.08 0.15 0.30 0.42 0.45 0.45 0.45 0.45 0.37 0.22 0.16
    3      0.01 0.01 0.10 0.18 0.35 0.37 0.37 0.37 0.37 0.30 0.20 0.10
    4      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  END MON-LZETPARM

  PWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
    # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
    1           0.03       0.1      1.20       2.0       6.5      2.00      0.05
    2           0.05       0.1      1.60       2.0       4.0      2.00      0.10
    3           0.03       0.1      1.20       2.0       4.0      2.00      0.10
    4           0.00       0.1      0.30       2.0       8.0      2.00      0.05
  END PWAT-STATE1
END PERLND

IMPLND
  ACTIVITY
    <ILS >              Active Sections  ***
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL  ***
    1               1
  END ACTIVITY

  PRINT-INFO
    <PLS >          Print-flags ******** PIVL  PYR
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL *********
    1               5                        12
  END PRINT-INFO

  GEN-INFO
    <ILS ><-------Name------->        Unit-systems   Printer ***
    # -  #                          User  t-series Engl Metr ***
                                            in  out           ***
    1     RESIDENTIAL             1    1    1    1    1    0
  END GEN-INFO
```

```
*** Section IWATER ***

  IWAT-PARM1
    <ILS >           Flags          ***
    # -  # CSNO RTOP  VRS  VNN RTLI  ***
    1                  1    1
  END IWAT-PARM1

  IWAT-PARM2
    <ILS >                                        ***
    # -  #      LSUR     SLSUR     NSUR    RETSC  ***
    1           350.      .010     .014     0.01
  END IWAT-PARM2

  IWAT-PARM3
    <ILS >   Only required if CSNO=1  ***
    # -  #*** PETMAX    PETMIN
    1            40.       35.
  END IWAT-PARM3

  MON-RETN
    <ILS >  Only required if VRSFG=1 in IWAT-PARM1 is 1            ***
            Retention storage capacity at the start of each month  ***
    # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1       .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01
  END MON-RETN

  MON-MANNING
    <ILS >  Only required if VNNFG=1 in IWAT-PARM1 is 1            ***
            Manning's n for overland flow at start of each month   ***
    # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1      .014 .014 .014 .014 .014 .014 .014 .014 .014 .014 .014 .014
  END MON-MANNING

  IWAT-STATE1
    <ILS >  IWATER State variables; cond's at the start of simulation ***
    # -  #***   RETS      SURS
    1           .001      0.01
  END IWAT-STATE1
END IMPLND

RCHRES
  ACTIVITY
    RCHRES   Active sections***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG***
    1    8    1
  END ACTIVITY

  PRINT-INFO
    RCHRES          Print-flags ******** PIVL  PYR
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR***
    1    8    4                                              10   12
  END PRINT-INFO
```

```
  GEN-INFO
    RCHRES         Name        Nexits   Unit-systems   Printer      ***
    # -  #                            User  t-series Engl Metr LKFG***
                                             in  out                ***
    1      REACH 1                    1     1    1          0         0
    2      REACH 2                    1     1    1          0         0
    3      REACH 3                    1     1    1          0         0
    4      REACH 4                    1     1    1          0         0
    5      REACH 5                    1     1    1          0         0
    6      REACH 6                    1     1    1          0         0
    7      REACH 7                    1     1    1          0         0
    8      REACH 8                    1     1    1          0         0
  END GEN-INFO

*** Section HYDR ***

  HYDR-PARM1
    RCHRES  Flags for HYDR section***
    # -  #  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each    FUNCT for  each
            FG FG FG FG  possible   exit *** possible   exit    possible   exit
    1    8   0  0  0  0    4  0  0  0  0       0  0  0  0  0
  END HYDR-PARM1

  HYDR-PARM2
    RCHRES  ***
    # -  #    FTABNO       LEN     DELTH      STCOR          KS***    DB50
    1              1       6.0       50.        0.0            .2      0.1
    2              2       6.7      112.        0.0            .2      0.1
    3              3       5.3      107.        0.0            .2      0.1
    4              4       7.3      217.        0.0            .2      0.1
    5              5       1.4       41.        0.0            .2      0.1
    6              6       1.8       11.        0.0            .2      0.1
    7              7       1.7       39.        0.0            .2      0.1
    8              8       3.4       25.        0.0            .2      0.1
  END HYDR-PARM2

  MON-CONVF
    RCHRES  Monthly F(VOL) adjustment factors ***
    # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1       .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00
  END MON-CONVF

  HYDR-INIT
    RCHRES   Initial conditions for HYDR section***
    # -  #***     VOL      Initial  value  of COLIND      initial  value of OUTDGT
         ***    ac-ft      for each  possible   exit      for each  possible  exit
    1             11.        0.0  0.0  0.0  0.0  0.0        0.0  0.0  0.0  0.0  0.0
    2             11.        0.0  0.0  0.0  0.0  0.0        0.0  0.0  0.0  0.0  0.0
    3             10.        0.0  0.0  0.0  0.0  0.0        0.0  0.0  0.0  0.0  0.0
    4             10.        0.0  0.0  0.0  0.0  0.0        0.0  0.0  0.0  0.0  0.0
    5              2.        0.0  0.0  0.0  0.0  0.0        0.0  0.0  0.0  0.0  0.0
    6             14.        0.0  0.0  0.0  0.0  0.0        0.0  0.0  0.0  0.0  0.0
    7             11.        0.0  0.0  0.0  0.0  0.0        0.0  0.0  0.0  0.0  0.0
    8             25.        0.0  0.0  0.0  0.0  0.0        0.0  0.0  0.0  0.0  0.0
  END HYDR-INIT
END RCHRES
```

```
FTABLES
  FTABLE       1
 ROWS COLS    (R1)                ***
   2    4
     DEPTH      AREA     VOLUME    FLOW     ***
      (FT)    (ACRES)  (ACRE-FT)  (ft^3/sec)***
       0.0       0.0       0.0       0.0
       7.3      21.8      74.4    1157.5
  END FTABLE   1

  FTABLE       2
 ROWS COLS    (R2)                ***
   2    4
     DEPTH      AREA     VOLUME    FLOW       ***
      (FT)    (ACRES)  (ACRE-FT)  (ft^3/sec) ***
       0.0       0.0       0.0       0.0
       9.4      28.4     147.7    5106.1
  END FTABLE   2

  FTABLE       3
 ROWS COLS     (R3)               ***
   2    4
     DEPTH      AREA     VOLUME      FLOW     ***
      (FT)    (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0       0.0       0.0       0.0
       7.9      10.1      36.9    1318.2
  END FTABLE   3

  FTABLE       4
 ROWS COLS     (R4)               ***
   2    4
     DEPTH      AREA     VOLUME      FLOW     ***
      (FT)    (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0       0.0       0.0       0.0
      21.9     137.5    1011.3   41968.0
  END FTABLE   4

  FTABLE       5
 ROWS COLS    (R5)                ***
   2    4
     DEPTH      AREA     VOLUME      FLOW     ***
      (FT)    (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0       0.0       0.0       0.0
       4.3       2.3       3.2     300.1
  END FTABLE   5

  FTABLE       6
 ROWS COLS    (R6)                ***
   2    4
     DEPTH      AREA     VOLUME      FLOW     ***
      (FT)    (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0       0.0       0.0       0.0
       6.2      23.2      95.8    2063.3
  END FTABLE   6
```

```
  FTABLE      7
 ROWS COLS    (R7)               ***
   2    4
     DEPTH       AREA      VOLUME      FLOW    ***
      (FT)    (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0       0.0       0.0       0.0
       7.6      15.4     100.2    3909.7
  END FTABLE  7

  FTABLE      8
 ROWS COLS    (R8)               ***
   2    4
     DEPTH       AREA      VOLUME      FLOW    ***
      (FT)    (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0       0.0       0.0       0.0
       7.6      30.0     200.4    2227.1
  END FTABLE  8
END FTABLES

DISPLY
  DISPLY-INFO1
*** # -  #<----------Title----------->***TRAN PIVL DIG1 FIL1  PYR DIG2 FIL2 YRND
    1      RUNOFF (IN), CUB RUN w/RCHS    SUM                    1    2   62   12
    2      RUNOFF (cfs),CUB RUN w/RCHS    SUM                    1    2   62   12
    3      PERO   (cfs)                   SUM                    1    2   62   12
    4      PERO   (in)                    SUM                    1    2   62   12
    5      SURO   (cfs)                   SUM                    1    2   62   12
    6      SURO   (in)                    SUM                    1    2   62   12
    7      AGWO   (cfs)                   SUM                    1    2   62   12
    8      AGWO   (in)                    SUM                    1    2   62   12
    9      IFWO   (cfs)                   SUM                    1    2   62   12
   10      IFWO   (in)                    SUM                    1    2   62   12
   11      TAET   (in)                    SUM                    1    2   62   12
  END DISPLY-INFO1
END DISPLY

PLTGEN
  PLOTINFO
    #thru# FILE  NPT  NMN Labl  PYR PIVL  ***
    1        63         1         1   12
  END PLOTINFO

  GEN-LABELS
    #THRU#<----    TITLE                    --------->   ***    <----YLABL------- >
    1      DISCHARGE  (IN)
  END GEN-LABELS

  SCALING
    #THRU#<--YMIN--><--YMAX--><-IVLIN-->***
    1                 2.0        .01
  END SCALING

  CURV-DATA
  PLOT-OPN    ***
    #THRU#   <---CURVE LABEL-> LINE INTG  COL TRAN ***
    1          DISCHARGE
  END CURV-DATA
END PLTGEN
```

```
COPY
  TIMESERIES
    # -  #  NPT  NMN***
    1            1
    2            1
    3            1
    4            1
    5            1
  END TIMESERIES
END COPY

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
TSS      2 PRECIP   ENGLZERO   1.1         PERLND   1   4 EXTNL  PREC
TSS      8 EVAPOR   ENGL        .7         PERLND   1   4 EXTNL  PETINP
TSS      2 PRECIP   ENGLZERO   1.1         IMPLND   1     EXTNL  PREC
TSS      8 EVAPOR   ENGL        .7         IMPLND   1     EXTNL  PETINP
END EXT SOURCES

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
PERLND   1 PWATER PERO           26.82     RCHRES   1     INFLOW IVOL
PERLND   2 PWATER PERO          329.16     RCHRES   1     INFLOW IVOL
PERLND   3 PWATER PERO          407.75     RCHRES   1     INFLOW IVOL
PERLND   4 PWATER PERO           22.69     RCHRES   1     INFLOW IVOL
IMPLND   1 IWATER SURO           44.38     RCHRES   1     INFLOW IVOL
RCHRES   1 ROFLOW                 1.00     RCHRES   6     INFLOW
PERLND   1 PWATER PERO            8.12     RCHRES   2     INFLOW IVOL
PERLND   2 PWATER PERO          264.62     RCHRES   2     INFLOW IVOL
PERLND   3 PWATER PERO          336.06     RCHRES   2     INFLOW IVOL
IMPLND   1 IWATER SURO           10.39     RCHRES   2     INFLOW IVOL
RCHRES   2 ROFLOW                 1.00     RCHRES   6     INFLOW
PERLND   1 PWATER PERO           47.98     RCHRES   3     INFLOW IVOL
PERLND   2 PWATER PERO          159.98     RCHRES   3     INFLOW IVOL
PERLND   3 PWATER PERO          140.24     RCHRES   3     INFLOW IVOL
PERLND   4 PWATER PERO           35.25     RCHRES   3     INFLOW IVOL
IMPLND   1 IWATER SURO           34.63     RCHRES   3     INFLOW IVOL
RCHRES   3 ROFLOW                 1.00     RCHRES   6     INFLOW
PERLND   1 PWATER PERO            7.32     RCHRES   6     INFLOW IVOL
PERLND   2 PWATER PERO           46.31     RCHRES   6     INFLOW IVOL
PERLND   3 PWATER PERO           20.85     RCHRES   6     INFLOW IVOL
IMPLND   1 IWATER SURO            5.09     RCHRES   6     INFLOW IVOL
RCHRES   6 ROFLOW                 1.00     RCHRES   7     INFLOW
PERLND   1 PWATER PERO           13.77     RCHRES   5     INFLOW IVOL
PERLND   2 PWATER PERO           39.35     RCHRES   5     INFLOW IVOL
PERLND   3 PWATER PERO           19.33     RCHRES   5     INFLOW IVOL
PERLND   4 PWATER PERO            7.30     RCHRES   5     INFLOW IVOL
IMPLND   1 IWATER SURO            9.57     RCHRES   5     INFLOW IVOL
RCHRES   5 ROFLOW                 1.00     RCHRES   7     INFLOW
PERLND   1 PWATER PERO            2.81     RCHRES   7     INFLOW IVOL
PERLND   2 PWATER PERO           61.98     RCHRES   7     INFLOW IVOL
PERLND   3 PWATER PERO            5.57     RCHRES   7     INFLOW IVOL
PERLND   4 PWATER PERO            1.36     RCHRES   7     INFLOW IVOL
IMPLND   1 IWATER SURO            7.63     RCHRES   7     INFLOW IVOL
RCHRES   7 ROFLOW                 1.00     RCHRES   8     INFLOW
PERLND   1 PWATER PERO           82.80     RCHRES   4     INFLOW IVOL
PERLND   2 PWATER PERO          273.16     RCHRES   4     INFLOW IVOL
PERLND   3 PWATER PERO           63.73     RCHRES   4     INFLOW IVOL
PERLND   4 PWATER PERO           30.46     RCHRES   4     INFLOW IVOL
IMPLND   1 IWATER SURO           58.62     RCHRES   4     INFLOW IVOL
RCHRES   4 ROFLOW                 1.00     RCHRES   8     INFLOW
PERLND   1 PWATER PERO            5.06     RCHRES   8     INFLOW IVOL
PERLND   2 PWATER PERO          118.48     RCHRES   8     INFLOW IVOL
PERLND   3 PWATER PERO           46.95     RCHRES   8     INFLOW IVOL
PERLND   4 PWATER PERO            0.66     RCHRES   8     INFLOW IVOL
IMPLND   1 IWATER SURO            2.70     RCHRES   8     INFLOW IVOL
RCHRES   8 HYDR   ROVOL        .000357     DISPLY   1     INPUT  TIMSER
```

```
*** ROVOL units are acre-ft/day;.504 converts acre-ft/day to cubic feet/sec
RCHRES   8 HYDR   ROVOL            .504     DISPLY   2     INPUT  TIMSER
***
*** The following conversions represent each land segment contribution
*** to watershed output in terms of cfs without reaches.
***
PERLND   1 PWATER PERO           194.68     COPY     1     INPUT  MEAN    1
PERLND   2 PWATER PERO          1293.04     COPY     1     INPUT  MEAN    1
PERLND   3 PWATER PERO          1040.49     COPY     1     INPUT  MEAN    1
PERLND   4 PWATER PERO            97.72     COPY     1     INPUT  MEAN    1
IMPLND   1 IWATER SURO           173.00     COPY     1     INPUT  MEAN    1
COPY     1 OUTPUT MEAN   1         .504     DISPLY   3     INPUT  TIMSER
COPY     1 OUTPUT MEAN   1      .000357     DISPLY   4     INPUT  TIMSER
***
*** The following conversions represent each land segment contribution
*** to watershed output in terms of SURFACE FLOW without reahces.
***
PERLND   1 PWATER SURO           194.68     COPY     2     INPUT  MEAN    1
PERLND   2 PWATER SURO          1293.04     COPY     2     INPUT  MEAN    1
PERLND   3 PWATER SURO          1040.49     COPY     2     INPUT  MEAN    1
PERLND   4 PWATER SURO            97.72     COPY     2     INPUT  MEAN    1
IMPLND   1 IWATER SURO           173.00     COPY     2     INPUT  MEAN    1
COPY     2 OUTPUT MEAN   1         .504     DISPLY   5     INPUT  TIMSER
COPY     2 OUTPUT MEAN   1      .000357     DISPLY   6     INPUT  TIMSER
***
*** The following conversions represent each land segment contribution
*** to watershed output in terms of GROUND WATER without reaches.
***
PERLND   1 PWATER AGWO           194.68     COPY     3     INPUT  MEAN    1
PERLND   2 PWATER AGWO          1293.04     COPY     3     INPUT  MEAN    1
PERLND   3 PWATER AGWO          1040.49     COPY     3     INPUT  MEAN    1
PERLND   4 PWATER AGWO            97.72     COPY     3     INPUT  MEAN    1
COPY     3 OUTPUT MEAN   1         .504     DISPLY   7     INPUT  TIMSER
COPY     3 OUTPUT MEAN   1      .000357     DISPLY   8     INPUT  TIMSER
***
*** The following conversions represent each land segment contribution
*** to watershed output in terms of INTERFLOW without reaches.
***
PERLND   1 PWATER IFWO           194.68     COPY     4     INPUT  MEAN    1
PERLND   2 PWATER IFWO          1293.04     COPY     4     INPUT  MEAN    1
PERLND   3 PWATER IFWO          1040.49     COPY     4     INPUT  MEAN    1
PERLND   4 PWATER IFWO            97.72     COPY     4     INPUT  MEAN    1
COPY     4 OUTPUT MEAN   1         .504     DISPLY   9     INPUT  TIMSER
COPY     4 OUTPUT MEAN   1      .000357     DISPLY  10     INPUT  TIMSER
***
```

```
*** The following conversions represent each land segment contribution
*** to watershed output in terms of TOTAL EVPOTRANS w/o reaches
***
PERLND   1 PWATER TAET          194.68     COPY     5     INPUT  MEAN   1
PERLND   2 PWATER TAET         1293.04     COPY     5     INPUT  MEAN   1
PERLND   3 PWATER TAET         1040.49     COPY     5     INPUT  MEAN   1
PERLND   4 PWATER TAET           97.72     COPY     5     INPUT  MEAN   1
COPY     5 OUTPUT MEAN   1     .000357     DISPLY  11     INPUT  TIMSER
*** ROVOL units are acre-ft/day; .50 converts acre-ft/day to cfs
RCHRES   8 HYDR   ROVOL   ***      .50     PLTGEN   1     INPUT  MEAN   1
END NETWORK

END RUN
```

```
RUN

GLOBAL
  Version 8.0 test run:  CR88FT.INP:  PERLND w/ PWATER; IMPLND w/ IWATER; RCHRES
  START       1987               END    1989
  RUN INTERP OUTPUT LEVEL    1
  RESUME     0 RUN     1 TSSFL    15 WDMSFL   16
END GLOBAL

OPN SEQUENCE
    INGRP              INDELT  1:00
      PERLND       1
      PERLND       2
      PERLND       3
      PERLND       4
      IMPLND       1
      RCHRES       1
      RCHRES       2
      RCHRES       3
      RCHRES       4
      RCHRES       5
      RCHRES       6
      RCHRES       7
      RCHRES       8
***   COPY         1
***   COPY         2
***   COPY         3
***   COPY         4
***   COPY         5
      DISPLY       1
      DISPLY       2
***   DISPLY       3
***   DISPLY       4
***   DISPLY       5
***   DISPLY       6
***   DISPLY       7
***   DISPLY       8
***   DISPLY       9
***   DISPLY      10
***   DISPLY      11
***   PLTGEN       1
    END INGRP
END OPN SEQUENCE

PERLND
  ACTIVITY
    <PLS >          Active Sections (1=Active; 0=Inactive)             ***
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
    1    4              1
  END ACTIVITY

  PRINT-INFO
    <PLS >          Print-flags                                    *** PIVL  PYR
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC       ***
    1    4              5                                                    12
  END PRINT-INFO
```

```
GEN-INFO
  <PLS ><-------Name------->NBLKS  Unit-systems   Printer ***
  # -  #                        User  t-series Engl Metr ***
                                       in  out            ***
  1     RESIDENTIAL            1    1    1    1    1    0
  2     FOREST                 1    1    1    1    1    0
  3     AGRICULTURAL           1    1    1    1    1    0
  4     CONSTRUCTION           1    1    1    1    1    0
END GEN-INFO

*** Section PWATER ***

PWAT-PARM1
  <PLS >  PWATER variable monthly parameter value flags ***
  # -  # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE   ***
  1    4    0    0    0    1    1    1    1    0    1
END PWAT-PARM1

PWAT-PARM2
  <PLS > ***  PWATER input info: Part 2
  # -  # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
  1          0.000       9.0     0.015      350.     0.010       0.5      0.98
  2          0.010       8.0     0.020      350.     0.010       0.5      0.98
  3          0.000       8.0     0.017      350.     0.010       0.5      0.98
  4          0.000       2.0     0.006      350.     0.010       0.5      0.98
END PWAT-PARM2

PWAT-PARM3
  <PLS > ***  PWATER input i1Qo: Part 3
  # -  # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
  1    4       40.       35.       2.0       2.0      0.56       .05      0.08
END PWAT-PARM3

PWAT-PARM4
  <PLS >     PWATER input info: Part 4                               ***
  # -  #     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
  1           0.15      1.40       0.4       1.0      0.60      0.35
  2           0.25      2.00       0.6       1.2      0.80      0.42
  3           0.21      1.40       0.4       1.0      0.70      0.35
  4           0.01      0.30       0.1       1.0      0.40      0.01
END PWAT-PARM4

MON-INTERCEP
  <PLS>   Only required if VCSFG=1 in PWAT-PARM1                     ***
  # -  #  Interception storage capacity at start of each month       ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1      0.10 0.10 0.12 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.13 0.10
  2      0.18 0.18 0.21 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.23 0.18
  3      0.10 0.10 0.15 0.21 0.21 0.21 0.21 0.21 0.21 0.15 0.12 0.10
  4      0.01 0.01 0.01 0.02 0.02 0.02 0.02 0.02 0.02 0.01 0.01 0.01
END MON-INTERCEP

MON-UZSN
  <PLS>   Only required if VUZFG=1 in PWAT-PARM1                     ***
  # -  #  Upper zone storage at start of each month                  ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       1.6  1.6  1.4  1.4  1.4  1.6  1.6  1.6  1.6  1.4  1.4  1.6
  2       2.2  2.2  2.0  2.0  2.0  2.2  2.2  2.2  2.2  2.0  2.0  2.2
  3       1.6  1.6  1.4  1.4  1.4  1.6  1.6  1.6  1.6  1.4  1.4  1.6
  4       0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3
END MON-UZSN

MON-MANNING
  <PLS >  Only required if VNNFG=1 in PWAT-PARM1                     ***
  # -  #  Manning's n for overland flow at start of each month       ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1      0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40
  2      0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60
  3      0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40
```

```
    4      0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10
  END MON-MANNING

  MON-INTERFLW
    <PLS >  Only required if VIFW=1 in PWAT-PARM1                      ***
    # -  #  Interflow inflow parameter for the start of each month     ***
             JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1      1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
    2      1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20
    3      1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
    4      1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
  END MON-INTERFLW

  MON-LZETPARM
    <PLS >  Only required if VLEFG=1 in PWAT-PARM1                     ***
    # -  #  Lower zone ET parameter at start of each month             ***
             JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1      0.01 0.01 0.10 0.18 0.35 0.37 0.37 0.37 0.37 0.31 0.20 0.10
    2      0.08 0.08 0.15 0.30 0.42 0.45 0.45 0.45 0.45 0.37 0.22 0.16
    3      0.01 0.01 0.10 0.18 0.35 0.37 0.37 0.37 0.37 0.30 0.20 0.10
    4      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  END MON-LZETPARM

  PWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
    # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
    1           0.03       0.1      1.20       2.0       6.5      2.00      0.05
    2           0.05       0.1      1.60       2.0       4.0      2.00      0.10
    3           0.03       0.1      1.20       2.0       4.0      2.00      0.10
    4           0.00       0.1      0.30       2.0       1.8      2.00      0.05
  END PWAT-STATE1
END PERLND

IMPLND
  ACTIVITY
    <ILS >               Active Sections  ***
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL  ***
    1                 1
  END ACTIVITY

  PRINT-INFO
    <PLS >          Print-flags ******** PIVL  PYR
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL *********
    1                 5                        12
  END PRINT-INFO

  GEN-INFO
    <ILS ><-------Name------->        Unit-systems   Printer ***
    # -  #                          User  t-series Engl Metr ***
                                           in  out           ***
    1     RESIDENTIAL              1    1    1    1    1    0
  END GEN-INFO

*** Section IWATER ***

  IWAT-PARM1
    <ILS >          Flags            ***
    # -  # CSNO RTOP  VRS  VNN RTLI  ***
    1               1    1
  END IWAT-PARM1

  IWAT-PARM2
    <ILS >                                         ***
    # -  #      LSUR     SLSUR      NSUR     RETSC ***
    1           350.      .010      .014      0.01
  END IWAT-PARM2

  IWAT-PARM3
    <ILS >   Only required if CSNO=1  ***
```

```
    # -  #*** PETMAX    PETMIN
    1           40.       35.
  END IWAT-PARM3

  MON-RETN
    <ILS >  Only required if VRSFG=1 in IWAT-PARM1 is 1               ***
            Retention storage capacity at the start of each month     ***
    # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1       .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01
  END MON-RETN

  MON-MANNING
    <ILS >  Only required if VNNFG=1 in IWAT-PARM1 is 1               ***
            Manning's n for overland flow at start of each month      ***
    # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1      .014 .014 .014 .014 .014 .014 .014 .014 .014 .014 .014 .014
  END MON-MANNING

  IWAT-STATE1
    <ILS >  IWATER State variables; cond's at the start of simulation ***
    # -  #***   RETS      SURS
    1           .001      0.01
  END IWAT-STATE1
END IMPLND

RCHRES
  ACTIVITY
    RCHRES   Active sections***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG***
    1    8    1
  END ACTIVITY

  PRINT-INFO
    RCHRES          Print-flags ******** PIVL  PYR
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR***
    1    8    4                                                10   12
  END PRINT-INFO
```

```
  GEN-INFO
    RCHRES        Name        Nexits   Unit-systems   Printer     ***
    # -  #                          User  t-series Engl Metr LKFG***
                                           in  out               ***
    1      REACH 1                   1    1    1        0         0
    2      REACH 2                   1    1    1        0         0
    3      REACH 3                   1    1    1        0         0
    4      REACH 4                   1    1    1        0         0
    5      REACH 5                   1    1    1        0         0
    6      REACH 6                   1    1    1        0         0
    7      REACH 7                   1    1    1        0         0
    8      REACH 8                   1    1    1        0         0
  END GEN-INFO

*** Section HYDR ***

  HYDR-PARM1
    RCHRES  Flags for HYDR section***
    # -  #  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each    FUNCT for  each
            FG FG FG FG  possible   exit *** possible   exit    possible   exit
    1    8   0  0  0  0    4  0  0  0  0       0  0  0  0  0
  END HYDR-PARM1

  HYDR-PARM2
    RCHRES  ***
    # -  #    FTABNO       LEN     DELTH      STCOR        KS***    DB50
    1              1       6.1       72.        0.0         .2       0.1
    2              2       6.7      105.        0.0         .2       0.1
    3              3       5.3      210.        0.0         .2       0.1
    4              4       7.3      279.        0.0         .2       0.1
    5              5       1.4      125.        0.0         .2       0.1
    6              6       1.8       20.        0.0         .2       0.1
    7              7       1.7       23.        0.0         .2       0.1
    8              8       3.4       33.        0.0         .2       0.1
  END HYDR-PARM2

  MON-CONVF
    RCHRES  Monthly F(VOL) adjustment factors ***
    # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1       .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00
  END MON-CONVF

  HYDR-INIT
    RCHRES   Initial conditions for HYDR section***
    # -  #***     VOL     Initial  value  of COLIND    initial  value of OUTDGT
          ***    ac-ft    for each  possible   exit    for each  possible  exit
    1             11.       0.0  0.0  0.0  0.0  0.0     0.0  0.0  0.0  0.0  0.0
    2             11.       0.0  0.0  0.0  0.0  0.0     0.0  0.0  0.0  0.0  0.0
    3             10.       0.0  0.0  0.0  0.0  0.0     0.0  0.0  0.0  0.0  0.0
    4             10.       0.0  0.0  0.0  0.0  0.0     0.0  0.0  0.0  0.0  0.0
    5              2.       0.0  0.0  0.0  0.0  0.0     0.0  0.0  0.0  0.0  0.0
    6             14.       0.0  0.0  0.0  0.0  0.0     0.0  0.0  0.0  0.0  0.0
    7             11.       0.0  0.0  0.0  0.0  0.0     0.0  0.0  0.0  0.0  0.0
    8             25.       0.0  0.0  0.0  0.0  0.0     0.0  0.0  0.0  0.0  0.0
  END HYDR-INIT
END RCHRES
```

```
FTABLES
  FTABLE       1
 ROWS COLS   (R1)              ***
    2    4
     DEPTH      AREA     VOLUME     FLOW     ***
      (FT)   (ACRES)  (ACRE-FT)  (ft^3/sec)***
       0.0       0.0        0.0       0.0
       7.3      21.8       74.4    1157.5
  END FTABLE  1

  FTABLE       2
 ROWS COLS   (R2)              ***
    2    4
     DEPTH      AREA     VOLUME     FLOW      ***
      (FT)   (ACRES)  (ACRE-FT)  (ft^3/sec) ***
       0.0       0.0        0.0       0.0
       9.4      28.4      147.7     5106.2
  END FTABLE  2

  FTABLE       3
 ROWS COLS   (R3)              ***
    2    4
     DEPTH      AREA     VOLUME      FLOW     ***
      (FT)   (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0       0.0        0.0       0.0
       7.9      10.1       36.9    1318.2
  END FTABLE  3

  FTABLE       4
 ROWS COLS    (R4)             ***
    2    4
     DEPTH      AREA     VOLUME      FLOW     ***
      (FT)   (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0       0.0        0.0       0.0
      21.9     137.5     1011.3   41968.0
  END FTABLE  4

  FTABLE       5
 ROWS COLS   (R5)              ***
    2    4
     DEPTH      AREA     VOLUME      FLOW     ***
      (FT)   (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0       0.0        0.0       0.0
       4.3       2.3        3.2     300.1
  END FTABLE  5

  FTABLE       6
 ROWS COLS   (R6)              ***
    2    4
     DEPTH      AREA     VOLUME      FLOW     ***
      (FT)   (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0       0.0        0.0       0.0
       6.2      23.2       95.8    2063.3
  END FTABLE  6
```

```
  FTABLE      7
 ROWS COLS    (R7)             ***
    2    4
     DEPTH       AREA      VOLUME      FLOW     ***
      (FT)    (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0        0.0        0.0        0.0
       7.6       15.4      100.2     3909.7
  END FTABLE  7

  FTABLE      8
 ROWS COLS    (R8)             ***
    2    4
     DEPTH       AREA      VOLUME      FLOW     ***
      (FT)    (ACRES)  (ACRE-FT)   (ft^3/sec)***
       0.0        0.0        0.0        0.0
       7.6       30.0      200.4     2227.1
  END FTABLE  8
END FTABLES

DISPLY
  DISPLY-INFO1
*** # -  #<----------Title----------->***TRAN PIVL DIG1 FIL1  PYR DIG2 FIL2 YRND
    1     RUNOFF (IN), CUB RUN w/RCHS    SUM                    1    2   62   12
    2     RUNOFF (cfs),CUB RUN w/RCHS    SUM                    1    2   62   12
    3     PERO   (cfs)                   SUM                    1    2   62   12
    4     PERO   (in)                    SUM                    1    2   62   12
    5     SURO   (cfs)                   SUM                    1    2   62   12
    6     SURO   (in)                    SUM                    1    2   62   12
    7     AGWO   (cfs)                   SUM                    1    2   62   12
    8     AGWO   (in)                    SUM                    1    2   62   12
    9     IFWO   (cfs)                   SUM                    1    2   62   12
   10     IFWO   (in)                    SUM                    1    2   62   12
   11     TAET   (in)                    SUM                    1    2   62   12
  END DISPLY-INFO1
END DISPLY

PLTGEN
  PLOTINFO
    #thru# FILE  NPT  NMN Labl  PYR PIVL  ***
    1        63         1         1   12
  END PLOTINFO

  GEN-LABELS
    #THRU#<----   TITLE                  --------->    ***    <----YLABL------- >
    1       DISCHARGE  (IN)
  END GEN-LABELS

  SCALING
    #THRU#<--YMIN--><--YMAX--><-IVLIN-->***
    1                  2.0        .01
  END SCALING

  CURV-DATA
  PLOT-OPN     ***
    #THRU#   <---CURVE LABEL-> LINE INTG  COL TRAN ***
    1           DISCHARGE
  END CURV-DATA
END PLTGEN
```

```
COPY
  TIMESERIES
    # -  #  NPT  NMN***
    1             1
    2             1
    3             1
    4             1
    5             1
  END TIMESERIES
END COPY

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
TSS      2 PRECIP   ENGLZERO               PERLND   1   4 EXTNL  PREC
TSS      8 EVAPOR   ENGL        .7         PERLND   1   4 EXTNL  PETINP
TSS      2 PRECIP   ENGLZERO               IMPLND   1     EXTNL  PREC
TSS      8 EVAPOR   ENGL        .7         IMPLND   1     EXTNL  PETINP
END EXT SOURCES

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
PERLND   1 PWATER PERO           41.62     RCHRES   1      INFLOW IVOL
PERLND   2 PWATER PERO          322.93     RCHRES   1      INFLOW IVOL
PERLND   3 PWATER PERO          332.59     RCHRES   1      INFLOW IVOL
PERLND   4 PWATER PERO           54.11     RCHRES   1      INFLOW IVOL
IMPLND   1 IWATER SURO           79.54     RCHRES   1      INFLOW IVOL
RCHRES   1 ROFLOW                 1.00     RCHRES   6      INFLOW
PERLND   1 PWATER PERO            9.63     RCHRES   2      INFLOW IVOL
PERLND   2 PWATER PERO          272.34     RCHRES   2      INFLOW IVOL
PERLND   3 PWATER PERO          324.48     RCHRES   2      INFLOW IVOL
PERLND   4 PWATER PERO            2.62     RCHRES   2      INFLOW IVOL
IMPLND   1 IWATER SURO           10.12     RCHRES   2      INFLOW IVOL
RCHRES   2 ROFLOW                 1.00     RCHRES   6      INFLOW
PERLND   1 PWATER PERO           91.48     RCHRES   3      INFLOW IVOL
PERLND   2 PWATER PERO          123.54     RCHRES   3      INFLOW IVOL
PERLND   3 PWATER PERO           99.64     RCHRES   3      INFLOW IVOL
PERLND   4 PWATER PERO           20.82     RCHRES   3      INFLOW IVOL
IMPLND   1 IWATER SURO           82.60     RCHRES   3      INFLOW IVOL
RCHRES   3 ROFLOW                 1.00     RCHRES   6      INFLOW
PERLND   1 PWATER PERO            8.04     RCHRES   6      INFLOW IVOL
PERLND   2 PWATER PERO           33.18     RCHRES   6      INFLOW IVOL
PERLND   3 PWATER PERO           11.30     RCHRES   6      INFLOW IVOL
PERLND   4 PWATER PERO           21.46     RCHRES   6      INFLOW IVOL
IMPLND   1 IWATER SURO            5.59     RCHRES   6      INFLOW IVOL
RCHRES   6 ROFLOW                 1.00     RCHRES   7      INFLOW
PERLND   1 PWATER PERO           19.00     RCHRES   5      INFLOW IVOL
PERLND   2 PWATER PERO           30.27     RCHRES   5      INFLOW IVOL
PERLND   3 PWATER PERO           15.47     RCHRES   5      INFLOW IVOL
PERLND   4 PWATER PERO            9.94     RCHRES   5      INFLOW IVOL
IMPLND   1 IWATER SURO           14.64     RCHRES   5      INFLOW IVOL
RCHRES   5 ROFLOW                 1.00     RCHRES   7      INFLOW
PERLND   1 PWATER PERO            3.88     RCHRES   7      INFLOW IVOL
PERLND   2 PWATER PERO           28.20     RCHRES   7      INFLOW IVOL
PERLND   3 PWATER PERO            5.52     RCHRES   7      INFLOW IVOL
PERLND   4 PWATER PERO           30.72     RCHRES   7      INFLOW IVOL
IMPLND   1 IWATER SURO           11.03     RCHRES   7      INFLOW IVOL
RCHRES   7 ROFLOW                 1.00     RCHRES   8      INFLOW
PERLND   1 PWATER PERO          106.60     RCHRES   4      INFLOW IVOL
PERLND   2 PWATER PERO          221.17     RCHRES   4      INFLOW IVOL
PERLND   3 PWATER PERO           51.67     RCHRES   4      INFLOW IVOL
PERLND   4 PWATER PERO           25.46     RCHRES   4      INFLOW IVOL
IMPLND   1 IWATER SURO          103.85     RCHRES   4      INFLOW IVOL
RCHRES   4 ROFLOW                 1.00     RCHRES   8      INFLOW
PERLND   1 PWATER PERO            5.95     RCHRES   8      INFLOW IVOL
PERLND   2 PWATER PERO          105.45     RCHRES   8      INFLOW IVOL
PERLND   3 PWATER PERO           47.03     RCHRES   8      INFLOW IVOL
PERLND   4 PWATER PERO           11.74     RCHRES   8      INFLOW IVOL
```

```
IMPLND    1 IWATER SURO            3.68      RCHRES   8      INFLOW IVOL
RCHRES    8 HYDR   ROVOL        .000357      DISPLY   1      INPUT  TIMSER
*** ROVOL units are acre-ft/day;.504 converts acre-ft/day to cubic feet/sec
RCHRES    8 HYDR   ROVOL           .504      DISPLY   2      INPUT  TIMSER
***
*** The following conversions represent each land segment contribution
*** to watershed output in terms of cfs without reaches.
***
PERLND    1 PWATER PERO          286.21      COPY     1      INPUT  MEAN   1
PERLND    2 PWATER PERO         1137.07      COPY     1      INPUT  MEAN   1
PERLND    3 PWATER PERO          887.71      COPY     1      INPUT  MEAN   1
PERLND    4 PWATER PERO          176.87      COPY     1      INPUT  MEAN   1
IMPLND    1 IWATER SURO          311.05      COPY     1      INPUT  MEAN   1
COPY      1 OUTPUT MEAN   1        .504      DISPLY   3      INPUT  TIMSER
COPY      1 OUTPUT MEAN   1     .000357      DISPLY   4      INPUT  TIMSER
***
*** The following conversions represent each land segment contribution
*** to watershed output in terms of SURFACE FLOW without reahces.
***
PERLND    1 PWATER SURO          286.21      COPY     2      INPUT  MEAN   1
PERLND    2 PWATER SURO         1137.07      COPY     2      INPUT  MEAN   1
PERLND    3 PWATER SURO          887.71      COPY     2      INPUT  MEAN   1
PERLND    4 PWATER SURO          176.87      COPY     2      INPUT  MEAN   1
IMPLND    1 IWATER SURO          311.05      COPY     2      INPUT  MEAN   1
COPY      2 OUTPUT MEAN   1        .504      DISPLY   5      INPUT  TIMSER
COPY      2 OUTPUT MEAN   1     .000357      DISPLY   6      INPUT  TIMSER
***
*** The following conversions represent each land segment contribution
*** to watershed output in terms of GROUND WATER without reaches.
***
PERLND    1 PWATER AGWO          286.21      COPY     3      INPUT  MEAN   1
PERLND    2 PWATER AGWO         1137.07      COPY     3      INPUT  MEAN   1
PERLND    3 PWATER AGWO          887.71      COPY     3      INPUT  MEAN   1
PERLND    4 PWATER AGWO          176.87      COPY     3      INPUT  MEAN   1
COPY      3 OUTPUT MEAN   1        .504      DISPLY   7      INPUT  TIMSER
COPY      3 OUTPUT MEAN   1     .000357      DISPLY   8      INPUT  TIMSER
***
*** The following conversions represent each land segment contribution
*** to watershed output in terms of INTERFLOW without reaches.
***
PERLND    1 PWATER IFWO          286.21      COPY     4      INPUT  MEAN   1
PERLND    2 PWATER IFWO         1137.07      COPY     4      INPUT  MEAN   1
PERLND    3 PWATER IFWO          887.71      COPY     4      INPUT  MEAN   1
PERLND    4 PWATER IFWO          176.87      COPY     4      INPUT  MEAN   1
COPY      4 OUTPUT MEAN   1        .504      DISPLY   9      INPUT  TIMSER
COPY      4 OUTPUT MEAN   1     .000357      DISPLY  10      INPUT  TIMSER
***
```

```
*** The following conversions represent each land segment contribution
*** to watershed output in terms of TOTAL EVPOTRANS w/o reaches
***
PERLND   1 PWATER TAET          286.21     COPY     5     INPUT  MEAN   1
PERLND   2 PWATER TAET         1137.07     COPY     5     INPUT  MEAN   1
PERLND   3 PWATER TAET          887.71     COPY     5     INPUT  MEAN   1
PERLND   4 PWATER TAET          176.87     COPY     5     INPUT  MEAN   1
COPY     5 OUTPUT MEAN   1     .000357     DISPLY  11     INPUT  TIMSER
*** ROVOL units are acre-ft/day; .50 converts acre-ft/day to cfs
RCHRES   8 HYDR   ROVOL   ***      .50     PLTGEN   1     INPUT  MEAN   1
END NETWORK

END RUN
```

APPENDIX 5

HSPF Suspended Solids Simulation Input Files

```
RUN

GLOBAL
  Version 8.0 test run:  CRSED79.INP: Suspended Solids Simulation using PERLND and IMPLND
  START       1978              END    1980
  RUN INTERP OUTPUT LEVEL    1
  RESUME     0 RUN     1 TSSFL    15 WDMSFL   16
END GLOBAL

OPN SEQUENCE
    INGRP              INDELT  1:00
      PERLND       1
      PERLND       2
      PERLND       3
      PERLND       4
      IMPLND       1
      COPY         1
***   COPY         2
      COPY         6
      COPY        12
      COPY        13
      COPY        14
      COPY        15
***   DISPLY       3
***   DISPLY       4
      DISPLY       6
      DISPLY      12
      DISPLY      13
      DISPLY      14
      DISPLY      15
    END INGRP
END OPN SEQUENCE

PERLND
  ACTIVITY
    <PLS >          Active Sections (1=Active; 0=Inactive)            ***
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
    1    4              1    1
  END ACTIVITY

  PRINT-INFO
    <PLS >          Print-flags                                   *** PIVL  PYR
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC       ***
    1    4              5    5                                             12
  END PRINT-INFO

  GEN-INFO
    <PLS ><-------Name------->NBLKS   Unit-systems   Printer ***
    # -  #                          User  t-series Engl Metr ***
                                          in  out            ***
    1     RESIDENTIAL             1    1    1    1    1    0
    2     FOREST                  1    1    1    1    1    0
    3     AGRICULTURAL            1    1    1    1    1    0
    4     CONSTRUCTION            1    1    1    1    1    0
  END GEN-INFO
```

```
*** Section PWATER ***

PWAT-PARM1
  <PLS >  PWATER variable monthly parameter value flags ***
  # -  # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE    ***
  1    4    0    0    0    1    1    1    1    0    1
END PWAT-PARM1

PWAT-PARM2
  <PLS > ***  PWATER input info: Part 2
  # -  # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
  1           0.000      9.0     0.015      350.     0.010       0.5      0.98
  2           0.010      8.0     0.020      350.     0.010       0.5      0.98
  3           0.000      8.0     0.017      350.     0.010       0.5      0.98
  4           0.000      2.0     0.006      350.     0.010       0.5      0.98
END PWAT-PARM2

PWAT-PARM3
  <PLS > ***  PWATER input info: Part 3
  # -  # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
  1    4       40.       35.       2.0       2.0      0.56       .05      0.08
END PWAT-PARM3

PWAT-PARM4
  <PLS >     PWATER input info: Part 4                                ***
  # -  #     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
  1           0.15      1.40       0.4       1.0      0.60      0.35
  2           0.25      2.00       0.6       1.2      0.80      0.42
  3           0.21      1.40       0.4       1.0      0.70      0.35
  4           0.01      0.30       0.1       1.0      0.40      0.01
END PWAT-PARM4

MON-INTERCEP
  <PLS>   Only required if VCSFG=1 in PWAT-PARM1                      ***
  # -  #  Interception storage capacity at start of each month        ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1      0.10 0.10 0.12 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.13 0.10
  2      0.18 0.18 0.21 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.23 0.18
  3      0.10 0.10 0.15 0.21 0.21 0.21 0.21 0.21 0.21 0.15 0.12 0.10
  4      0.01 0.01 0.01 0.02 0.02 0.02 0.02 0.02 0.02 0.01 0.01 0.01
END MON-INTERCEP

MON-UZSN
  <PLS>   Only required if VUZFG=1 in PWAT-PARM1                      ***
  # -  #  Upper zone storage at start of each month                   ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       1.6  1.6  1.4  1.4  1.4  1.6  1.6  1.6  1.6  1.4  1.4  1.6
  2       2.2  2.2  2.0  2.0  2.0  2.2  2.2  2.2  2.2  2.0  2.0  2.2
  3       1.6  1.6  1.4  1.4  1.4  1.6  1.6  1.6  1.6  1.4  1.4  1.6
  4       0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3
END MON-UZSN

MON-MANNING
  <PLS >  Only required if VNNFG=1 in PWAT-PARM1                      ***
  # -  #  Manning's n for overland flow at start of each month        ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1      0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40
  2      0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60
  3      0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40
  4      0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10
END MON-MANNING

MON-INTERFLW
  <PLS >  Only required if VIFW=1 in PWAT-PARM1                       ***
  # -  #  Interflow inflow parameter for the start of each month      ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1      1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
  2      1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20
  3      1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
```

```
  4      1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
END MON-INTERFLW

MON-LZETPARM
  <PLS >  Only required if VLEFG=1 in PWAT-PARM1                  ***
  # -  #  Lower zone ET parameter at start of each month          ***
         JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1      0.01 0.01 0.10 0.18 0.35 0.37 0.37 0.37 0.37 0.31 0.20 0.10
  2      0.08 0.08 0.15 0.30 0.42 0.45 0.45 0.45 0.45 0.37 0.22 0.16
  3      0.01 0.01 0.10 0.18 0.35 0.37 0.37 0.37 0.37 0.30 0.20 0.10
  4      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
END MON-LZETPARM

PWAT-STATE1
  <PLS > *** Initial conditions at start of simulation
  # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  1           0.03       0.1      1.20       2.0       6.5      2.00      0.05
  2           0.05       0.1      1.60       2.0       4.0      2.00      0.10
  3           0.03       0.1      1.20       2.0       4.0      2.00      0.10
  4           0.00       0.1      0.30       2.0       1.8      2.00      0.05
END PWAT-STATE1

*** Section SEDMNT ***

SED-PARM1
  <PLS > ***
  # -  #  CRV VSIV SDOP ***
  1    4    1    0    1
END SED-PARM1

SED-PARM2
  <PLS > ***
  # -  #      SMPF      KRER      JRER     AFFIX     COVER      NVSI ***
  1    3       1.0       .30      1.65      .030      0.90       0.0
  4            1.0       .30      1.65      .030      0.10       0.0
END SED-PARM2

SED-PARM3
  <PLS > ***
  # -  #      KSER      JSER      KGER      JGER ***
  1    3       .06       .95       0.0       1.0
  4            .06       .95      0.06       1.4
END SED-PARM3

MON-COVER
  <PLS >  Monthly values for erosion-related land cover           ***
  # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       .85  .85  .89  .92  .92  .92  .92  .92  .92  .92  .90  .85
  2       .85  .85  .85  .90  .93  .93  .93  .93  .93  .89  .85  .85
  3       .87  .87  .87  .91  .94  .94  .94  .94  .94  .91  .90  .87
  4       .01  .01  .02  .03  .05  .05  .05  .05  .05  .03  .01  .01
END MON-COVER
```

```
  SED-STOR
    <PLS >  Detached sediment storage (tons/acre)            ***
    # -  #     BLOCK1      BLK2      BLK3      BLK4      BLK5 ***
    1    4        0.1
  END SED-STOR
END PERLND

IMPLND
  ACTIVITY
    <ILS >              Active Sections  ***
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL  ***
    1                 1    1
  END ACTIVITY

  PRINT-INFO
    <PLS >          Print-flags ********* PIVL  PYR
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL *********
    1                 5                         12
  END PRINT-INFO

  GEN-INFO
    <ILS ><-------Name------->       Unit-systems   Printer ***
    # -  #                         User  t-series Engl Metr ***
                                          in  out           ***
    1      RESIDENTIAL            1    1    1    1    1    0
  END GEN-INFO

*** Section IWATER ***

  IWAT-PARM1
    <ILS >          Flags             ***
    # -  # CSNO RTOP  VRS  VNN RTLI   ***
    1                1    1
  END IWAT-PARM1

  IWAT-PARM2
    <ILS >                                                 ***
    # -  #      LSUR     SLSUR      NSUR     RETSC      ***
    1           350.      .010      .014      0.01
  END IWAT-PARM2

  IWAT-PARM3
    <ILS >   Only required if CSNO=1  ***
    # -  #*** PETMAX    PETMIN
    1            40.       35.
  END IWAT-PARM3

  MON-RETN
    <ILS >  Only required if VRSFG=1 in IWAT-PARM1 is 1            ***
            Retention storage capacity at the start of each month  ***
    # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1       .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01
  END MON-RETN

  MON-MANNING
    <ILS >  Only required if VNNFG=1 in IWAT-PARM1 is 1            ***
            Manning's n for overland flow at start of each month   ***
    # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1      .014 .014 .014 .014 .014 .014 .014 .014 .014 .014 .014 .014
  END MON-MANNING
```

```
  IWAT-STATE1
    <ILS >  IWATER State variables; cond's at the start of simulation ***
    # -  #***   RETS      SURS
    1           .001      0.01
  END IWAT-STATE1

  SLD-PARM1
    <ILS >            Flags            ***
    # -  # VASD VRSD  SDOP             ***
    1                   1
  END SLD-PARM1

  SLD-PARM2
    <ILS >                                           ***
    # -  #      KEIM      JEIM    ACCSDP    REMSDP   ***
    1            .05       1.0      .005      .001
  END SLD-PARM2

END IMPLND

DISPLY
  DISPLY-INFO1
*** # -  #<----------Title----------->***TRAN PIVL DIG1 FIL1  PYR DIG2 FIL2 YRND
    4    RUNOFF (IN), CUB RUN w/RCHS    SUM                     1    2   62   12
    3    RUNOFF (cfs),CUB RUN w/RCHS    SUM                     1    2   62   12
    6    DETS PERLND (tons/acre)        SUM                     1    2   62   12
   12    SLDS IMPLND (tons/acre)        SUM                     1    2   62   12
   13    IMPLND SOSLD (tons)            SUM                     1    2   62   12
   14    PERLND & IMPLND TSS  (tons)    SUM                     1    2   62   12
   15    PERLND SOSED (tons)            SUM                     1    2   62   12
  END DISPLY-INFO1
END DISPLY

COPY
  TIMESERIES
    # -  #  NPT  NMN***
    1             1
    6             1
    7             1
   12             1
   13             1
   14             1
   15             1
  END TIMESERIES
END COPY

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
TSS      2 PRECIP   ENGLZERO               PERLND   1   4 EXTNL  PREC
TSS      8 EVAPOR   ENGL        .7         PERLND   1   4 EXTNL  PETINP
TSS      2 PRECIP   ENGLZERO               IMPLND   1     EXTNL  PREC
TSS      8 EVAPOR   ENGL        .7         IMPLND   1     EXTNL  PETINP
END EXT SOURCES
```

```
NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
*** The following conversions represent each land segment contribution
*** to watershed output in terms of cfs without reaches.
***
PERLND   1 PWATER PERO          141.00     COPY     1      INPUT  MEAN   1  ***
PERLND   2 PWATER PERO         1249.49     COPY     1      INPUT  MEAN   1  ***
PERLND   3 PWATER PERO         1247.49     COPY     1      INPUT  MEAN   1  ***
PERLND   4 PWATER PERO           30.33     COPY     1      INPUT  MEAN   1  ***
IMPLND   1 IWATER SURO          130.13     COPY     1      INPUT  MEAN   1
COPY     1 OUTPUT MEAN   1        .504     DISPLY   3      INPUT  TIMSER
COPY     1 OUTPUT MEAN   1     .000357     DISPLY   4      INPUT  TIMSER
***
*** The following section represents suspended sediment output
***
PERLND   1 SEDMNT DETS                     COPY     6      INPUT  MEAN   1
PERLND   2 SEDMNT DETS                     COPY     6      INPUT  MEAN   1
PERLND   3 SEDMNT DETS                     COPY     6      INPUT  MEAN   1
PERLND   4 SEDMNT DETS                     COPY     6      INPUT  MEAN   1
COPY     6 OUTPUT MEAN   1                 DISPLY   6      INPUT  TIMSER
IMPLND   1 SOLIDS SLDS                     COPY    12      INPUT  MEAN   1
IMPLND   1 SOLIDS SOSLD        1562.22     COPY    13      INPUT  MEAN   1
COPY    12 OUTPUT MEAN   1                 DISPLY  12      INPUT  TIMSER
COPY    13 OUTPUT MEAN   1                 DISPLY  13      INPUT  TIMSER
PERLND   1 SEDMNT SOSED        1692.66     COPY    14      INPUT  MEAN   1
PERLND   2 SEDMNT SOSED       15005.80     COPY    14      INPUT  MEAN   1
PERLND   3 SEDMNT SOSED       14975.88     COPY    14      INPUT  MEAN   1
PERLND   4 SEDMNT SOSED         364.12     COPY    14      INPUT  MEAN   1
IMPLND   1 SOLIDS SOSLD        1562.22     COPY    14      INPUT  MEAN   1
COPY    14 OUTPUT MEAN   1                 DISPLY  14      INPUT  TIMSER
PERLND   1 SEDMNT SOSED        1692.66     COPY    15      INPUT  MEAN   1
PERLND   2 SEDMNT SOSED       15005.80     COPY    15      INPUT  MEAN   1
PERLND   3 SEDMNT SOSED       14975.88     COPY    15      INPUT  MEAN   1
PERLND   4 SEDMNT SOSED         364.12     COPY    15      INPUT  MEAN   1
COPY    15 OUTPUT MEAN   1                 DISPLY  15      INPUT  TIMSER
END NETWORK

END RUN
```

```
RUN

GLOBAL
  Version 8.0 test run:  CRSED85.INP: Suspended Solids Simulation using PERLND and IMPLND
  START       1984              END    1986
  RUN INTERP OUTPUT LEVEL    1
  RESUME     0 RUN     1 TSSFL    15 WDMSFL   16
END GLOBAL

OPN SEQUENCE
    INGRP              INDELT  1:00
      PERLND       1
      PERLND       2
      PERLND       3
      PERLND       4
      IMPLND       1
      COPY         1
***   COPY         2
      COPY         6
      COPY        12
      COPY        13
      COPY        14
      COPY        15
      COPY        16
***   DISPLY       3
***   DISPLY       4
      DISPLY       6
      DISPLY      12
      DISPLY      13
      DISPLY      14
      DISPLY      15
      DISPLY      16
    END INGRP
END OPN SEQUENCE

PERLND
  ACTIVITY
    <PLS >          Active Sections (1=Active; 0=Inactive)             ***
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
    1    4              1    1
  END ACTIVITY

  PRINT-INFO
    <PLS >          Print-flags                                    *** PIVL  PYR
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC       ***
    1    4              5    5                                               12
  END PRINT-INFO

  GEN-INFO
    <PLS ><-------Name------->NBLKS  Unit-systems   Printer ***
    # -  #                         User  t-series Engl Metr ***
                                          in  out           ***
    1     RESIDENTIAL            1    1    1    1    1    0
    2     FOREST                 1    1    1    1    1    0
    3     AGRICULTURAL           1    1    1    1    1    0
    4     CONSTRUCTION           1    1    1    1    1    0
  END GEN-INFO
```

```
*** Section PWATER ***

PWAT-PARM1
  <PLS >  PWATER variable monthly parameter value flags ***
  # -  # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE    ***
  1    4    0    0    0    1    1    1    1    0    1
END PWAT-PARM1

PWAT-PARM2
  <PLS > ***  PWATER input info: Part 2
  # -  # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
  1           0.000      9.0     0.015      350.     0.010       0.5      0.98
  2           0.010      8.0     0.020      350.     0.010       0.5      0.98
  3           0.000      8.0     0.017      350.     0.010       0.5      0.98
  4           0.000      2.0     0.006      350.     0.010       0.5      0.98
END PWAT-PARM2

PWAT-PARM3
  <PLS > ***  PWATER input info: Part 3
  # -  # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
  1    4       40.       35.       2.0       2.0      0.56       .05      0.08
END PWAT-PARM3

PWAT-PARM4
  <PLS >      PWATER input info: Part 4                                    ***
  # -  #      CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
  1            0.15      1.40       0.4       1.0      0.60      0.35
  2            0.25      2.00       0.6       1.2      0.80      0.42
  3            0.21      1.40       0.4       1.0      0.70      0.35
  4            0.01      0.30       0.1       1.0      0.40      0.01
END PWAT-PARM4

MON-INTERCEP
  <PLS>   Only required if VCSFG=1 in PWAT-PARM1                           ***
  # -  #   Interception storage capacity at start of each month            ***
           JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       0.10 0.10 0.12 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.13 0.10
  2       0.18 0.18 0.21 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.23 0.18
  3       0.10 0.10 0.15 0.21 0.21 0.21 0.21 0.21 0.21 0.15 0.12 0.10
  4       0.01 0.01 0.01 0.02 0.02 0.02 0.02 0.02 0.02 0.01 0.01 0.01
END MON-INTERCEP

MON-UZSN
  <PLS>   Only required if VUZFG=1 in PWAT-PARM1                          ***
  # -  #  Upper zone storage at start of each month                       ***
           JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1        1.6  1.6  1.4  1.4  1.4  1.6  1.6  1.6  1.6  1.4  1.4  1.6
  2        2.2  2.2  2.0  2.0  2.0  2.2  2.2  2.2  2.2  2.0  2.0  2.2
  3        1.6  1.6  1.4  1.4  1.4  1.6  1.6  1.6  1.6  1.4  1.4  1.6
  4        0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3
END MON-UZSN

MON-MANNING
  <PLS >  Only required if VNNFG=1 in PWAT-PARM1                          ***
  # -  #  Manning's n for overland flow at start of each month            ***
           JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40
  2       0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60
  3       0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40
  4       0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10
END MON-MANNING

MON-INTERFLW
  <PLS >  Only required if VIFW=1 in PWAT-PARM1                           ***
  # -  #  Interflow inflow parameter for the start of each month          ***
           JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
  2       1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20
  3       1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
```

```
  4      1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
END MON-INTERFLW

MON-LZETPARM
  <PLS >  Only required if VLEFG=1 in PWAT-PARM1                    ***
  # -  #  Lower zone ET parameter at start of each month            ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1      0.01 0.01 0.10 0.18 0.35 0.37 0.37 0.37 0.37 0.31 0.20 0.10
  2      0.08 0.08 0.15 0.30 0.42 0.45 0.45 0.45 0.45 0.37 0.22 0.16
  3      0.01 0.01 0.10 0.18 0.35 0.37 0.37 0.37 0.37 0.30 0.20 0.10
  4      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
END MON-LZETPARM

PWAT-STATE1
  <PLS > *** Initial conditions at start of simulation
  # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  1           0.03       0.1      1.20       2.0       6.5      2.00      0.05
  2           0.05       0.1      1.60       2.0       4.0      2.00      0.10
  3           0.03       0.1      1.20       2.0       4.0      2.00      0.10
  4           0.00       0.1      0.30       2.0       1.8      2.00      0.05
END PWAT-STATE1

*** Section SEDMNT ***

SED-PARM1
  <PLS > ***
  # -  #  CRV VSIV SDOP ***
  1    4    1    0    1
END SED-PARM1

SED-PARM2
  <PLS > ***
  # -  #      SMPF      KRER      JRER     AFFIX     COVER      NVSI ***
  1    3       1.0       .30      1.65      .030      0.90       0.0
  4            1.0       .30      1.65      .030      0.10       0.0
END SED-PARM2

SED-PARM3
  <PLS > ***
  # -  #      KSER      JSER      KGER      JGER ***
  1    3       .06       .95       0.0       1.0
  4            .06       .95      0.06       1.4
END SED-PARM3

MON-COVER
  <PLS >  Monthly values for erosion-related land cover             ***
  # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       .85  .85  .89  .92  .92  .92  .92  .92  .92  .92  .90  .85
  2       .85  .85  .85  .90  .93  .93  .93  .93  .93  .89  .85  .85
  3       .87  .87  .87  .91  .94  .94  .94  .94  .94  .91  .90  .87
  4       .01  .01  .02  .03  .05  .05  .05  .05  .05  .03  .01  .01
END MON-COVER
```

```
  SED-STOR
    <PLS >  Detached sediment storage (tons/acre)            ***
    # -  #    BLOCK1      BLK2      BLK3      BLK4      BLK5 ***
    1    4      0.1
  END SED-STOR
END PERLND

IMPLND
  ACTIVITY
    <ILS >              Active Sections  ***
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL  ***
    1              1    1
  END ACTIVITY

  PRINT-INFO
    <PLS >         Print-flags ******** PIVL  PYR
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL *********
    1              5                        12
  END PRINT-INFO

  GEN-INFO
    <ILS ><-------Name------->       Unit-systems   Printer ***
    # -  #                          User  t-series Engl Metr ***
                                           in  out           ***
    1     RESIDENTIAL             1    1    1    1    1    0
  END GEN-INFO

*** Section IWATER ***

  IWAT-PARM1
    <ILS >          Flags              ***
    # -  # CSNO RTOP  VRS  VNN RTLI    ***
    1                 1    1
  END IWAT-PARM1

  IWAT-PARM2
    <ILS >                                          ***
    # -  #      LSUR     SLSUR      NSUR     RETSC   ***
    1           350.      .010      .014      0.01
  END IWAT-PARM2

  IWAT-PARM3
    <ILS >  Only required if CSNO=1  ***
    # -  #*** PETMAX    PETMIN
    1           40.       35.
  END IWAT-PARM3

  MON-RETN
    <ILS >  Only required if VRSFG=1 in IWAT-PARM1 is 1           ***
            Retention storage capacity at the start of each month ***
    # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1       .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01
  END MON-RETN

  MON-MANNING
    <ILS >  Only required if VNNFG=1 in IWAT-PARM1 is 1           ***
            Manning's n for overland flow at start of each month  ***
    # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1      .014 .014 .014 .014 .014 .014 .014 .014 .014 .014 .014 .014
  END MON-MANNING
```

```
  IWAT-STATE1
    <ILS >  IWATER State variables; cond's at the start of simulation ***
    # -  #***   RETS      SURS
    1           .001      0.01
  END IWAT-STATE1

  SLD-PARM1
    <ILS >            Flags             ***
    # -  # VASD VRSD  SDOP              ***
    1                    1
  END SLD-PARM1

  SLD-PARM2
    <ILS >                                        ***
    # -  #       KEIM      JEIM    ACCSDP    REMSDP   ***
    1             .05       1.0      .005      .001
  END SLD-PARM2

END IMPLND

DISPLY
  DISPLY-INFO1
*** # -  #<----------Title----------->***TRAN PIVL DIG1 FIL1  PYR DIG2 FIL2 YRND
    4     RUNOFF (IN), CUB RUN w/RCHS    SUM                    1    2   62   12
    3     RUNOFF (cfs),CUB RUN w/RCHS    SUM                    1    2   62   12
    6     DETS PERLND (tons/acre)        SUM                    1    2   62   12
   12     SLDS IMPLND (tons/acre)        SUM                    1    2   62   12
   13     IMPLND SOSLD (tons)            SUM                    1    2   62   12
   14     PERLND & IMPLND TSS  (tons)    SUM                    1    2   62   12
   15     PERLND SOSED (tons)            SUM                    1    2   62   12
   16     PERLND STCAP (tons)            SUM                    1    2   62   12
  END DISPLY-INFO1
END DISPLY

COPY
  TIMESERIES
    # -  #  NPT  NMN***
    1             1
    6             1
    7             1
   12             1
   13             1
   14             1
   15             1
   16             1
  END TIMESERIES
END COPY

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
TSS      2 PRECIP   ENGLZERO               PERLND   1   4 EXTNL  PREC
TSS      8 EVAPOR   ENGL        .7         PERLND   1   4 EXTNL  PETINP
TSS      2 PRECIP   ENGLZERO               IMPLND   1     EXTNL  PREC
TSS      8 EVAPOR   ENGL        .7         IMPLND   1     EXTNL  PETINP
END EXT SOURCES
```

```
NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #  #        <Name> # #  ***
*** The following conversions represent each land segment contribution
*** to watershed output in terms of cfs without reaches.
***
PERLND   1 PWATER PERO           194.68      COPY     1      INPUT  MEAN   1
PERLND   2 PWATER PERO          1293.04      COPY     1      INPUT  MEAN   1
PERLND   3 PWATER PERO          1040.49      COPY     1      INPUT  MEAN   1
PERLND   4 PWATER PERO            97.72      COPY     1      INPUT  MEAN   1
IMPLND   1 IWATER SURO           173.00      COPY     1      INPUT  MEAN   1
COPY     1 OUTPUT MEAN   1         .504      DISPLY   3      INPUT  TIMSER
COPY     1 OUTPUT MEAN   1      .000357      DISPLY   4      INPUT  TIMSER
***
*** The following section represents suspended sediment output
***
PERLND   1 SEDMNT DETS                       COPY     6      INPUT  MEAN   1
PERLND   2 SEDMNT DETS                       COPY     6      INPUT  MEAN   1
PERLND   3 SEDMNT DETS                       COPY     6      INPUT  MEAN   1
PERLND   4 SEDMNT DETS                       COPY     6      INPUT  MEAN   1
COPY     6 OUTPUT MEAN   1                   DISPLY   6      INPUT  TIMSER
IMPLND   1 SOLIDS SLDS                       COPY    12      INPUT  MEAN   1
IMPLND   1 SOLIDS SOSLD          2076.82     COPY    13      INPUT  MEAN   1
COPY    12 OUTPUT MEAN   1                   DISPLY  12      INPUT  TIMSER
COPY    13 OUTPUT MEAN   1                   DISPLY  13      INPUT  TIMSER
PERLND   1 SEDMNT SOSED          2337.11     COPY    14      INPUT  MEAN   1
PERLND   2 SEDMNT SOSED         15522.73     COPY    14      INPUT  MEAN   1
PERLND   3 SEDMNT SOSED         12490.92     COPY    14      INPUT  MEAN   1
PERLND   4 SEDMNT SOSED          1173.09     COPY    14      INPUT  MEAN   1
IMPLND   1 SOLIDS SOSLD          2076.82     COPY    14      INPUT  MEAN   1
COPY    14 OUTPUT MEAN   1                   DISPLY  14      INPUT  TIMSER
PERLND   1 SEDMNT SOSED          2337.11     COPY    15      INPUT  MEAN   1
PERLND   2 SEDMNT SOSED         15522.25     COPY    15      INPUT  MEAN   1
PERLND   3 SEDMNT SOSED         12490.92     COPY    15      INPUT  MEAN   1
PERLND   4 SEDMNT SOSED          1173.09     COPY    15      INPUT  MEAN   1
COPY    15 OUTPUT MEAN   1                   DISPLY  15      INPUT  TIMSER
PERLND   1 SEDMNT STCAP          2337.11     COPY    16      INPUT  MEAN   1
PERLND   2 SEDMNT STCAP         15522.25     COPY    16      INPUT  MEAN   1
PERLND   3 SEDMNT STCAP         12490.92     COPY    16      INPUT  MEAN   1
PERLND   4 SEDMNT STCAP          1173.09     COPY    16      INPUT  MEAN   1
COPY    16 OUTPUT MEAN   1                   DISPLY  16      INPUT  TIMSER
END NETWORK

END RUN
```

```
RUN

GLOBAL
  Version 8.0 test run:  CRSED88.INP: Suspended Solids Simulation using PERLND and IMPLND
  START       1987              END    1989
  RUN INTERP OUTPUT LEVEL    1
  RESUME     0 RUN     1 TSSFL    15 WDMSFL   16
END GLOBAL

OPN SEQUENCE
    INGRP              INDELT  1:00
      PERLND      1
      PERLND      2
      PERLND      3
      PERLND      4
      IMPLND      1
      COPY        1
***   COPY        2
      COPY        6
      COPY       12
      COPY       13
      COPY       14
      COPY       15
      COPY       16
***   DISPLY      3
***   DISPLY      4
      DISPLY      6
      DISPLY     12
      DISPLY     13
      DISPLY     14
      DISPLY     15
      DISPLY     16
    END INGRP
END OPN SEQUENCE

PERLND
  ACTIVITY
    <PLS >          Active Sections (1=Active; 0=Inactive)             ***
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
    1    4             1    1
  END ACTIVITY

  PRINT-INFO
    <PLS >          Print-flags                                    *** PIVL  PYR
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC       ***
    1    4             5    5                                                 12
  END PRINT-INFO

  GEN-INFO
    <PLS ><-------Name------->NBLKS  Unit-systems   Printer ***
    # -  #                          User  t-series Engl Metr ***
                                          in  out            ***
    1     RESIDENTIAL           1    1    1    1    1    0
    2     FOREST                1    1    1    1    1    0
    3     AGRICULTURAL          1    1    1    1    1    0
    4     CONSTRUCTION          1    1    1    1    1    0
  END GEN-INFO
```

```
*** Section PWATER ***

PWAT-PARM1
  <PLS >  PWATER variable monthly parameter value flags ***
  # -  # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE    ***
  1    4    0    0    0    1    1    1    1    0    1
END PWAT-PARM1

PWAT-PARM2
  <PLS > ***  PWATER input info: Part 2
  # -  # ***FOREST      LZSN     INFILT      LSUR      SLSUR      KVARY      AGWRC
  1          0.000       9.0      0.015      350.      0.010        0.5       0.98
  2          0.010       8.0      0.020      350.      0.010        0.5       0.98
  3          0.000       8.0      0.017      350.      0.010        0.5       0.98
  4          0.000       2.0      0.006      350.      0.010        0.5       0.98
END PWAT-PARM2

PWAT-PARM3
  <PLS > ***  PWATER input info: Part 3
  # -  # ***PETMAX    PETMIN     INFEXP     INFILD     DEEPFR     BASETP     AGWETP
  1    4       40.       35.        2.0        2.0       0.56        .05       0.08
END PWAT-PARM3

PWAT-PARM4
  <PLS >     PWATER input info: Part 4                                    ***
  # -  #     CEPSC      UZSN       NSUR      INTFW        IRC      LZETP ***
  1           0.15      1.40        0.4        1.0       0.60       0.35
  2           0.25      2.00        0.6        1.2       0.80       0.42
  3           0.21      1.40        0.4        1.0       0.70       0.35
  4           0.01      0.30        0.1        1.0       0.40       0.01
END PWAT-PARM4

MON-INTERCEP
  <PLS>   Only required if VCSFG=1 in PWAT-PARM1                          ***
  # -  #  Interception storage capacity at start of each month            ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1      0.10 0.10 0.12 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.13 0.10
  2      0.18 0.18 0.21 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.23 0.18
  3      0.10 0.10 0.15 0.21 0.21 0.21 0.21 0.21 0.21 0.15 0.12 0.10
  4      0.01 0.01 0.01 0.02 0.02 0.02 0.02 0.02 0.02 0.01 0.01 0.01
END MON-INTERCEP

MON-UZSN
  <PLS>   Only required if VUZFG=1 in PWAT-PARM1                          ***
  # -  #  Upper zone storage at start of each month                       ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       1.6  1.6  1.4  1.4  1.4  1.6  1.6  1.6  1.6  1.4  1.4  1.6
  2       2.2  2.2  2.0  2.0  2.0  2.2  2.2  2.2  2.2  2.0  2.0  2.2
  3       1.6  1.6  1.4  1.4  1.4  1.6  1.6  1.6  1.6  1.4  1.4  1.6
  4       0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3  0.3
END MON-UZSN

MON-MANNING
  <PLS >  Only required if VNNFG=1 in PWAT-PARM1                          ***
  # -  #  Manning's n for overland flow at start of each month            ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1      0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40
  2      0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60
  3      0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40
  4      0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10
END MON-MANNING

MON-INTERFLW
  <PLS >  Only required if VIFW=1 in PWAT-PARM1                           ***
  # -  #  Interflow inflow parameter for the start of each month          ***
          JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1      1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
  2      1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20 1.20
  3      1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
```

```
    4      1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
  END MON-INTERFLW

  MON-LZETPARM
    <PLS >  Only required if VLEFG=1 in PWAT-PARM1                   ***
    # -  #  Lower zone ET parameter at start of each month           ***
             JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1      0.01 0.01 0.10 0.18 0.35 0.37 0.37 0.37 0.37 0.31 0.20 0.10
    2      0.08 0.08 0.15 0.30 0.42 0.45 0.45 0.45 0.45 0.37 0.22 0.16
    3      0.01 0.01 0.10 0.18 0.35 0.37 0.37 0.37 0.37 0.30 0.20 0.10
    4      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  END MON-LZETPARM

  PWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
    # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
    1           0.03       0.1      1.20       2.0       6.5      2.00      0.05
    2           0.05       0.1      1.60       2.0       4.0      2.00      0.10
    3           0.03       0.1      1.20       2.0       4.0      2.00      0.10
    4           0.00       0.1      0.30       2.0       1.8      2.00      0.05
  END PWAT-STATE1

*** Section SEDMNT ***

  SED-PARM1
    <PLS > ***
    # -  #  CRV VSIV SDOP ***
    1    4    1    0    1
  END SED-PARM1

  SED-PARM2
    <PLS > ***
    # -  #      SMPF      KRER      JRER     AFFIX     COVER      NVSI ***
    1    3       1.0       .30      1.65      .030      0.90       0.0
    4            1.0       .30      1.65      .030      0.10       0.0
  END SED-PARM2

  SED-PARM3
    <PLS > ***
    # -  #      KSER      JSER      KGER      JGER ***
    1    3       .06       .95       0.0       1.0
    4            .06       .95      0.06       1.4
  END SED-PARM3

  MON-COVER
    <PLS >  Monthly values for erosion-related land cover             ***
    # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1       .85  .85  .89  .92  .92  .92  .92  .92  .92  .92  .90  .85
    2       .85  .85  .85  .90  .93  .93  .93  .93  .93  .89  .85  .85
    3       .87  .87  .87  .91  .94  .94  .94  .94  .94  .91  .90  .87
    4       .01  .01  .02  .03  .05  .05  .05  .05  .05  .03  .01  .01
  END MON-COVER
```

```
  SED-STOR
    <PLS >  Detached sediment storage (tons/acre)             ***
    # - #     BLOCK1      BLK2      BLK3      BLK4      BLK5 ***
    1   4       0.1
  END SED-STOR
END PERLND

IMPLND
  ACTIVITY
    <ILS >               Active Sections  ***
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL  ***
    1                 1    1
  END ACTIVITY

  PRINT-INFO
    <PLS >          Print-flags ******** PIVL  PYR
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL *********
    1                 5                        12
  END PRINT-INFO

  GEN-INFO
    <ILS ><-------Name------->        Unit-systems   Printer ***
    # -  #                          User  t-series Engl Metr ***
                                           in  out           ***
    1     RESIDENTIAL             1    1    1    1    1    0
  END GEN-INFO

*** Section IWATER ***

  IWAT-PARM1
    <ILS >          Flags             ***
    # -  # CSNO RTOP  VRS  VNN RTLI   ***
    1                1    1
  END IWAT-PARM1

  IWAT-PARM2
    <ILS >                                           ***
    # -  #      LSUR     SLSUR      NSUR     RETSC   ***
    1           350.      .010      .014      0.01
  END IWAT-PARM2

  IWAT-PARM3
    <ILS >   Only required if CSNO=1  ***
    # -  #*** PETMAX    PETMIN
    1            40.       35.
  END IWAT-PARM3

  MON-RETN
    <ILS >  Only required if VRSFG=1 in IWAT-PARM1 is 1            ***
            Retention storage capacity at the start of each month   ***
    # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1       .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01
  END MON-RETN

  MON-MANNING
    <ILS >  Only required if VNNFG=1 in IWAT-PARM1 is 1            ***
            Manning's n for overland flow at start of each month    ***
    # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1      .014 .014 .014 .014 .014 .014 .014 .014 .014 .014 .014 .014
  END MON-MANNING
```

```
  IWAT-STATE1
    <ILS >  IWATER State variables; cond's at the start of simulation ***
    # -  #***    RETS      SURS
    1           .001      0.01
  END IWAT-STATE1

  SLD-PARM1
    <ILS >           Flags             ***
    # -  # VASD VRSD  SDOP             ***
    1                   1
  END SLD-PARM1

  SLD-PARM2
    <ILS >                                                ***
    # -  #       KEIM      JEIM    ACCSDP    REMSDP      ***
    1             .05       1.0      .005      .001
  END SLD-PARM2

END IMPLND

DISPLY
  DISPLY-INFO1
*** # -  #<----------Title----------->***TRAN PIVL DIG1 FIL1  PYR DIG2 FIL2 YRND
    4     RUNOFF (IN), CUB RUN w/RCHS    SUM                     1    2   62   12
    3     RUNOFF (cfs),CUB RUN w/RCHS    SUM                     1    2   62   12
    6     DETS PERLND (tons/acre)        SUM                     1    2   62   12
   12     SLDS IMPLND (tons/acre)        SUM                     1    2   62   12
   13     IMPLND SOSLD (tons)            SUM                     1    2   62   12
   14     PERLND & IMPLND TSS  (tons)    SUM                     1    2   62   12
   15     PERLND SOSED (tons)            SUM                     1    2   62   12
   16     PERLND STCAP (tons)            SUM                     1    2   62   12
  END DISPLY-INFO1
END DISPLY

COPY
  TIMESERIES
    # -  #  NPT  NMN***
    1             1
    6             1
    7             1
   12             1
   13             1
   14             1
   15             1
   16             1
  END TIMESERIES
END COPY

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
TSS      2 PRECIP   ENGLZERO               PERLND   1   4 EXTNL  PREC
TSS      8 EVAPOR   ENGL        .7         PERLND   1   4 EXTNL  PETINP
TSS      2 PRECIP   ENGLZERO               IMPLND   1     EXTNL  PREC
TSS      8 EVAPOR   ENGL        .7         IMPLND   1     EXTNL  PETINP
END EXT SOURCES
```

```
NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
*** The following conversions represent each land segment contribution
*** to watershed output in terms of cfs without reaches.
***
PERLND    1 PWATER PERO          286.21     COPY      1      INPUT  MEAN    1  ***
PERLND    2 PWATER PERO         1137.07     COPY      1      INPUT  MEAN    1  ***
PERLND    3 PWATER PERO          887.71     COPY      1      INPUT  MEAN    1  ***
PERLND    4 PWATER PERO          176.87     COPY      1      INPUT  MEAN    1  ***
IMPLND    1 IWATER SURO          311.05     COPY      1      INPUT  MEAN    1
COPY      1 OUTPUT MEAN    1       .504     DISPLY    3      INPUT  TIMSER
COPY      1 OUTPUT MEAN    1    .000357     DISPLY    4      INPUT  TIMSER
***
*** The following section represents suspended sediment output
***
PERLND    1 SEDMNT DETS                     COPY      6      INPUT  MEAN    1
PERLND    2 SEDMNT DETS                     COPY      6      INPUT  MEAN    1
PERLND    3 SEDMNT DETS                     COPY      6      INPUT  MEAN    1
PERLND    4 SEDMNT DETS                     COPY      6      INPUT  MEAN    1
COPY      6 OUTPUT MEAN    1                DISPLY    6      INPUT  TIMSER
IMPLND    1 SOLIDS SLDS                     COPY     12      INPUT  MEAN    1
IMPLND    1 SOLIDS SOSLD         3734.12    COPY     13      INPUT  MEAN    1
COPY     12 OUTPUT MEAN    1                DISPLY   12      INPUT  TIMSER
COPY     13 OUTPUT MEAN    1                DISPLY   13      INPUT  TIMSER
PERLND    1 SEDMNT SOSED         3435.90    COPY     14      INPUT  MEAN    1
PERLND    2 SEDMNT SOSED        13650.25    COPY     14      INPUT  MEAN    1
PERLND    3 SEDMNT SOSED        10656.78    COPY     14      INPUT  MEAN    1
PERLND    4 SEDMNT SOSED         2123.28    COPY     14      INPUT  MEAN    1
IMPLND    1 SOLIDS SOSLD         3734.12    COPY     14      INPUT  MEAN    1
COPY     14 OUTPUT MEAN    1                DISPLY   14      INPUT  TIMSER
PERLND    1 SEDMNT SOSED         3435.90    COPY     15      INPUT  MEAN    1
PERLND    2 SEDMNT SOSED        13650.25    COPY     15      INPUT  MEAN    1
PERLND    3 SEDMNT SOSED        10656.78    COPY     15      INPUT  MEAN    1
PERLND    4 SEDMNT SOSED         2123.28    COPY     15      INPUT  MEAN    1
COPY     15 OUTPUT MEAN    1                DISPLY   15      INPUT  TIMSER
PERLND    1 SEDMNT STCAP         3435.90    COPY     16      INPUT  MEAN    1
PERLND    2 SEDMNT STCAP        13650.25    COPY     16      INPUT  MEAN    1
PERLND    3 SEDMNT STCAP        10656.78    COPY     16      INPUT  MEAN    1
PERLND    4 SEDMNT STCAP         3734.12    COPY     16      INPUT  MEAN    1
COPY     16 OUTPUT MEAN    1                DISPLY   16      INPUT  TIMSER
END NETWORK

END RUN
```

VITA

Mike Fauss was born on February 28, 1960. He obtained a B.S. degree in Geology from George Mason University in Fairfax, Virginia. He worked for the Environmental Protection Agency's, Environmental Photographic Interpretation Center in Warrenton, Virginia for approximately four years. His work experience was focused on the application of current and historical aerial photography to a variety of site specific environmental problems and issues. He pursued graduate studies at the Virginia Polytechnic Institute and State University in Blacksburg, Virginia where he received a M.S. in Environmental Science and Engineering, Spring 1992.